

PERCEPTION OF BARRIERS TO CAREER PROGRESSION BY WOMEN ENGINEERS AND ENGINEERING STUDENTS

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ABSTRACT

Although the common view that engineering is best suited for men is changing, there is anecdotal evidence suggesting gender imbalance in the engineering industry. Efforts take place throughout New Zealand to encourage participation and career progression of females in engineering. These occur through the formation and activities of societies such as Women in Engineering(WIE) in NZ Universities and provision of support by Institution of Professional Engineers of New Zealand(IPENZ). These enable networking opportunities and celebrate achievements of women engineers. However despite these, a small sample of female engineers revealed that they feel the presence of more barriers to them than for their male counterparts to be able to accomplish in the profession. This in turn may discourage prospective students who value a good balance between their role as an engineer, mother and a home-maker.

A survey was conducted to assess the perception by female engineers/engineering students of these barriers, and how prepared the engineering industries/educational institutes are to cater for the specific needs of a woman as she progresses through the career, balancing the familial responsibilities.

Based on findings some measures are proposed to encourage female participation and retention in engineering industry; implementing them can be invaluable in preventing the loss of highly skilled engineers to the industry especially when a young female engineer chooses family over engineering work – either by changing her career path to obtain more flexible working conditions or by stopping work all together. Both of these scenarios are equally detrimental to the individual and the industry.

BACKGROUND

Women have been under-represented in Engineering and therefore are accustomed to being in the minority. The engineering profession has always had the somewhat unsavoury standing as the most male-dominated profession. Numerous studies have high-lighted this under-representation in many countries throughout the world, such as USA(Reardon, 2004 ; SWE, 2004), UK (EngineeringUK, 2010a, 2010b) and India (Pareek, 2007).

From a 2006 census of population and dwellings by Statistics in 2006 the Department of Labour in New Zealand (DoL, 2006), revealed that on average for all occupations there is a 47% female participation. However, only 16% females work as architects, engineering related professionals, and technicians in New Zealand. It also reported that

female enrolment of engineering students at tertiary level was just under 18%. Their report “Engineers in the labour market” (DoL, 2006) stated the need to widen the pool of future potential engineers and identified that Maori and pacific populations were not well-represented. The report did not mention considering ways of increasing female participation in engineering.

According to an IPENZ report (IPENZ, 2011) only 6% of the registered chartered professional engineers in New Zealand are women (Fig. 1). This is in line with internationally well-known fact that women participation in engineering is low with perhaps the only exception of China (40%) and the former USSR (58%) (CERT, 2010).

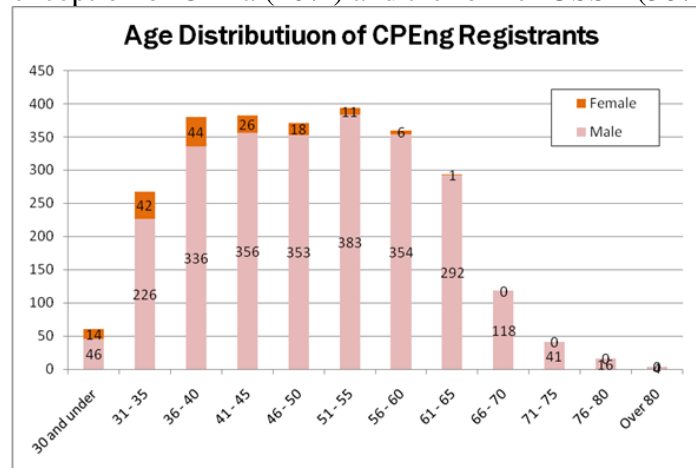


Fig. 1: Distribution of female CPEng registrants in New Zealand (IPENZ, 2011)

While attracting females to a profession perceived to be one of male domination is one great challenge, retaining those who do enter the industry is another. Out of concern that female engineers do not seem to continue in their engineering careers as long as their male counterparts, IPENZ carried out a comprehensive survey in 2008 to find out what happens to them in the work force. The data revealed gender-based prejudices in sexual harassment, gender discrimination, and remuneration. The report also acknowledged that women engineers left their professional status for travel, to undertake further study, or for maternity or childcare reasons (IPENZ, 2009). Although a pay disparity was observed in the data, it was not reported as a reason for departure. In contrast, a report (Kiviat, 2010) based on a survey of women engineers in Canada by Prof. Jennifer Hunt, an engineer turned economist, concluded that although more women than men left engineering for family-related reasons, the gender gap was similar to that in non-engineering professions. In fact, it found that more than 60% of the women leaving engineering did so because of dissatisfaction with pay and promotion opportunities.

This study was conducted to assess the perception by female engineers and engineering students of the barriers, and how well or badly prepared the engineering industries and educational institutes currently are to cater for the specific needs of a woman as she progresses through the career while balancing familial responsibilities.

An anonymous survey was conducted to collect data from female engineers and engineering students through a questionnaire (conducted in Survey Monkey[®]). The data were analysed and findings summarised.

THE SURVEY

The recipients of the survey were females who were academics/students tertiary engineering education or working in the engineering industry in New Zealand. Participation in the survey was voluntary and was initially distributed to a total of 37 female civil engineers/academics/engineering students (5 students) known to the researcher with a request to forward the survey link to other female engineers fitting the given description. The total number of respondents was 47. The survey comprised of 5 sections with a total of 38 questions.

Section 1 – Identifying the status

The composition of the participants is shown in Fig. 2. The numbers add up to 54 rather than 47 as some of the participants fall into more than one group. The majority (74.5% or 35 participants) are engaged in full time work in engineering industry; of these, three are studying part time. Similarly there are 6 who are full time students out of which two are working part time. Four are taking a break away from work. Four are taking a break away from work.

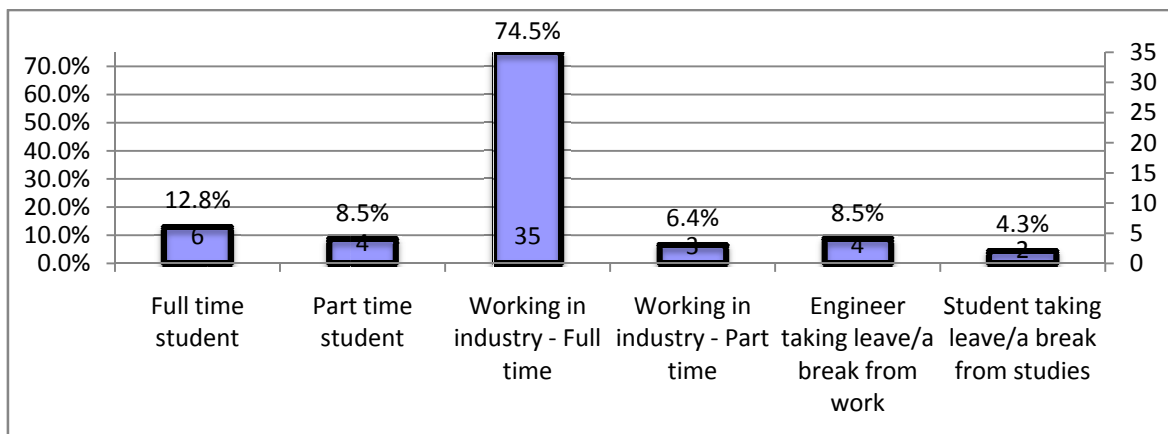


Fig. 2: The composition (number and %) of the surveyed sample

Analysis of Section 1

The overall sample is medium-sized. Judging from the number in sub-classes, it should be acknowledged that the samples representing categories other than full-time employed are very small. As such, sub-sample analyses of information were not done. It should also be noted that all the percentage values represent extrapolations to 100 from a smaller sample, are indicative but suffice for the purpose of this study.

Section 2 – Perception of engineering as a profession and the place of women in Engineering

There were five questions in this section. It is noted that the widely held view that “Engineering is a man’s world” is fading with 70% thinking it is not (Fig. 3). As expected 89% see that the women:men ratio is not balanced in their place of work/study (Fig. 4).

When asked whether the ratio is balanced in engineering industry in general, an overwhelming 96% responded with a “No”. As to what the women:men ratio would they like it to be, the most common response was 50:50. While the responses varied widely, there were five who did not have any specific preference (Fig. 5).

With respect to working hours, 61% say that there is a need to dedicate long hours to work to succeed in the engineering industry in general. A specific question whether they have to spend long hours in their *own* workplace comes up later in Section 5.

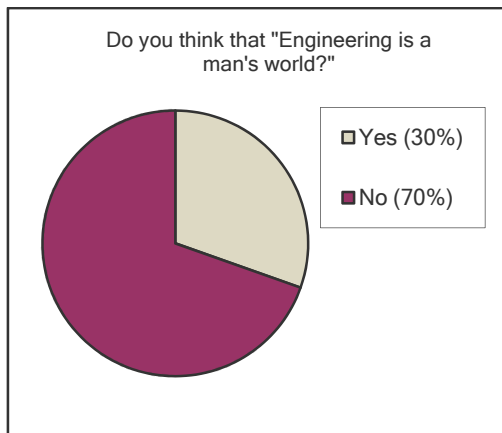


Fig. 3: Engineering a “man’s world?”

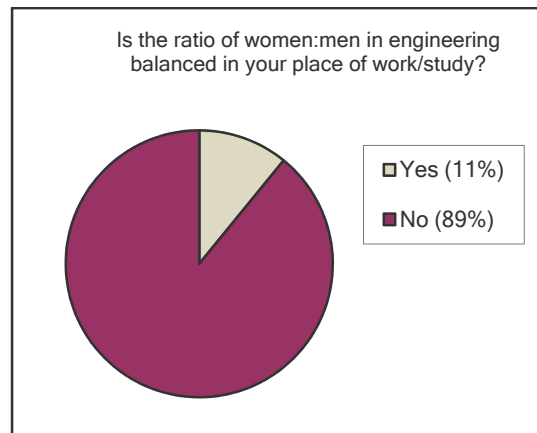


Fig. 4: Gender imbalance in work place/study

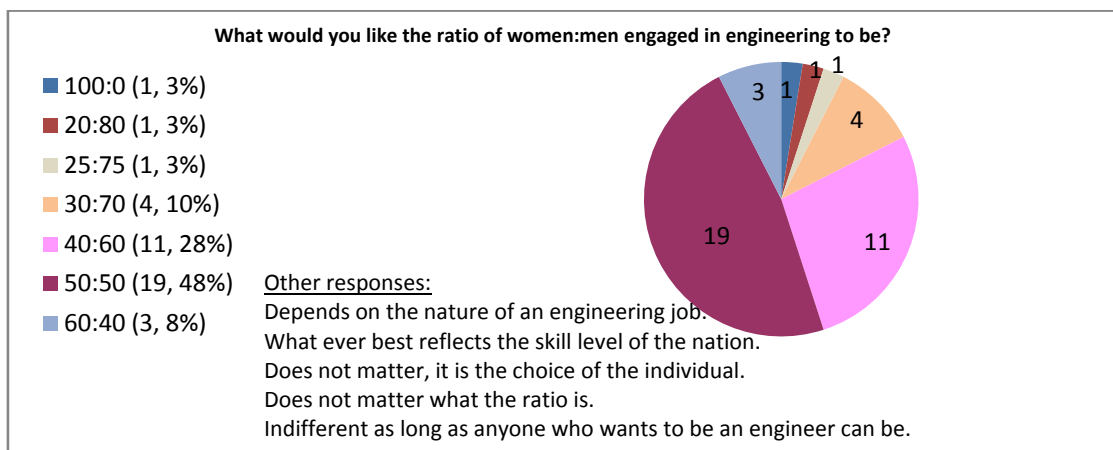


Fig. 5: Preference of women:men ratio in engineering

Analysis of Section 2

The perception that the ratio should be more balanced aligns with the global view.

Section 3 – Identifying inhibitors

This comprised six questions drawn from existing literature supported by observed anecdotal evidence to check whether the views that inhibit the advancement of women engineers were widely shared by the NZ sample.

The results summarised in Table 1 (with highest percentage underlined), show that the respondents largely share these views with the only exception of pay parity. However, 31% still perceive pay parity as a concern. It should be noted that the participants are very likely to be unaware of the actual salary their male counterparts draw. A survey on actual remuneration with a small sample size of females over 35 years and conducted by IPENZ (IPENZ, 2009), showed that women with Chartered Professional Engineer (CPEng) status got paid consistently lower than their male counterparts across all age

groups. Similarly a survey carried out in the UK in 2008 (Whitelaw, 2008) showed that women who were Members of the Institution of Civil Engineers (MICE) received 32% less pay than MICE males.

Tab. 1: Agreement with prevalence of obstacles to career progression

Obstacle	Disagree	Neutral	Agree
Women face more opposition in leadership roles than men.	22%	26%	<u>52%</u>
Some men do not feel comfortable with having to report to women.	17%	24%	<u>60%</u>
Female engineers have to work harder to get ahead in the work place.	24%	17%	<u>59%</u>
Women engineers are smart people; but they still have to put in more time, deliver better quality to earn the status/ reputation/ appreciation a man gets by doing less.	29%	26%	<u>45%</u>
There is no pay parity between women and men in engineering for similar work. Women get paid less.	33%	<u>36%</u>	31%
An assertive woman is perceived to be strong-willed while a man is expected to be assertive.	19%	29%	<u>52%</u>

Analysis of Section 3

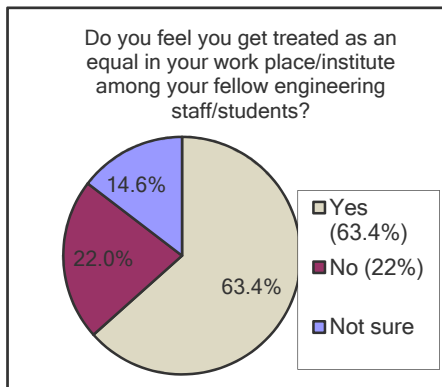
A very interesting finding from a survey carried out in Canada is that women leave engineering for the same reason that a man leaves a job, i.e. pay and promotion concerns or opportunities (Flynn, 2010; Kiviat, 2010). It deduces that women seem to disproportionately leave male-dominated fields one of which is Engineering.

The factors in the table above also seem to suggest that females here do feel that they have obstacles to getting ahead in the work place. Although they have not been found to be leading factors in any survey done so far, the cumulative effect of these factors are bound to have *some* influence on feeling justified of leaving work when family and other reasons surface.

Section 4 – Engineering education

This section attempted to gather information regarding the perception of equal treatment in engineering education and if co-education or girls-only education is likely to promote equal treatment. All the respondents (100%) confirmed the worldwide accepted worrying trend of being in the minority during tertiary education (all less than 40%). Data revealed that there was no intentional difference (positive or negative) in the manner in which male and female academics treated the female students compared to their male counterparts. This confirms the view that the educationalists by and large treat the female minority with equity.

When it comes to treatment by work colleagues however, the data (Fig. 6) suggests that while a majority (63.4%) felt they were treated as equals, 22% (9) of the 41 respondents said they did not which is concerning. None of these 9 are students, five are working full time, three working part time and one taking a break away from work.



The data supports correction of such an imbalance through co-education, as this promotes mutual understanding at an early age. Fig. 7 clearly shows that only a small minority (7%) see co-education not being the better option. Fig. 8 on the other hand, indicates ambivalence of all-girls education up to secondary schools although supposedly it leads to gender issues never surfacing and girls growing up believing they can do anything.

Fig. 6: Perceived treatment as an equal by colleagues

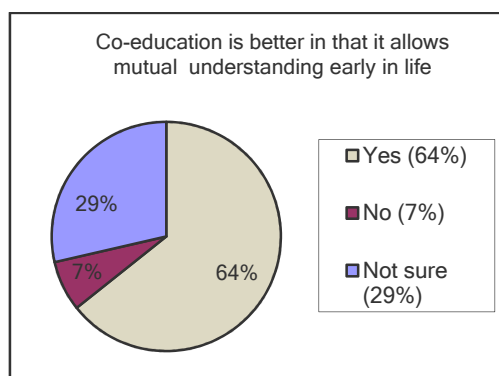


Fig. 7: Benefits of co-education

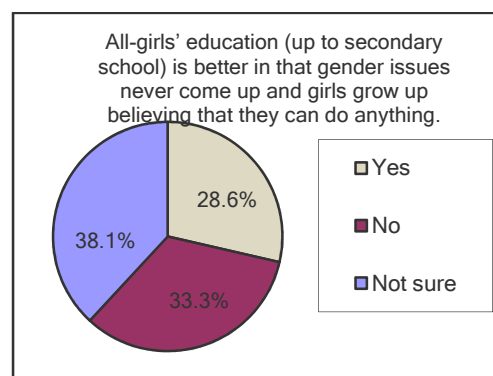


Fig. 8: Benefits of early education for girls-only

Analysis of Section 4

Co-education is key to promoting confidence and understanding between opposite sexes as both academic confidence and self-efficacy are essential for academic success. Back in late 90s, women in the US criticised engineering educators for being rigid, closed, and condescending (Seymour & Hewitt, 1997) which seemingly lowered women's self confidence and self-efficacy. It is comforting to know that none in this study felt they were treated differently by their educators. It is possible that some of the participants were educated overseas. Overall, gender inequities would have undoubtedly reduced over the decades, but it is crucial not to abandon the educational efforts in the light of favourable recent statistics.

This survey did not query if the females experienced gender discrimination by their fellow students. However, an excellent analysis on determining students' success in engineering programs in the USA (Vogt, Hocesvar, & Hagedorn, 2007) revealed that female students there reported greater perceived gender discrimination than the male sub samples. It also showed that women students had lower engineering self-efficacy and lower levels of critical thinking. They conclude that it may be the cumulative effect of these variables that dissuade some females from engineering and in to other majors.

With the need to retain those who choose to study engineering, it is paramount that the educators adapt their delivery to take advantage of the female traits such as such as willingness to seek help (Shachaf & Snyder, 2007) and preference to ask questions after

or outside of a class, rather than *in* class [(Margolis, Fisher, & Miller, 2011) and personal observations].

Section 5 – Identifying work place issues

This section was designed to capture what reinforcements would encourage the females to succeed more. While it is clear that having mere large numbers in the study group/work place is not necessarily a great encouragement (Fig. 9), having more females in leadership positions would help (Fig.10).

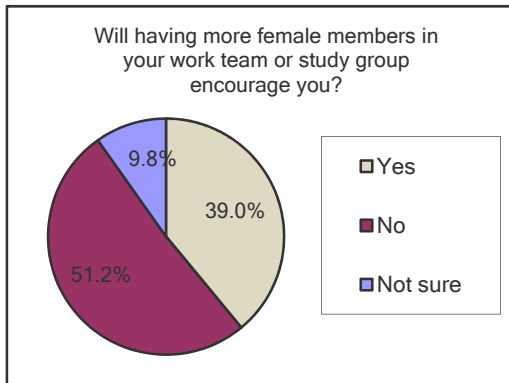


Fig. 9: Benefit of more female members

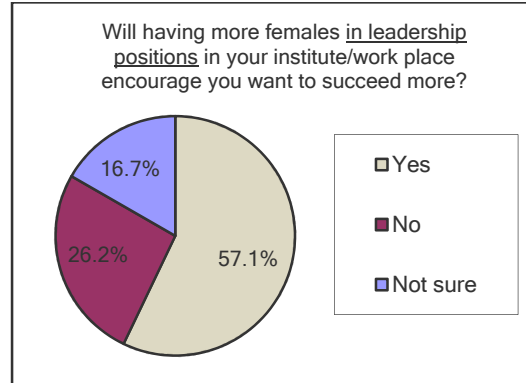


Fig. 10: Benefit of more females as leaders

At their own work places, 50% of the participants feel they have to work long hours to succeed. While 74% of the participants feel that there was(will be) a time in their engineering career when they had (will have) to choose between family and career (Fig. 11), only 12% would prioritise career (Fig. 12).

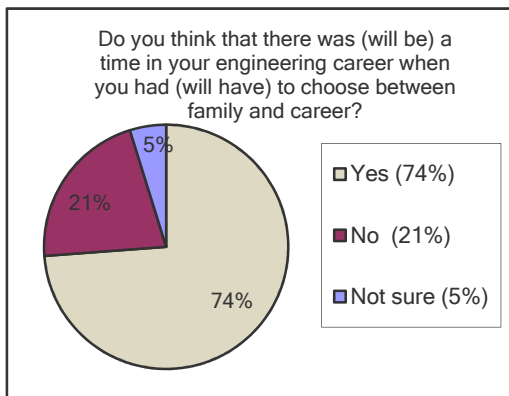


Fig. 11: Having to choose Family/career

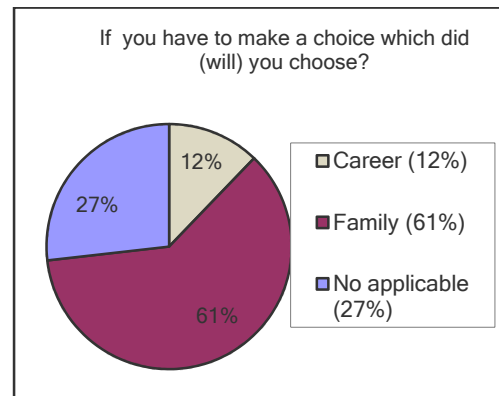


Fig. 12: Choice of Family/Career

One of the main concerns is the the loss of women engineers all together from engineering industry. Fig. 13 shows that while a vast majority wish to eventually return to engineering, 10% intend to leave engineering for another line of work. This must be related to, among other things, the desire to prioritise family, the need for investing long hours to engineering work, and the perceived difficulties in balancing life and work in an engineering career as opposed in other work/trades.

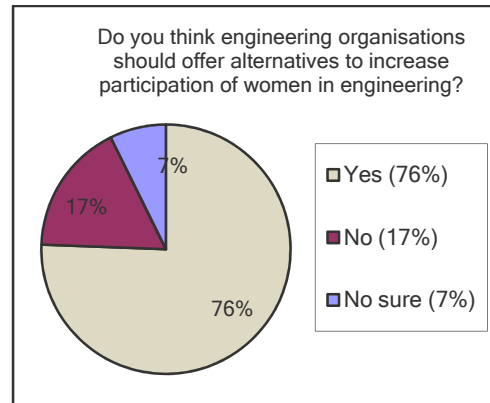
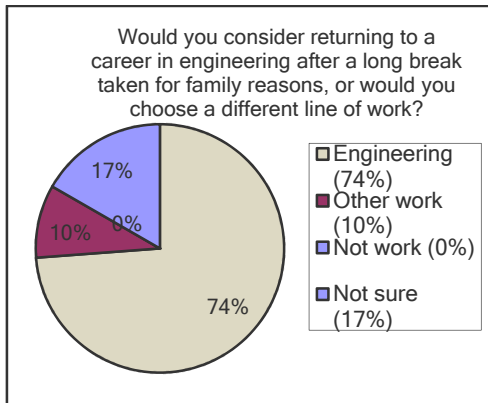


Fig. 13: Desire to return to Engineering Fig. 14: Organisations offer alternatives?

A vast majority (76%) considers that engineering organisations should offer alternatives to increase participation of women in engineering while 17% say no (Fig. 14). Given a few choices of helpful alternatives, the participants voted as shown in Tab. 2.

Tab. 2: Provisions already available in some organisations

Provision by organisation	Number of votes
Flexible Longer breaks for those who have children	15
Flexible work hours	30
Opportunities to work from home	26
Provision of childcare at work place	13
Not sure	1
Not applicable	6

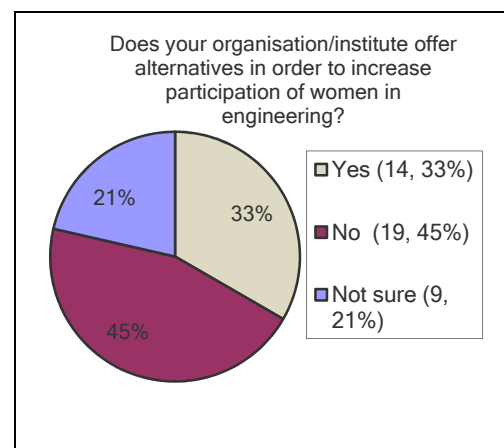


Fig.15: Organisations offering alternatives

As shown in Fig. 15, 17% of participants stated their organisation did not offer the provisions in Table 2 while 7% stated they are not sure if such alternatives were available to them.

Tab. 3: Provisions already available in some organisations

Provision by organisation	Number of votes
Flexible hours	13
Opportunities to work from home	10
Contracts arrangements	2
Part time work options	2
Opportunities to work from home for both men and women	1
Decreased work hours. eg 30 hr week instead of 40	1
Women only social events	1
Flexible work hours - manager dependent	1

The 14 individuals who said their organisations offer alternatives gave the provisions in the above table (Tab. 3) as the ones they get to enjoy.

Analysis of Section 5

Women engineers in leading positions capable of mentoring and acting as role models is clearly a motivator. There is inconsistency in providing alternative work arrangements across organisations. Flexible work hours and work from home are the most common offering and perhaps is a good start for those organisations who do not offer any.

There are other international surveys that reflect the same trends observed in this survey. Patricia (Lee, 2006) also found that the biggest obstacle for the aged between 31-40 was time management, specifically, that of balancing the demands of home/family against those of job/career ultimately having no time for themselves. Her respondents between the ages of 41-50 cited discrimination, primarily gender-based, as their biggest obstacle, some citing age discrimination as their career issue.

Section 6 – Identifying the wish list

When asked what provisions they would like organisations to offer in order to increase participation of women in engineering, the participants suggested the following options:

From Academic institutes: Distance learning

From Professional bodies: Competency evaluation holidays

From employers:

- Opportunities to work from home
- Flexi work hours
- Part time work arrangements
- Opportunities to provide "consultancy" to the company, for a few hours a week (for those with children)
- Paid/unpaid leave for extended periods
- Increased sick leave due to sickness of children
- Childcare facilities at workplace
- Leave during school holiday periods
- Information (e.g. interviews) on female engineering leaders
- More women in leadership positions for us to look up to
- Informal and formal mentoring
- Treat equally (for example some managers are reluctant to hand over responsibilities to female counter parts)

Analysis of Section 6

Participants show that the organisations can do much more to increase participation of women in engineering industry. Most of the expectations are centred round flexibility, both in work place as well as in education.

SUMMARY AND RECOMMENDATIONS

In summary, the majority of the cohort of 47 female engineers/students confirmed that there is gender imbalance in the numbers and would like to see more women. They also perceive several obstacles to advancing their careers in this male-dominated industry

and suggest number of actions the employers, institutes can take to encourage them to succeed more as well as to keep them in industry longer.

The following recommendations will assist with improving the number of women engineers:

Professional bodies such as IPENZ could consider making some exemptions to those who had taken time off within the 5 year evaluation period for retaining CPEng status. This will need further discussion, careful thought to ensure professional standards of the practitioner are maintained, and proper evaluation processes put in place; after all women engineers will not want to appear to be given special treatment but only fair treatment. A recent policy (Engineers-Australia-Council, 2008) aims to provide flexibility to those who take a career break of six months to five years, by altering the CPD requirements. This is one example of an engineering professional institute taking steps to prevent individuals taking a career break being disadvantaged when they choose to return to workforce.

Apart from flexible work arrangements, any positive action taken to nurture, mentor and support women engineers in a male dominated environment where there are perceptions of unequal treatment will definitely promote the confidence and hence the contribution of women engineers to industry.

Considering implementation of the suggestions, some of which need only a change of attitude, can be quite valuable as the loss of valuable workforce to engineering industry as a young female engineer chooses family over engineering work – either by changing career path that allows more flexible working conditions or by stopping work all together – can be equally wasteful to the individual and the engineering industry.

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PAINTING THE PICTURE – A STATISTICAL UPDATE ON WOMEN IN ENGINEERING IN AUSTRALIA

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ABSTRACT

The paper examines women's participation in engineering education and workforce in Australia. Using data from recent editions of Engineers Australia's The Engineering Profession: A Statistical Overview and drawing heavily on a detailed analysis of 2006 Population Census data, the aim is to show trends in the commencements, enrolments and graduations of female engineering students and to give an overview of the nature of female participation in the engineering workforce.

Key findings include:

- slight increases in female percentage participation in engineering studies from 2001 to 2008, with growth in overseas and postgraduate students;
- the 2006 engineering labour force included 9.8% women, while 10.7% of individuals with engineering qualifications were women;
- unique and significant gender differences in the uptake of full-time and part-time employment exist;
- the gender pay gap is evident, with female engineers in full and part-time positions earning lower average weekly salaries than male engineers;
- a higher percentage of qualified engineering women are not in the labour force, compared to men, with a notable difference in the age groups around 35 years; and
- gender segregation of the engineering labour force by occupation and industry is seen, with a higher proportion of women in clerical / administrative and sales roles and health care & social and accommodation & food sectors.

The work is the foundation for a regular update of gendered statistical data that will establish a detailed picture of engineering women in Australia and will assist with targeted progression of issues.

INTRODUCTION

The Women in Engineering movement has been active in Australia since the late 1970's. Initiatives implemented and supported by government, industry bodies, academic institutions and companies in Australia have aimed to attract and retain women in the engineering profession. An increase in the participation of women in the profession was marked through the 1980's and 1990's (Burrowes, 2006). In the last decade, however, minimal progress has been made and a plateau in the uptake of engineering studies and subsequent participation in the engineering workforce is observed.

The minority status of women in the engineering workforce is well documented. Statistics pertaining to the engineering profession are published regularly by Engineers Australia (EA) and the Association for Professional Engineers, Scientists and Managers (APESMA). Substantial and important research on women in engineering in Australia has covered girl's participation in engineering enabling subjects, understanding of pathways to engineering and understanding of the engineering occupation (Gill et al., 2005, Gill et al., 2008) and women's educational and workplace experiences (Gill et al., 2005, Mills et al., 2006). Recent work, including the Career Review of Engineering Women study, revised in 2007 (Mills et al., 2008), suggests that women engineers in Australia are a struggling minority and do not have the critical mass to influence the communication and culture of their workplaces, nor attract more women into the profession. Current research by Marinelli (Marinelli, 2010, Marinelli, 2011 (pending)) focuses on success stories of women who have persisted and progressed in the profession and aims to provide insights and new ways to address the issue of lack of representation.

Motivation

The motivation for this work arose from the authors' involvement in Engineers Australia Women in Engineering activities both on national and state levels. Being involved in activities focussed on attracting women, as well as retaining and supporting women in their engineering careers naturally leads to the question, how effective are these efforts and is progress actually made?

The Engineers Australia National Committee for Women in Engineering (NCWIE) recognises the need for regular publication of gender specific statistics to be able to analyse trends. Gender specific statistical information with historical trends is to some extent available through the Statistical Overviews (Kaspura, 2008, Kaspura, 2009, Kaspura, 2010a) regularly published by Engineers Australia. Additionally the NCWIE has commissioned and/or made a number of publications available through their webpage (Engineers Australia Women in Engineering, 2011), most notably these include "The Careers Review of Engineering Women" (Roberts and Ayre, 2002) and its follow up publication in 2008: "CREW revisited in 2007 The Year of Women in Engineering – An update on women's progress in the Australian engineering workforce" (Mills et al., 2008).

This publication aims to provide an initial template on selected statistics which are of interest to the engineering profession in Australia and which can be regularly updated (preferably annually). Engineering workforce statistics, as well as commencements, enrolments and graduations of female engineering students are key focus areas, statistics specific to engineering disciplines are also of interest but this level of detail is not provided in this publication. The collation and presentation of detailed gender disaggregated statistics is believed to be a key means to measure and monitor the attraction and retention of women to the engineering profession and gender equity in the engineering workforce. This work is complementary to recent work mentioned, which utilises surveys and interviews to establish a picture of the life as a women engineer and an insight into the nature of the engineering profession. It is hoped that the NCWIE and EA continue to support this initiative to members and the community in future.

It should be noted, that other engineering organisations, such as the Association of German Engineers (VDI) or the Society of Women Engineers (US) publish comprehensive women in engineering statistics on their websites (Society of Women Engineers, 2011). VDI maintains an impressive website listing (historical) statistics presenting high school leavers, university and workforce data with gender information, state and discipline details, where the user can choose specific areas of interest to

generate individual graphs (Verein Deutscher Ingenieure (The Association of German Engineers), 2011).

The question of “Are the increased efforts that have been made by both Engineers Australia and several engineering organisations to implement equity and diversity policies and practices successful?” can be better answered through regular updates of gender specific statistics. By painting the picture of women in engineering in Australia, interested parties will be able to clearly see and assess women’s involvement in engineering, and identify issues and problem areas and effectively target interventions for progress.

Data source

The main source for data presented in this section are the EA reports “The Engineering Profession, A Statistical Overview, Seventh Edition” (Kaspura, 2010a) and “The Engineering Profession in Australia; A Profile from the 2006 Population Census” (Kaspura, 2010b) which in turn are based on Australian Bureau of Statistics (ABS) 2006 Census Data and data from the Department of Education, Employment and Workplace Relations (DEEWR).

Although the link between formal qualifications and subsequent workforce destinations is reasonably close for the engineering discipline, the range of occupations where engineers work is large and expanding. Our selection criterion for being considered as part of the engineering labour force is a formal educational qualification in engineering, regardless of where individuals are employed (engineering or generic work) (i.e. we refer to Chapter 2 in (Kaspura, 2010b). The reason for this is the nature of the ABS census data, which assesses the individual highest qualification only for allocation to the engineering labour force. The *Engineering Labour Force*, which we focus on, should therefore be distinguished from the *Engineering Profession*, which is the engineering labour force that is engaged in engineering work only (the Engineering Profession is topic of Chapter 3 in (Kaspura, 2010b) but not referred to in this publication). Formal educational qualifications in engineering are: i) at least a 4 year bachelors degree in engineering for Professional Engineers, ii) at least a three year bachelors degree in engineering for Engineering Technologists and iii) at least an Australian Qualification Framework (AQF) Diploma or Advanced Diploma in engineering for Associate Engineers.

In order to relate the findings to equivalently trained individuals, data from a comparison group is used as in (Kaspura, 2010b) where individuals have the same level of qualification but for a wider range of disciplines including engineering, natural and physical sciences, information technology, architecture and building, agriculture, environmental and related studies, health, education, management and commerce, society and culture, creative arts, food, hospitality and personal services and mixed field programs (general education). The population of the engineering subgroup of this comparison group comprises of 305,931 individuals (273,117 (= 89.3%) males and 32,814 (= 10.7%) females). The engineering subgroup constitutes 8.5% of the comparison group of 3,600,668 individuals (1,622,719 (=45.1%) males and 1,977,949 (=54.9%) females).

There are a number of issues associated with the ABS census data:

- Basing the association with the engineering labour force on the highest qualification of an individual only, poses a problem, since approximately 20% (according to EA and APESMA salary surveys) of practicing engineers possess post graduate qualifications in non-engineering fields, so the census allocates these to the non-engineering fields, although they may well be working in engineering jobs.

- The census is conducted every 5 years, so statistics are not annually updated.

However, its consistent data definitions, new tools (such as the 2006 Census Tablebuilder facility released by the ABS in 2009) allow for the extraction of relevant/interesting/gender statistics and every other means of collecting data is expensive and involved.

Method

The statistics presented in this paper are based on data from Kaspura 2010a and 2010b. The data was taken directly from these reports and segmented by gender. The data was then processed graphically to assist with analysis and presentation. The data concerning participation in engineering studies is presented for the period 2001 to 2008 and are based on data from DEEWR. Statistics on women in the engineering labour force, including remuneration, are based on ABS 2006 Census Data and as such are a snapshot of the profession at that time.

FINDINGS

Participation in Engineering Studies

A slight increase in the female percentage participation in engineering studies in Australia is observed from 2001 to 2008. The proportion of female students commencing all engineering courses, including undergraduate diploma, bachelor and postgraduate degrees, has increased from 15.9% to 17.3% (Figure 1 (a)).

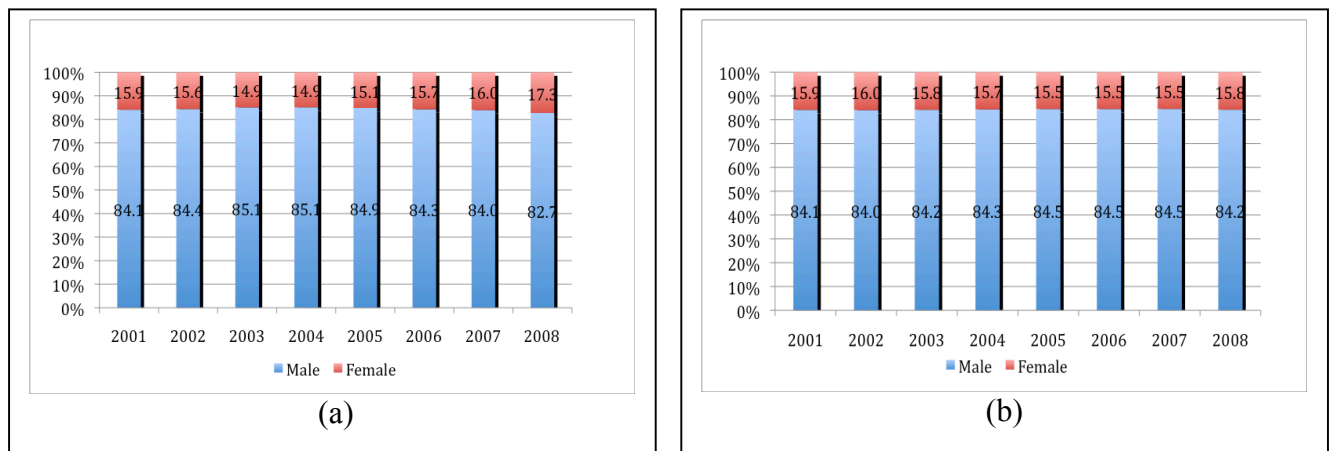


Figure 1 – Percentage graph of students (a) commencing engineering courses and (b) enrolled in engineering courses by gender

The increase in commencements corresponds to an increase from 3,074 to 4,020 female engineering students. The growth is driven by an increase in the number of women commencing postgraduate degrees (566 postgraduate positions). The increase in female commencements is also driven by growth in female students from overseas (708 students) rather than domestic students (238 students). Female students comprise 24.3% of overseas students commencing engineering courses in 2008, as compared to 16.6% of domestic engineering student commencements.

The percentage of females enrolled in engineering courses has remained constant for the period 2001 to 2008, hovering between 15.5 and 16.0% (Figure 1 (b)). This corresponds to an increase in female postgraduate enrolments (18.5% to 19.9%) and a slight decrease in female undergraduate enrolments (15.4% to 14.7%).

Despite the flat-line in percentage of enrolments, the total number of women enrolled in engineering has increased from 9,296 to 11,617 over this period. This increase of 2,321 enrolments is divided evenly between undergraduate and postgraduate enrolments. The growth in the number of female enrolments is strongly driven by overseas students, with 88% of the increased female student numbers being from overseas. In fact, over this time period the percentage of domestic female enrolments has dropped from 15.6% to 14.8%.

The proportion of engineering qualifications achieved by women has increased from 17.1% to 17.6% of engineering course completions during the period 2001 to 2008 (Figure 2). This corresponds to 601 additional female engineering graduates in 2008, as compared to 2001.

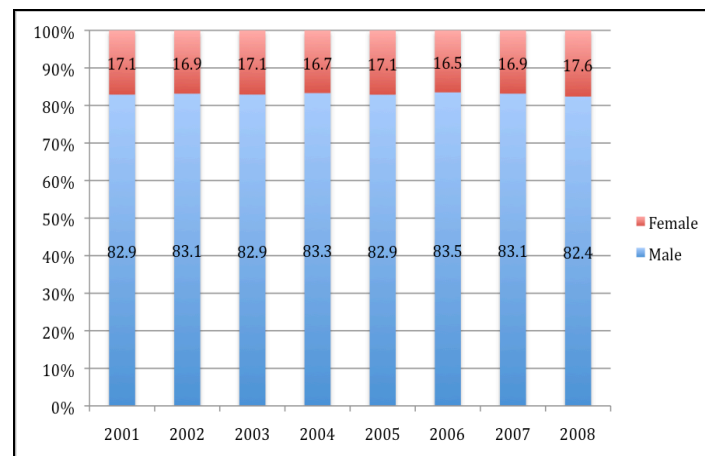


Figure 2 – Percentage graph of completion of engineering courses by gender

This growth consists entirely of female overseas students, with 62% of growth in postgraduate completions (372 additional graduates) and 38% in undergraduate completions (229 additional graduates). Of interest is the decrease in the actual number of domestic female undergraduate completions from 1,030 to 920 graduates (16.3% to 14.6% of domestic graduates).

Women with Engineering Qualifications

According to Kaspura (Kaspura, 2010b) there were 305,931 individuals in Australia possessing a formal engineering qualification in 2006. Of these, 249,788 individuals were employed, or unemployed looking for full-time or part-time work (referred to as the *engineering labour force*). The engineering labour force in 2006 shows a distinct gender imbalance with 9.8% female and 90.2% male.

Figure 3 illustrates the percentage of males and females with engineering qualifications that are employed, unemployed or “not in the labour force”. These statistics on the engineering labour force can be related to the equivalent labour force graph of the comparison group in Figure 4. Comparing the two groups, there are few differences amongst the males, but notable differences amongst the females in relation to full and part-time employment. Part-time employment of females in the comparison group is significantly more widespread than with females with engineering qualifications (27% as opposed to 18%).



Figure 3 - Percentage graph of (a) males and (b) females with engineering qualifications

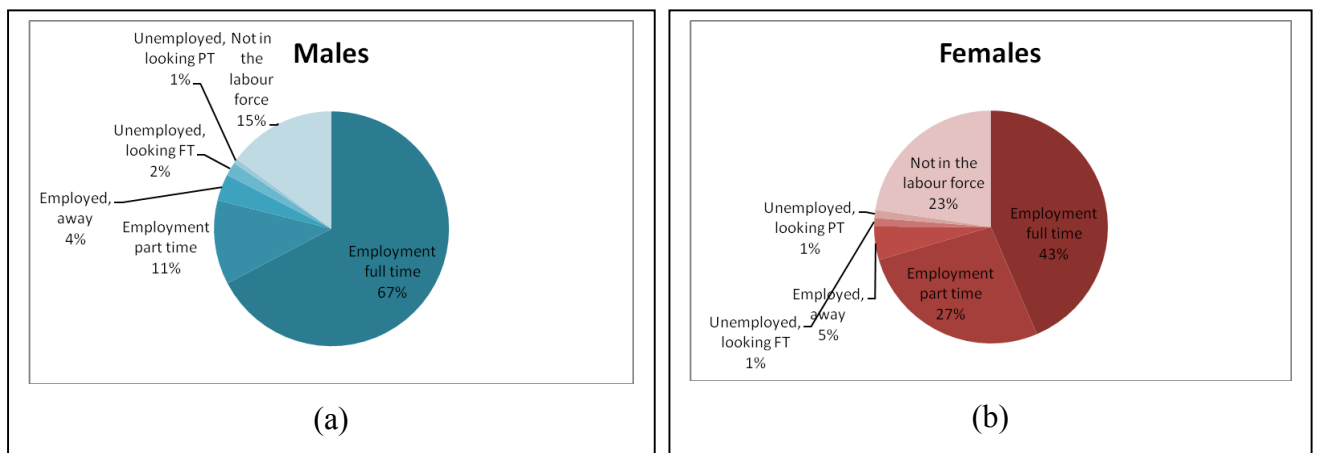


Figure 4 - Percentage graph of comparison group (a) males and (b) females

Among those with engineering qualifications, but not in the labour force, there are gender differences in regards to the age structure. Of those not in the engineering labour force, a higher percentage of females are in full-time study or not employed due to family responsibilities than males. Figure 5 shows these differences. The comparison group produces very similar graphs.

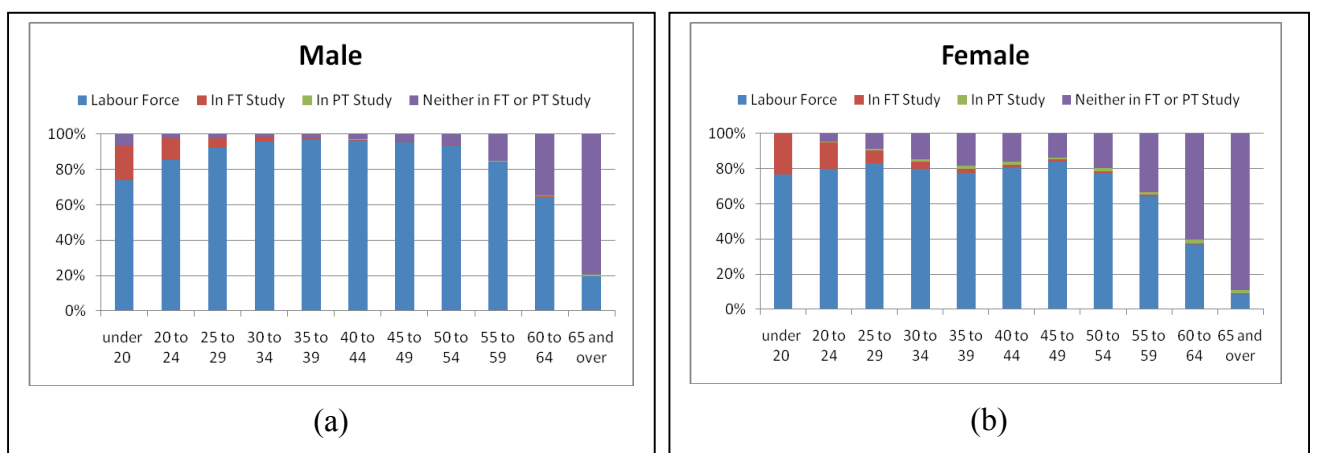


Figure 5 - Percentage graphs showing the age of (a) males and (b) females in or not in the engineering labour force (FT: Full-time, PT: Part-time).

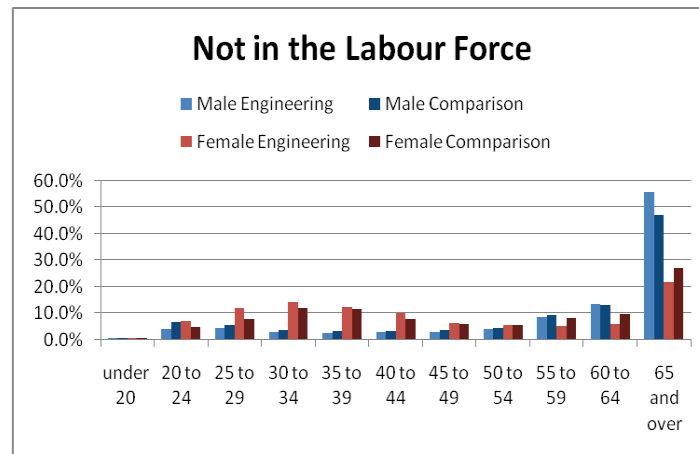


Figure 6 - Percentage graph of males and females not in the labour force by age group

The majority of males not in the engineering labour force are retired (56% are 65 years and over) whereas of the females not in the engineering labour force only 22% are 65 years and over (Figure 6). Figure 6 also shows that a higher proportion of females with engineering qualifications do not participate in the workforce during the childbearing years than females in the comparison group.

Gender Pay Gap

Figure 7 (a) and (b) present average gross weekly incomes earned by the engineering labour force for full-time and part-time positions. A pay gap is evident with female engineers in both full-time and part-time positions earning lower average weekly salaries than male engineers.

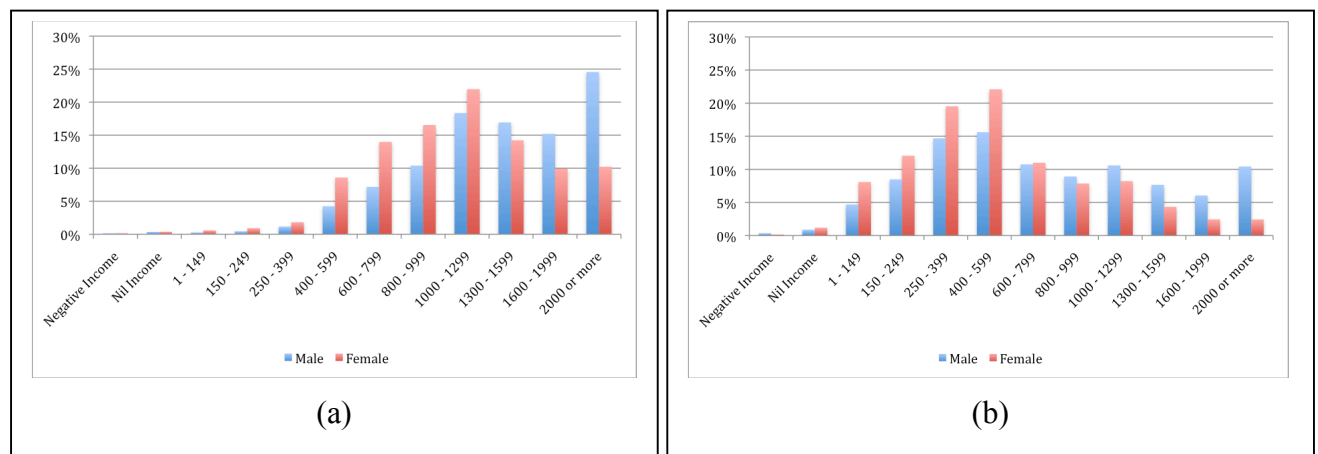


Figure 7 - Weekly income earned by (a) full-time employees and (b) part-time employees in the engineering labour force (% of gender group)

For engineers in full-time employment, 65% of female engineers earn \$1300 or less per week, as compared to 42% of male engineers. 25% of male engineers earn \$2000 or more per week, in comparison with 10% of female engineers.

Female engineers engaged in part-time employment earn less than male engineers, with 63% of female engineers earning less than \$600 per week as compared to 45% of male engineers. Notably, a much large proportion of male engineers working part-time still earn over \$2000 per week (10% of part-time male engineers), as compared to 2% of part-time female engineers. A breakdown of the part-time earnings data by hours worked for the bands of 1-15 hours, 16-24 hours and 25-34 hours revealed that female

engineers earn less than male engineers across all bands, providing further evidence of a gender pay gap in the profession.

Gender Segregation of the Engineering Labour Force

This section examines the distribution of the engineering labour force by gender, focusing on employment by economic sector, industry sector and occupation type. There is little difference between the proportion of male and female engineers employed in the economic sectors (Figure 8 (a) and (b)). For both male and female engineers, the primary employment sector is the private sector, which employs over 80% of both male and female engineers.

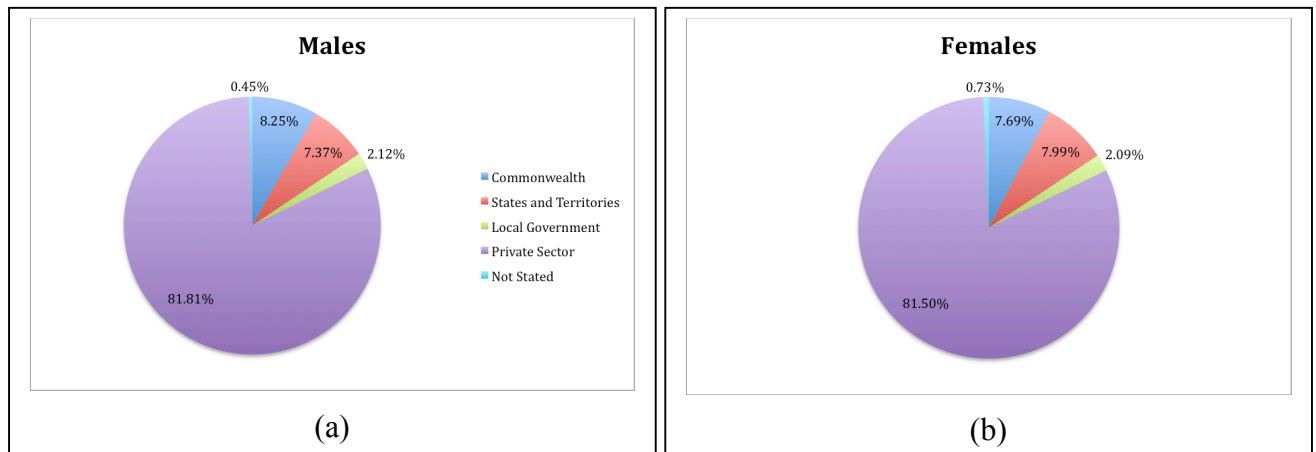


Figure 8 - Economic sector percentage distribution - (a) males and (b) females

When employment distribution by Industry group is examined, differences are apparent (Figure 9). A higher proportion of female engineers are employed in the Health Care & Social (26.5% of engineers are female), Accommodation & Food (18.6%), and Retail Trade (17.7%). Sectors employing the lowest proportion of female engineers are Construction (5.3%), Transport & Postal (6.0%) and Mining (7.2%).

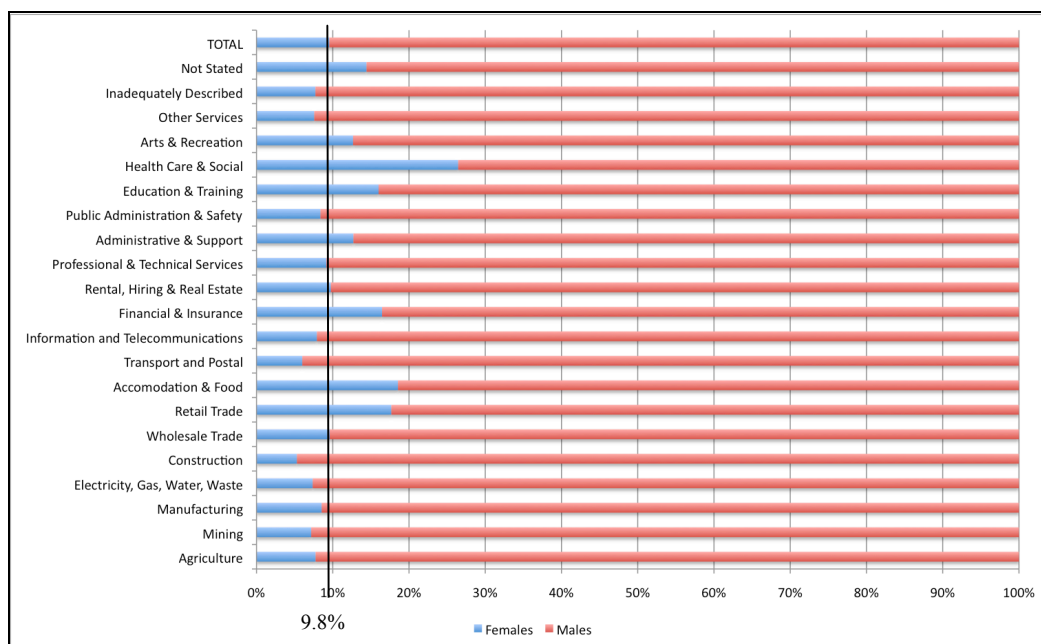


Figure 9 – Percentage graph of employment by industry sector

Segregation is also evident when examining the distribution of the engineering labour force across major occupational groups (Figure 10). Women are more highly

represented in Clerical & Administrative (22.6%), Community/Personal Service (19.9%), and Sales (19.1%). Fewest women are found as Machinery Operators (5.0%), in Technicians & Trades (5.9%) and Management (6.3%).

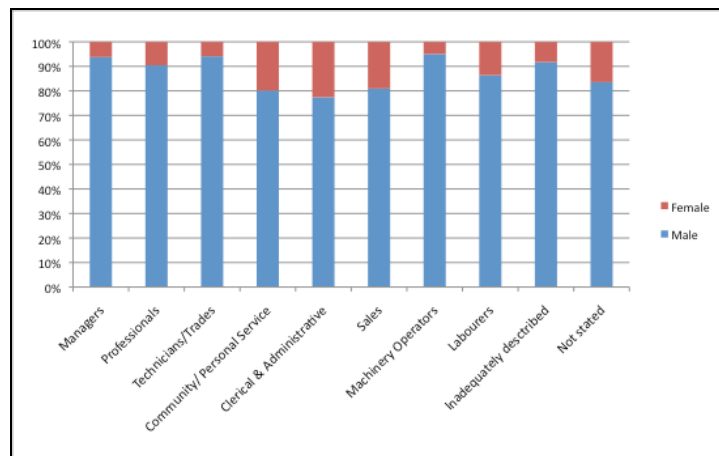


Figure 10 - The occupational distribution of the employed engineering labour force

DISCUSSION

The statistics regarding female participation in engineering studies from 2001 to 2008 presented in this paper reaffirm previous studies highlighting the female minority in this profession. In fact, engineering has the lowest proportion of female enrolments (combined undergraduate and postgraduate positions) of any field of education in Australia, followed by Information Technology and Architecture and Building (20% and 41% in 2009) (Department of Education Employment and Workplace Relations, 2009).

While there has been a slight increase in the commencement and completions of engineering studies by female students driven by increases in female students from overseas and enrolment into postgraduate research degrees, the rate of increase is glacial and the overall proportion of female engineering students borders on token (Kanter, 1977). Of particular concern is the decrease in the proportion of women enrolled in undergraduate courses and the decrease in actual number of domestic women enrolling and completing undergraduate engineering courses. Graduates from Bachelor and other undergraduate degrees are the feedstock for the Australia's engineering labour market and declining numbers at this point of the supply chain will not serve to increase the participation of women in the profession as a whole.

The observation of the increase in participation in engineering courses by female overseas students and the decrease in the proportion of domestic female engineering students has not been addressed in the published women in engineering literature. Several questions stem from this observation: why are female students from overseas enrolling in and completing engineering qualification in higher proportions than domestic women? What can we learn from them? What are the implications of this trend on the engineering labour market in Australia? What do we know about potential domestic female engineering students and the gender data for mathematics and science subjects, which lead into engineering? What is their knowledge of potential female engineers on the engineering study pathways and what is their understanding of the engineering profession?

Distinct differences between females in the comparison group to females with engineering qualifications in terms of uptake of part-time work exist as well as a higher

percentage of engineering women not in the labour force during childbearing years is notable. This aligns with findings in survey based work (such as (Mills et al., 2008, Mills et al., 2006, Roberts and Ayre, 2002)) about the culture and structure of engineering work presenting challenges to women in the engineering profession. It also interesting to note, that the number of children born per female with engineering qualifications is 0.56 as opposed to 0.61 for a female in the comparison group. These findings suggest that research and interventions should be focused on retaining women in the workforce around and post-childbearing age and increasing availability of part-time work for engineering women.

The statistics presented on average income for members of the engineering labour force make evident a gender pay gap. Women earn less than men in both full-time and part-time employment. This is concurrent with data from APESMA's 2010 Professional Engineer Remuneration Survey, which showed that from the beginning of their careers, women engineers typically earn less than men of equivalent experience (Association of Professional Engineers Scientist and Managers Australia, 2010).

The APESMA survey also highlighted the awareness and concern that women engineers have about pay inequality in their profession. Respondents were asked to nominate three issues that they would like to see addressed by government and industry. Equal pay was a top priority, following flexible work arrangements and work/life balance.

Gender segregation of the engineering workforce exists, with disparate proportions of female engineers employed across industry groups. Women with engineering qualifications cluster in sectors such as health care & social, accommodation and food, and retail trade, while a more marked absence of women is observed in Construction and Mining – two sectors which have prominence in the Australian economy and are highly paid. The pay inequity observed in the Engineers Australia and APESMA data discussed above may be partly explained by this distribution of women across industry sectors in Australia.

The choice of employment in the Australian resources and construction sectors is the subject of recent research (Chamber of Minerals and Energy, 2008, Minerals Council of Australia and Australian Government Office for Women, 2007). Factors impacting women's engagement in these sectors include low levels of part-time work, a culture of overwork, long hours that is incompatible with non-work responsibilities and the remote nature of work in the industry sector. Initiatives by the Australian Government and groups such as the Minerals Council of Australia indicate that the industry recognizes the business imperative of increasing the participation of women in their sectors.

CONCLUSIONS

This paper has presented gender specific statistics on women's participation in engineering education and workforce in Australia. Low increases in female commencements, enrolments and completions of engineering studies from 2001 to 2008, a 9.8% female participation in 2006 in the engineering labour force, low uptake in part-time work by females with engineering qualifications, and a prominent gender pay gap highlight issues which need to be addressed and monitored through a regular update on these statistics.

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PROVIDING A GENDER BALANCED WORKPLACE – IT’S NOT JUST A NUMBERS GAME

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ABSTRACT

All large organisations have policies to provide equal opportunities to women in the workplace, but my aim is to take it one step further and provide a gender balanced workplace.

My vision of a gender balanced workplace has equal (or close to it) numbers of men and women in the workplace. More than that, it is a workplace where all things are gender neutral, or balanced.

This paper will discuss the moves I am taking within Opus International Consultants to provide a gender balanced workplace, and it’s not just a numbers game. Providing a gender balanced workplace is covered in two main areas:

1. Improving the ratio of women to men
2. Shifting the work culture

The first area, improving the female to male ratio, has two key components:

1. Recruitment – attracting more women into engineering and the organisation; changing the stereotype of the engineer; deliberate targeting to prospective female employees
2. Retention –retaining women in the organisation; providing structured network groups for women; mentoring for young women engineers; providing tailored professional development for women in engineering and leadership.

The second area, shifting the work culture, requires change in some key areas of work practices. Often minimal change to some key practices can effect strong change in the work environment. It means celebrating the gender differences, and empowering women in the workplace so they can implement change.

This paper details my vision for the future and what I am currently doing to improve the gender balance in my workplace.

INTRODUCTION

I work as a female civil engineer, so have come to accept that I am part of a minority group in my workplace. On the whole this does not impede the delivery of my work. However, there are specific challenges that arise from working in an environment with a strong gender imbalance. The gender imbalance is due to the high ratio of men to women in my workplace, but it is also attributed to the strong male culture in my workplace.

Providing a gender balanced workplace has benefits to the organisation, the individual and to the profession as a whole. The first step in providing a gender balanced workplace is to identify the degree of gender bias that currently exists. The next step is to incite a desire for change.

A GENDER BALANCED WORKPLACE

What is a Gender Balanced Workplace?

A gender balanced workplace consists of equal, or close to it, numbers of men and women. However, the ratio of men to women is not always the primary influence of gender imbalance. The culture in the workplace can equally impact on the gender balance; whether this culture is male dominated (as in engineering) or balanced.

Gender Imbalance in the Engineering Workplace

Engineering, and in particular civil engineering, has always been a male dominated arena. In 1980 only 3.3% of students studying engineering in Australia were female. Over the past 25 years the number of women studying engineering has increased, but it has not risen over 18% in Australia (Hobart et al, 2006). In New Zealand 17% of graduates completing engineering degrees in 2008 were female, falling from a peak of 23% in 2002 (<<http://www.educationcounts.govt.nz>>).

Opus Statistics

Opus International Consultants Limited (Opus) is an international multi-disciplinary consultancy. The company has approximately 2300 staff in offices and laboratories throughout Australia, Canada, the United Kingdom and New Zealand. Opus began in NZ as a state owned department, and still is predominately located in NZ. Opus' main areas of work remains around civil engineering, and providing professional services to clients.

In Opus in New Zealand the staff comprises 24% women. This includes both technical and non-technical staff. When the non-technical staff are removed from this figure, the percentage of technical women employed in Opus (NZ) falls to 15%. The percentage of female engineers in the company is even less. This figure is in line with national and international figures which indicate a range of 10 - 15% of the engineering workforce are women. Therefore 85 – 90% of engineers in the current workforce are male.

Professional Institute's Statistics

IPENZ (Institute of Professional Engineers New Zealand) advised that 12% of their membership base is female, up from 11% in 2009 (IPENZ were not able to produce any further information on age distribution or historical data to provide trends).

Engineers Australia (EA) published statistics show an increase in female members from 6% in 2000 to 10% in 2010 (<<http://www.engineersaustralia.org.au>>).

Academic Trends

Over the past 25 years the number of women studying engineering in Australia has increased from 3.3% (in 1980) to 17.4% (in 2005). The number steadily rose to 15.8% in 2001, but since then has remained relatively static (Hobart et al, 2006). The number of women studying engineering in New Zealand indicates similar percentages, with women making up 17% of engineering graduates in 2008 (<<http://www.educationcounts.govt.nz>>).

The percentage of women studying engineering in Australia has plateaued since 2005, with no significant growth in the past five years (Hobart et al, 2006). The New Zealand Department of Education statistics show a declining trend in New Zealand, with a fall from 23% of graduates in 2002 being female, to 17% in 2002 (<<http://www.educationcounts.govt.nz>>).

The Benefits of a Gender Balanced Workplace

There are a number of very strong and recognised benefits of having a gender balanced workplace. If there is gender diversity in the workplace, it follows that innovation will increase. It is well documented that in general, men and women differ in their approaches to problem solving. These varying approaches create a balance that can enable better decision making to take place. It is well known that there is often more than one way to solve a problem, and by having diversity in the workplace (gender diversity included) the variety of problem solving techniques increases, as does innovation.

There are social benefits from providing a gender balanced workplace. Gender diversity in the workplace can provide a better work environment as women and men bring differing social skills to the workplace.

Providing a gender balanced workplace is not always about the numbers. Providing a workplace that removes the gender stereotypes and barriers between men and women can have similar benefits to a business with balanced numbers of women and men. Where women are the minority in number, but do not work in a male dominated culture, they are more likely to feel comfortable expressing themselves, increasing the perception of balance in the workplace.

IMPROVING THE RATIO

One way of improving the gender balance in engineering is to increase the number of women in the profession. In order to improve the ratio in the workplace there needs to be more women in the available labour pool for employers to choose from. This requires an increase in the number of women studying engineering. Secondly the

women who enter the field need to stay in the field. Therefore the two key areas of focus for improving the numbers in the balance are recruitment and retention.

Recruitment

Recruitment covers both the initial decision to enter the field of engineering; into the academic institutes, then the engagement into the workplace.

In the past 15 years the academic institutes in New Zealand and Australia have worked hard to increase the numbers of women entering engineering. They recognised the under-representation of women in the field long before industry began to show concern. The number of women in other previously male dominated fields such as medicine and law was significantly increasing in the 1980's, but the number of women studying engineering did not grow to the same extent. Women are now well represented in many fields, except engineering.

The percentage of women studying engineering has now plateaued, despite considerable efforts by university faculties to attract more women into their institutes. I believe this indicates that it is now the duty of industry to identify ways to reignite the growth in these figures.

Retention

Studies show a higher rate of women leave engineering in the first 10 years of practicing than in other professions (Hunt, 2010; Kiviat, 2010). These are women that leave engineering for alternative work, not women who choose to leave the workforce.

Industry needs to identify the reason for this loss of female engineers, and further investigation into this area is required. The surveys I was able to access were completed by women still in the industry, so the reasons behind the higher than normal attrition rate are not well documented.

In my personal experience there are a number of issues that women specifically face in the engineering field due predominately to the fact that they are the minority. Working as a minority means that the workplace culture is male dominated (as discussed later), but it also means that there is a lack of female role models to aspire to. There is also a lack of female network groups.

I found that my network groups at work were very male dominated, which made me behave differently. My social network groups were more female dominated, but I found these women who were great friends and support, were not technical. I lacked a network where I could express my female side as well as my technical side.

During my career I have had very few female role models, and until recently I have also had little opportunity to be a role model for other women. These facets of every person's work life are important; we need to be able to celebrate our own success, as well as benchmark our success against others.

Furthermore, women need to have access to a range of female colleagues. Often it is the high achieving women that are showcased, and young female engineers (or high school students contemplating engineering as a career) may feel that they need to be outstanding in their field to be successful in engineering. Women need to have access to everyday female engineers, as well as the highly successful women.

SHIFTING THE WORK CULTURE

Background

In my career I have worked as a civil engineer in construction, Local Authority, and consultancy. These workplaces have all had a male dominated culture, to varying degrees. I found that the Local Authority environment, where the ratio of women is higher (even though the number of female engineers is still low) tend to have less of a male dominated culture. The construction industry, however, has a high dominance of men in the entire workforce, and demonstrates a strong male dominated culture.

Male Dominated Culture

Work hours

Jacqueline Watts (Watts, 2009) discusses the long work hour culture apparent in engineering, specifically in the construction industry. She talks about the “presenteeism” culture of the industry, where workers are available to work when, where and for as long as is required to get the job done. Watts says that this level of professional commitment “has at its core the prioritisation of work as the norm, as a way of life, with other personal and family interests having to fit around this corporate ethos” (Watts 2009:40). This concept is underpinned by the assumption that the professional has unlimited hours in the day to dedicate to his/her job. Watts argues that “this is a gendered assumption rooted in idealized images of masculinity” (Watts 2009:40). Watts goes on to write that men and women may both want to prioritise work over childcare responsibilities, but women feel the pressures from society to spend more time with their children. This may portray them as less committed to their work than their male colleagues.

Women may decline advancement because of what is expected of them in higher roles. If they feel that the promotion will require an increase in dedication, or “presenteeism”, they may avoid or defer advancement until later in their career when they outgrow the responsibilities of childcare.

The IPENZ remuneration survey in 2009 showed that men and women were on similar remuneration packets up to the 36-40 years age bracket; after that there is a significant difference between men’s and women’s remuneration, to the tune of over \$20,000 per year. This pay gap may be due to women not being promoted in the workplace, either by their reluctance to pursue these promotions, or other external factors.

A male manager may unknowingly overlook a female employee for promotion if he feels that “she already has too much on her plate” when raising a young family. The same assumption of time commitments for a male colleague parenting young children may not be rendered. This is tied to society’s expectation that the mother will carry the majority of responsibility for childcare.

Significance of Technical Aspects of Engineering

Lesley Jolly in her paper entitled “Women, Men and the Practice of Engineering” introduces the concept of “real engineering”. Engineers place higher prestige on the highly technical and heroic side of engineering, where the co-ordination and management tasks are downplayed and seen to have less professional significance (Jolly, 2007).

Women tend to be stereotyped as being more nurturing, caring and relational, and therefore more competent in the less technical areas of engineering; areas that hold less

value. Although we know that these qualities are evident in men and women, the value of these skills, whether in a man or a woman, are undervalued when there is such a high emphasis on the technical and “tough” side of engineering.

I recently had a conversation with a male colleague about another male colleague. He was undermining the ability of his male counterpart (who is a very professional, but not highly technical, manager). His comment was “I bet he’s never built a thing in his life.” This illustrates the significance of practical experience held by engineers.

Jolly suggests we look more holistically at the engineering practice, and start focussing the gender discussions on “practices” rather than women (Jolly, 2007).

General Workplace Culture

In a male dominated profession such as engineering, the language (written and spoken) is very male orientated. Engineers are often referred to as “he” in documents and presentations.

I have found that there is an expectation to show strength and assertiveness in the workplace. These attributes are well recognised and rewarded. I know a fellow graduate engineer who had his first placement in a bridge maintenance team. He was ridiculed when he showed a fear of heights, and was told to “get over it, and get on with the job”. This illustrates how showing fear in the engineering environment is seen as a weakness, and in this instance was not tolerated.

In general the workplace activities are based around male dominated activities; the clients are invited to golf days and to rugby matches. There is a strong pub culture, and workers are expected to entertain clients outside of work hours. Although these activities can be well supported and enjoyed by women as much as men, there is a strong expectation for both sexes to conform to this culture, which can be restricting for some men and some women.

Another example of male domination in the engineering industry is the work wear design and sizing. On corporate outings I am often supplied with a men’s polo shirt to wear. I started my career with a construction company and I was required to wear safety boots. It was impossible at that time to find any boots in small sizes, let alone in a woman’s fit. Fortunately this is one area which has vastly improved.

The spouse’s programmes at engineering conferences invariably include garden tours, cooking classes, wine tours, shopping and art gallery visits. The activities are targeted to the female spouse’s of the men (who are expected to be the majority of the attendees).

How other non-technical women in the office are treated can also illustrate how diverse the workplace culture is. At one of my early workplaces it was expected that the female office staff would clean the communal kitchen. It didn’t take me long to suggest to management that since we all used the kitchen, we should implement a roster system for its cleaning. Often the others in the office are unaware of the gender bias in the office, and will be willing to change when it’s suggested. Analysing how all the female employees in the office are treated (technical and non-technical staff) can start to indicate the level of gender bias (or gender equality) in a workplace.

MY PROPOSAL

Current Initiatives

As an experienced female engineer in my workplace, I have identified that there is a lot that I can do to provide support for my female colleagues. I am a strong role model to the few women in my office, but other women in the company lack these role models. I am taking every opportunity to give the women at Opus access to role models (and the opportunity to be role models), and to have the chance to network with other female engineers. This will counter the feeling of isolation from working in a gender imbalanced workplace, and will improve the retention of women in our profession.

Workshops

In November 2010 I ran my first pilot workshop for Opus Women in Leadership (OWL). This workshop was a half day workshop which was targeted at women in Opus that were in leadership roles, or had leadership potential. Due to the nature of our work, the group of 12 women included 11 engineers.

The workshop included leadership training facilitated by an experienced personal development coach and leadership training facilitator. The leadership training provided the purpose for the workshop, but the real benefits were in developing network groups, and in starting to ensure these women feel less isolated in their workplace.

The workshop was attended by a range of women from new graduate level to highly experienced professional engineers.

My objective is to hold these workshops four times a year, with them being attended by the same group of 12 women. I then want these workshops to be offered to all technical women in Opus.

Mentoring

Opus has a very strong mentoring system where graduate engineers are appointed a qualified mentor to assist them to achieve Chartered Professional Engineer status. This programme works well, and is well supported. To compliment this programme I am setting up a mentor programme for female graduates to provide them access to a senior female engineer. This may be the same person as their professional mentor, or it may be the introduction of a secondary mentor. The purpose of this mentor is to provide the female graduate with another perspective, and to give her access to someone who can provide their own experiences regarding questions around family and issues particular to women.

Change the Stereotype

In general the stereotypical civil engineer is a middle aged conservative man. Changing this stereotype is pivotal in recruiting more women into engineering. To start to change this stereotype I take any opportunity to raise my profile in the workplace and the community. I also encourage other women in the company to attend community based programmes, and to join campaigns such as Future-InTech and Neighbourhood Engineers. I encourage any female engineers I know to join IPENZ, and to attend their meetings and seminars.

I ensure that any public events attended to by Opus staff members include representation by a female engineer. These engagements range from careers days at the local school to community events and open days.

Recruitment

There are still low numbers of women entering the engineering field. In 2008 I embarked on a programme to increase the recruitment of females in engineering. I visited a number of girl's schools in Auckland and in Christchurch, and specifically presented to these young women, showcasing engineering as a career.

I have a standing spot at the careers night at our local high school which I have attended for the past four years. I ensure that the engineers attending this evening are a mix of male and female.

I am passionate about my work, and I ensure that I take every opportunity to showcase engineering as a career. I especially encourage any young women I meet to consider engineering as a career, and I speak keenly and enthusiastically about my own career.

On one occasion I had a father talk to me about engineering as a career option for his school age son. During our discussion I discovered he also had a daughter of much the same age, and I convinced him to send his daughter to talk to me. As a result of that conversation his daughter is now an up and coming engineer at Opus!

Future Initiatives

The work I am doing is just the beginning. There is much more work to be done to start to improve the gender balance in our workplace.

It is obvious from my personal experience, and from the literature I have read, that the workplaces of engineers are still dominated by males, both in numbers and in culture. This appears to depend on the industry, with the male dominated culture being more prevalent in the construction industry than in Local Authorities. I work for an Engineering Consultancy (though have worked for a construction company and a Local Authority in the past), and I feel that this lies somewhere in the middle. The gender bias of the workplace culture is somewhat dependant on the overall percentage of women in the workplace, and not just influenced by the number of female engineers.

Changing the Work Culture

Changing the work culture will be a slow process, but it has to start somewhere. I have identified a number of steps in this process, which I am initiating.

The first step is to identify the current practices in our workplace that are inherently male dominated. This covers the areas of language, work life balance, "presenteeism", and expectations based on gender.

The second step in this process is to get a commitment from management that a change in these areas is desirable. This is followed by the implementation of change.

In general, women won't trail-blaze these changes. Women will generally accept the work culture, and either "put up with it" or leave. Unfortunately there are a number who leave. Women will generally not want to "rock the boat", or to attract special attention. Asking for help, or change in these areas, may make them feel like they are

admitting defeat, or showing weakness. Or, like me, it may make them feel that they are admitting their mother was right after all, and engineering's no place for women!

Management in the organisation cannot expect women to drive these changes, and they also cannot assume that issues don't exist just because women don't complain. In order for change to be implemented, these changes need to be championed by the senior males in the workplace, as well as the senior females. My challenge is to co-ordinate this change.

Future Vision

With the support of the industry, academic institutes will soon be able to again see an increase in their numbers of women in engineering. These women will work in an environment which is much more gender balanced, by culture to start, but soon by number. They will feel like they belong; they will have strong network groups and role models. The success of the female engineer will be showcased, and celebrated.

The stereotypical engineer will no longer be a middle aged male; people will not raise their eyebrows when a female replies "I'm an engineer" to the age old question "What do you do?" The non-technical side of engineering will carry as much prestige and acknowledgement as the technical side of engineering. "Real engineering" will cover much more than building things!

Changing the gender balance in the engineering profession is a slow but steady process. Over time the number of women in the profession will improve. In the meantime there are many areas of our workplace that can be improved so that even while the numbers show a male dominated workplace, the culture is gender neutral.

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TODAY'S RELEVANCE OF FEMINIST THEORY AND GENDER INCLUSIVE ENGINEERING CURRICULA TO HELP STUDENTS OVERCOME THRESHOLDS IN ENGINEERING EDUCATION

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ABSTRACT

Recommendations to improve gender inclusivity of engineering curricula have existed for well over a decade in Australia. Particularly in response to the Johnson review of engineering education (1996), cultures in engineering faculties have improved (Mills 2010). This paper asks whether feminist literature in the field of engineering education can contribute to curriculum development in 2011.

The paper has two parts. The theoretical framework for the first part has been adapted from threshold concept theory. This theory recognises that any discipline has concepts that are transformational for students, critical to students' progress and yet troublesome for many students. The theory can be used to focus students' and teachers' attention on critical concepts in a curriculum.

The first part of the paper focuses on a small sample of a new curriculum development process at The University of Western Australia. Three thresholds identified by participants in two workshops are selected for discussion.

The second part of the paper presents an alternative, yet complementary perspective from feminist and engineering education literature. This literature has also identified these same threshold areas as troublesome for female students, and furthermore, contributes a possible explanation for and recommendation to address one of the thresholds.

The consistencies support the conclusion that long-standing recommendations for gender inclusive engineering education are likely to help many students, not only women. These examples provide incentive for continued improvement of engineering education programs, as recommended for gender inclusivity, and using approaches that are integrated with feminist theories and experience in the field of gender inclusivity in engineering education.

INTRODUCTION

Engineering education has evolved in the last two decades, from curricula honed around engineering science, to broader curricula. As recommended by the Johnson review of engineering education in Australia (1996), accredited engineering programs in Australia must now demonstrate that graduates have developed graduate attributes that include communication skills, leadership, and concern for the environment and society. Initiatives have been taken specifically to improve the gender inclusivity of engineering programs. Guides to achieve this have included recommendations to teach concepts

within contexts, consider society and the environment, and promote teamwork. Progress has been made, although more is needed (Mills 2010).

The University of Western Australia (UWA) is designing a new engineering curriculum for 2012, using current higher education theories as part of the approach. This study asks whether feminist literature on engineering education, including long-standing recommendations to improve gender inclusivity in engineering education, can contribute.

One of the major higher education theories we are applying is threshold concept theory. Approaching engineering curriculum development using this theory has helped us to focus on concepts that are critical to students' progress, transformative for students, and yet troublesome for many students. This paper combines this approach to curriculum design with a reflection on literature on gender in engineering and gender in engineering education.

The first part of the paper focuses on our approach to curriculum design using threshold concept theory, which is introduced in the next section. Our application of the theory to curriculum development is then outlined. Two workshops are reported and three threshold concepts identified and investigated by participants are described.

In the second part of the paper I reflect on the identified threshold concepts using literature on gender in engineering education. This reveals that there are consistencies between thresholds identified using thresholds concept theory and thresholds identified in feminist literature. Furthermore, the feminist literature in engineering education provides a possible explanation and recommendation for addressing one of the issues identified using threshold concept theory.

THRESHOLD CONCEPT THEORY

Threshold concept theory is a major theory in higher education. The theory states that within any discipline there are concepts that are critical to students' progress, transformative for students, and yet troublesome for many students (Meyer and Land 2003). Perkins (1999: 8-10) has described some ways in which knowledge can be troublesome. Troublesome knowledge can be *inert* (abstract, unconnected), *ritual* (routine rather than meaningful), *conceptually difficult*, or *foreign* (inconsistent with a student's former understanding).

Teaching, learning, and assessment in a discipline can be focused and improved by identifying the threshold concepts, and investigating how these concepts are transformative and troublesome for students (Cousin 2006). By identifying factors that make a concept troublesome, it is possible to design initiatives to help students overcome barriers to their learning.

THE ENGINEERING THRESHOLDS PROJECT

UWA is leading a research collaboration with Oxford and Birmingham Universities, to identify and investigate threshold concepts in foundation engineering programs. This is the first study of threshold concepts across all disciplines of foundation engineering programs. The research will help develop UWA's new engineering curriculum.

We are using interviews, focus groups and workshops with engineering educators and students at UWA to identify and investigate possible threshold concepts. Engineering educators are negotiating, extending, and further investigating these concepts, in workshops across Australia and internationally.

This paper focuses on possible threshold concepts identified in a series of two workshops: a student workshop and a consequent student-staff workshop.

THE WORKSHOPS

Student Workshop

In second semester 2010 a student workshop was held at UWA. The purpose was to identify and investigate concepts perceived as thresholds by engineering students.

Students were recruited through the education committee of the university's student engineers' club (UEC). Thirteen students (seven female) participated. Most were from senior undergraduate years. Their disciplines included computer science, chemical engineering, civil engineering, environmental engineering, mechatronic engineering and mechanical engineering.

Structure

- The facilitator introduced the project and threshold concept theory. The students worked in groups of two to four students from related disciplines. One group was designated as interdisciplinary.
- The students individually identified threshold concepts they had experienced or noticed other students experience.
- Each group consequently reduced their ideas to a smaller number of main possible threshold concepts.
- Each group selected one or two main concepts on which to focus and discussed these in detail, answering the questions below.
 1. What is the engineering threshold concept?
 2. How is the threshold concept transformative? (e.g. What is the change in thinking or perceiving that occurs as a student gains understanding of the threshold concept? Perhaps you can identify levels of understanding that a student undergoes while gaining understanding of the threshold concept.)
 3. What makes the threshold concept difficult? (e.g. misconceptions, features of the concept and features of opportunities for developing understanding of the concept within the engineering course)
 4. How could we reduce/remove barriers to help students understand the threshold concept?

Student-Staff Workshop

A student-staff workshop was held a month later, with two purposes. First, to further investigate thresholds identified in the first workshop, especially how to help students overcome the thresholds. Second, to give academics the opportunity to hear students' views first hand to help their current teaching and development of the new curriculum.

Students who had attended the student workshop were invited. All 135 academics in our faculty were also invited by email. Seven students (four female) and eight academics (three female) attended from various disciplines (Tab.1).

Tab.1: Disciplines of participants in student-staff workshop

School	Student Participants	Academic Participants
Civil and Resource Engineering	1 civil, 2 mining	
Computer Science and Software Engineering	1	3
Environmental Systems Engineering		1
Mathematics and Statistics		1
Mechanical and Chemical Engineering	3 mechanical	3

Structure

The facilitator introduced the project and the theory, and listed possible threshold concepts identified in the first workshop and by staff on other occasions.

As advised by email beforehand, the students were invited to each speak about a concept they had discussed in the student workshop. Academics and students selected concepts from these to discuss in small groups, each including at least one academic and one student.

Each group completed a handout on the threshold concept. The handout asked the same questions as listed previously for the student workshop.

Data Collection and Analysis

Parts of the discussions were audio recorded with consent. Responses written on the handouts were collected, and the facilitator recorded notes during the workshops. Participants' ideas about possible engineering thresholds were summarised from these.

The identification and investigation of engineering thresholds is a large ongoing project. The thresholds concepts identified by participants in these workshops are viewed as potential engineering thresholds. They are working models and continue to be further developed as more data are collected. They will also be negotiated in workshops with engineering academics nationally and internationally.

POTENTIAL THRESHOLDS IDENTIFIED IN THE WORKSHOPS

Participants in the student workshop identified nineteen threshold concepts. Most were technical. Examples were stress and strain and the Laplace Transform. Non-technical examples were referencing, and that engineering solutions depend on considerations that are broader than engineering science. Four of the threshold concepts were discussed further between students and staff in the second workshop. These four were (1) Mathematical concepts: moving between reality and models, (2) Communication of ideas, (3) Computing and (4) Scaling / dimensional analysis / order of magnitude estimates and up-scaling.

The thresholds are not necessarily "concepts" in the narrow sense of the word. An adapted theory has been developed that is more compatible with this reality (Baillie, Bowden et al. forthcoming). To accommodate this issue, I often refer to "thresholds" rather than "threshold concepts". This study focuses on the first three of the above four thresholds. Features of the thresholds, as suggested by workshop participants, are now described.

Mathematical concepts: moving between reality and models

The Threshold

The students discussed the difficulty of visualising the reality of a concept presented mathematically. An example was the difficulty of visualising multivariable shapes or systems such as tangent planes. This threshold was also part of the fourth threshold: scaling / dimensional analysis / order of magnitude estimates. Student and staff participants discussing the fourth threshold drew Fig.1, noting that their threshold requires that the process in Fig.1 is well-practised.

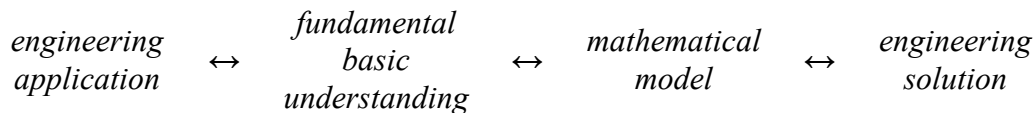


Fig.1 Process shown as important by participants discussing scaling / dimensional analysis/ order of magnitude estimates/ up-scaling

Moving between mathematical models, or other models, and visualisation of reality is a threshold that has been identified in specific cases by others. For example, Cartensen and Bernhard (2008) developed a similar model of concept-learning by observing students performing laboratory sessions using Laplace Transforms. They identified thresholds for some students understanding application of the analysis to the experiment, and for other students understanding the experiment from the analysis.

How it is Troublesome

Students and academics reported that it can be difficult to visualise a concept from a mathematical model, especially with more than three dimensions.

Participants' Recommendations

1. The participants recommended deferring the mathematical representation until after explaining and demonstrating shapes and systems so that students can visualise them.
2. Students also recommended indicating the engineering application of mathematical concepts at the time each mathematical concept is introduced.

The second suggestion has been adopted for the new curriculum. Where possible, slides showing engineering applications will be used to demonstrate the future relevance for students. Engineering students will also have mathematics tutorials using engineering examples. Other universities have seen the need for similar integration of mathematics and engineering applications. Similar initiatives have been introduced to help students understand threshold concepts at the University of Edinburgh (Hirst, Williamson et al. 2004) and the University of Southern Queensland (Wandel 2010).

Communication of Ideas

The Threshold

This threshold is how a student can help others understand his or her ideas. This includes explanations in written reports, one-to-one interactions, and oral presentations. A student in the student-staff workshop discussed a first year unit in which students presented their ideas to other students and wrote reports. He had noticed that students were not good at helping others understand their ideas. They were not good at explaining what they had done, why they had done it that way, and how another student could work with it. This also applied to pieces of computer programming.

I found that you work in groups and someone's working on a piece of code, but, they just give it to you, and you're like, hah, OK. You've got to really research it and find what they've been thinking rather than, if there were skills out there already, about this is how I've done it and this is what I've done and really force that into students then it would be a lot easier.

(male student participant, student-staff workshop, 12 October 2010)

How it is Troublesome

There was agreement among the student participants that most students did not see the importance of communication to engineering. This was a reason they did not communicate well in their courses. They did not understand the purpose of the exercise.

I was just actually going to say something. I think that students tend not to understand that communication is actually a big part of engineering... I've grown up around engineering so I know what it is. I mean I've listened to Perth car trips with my Dad on the phone to clients the whole *whole* car trip.

(female student participant, student-staff workshop, 12 October 2010)

Participants' Recommendations

1. Students recommended a stronger focus on communication in the course. They recommended helping students understand that communication is important, from the first lecture in first year.
2. Participants recommended emphasising the importance of teaching as a learning tool. Students need to understand that it will help them if they talk about the engineering they are learning with their peers.

Computing

The Threshold

Identifying the threshold concept was not simple. Students reported their first year computing unit to be troublesome. Students and staff members agreed that students need to understand that learning to program is not about learning every statement and every command. Rather, it is about learning the kinds of commands.

How it is Troublesome

The problems or barriers were about the assumed computer knowledge and the problem that students are asked to learn new computing concepts in conjunction with new technical concepts.

Participants' Recommendations

1. Participants in the student workshop expressed a desire for introductory computing, that assumed no background knowledge, to be offered to all students.
2. Participants in the student staff workshop suggested that the technical context of problems they are asked to solve using programming should rely on school-level science rather than university-level engineering science.

This illustrates the need to space threshold concepts in curricula.

CAN FEMINIST LITERATURE AND GENDER STUDIES IN ENGINEERING EDUCATION CONTRIBUTE TO UNDERSTANDING AND ADDRESSING THESE POSSIBLE THRESHOLDS?

Mathematical concepts: moving between reality and models

Feminist researchers have claimed that male-dominated engineering professions and engineering faculties honed engineering as a discipline focusing on abstract knowledge (Hacker 1981; Beder 1998). For at least 16 years in Australia, it has been recommended that engineering educators must present concepts in context, rather than abstractly, to improve gender inclusivity (Moxham and Roberts 1995; Roberts and Lewis 1996; Mills, Ayre et al. 2010). This is consistent with the recommendation made by the students in the workshops, to introduce mathematical concepts with indications of their engineering applications. The study reveals that this recommendation could help not only female students, but also male students.

Another related initiative, that has been introduced elsewhere to help female engineering students, is designed to address under-developed spatial visualisation skills. For more than a decade it has been recognised that spatial visualisation skills help engineering students to succeed (Sorby and Baartmans 2000). However these skills can be improved with practice. Offering spatial visualisation courses to first year engineering students has been found to help improve their success. Women are generally more likely to have poor spatial visualisation skills. Therefore initiatives to address this problem could be viewed as initiatives to improve the retention of female engineering students. In our study using threshold concept theory, male and female students, and male and female academics, raised visualisation of concepts as troublesome. Spatial visualisation courses are another example of an initiative that, although possibly designed to help female engineering students, helps many.

Communication of Ideas

Communication has not been given the necessary prominence in engineering education because it has not been seen as important (Williams 1988; Florman 1997; Trevelyan 2008). Just as Hacker and Beder and others described the masculine nature of the engineering profession and engineering education as giving status to abstract knowledge, conversely, they argued that masculinity marginalised practices related to caring for people or mothering. There are multiple studies supporting this suggestion. Acker (1990) developed a theory of gendered organization that explains that in an organization with a dominant gender, the culture reinforces a gendered hierarchy that favours all features of the dominant gender as ideal and features of the other gender as other than ideal. Adapting Acker's theory, in engineering, the dominance of the masculine gender can be expected to marginalise stereotypically motherhood characteristics as other than ideal for engineering. Fletcher found in an engineering design consultancy, that relational practice such as communication and teamwork was invisible. Although it was critical to the success of projects, neither women nor men noticed that it was being performed or that it was important. In study of mine, senior engineers, in an Australian survey on the importance of competencies to engineering work, under-rated stereotypically feminine competencies (Male, Bush et al. 2009). A body of work by Faulkner also supports the suggestion that a masculine culture in engineering has marginalised communication. Faulkner (2007) found that engineers saw technical engineering as engineering and people-related work as not engineering.

The studies noted above refer to communication as marginalised in engineering due to a masculine culture. Workshop participants expressed concern that students were not aware of the importance of communication to engineering. Education environments have been thought to reinforce cultures (Ihsen 2005) and features of masculine cultures have been found in engineering faculties (Godfrey 2003; Tonso 2007). Burack and Franks (2004) describe how maintaining the hierarchical status of hard above soft skills in engineering culture is one of the ways members of the masculine in-group among engineering students and academics confirm their status as apparently rightful members of engineering.

Therefore, literature on gender in engineering is consistent with the workshop participants' suggestion that many students do not understand the importance of communication in engineering. Furthermore, the feminist literature offers the explanation that this could be a cultural problem. This implies that cultural change in engineering faculties could help address the problem. This is consistent with views of engineering educators (Johnson 1996; Green 2001). Indeed the gradual cultural change in engineering education could be linked to a perception of improvement of graduates' communication skills over the years (Caldwell, Johnson et al. 1994; King 2008). The awareness of workshop participants suggests movement towards the necessary cultural change. By integrating threshold concept theory and feminist theories, I therefore conclude that addressing the masculine culture within engineering faculties is likely to help more engineering students accept that communication is an important part of engineering and therefore make the threshold of communicating ideas less foreign.

Rennie (2005) states that any education should teach students about the myths associated with their discipline. I suggest that it would help students to understand the theories about dominant masculine cultures in engineering faculties, in order to understand that the discipline is not value-free, and understand how communication and teamwork have mistakenly been marginalised as other than engineering. Integrating feminist and threshold concept theories, it becomes apparent that the suggestion that engineering education is shaped by masculinity would be troublesome for many engineering students because it is a foreign concept. Engineering students have been found to perceive engineering solutions to be gender-free (Godfrey and Parker 2010). Kelly (2010: 116) has taught concepts of cultural, gender and generational diversity to first year engineering students and describes a necessarily transformative pedagogy. Threshold concept theory predicts that many students take a considerable time to understand troublesome, transformative concepts. It can be expected that understanding the concept that engineering has been influenced by masculine culture will require several years for some students, and many will never accept it.

Computing

Discrepancies in prior computing experience were noted by the students in the workshops. Feminist literature has long recognised this, although it has been seen as a gendered issue. For example, Burrowes (2001) identified previous experiences as a factor linked to differences between the experiences of female and male students in an engineering class. Gender inclusive recommendations have included introductory computing assistance, and are therefore consistent with the students' recommendations in the engineering thresholds workshops. This study suggests that this assistance could benefit engineering students more generally.

CONCLUSIONS AND RECOMMENDATIONS

In this study, students revealed potential engineering thresholds – critical hurdles they experience as troublesome in their engineering courses. Literature on gender inclusive engineering education and feminist literature provided possible causes of these thresholds, and potential approaches to addressing the thresholds. Hence, this study has demonstrated that the knowledge developed during decades of commitment to improving gender inclusivity of engineering education has much to contribute to current commitments to engineering curriculum development more generally.

This study also found that initiatives previously undertaken to improve gender inclusivity are likely to be relevant more generally, helping both male and female students to overcome thresholds. It may be that thresholds which have been identified as troublesome to women are in fact troublesome to a much wider group. Many initiatives to improve inclusivity of engineering courses are offered to all students in order to remove any stigma attached to participating and hence improve student engagement. This study provides further justification for offering support to all students, rather than a minority group only.

In conclusion, findings of this study provide incentives for integration of feminist theories and experience with other higher education theories when designing curriculum enhancements. Findings also provide incentives for continued improvement of engineering education programs as recommended for gender inclusivity.

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WHY DO GIRLS CHOOSE ENGINEERING? A COMPARISON OF STUDENTS IN CIVIL, ENVIRONMENTAL AND CHEMICAL ENGINEERING

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ABSTRACT

A large number of initiatives have been implemented to increase the number of girls starting engineering programs, but while a few have initially increased the numbers, none have delivered lasting results. This indicates there is a poor understanding of what attracts women to engineering. Among engineering disciplines, two consistently attract more girls: chemical and environmental engineering typically has 20 to 40% girls, compared to civil engineering with 5 to 10% girls. Despite this there have been no studies on what influences girls to select their discipline of engineering.

This paper aims to evaluate what influences female students when selecting engineering as a university program and the particular discipline of engineering. Female engineering students from each discipline in the School of Civil Environmental and Chemical Engineering at RMIT University have been interviewed to explore why they chose that particular field of engineering and what influenced them in their choice. The results have been analysed to determine whether the factors are different when they choose different engineering disciplines and the outcomes will be used to develop strategies to encourage female students to choose engineering.

INTRODUCTION

Numerous studies have investigated influences, such as role models, single gender schools, high school environment, early science and math intervention, ability and personality, and extracurricular activities, on girls when selecting engineering as a university program. On the other hand, few studies have investigated what influences girls to choose their discipline of engineering. Although Hobart et al (2006) undertook an extensive study of engineering graduates across various disciplines what influenced student's discipline choice was not the main focus. This paper evaluates what influences female students when selecting engineering as a university program and the particular discipline of engineering. Female engineering students from each discipline in the School of Civil, Environmental and Chemical Engineering at RMIT University have been interviewed to explore why they chose that particular field of engineering and what influenced them in their choice. The specific interview questions were centred around establishing if influencing factors were different when they choose different engineering disciplines. RMIT University is a technology based university, with its main campus in the city of Melbourne. More than 70,000 students study at RMIT campuses in Melbourne, Vietnam and partner institutions throughout the world.

LITERATURE REVIEW

Engineering has remained one of the most male-dominated professions worldwide. In the US, women represent 11% of the engineering workforce and 18% of professional and practicing engineers. Women constitute between 17% and 20% of engineers in China, South Africa, Sweden and Portugal. In Australia, the engineering profession has traditionally attracted few women, with women accounting for only 6% of practicing and professional engineers and 15% of enrolments in engineering courses nationally (Little & Barra 2009; Tully & Jacobs 2010). In the University of Sydney, female engineering students form only 17% of the total student population in the engineering faculty (Mburu & Hu 2005). Nationally, the proportion of engineering undergraduates who are female peaked in 2001 at 16% and is now declining (Burrowes 2006).

Influence of intervention programs

Prior to 2001, the increase in women enrolling in engineering courses in Australia was attributed to the period of maximum state and federal funding for gender related intervention programmes in the education sectors from 1986 to 1990 (Lewis, Harris & Cox 2000). Secondary school recruitment and retention programmes were run to encourage more young women to maintain their mathematics and science subjects through years 11 and 12 in order to enhance their post school education and training options. Public awareness of participation of women in mathematics and physical sciences were raised. Initiatives were also directed at parents to encourage their daughters to retain mathematics at school. However, as the participation rate never approached parity these programs were considered ineffective and were discontinued.

Influence of role models

Several surveys have shown that young people whose parents have a high level of education and a good salary are greatly over-represented in both secondary and higher education (Kvande 1986). This has a positive effect on the recruitment of women to higher education. In terms of family background, 34% of the engineering students sampled in a study conducted by Woolnough (1994) showed at least one of their parents was an engineer.

Kvande (1986) emphasized the importance of local role models to provide extra encouragement or support to different kinds to women, which promoted motivation and self confidence. In the questionnaire, the students were asked to assess how far their parents had affected their decision to go to Technical University of Norway (NTH). Results showed that women said they were very much encouraged by both their parents to attend NTH. They also found that mothers in particular had talked of the importance of education for women, while the fathers had rather tried to influence which type of education their daughters should choose. They concluded that parents play an important role in the female students' choice of education, both through direct support and through acting as role models.

Hobart *et al.* (2006) also found that family members and teachers had a major influence on student's decision to study engineering, for both male and female students. Many students had an engineer in the family.

Influence of single gender schools

Australia has a much higher percentage of secondary students attending single-gender schools compared to the U.S. Approximately 22% of all the female secondary students in the state of New South Wales (NSW) attend an all-girls high school (Australian Bureau of Statistics 2007).

Thompson (2003) proposed that the culture within female, single-gender secondary schools shapes girls' perception and attitudes towards gender roles, directly affecting post secondary curricular paths. Also, Lee & Marks (1990) concluded that girls who attended single-gender schools carried less gender-based stereotypical views with them into their university years. Tully & Jacobs (2010) showed that 40% of University of Technology's, Sydney (UTS) female engineering student population attended a single-gender secondary school, which indicated a potential influence of school type on engineering enrolment patterns. Also, female students seem to benefit from verbal encouragement, contextualisation, same gender problem-solving groups and same classroom dynamics.

Tully & Jacobs (2010) investigated the impact of single-gender secondary mathematics learning environments on a female population of Australian university engineering students and the contributing factors that influenced their choice to pursue an engineering major. The study found positive correlations between students enrolled in an engineering university major and influences and motivations that contributed to the choice of major, self-perception of mathematical ability, whether students attended a single-gender secondary school, and secondary school mathematics learning experiences. There was a strong correlation for women between mathematics learning and selection of engineering as the major study.

Hobart *et al.* (2006) undertook a study of a large cohort of engineering undergraduates who were mainly from co-ed schools. They found this had little impact on the student's decision to study engineering.

Influence of high school environment

Students reflected positively on their favourite secondary school maths teacher recalled a teaching style that was interactive, congenial and collegial and promoted a classroom atmosphere that was relaxed and friendly (Tully & Jacobs 2010).

A survey by Little & Barra (2009) of students in a single sex high school revealed girls preferred working in small groups, learning through practical activities such as practicals and building things, and least preferred researching on the Internet or learning from a textbook. Similarly, Daly (2009) reported that girls' engagement with physical sciences increased with a teaching style with more group work, presentations and discussion time.

Influence of early science and mathematics education

Females display a similar intelligence and aptitude for quantitatively driven university majors yet the self-perception of female students towards their mathematical ability lags, potentially affecting their choice into an engineering course of study (Correll 2001; Tully & Jacobs 2010). Research studies confirmed that the number of mathematics courses taken in high school directly influences a young woman's selection of a quantitative undergraduate major (Ethington & Wolfle 1988; Hobart *et al.* 2006, Tully & Jacobs 2010). Little & Barra (2009) found that girls preferred learning about biological or environmental science in comparison to boys who preferred physical

sciences. They suggested that it is essential that science education be part of the curriculum from an early age to develop students' interests and motivations towards engineering. They further suggested that girls' motivation is enhanced by becoming familiar with fast-advancing developments in science. They also proposed that by having the "hands-on" science education approach, it is easier to motivate and interest girls in engineering.

Influence of ability and personality

Woolnough (1994) investigated the factors affecting students' choice of science and engineering and found that there were significant differences for the timing and reasons for choice, for preferred teaching styles and for group factors, which influenced students positively. The significance of home background and personality types was also demonstrated. The importance of both in-class and extracurricular activities were clearly shown. The investigation was based on the hypotheses that the students' choice would be affected by their ability and personality, by the experiences they had in school and out of school, and by the value that society placed on careers in science and engineering. Boys are more likely to take subjects that move them towards a career, even if they are not particularly good at those subjects, while girls are more risk averse, and pick courses they will do best at (Hatt 2002). This is consistent with the findings of Hobart *et al.* (2006): boys ranked "playing with gadgets" highest on their list of influences to study engineering, while girls ranked "did well at maths" highest. This, combined with a lack of confidence in their mathematical abilities, reduces the pool of female students undertaking maths and science subjects.

Influence of extracurricular activities

Fostering integrative learning "across courses, over time and between campus and community life" has been highlighted as an important goal of undergraduate education. Extracurricular activities play an important role in exposing students to broader challenges that enable them to utilise or complement their disciplinary knowledge. Quantitative data suggested that women place higher importance on extracurricular activities as well as reporting higher participation in both engineering-related and non-engineering-related extracurricular activities (Chachra *et al.* 2009). However, when students were asked which personal trait influenced their choice of engineering as a career, while the dominant trait reported by boys was "playing with gadgets" but for girls this only the 3rd ranked trait (Hobart *et al.* 2006). Hence, not all girls may be attracted to "hands on" programs.

Influence of choice of discipline

There are very few published studies on what influences the choice of female engineering student's choice of discipline. Hobart *et al.* (2006)'s extensive study of engineering undergraduates surveyed cohorts from civil, mechanical, electrical and mining engineering. They found no differences between student's influences in the different disciplines, except that more civil engineers enjoyed the outdoors, and more mechanical and electrical engineers liked playing with gadgets. It is unclear if this applied equally to male and female students. One of the limitations of the study by Hobart *et al.* (2006) is it focused on male dominated disciplines. The study did not include a cohort of environmental or chemical engineers as these are not taught at their university.

RESEARCH METHODOLOGY

Interviews were undertaken with female students currently enrolled in programs in our school in civil, environmental or chemical engineering, undergraduate and postgraduate. Call for volunteers was advertised to all students in the school via email. Due to ethics considerations personal approaches were not allowed. In total we interviewed 10 female engineering students, 3 chemical, 4 environmental and 3 civil engineering students. The students were in their second or fourth year of study. The interviews were done individually with a duration of up to 15 minutes and adopted a semi-structured approach that sought to identify a broad range of influences concerning the choices of prospective students when considering engineering undergraduate programs. An initial set of influences was identified from the literature and this set formed the basis of the interview questions. The interviews were transcribed verbatim and the content of the transcripts was analysed thematically.

Linking outcomes to inputs in educational research can be highly problematic. Sample sizes are generally small and there may be confounding factors. It is usually difficult to include a control sample. In this study, the sample size was small and there was no control sample. However, the authors argue that conclusions can be drawn by comparing each small group on several of the key themes. A clarificative approach is adopted, in which outcomes (intentional and incidental) are related to the objectives. The casual thinking that led to the program choices is examined and the influences on those choices are identified. The analysis would typically split the process into sequential components such as inputs (internet, parents, teachers), activities/processes (learning about engineering activities, open days), outputs (choice of program, university) and finally outcomes (longer term career aspirations). These are presented in the form of tables or flow charts (Owens 2007).

Results Framework

The logic for career choices for female students is shown below in Table 1. The students reported using these resources when they chose engineering and the particular discipline. Some students used only one input, others used two.

Table.1: Logic for program choice

Input	Activity/Process	Output	Outcome
Personal preferences	Choosing to continue a favourite subject or following a passion	Choice of engineering or discipline	Career aspiration to work in chemical, civil or environmental industry or academia
Resources	Doing research on the internet	Ditto	Ditto
Parents	Discussing career choices with family	Ditto	Ditto
Teachers	Discussing career choices with teachers	Ditto	Ditto
Single sex schooling	Avoidance of stereotypes	Ditto	Ditto

THEMATIC ANALYSIS

Personal Preferences

Personal preferences were frequently cited by the students as influences, either their favourite subject at school, or a strong personal interest or disinterest. This is similar to Woolnough's findings (1994) that students' choices are influenced by ability or personality. Chemical engineers said "I wanted to do something different", "I think I enjoyed chemistry", "[chemistry] was my favourite subject". Civil engineers said "I really like building and structures", "construction kinda interests me", "I like building things, designing big things". Further all civil engineering students said they were good at physics and this interest influenced their discipline choice. Environmental engineers said "I want to help save the world", "I am always interested in the environment" "I was always passionate about the environmental issues".

When asked "why did you choose your particular discipline of engineering and not one of the other two disciplines offered by the school?", all chemical, civil and environmental engineers had strong opinions as to why they did not choose any other discipline. For example chemical engineers said "I wasn't interested in civil", "civil is ..more building things...is more of a guy's thing". For Civil engineers they had strong personal preferences as to why they did choose civil engineering so environmental or chemical engineering was not considered at all. Whereas for environmental engineers most said they were not interested in civil or chemical engineering "civil was too much field work", "chemical engineering would be interesting ...but I don't like process engineering"

For a select few their discipline was second choice: "my scores were not high enough for *** and I didn't want to waste my scores", "My ENTER score was not high enough for *** and I ended up doing engineering." These comments highlight that most females that choose chemical, civil or environmental engineering at RMIT University do so with an understanding of their discipline choice.

Resources

There were surprisingly few references to use of resources in making the choice of engineering or discipline. When asked why you chose your particular discipline of engineering, one student said "Didn't really think about it". This was also evident when asked, why not another discipline of engineering? Answers included "I didn't know what chemical engineering meant" "...didn't really think of chemical engineering" "I'm not sure what chemical engineering was". Only one student replied, "I didn't know anything about engineering...so by reading the course guides I found it quite interesting so that's why I chose engineering." One student chose civil engineering because of an article in the paper about the Young Engineer of the Year. This lack of research by the female students suggests publications designed to attract female students may miss their mark.

Parents

None of our sample had engineers as parents. This is contrary to studies that found many engineering undergraduates had parents who were engineers. This may reflect the demographic of RMIT students: many are first generation Australians and the first family member to attend university.

Environmental engineers cited parents as a strong influence on motivation to study engineering. When asked why they chose environmental engineering, answers were

“It’s because of the way I grew up, my family.” Fathers in particular were a strong influence: “My dad wanted to do engineering when he was a kid but he didn’t so I ...can be the engineer in the family”, “My Dad was probably the influence because he studied electrical engineering”, “my Dad.. encouraged me to move into engineering”. Some civil engineering students also commented they were influenced by their parents: “my parents wanted to get into engineering so maybe I got the influence from them” and one was inspired by her father who was a draftsman. She liked “making stuff” with him. Chemical engineers were more equivocal, as none cited parents as influences: “[my parents] didn’t really encourage me.” One civil engineering student cited another type of role models: a female who won the Young Engineer of the Year. So environmental and civil engineering female students were influenced by parents while chemical engineering students were not.

Teachers

Influence of teachers was notably absent for the chemical and environmental engineers interviewed. When asked if teachers encouraged them to do maths or science, answers were “Not actively”, “The most influential teacher ...was my English teacher” “I couldn’t think of any way that they encouraged me”, “I don’t think any teachers encourage me to do anything. It was up to us”. Only one chemical engineer had a different experience and commented, “My chemistry teacher said I should look at [chemical engineering]”.

On the contrary, for Civil engineers the influence of teachers was prevalent. When asked “did your teachers in high school encourage you to do science and engineering?” all responded with a definite “yes” and then proceeded with comments such as “they were always encouraging, especially because I was one of the few good at physics”, “I did quite well in maths and science subjects and they [teachers] recommended me to keep going in the same direction”. Female student numbers in civil engineering at RMIT are only 5 to 10 % of the cohort. Other studies have suggested that there is a very small pool of female students who will consider engineering only if they have a very strong aptitude for maths and physics (Hatt 2007). The small proportion of female students and their responses about their influences are consistent Hatt’s findings.

Single sex schools

None of our sample attended single sex schools, so this factor could not be evaluated in our study.

DISCUSSION

There were some interesting similarities and some significant differences between influences on program choices in chemical and environmental engineering. The similarities included:

- Most had their engineering discipline as their first preference
- All students from the outset wanted to do their discipline of engineering and didn’t consider the others
- All students studied maths and English
- All civil engineers did physics
- Only about half of the students in the chemical and environmental discipline did physics

- Very few used resources such as the internet to make their choice
- None had an engineer in the family
- All civil engineers strongly encouraged from teachers at school
- All students attended co-ed schools

The findings are interesting compared to the literature. None of our female engineering students had engineers in the family. Perhaps things have changed since 1994 when Woolnough published that 34% of female students had an engineer in the family. Tully and Jacob's (2010) found that girls were more likely to do engineering if they had studied in single sex classes. They found 40% of female engineering students at UTS had attended single sex schools, significantly above the national average attendance at single sex schools of only 22%. Our students don't fit that trend: all the chemical, civil and environmental engineers had attended co-ed schools.

The differences are summarised in Table 2 below.

Table 2: Differences between the discipline choices

Chemical engineering female students	Civil engineering female students	Environmental engineering female students
All did specialist Maths	All did physics and most did specialist maths	Half liked maths, half "had" to do maths
No hobbies	Majority had drawing and construction based hobbies	Majority had science based hobbies
Driver was love of chemistry	Driver was love of maths and physics	Driver was passion for the environment
None encouraged by their families	Strongly encouraged by teachers to do engineering because of good performance in maths and science	Encouraged to do engineering as their fathers had wanted to do engineering or encouraged them to do engineering
Interested in continuing chemistry	Interested in the built environment and maths	Interested in environmental issues

The strongest influence for chemical engineers was personal preferences: they either loved chemistry or found engineering interesting. The strongest influences for environmental engineers were personal preferences and parents: interest in environmental issues and father's encouragement. The strongest influence for civil engineers was personal preferences: they loved both maths and physics.

Our findings are somewhat different to the literature on girls' choice of engineering as a career. Kvande (1986) and Hobart *et al.* (2006) emphasised the importance of personal role models for female engineering students, which is true for our civil and environmental female engineering students, who were inspired by their fathers, but not for female chemical engineering students. Charkra *et al.* (2009) found that female students place more emphasis on extra curricula activities, but this appeared to be a factor only for our female environmental engineer undergraduates in their choice of discipline. Other research studies found that the number of mathematics courses taken in high school correlated with likelihood of choosing a major like engineering

(Ethington & Wolfle 1988; Tully & Jacobs 2010). This was true for our chemical engineers and civil engineers but not for environmental engineers.

The implications for successful marketing of RMIT engineering programs are complex. The results suggest that different approaches are needed to increase the applicant pool. Attracting more girls to each discipline might vary as: hands-on small group activities for civil engineering, specially tailored to girls interests; activities to interest the fathers for environmental engineering and activities designed for both girls and boys for chemical engineering.

CONCLUSIONS

Some interesting findings have emerged from this study of a small sample of female undergraduates enrolled in three engineering disciplines in our School. The students are quite clear about what influenced them to choose engineering in their particular discipline. There are some striking similarities and differences between the influences on choices of particular disciplines. All the students had their discipline of as their first preference for engineering. None went to a single sex school.. None had an engineer in the family, and almost none did any research about their discipline before choosing it (or not choosing others). There were differences in interests in science courses at school. All the chemical engineering students had done specialist maths, all the civils physics, and half the environmentals didn't like maths at all. Personal preferences were a strong influence for all the students, but had led in different directions. Chemical engineering students loved chemistry, civils loved physics and maths, and environmentals were passionate about the environment. Parental influence was strong only for environmental students, and teachers' influence only for civils. Contrary to the literature, the motivation of personal role models was very varied, likewise hobbies and number of maths courses taken. The outlook for effective marketing strategies for programs is complex. Each discipline would benefit from promotional programs tailored to their market demographic, more small group hands-on for those programs with low proportions of female students, and more general programs for those programs already with a critical mass of female students.

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A HOLISTIC REVIEW OF GENDER DIFFERENCES IN ENGINEERING ADMISSIONS AND EARLY RETENTION

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ABSTRACT

World-wide research continues to seek to identify the reasons for the underrepresentation of women in engineering. This work is primarily focused on two broad areas: pre-college preparation, exposure and experiences (recruiting), and higher education experiences (retention). Many programs and practices have been implemented incorporating the results of these studies.

The university admissions process is also a gateway to engineering, but little has been done to understand if this process is gender biased. A nonparametric statistical analysis of several cohorts of applications and admission results in the College of Engineering at a large U.S. Midwestern University compares the medians of common admissions metrics (e.g. high school grade point averages, class rank, standardized test scores) of men and women. The data indicate that, in practice, admission may be biased against women. In exploring ways to reduce gender bias in the admissions process, a study of academic performance and self-reported affective measures were modelled using retention and graduation as outcomes. Though first year men and women report similar levels of each success measure, the relative importance of each measure in predicting retention was different for men and women.

Because of the data-based nature and the breadth of this work, these results have been used to inform changes in admissions practices on the studied campus. A more gender neutral set of admissions practices is essential for gender parity in engineering, particularly in light of recent research which suggests recruiting women into engineering is a larger issue than retaining women to graduation.

MOTIVATION

The University's College of Engineering (CoE) has been working to increase the representation of women in the first year class for many years. Over the last 5 years, we have seen a 46% increase in the number of applications received from women, but only a 24% increase in the number of women admitted. At the same time, casual analysis seemed to indicate that, on average, women admitted to the CoE have higher high school performance metrics than men admitted to the CoE.

Students are admitted to this University based on a holistic review of the following criteria:

- Subject matter expectations (These are the number of semesters of math, science, English and foreign language that each student is expected to have taken in high school or secondary school.
- Overall high school grade point average (GPA), on a 0 – 4.0 scale
- Core high school GPA (GPA of English, math, science, foreign language, and speech classes only. This is a subset of the student's overall secondary education coursework.), on a 0 – 4.0 scale

- High school class rank, in percentile
- Standardized test scores (Most US institutions require the SAT or ACT for admissions consideration. These instruments are stated to be predictors of first-year grades in university. SAT Verbal and Math parts are on a 200 – 800 scale, Therefore, SAT Total in this study is on a 400 – 1600 scale.)
- Overall grades in academic coursework
- Grades related to intended major
- Strength of student's overall high school curriculum
- Trends in achievement
- Ability to be successful in intended major
- Personal background and experiences
- Time of year student applies
- Space availability in intended program

It is difficult to quantify some of these factors, such as ability to be successful in intended major and personal background and experiences. This University has also stated that there are no “minimums” in terms of metrics, i.e. the lowest SAT or ACT test scores, the lowest GPA's, etc. for admission to take as much as possible into account during an admissions decision.

Therefore, the research questions for this study were:

1. Are the metrics of women admitted to CoE statistically higher than those of men admitted to CoE?
2. To what extent do affective and cognitive measures from the Student Access and Success Instrument (SASI) model differences of success as measured by retention and graduation based on sex?

STATISTICAL ANALYSIS METHODS AND RESULTS

For the entry years prior to 2009, the University's Office of Admissions stored information regarding each applicant in an Oracle database. A new database was created for each admissions cycle. Contained in each database were the demographics of each applicant (including sex, ethnicity, and residency), the metrics of each applicant (including standardized test scores, class rank, and overall and core high school GPA's), and the action taken on each applicant (including admittance to engineering, admittance to another college, denial to the university, or pending). These data were downloaded from the databases for 2006, 2007, and 2008 entry years. The data were then filtered so that only the following applicant records remained:

- Applicants to the College of Engineering (resulting in 26,396 total records over the 3 cohort years)
- Applicants who are considered “Beginners”. (Transfer students, for example, were filtered out) (25,587 total records remaining)
- Applicants for the Fall semester (25,361 total records remaining)
- Applicants with complete applications (incomplete applications were filtered out) (23,068 total records remaining)

The overall demographics of these applicants, disaggregated by gender, are shown below in Table 1.

Tab.1: Demographics of Applicants to Engineering

Demographics of Applicants		2008				2007				2006			
		Women		Men		Women		Men		Women		Men	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Total Number of Records		1632		5964		1652		6430		1369		6021	
Race / Ethnicity	Caucasian, Non-Hispanic	1116	74.5	4269	78.9	1037	71.4	4262	77.0	926	74.3	4023	76.8
	African American, Non-Hispanic	106	7.1	214	4.0	113	7.8	206	3.7	95	7.6	259	4.9
	Hispanic American	73	4.9	229	4.2	76	5.2	244	4.4	66	5.3	219	4.2
	Native American	15	1.0	44	0.8	6	0.4	46	0.8	5	0.4	44	0.8
	Aisan American / Pacific Islander	160	10.7	531	9.8	178	12.3	637	11.5	135	10.8	562	10.7
	Other	20	1.3	93	1.7	32	2.2	92	1.7	19	1.5	89	1.7
	Not Reported	8	0.5	29	0.5	10	0.7	46	0.8	1	0.1	43	0.8
Residency	All Domestic	1498	91.8	5409	90.7	1452	87.9	5533	86.0	1247	91.1	5239	87.0
	Indiana (% of Domestic)	334	22.3	1510	27.9	318	21.9	1624	29.4	272	21.8	1715	32.7
	International	134	8.2	555	9.3	200	12.1	897	14.0	122	8.9	782	13.0

It should be noted that not all metric data are available for each applicant. Some high schools, for example, do not rank their students; therefore some students will not have a high school class rank. Some international students do not take standardized tests. And certainly, not every student will take both the SAT test and the ACT test. In order to minimize the amount of missing data, all ACT test scores were converted into equivalent SAT Math and Verbal scores. This conversion was done according to the concordance published by the College Board, the administrator of the SAT (Dorans, 1999). In addition, many students take SAT and/or ACT tests more than once, in an effort to improve their test scores. The University's policy with regard to multiple tests is to use in the admissions process the highest scores from each part of the test, as opposed to just using the latest complete set of test data, or the highest overall set of test data. Because of this policy, only the maximum test scores were downloaded from the Oracle database.

Anderson-Darling normality tests were run on each metric distribution to determine if a normal probability distribution is adequate to describe the data; each metric was determined to be non-normal. Therefore, a nonparametric, 2-sample Mann-Whitney test at a 95% confidence level was used. This test can be used to make inferences about the difference between two population medians based on two independent random samples. An analysis of the pool of students admitted to Engineering is shown in Table 2, and includes the sample size for each metric, the median for each metric, and the p-value for each comparison.

For all analyses, a p-value of 0.05 or less was considered to be statistically significant. In the results tables, a statistical significance in the difference in the medians is denoted by a bolded higher median. Analyses were completed for each individual cohort year, and the results were quite similar each year, therefore just the combined cohort results are presented here. The medians of the women's overall GPA, Core GPA, Class Rank, and SAT Verbal scores are statistically higher than those of the men. The median of the men's SAT Math score was statistically higher than the median of the women's. In addition, while the median of the men's SAT Total score was higher than that of the women, the difference was not as statistically significant.

Tab.2: Statistical Analysis of Metric Medians for Admits to Engineering

All Admits to Engineering		Total		
		Women	Men	p-value
Overall GPA	Median	4.0	3.8	0.0000
	N	3829	12790	
Core GPA	Median	3.80	3.60	0.0000
	N	3935	13201	
Class Rank	Median	94	90	0.0000
	N	2558	7963	
SAT Verbal	Median	630	620	0.0000
	N	3911	13127	
SAT Math	Median	680	700	0.0000
	N	3911	13127	
SAT Total	Median	1320	1330	0.0100
	N	3911	13127	

The boxplots in Figure 1 show sample datum point distributions of overall GPA and SAT Total scores for the men and women admitted to engineering. The “box” represents the middle 50% of the data, and the line in the middle is the median. The lines from the top and bottom of the box are 1.5 quartiles in length; the asterisks denote individual datum points outside of that range. Note that the males have a much wider data spread, and longer tails, especially on the lower end. This distribution characteristic adds to the admission bias argument as such a longer tail is present in the overall application distributions but should not be present in the admission distribution. Figure 2 shows the boxplots of overall GPA and SAT Total scores of applicants by sex. Figure 2 data show that men with lower high school metrics apply for admission to engineering, whereas similar women do not apply.

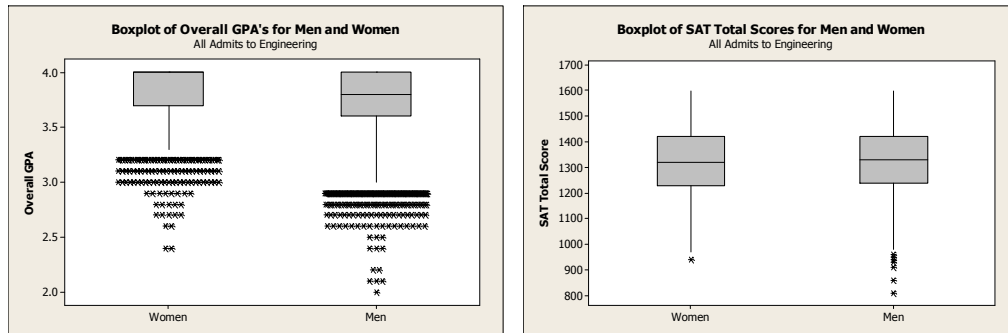


Fig. 1: Data Distribution of Overall GPA and SAT Total Scores for Admits to Eng.

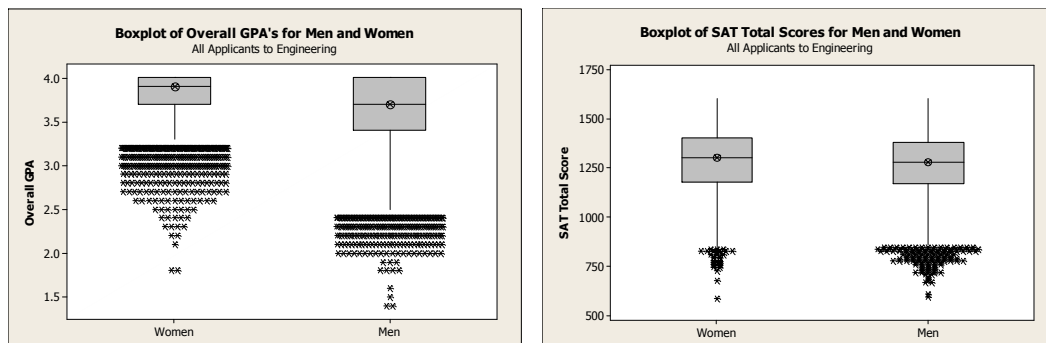


Fig. 2: Data Distribution of Overall GPA and SAT Total Scores for Applicants to Eng.

The records of applicants who were denied admission to the university were also analysed. The statistical analysis of this population is shown in Table 3. The medians of the women's overall GPA, Core GPA, and Class Rank are statistically higher than those of the men. The medians of the men's SAT Verbal score, SAT Math score and the SAT Total score were statistically higher than the medians of the women's.

Tab.3: Statistical Analysis of Metric Medians for Denies to Engineering

All Denies		Total		
		Women	Men	p-value
Overall GPA	Median	3.4	3.2	0.0000
	N	241	2071	
Core GPA	Median	3.06	2.91	0.0000
	N	255	2202	
Class Rank	Median	75	66	0.0000
	N	171	1485	
SAT Verbal	Median	490	510	0.0002
	N	277	2324	
SAT Math	Median	550	590	0.0000
	N	277	2324	
SAT Total	Median	1050	1110	0.0000
	N	277	2324	

Additionally, sample boxplots of overall GPA and SAT Total scores in Figure 3 show the datum point distributions for men and women. Note that the highest 25% of the denied women's overall GPA's are higher than the overall GPA's of the lowest 25% of the men admitted to engineering.

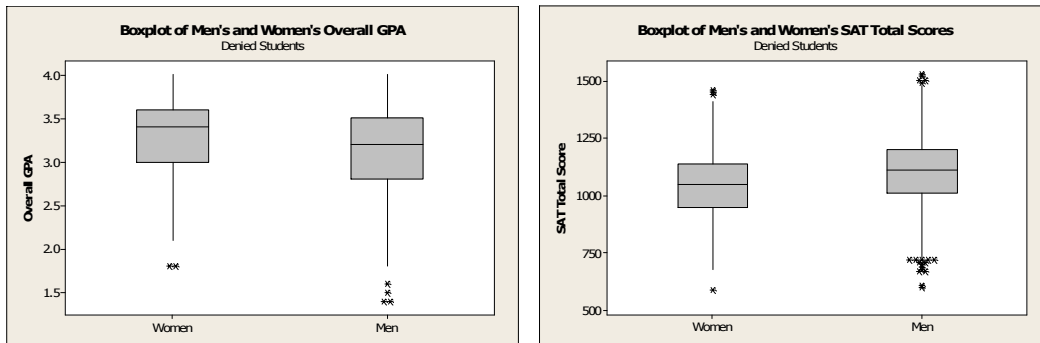


Fig. 3: Data Distribution of Overall GPA and SAT Total Scores for Denies to Eng.

STATISTICAL ANALYSIS DISCUSSION

In an ideal admissions process, it would be expected to see no significant difference in the metrics of the men and those of the women, especially in institutionally defined populations, i.e. those that the Office of Admissions controls, the admitted student population, the denied student population, etc. [There may still be differences in the overall population of applicants, but the Office of Admissions has much less control over the makeup of that group.] Unfortunately, that ideal admissions process does not exist at this university. Additionally, the university uses standardized tests as part of its admissions criteria. Admissions officers typically use standardized test scores to estimate the applicant's likelihood of academic success in university. However, research published by the College Board, the administrator of the SAT, shows that a student's high school record (grades and class rank) are a better predictor of first year college grades than a student's SAT score (Morgan, 1989 and Burton & Ramist, 2001). Thirty-seven different studies have also shown a consistent gender bias in standardized tests (Young & Kobrin, 2001). In particular, Wainer and Steinberg (1990) found that

males score 35 points higher on the SAT Math section than females who earn the same grades in the same college math courses. Sources of test bias are extremely difficult to identify and once identified instruments are typically corrected. Given these sets of research data as a backdrop, it might be expected to see no gender differences in the metrics of students' high school records, i.e. overall GPA's, core GPA's, and class ranks. It might also be expected that the standardized tests scores of women would be lower at the same high school metric level. However, the statistical analysis presented above shows that, across the board, the women have higher high school metrics than the men.

These observations and discussion points have led to discussions about a different method of admitted students to engineering, a method that does not place as much value on standardized test scores.

MODELING METHODS AND RESULTS

A discussion of academic admissions practices quickly gets to the question of what are indicators of student success. The difficulty of this discussion is that historically the factors used to answer this question have been cognitive, such as the ones discussed in the previous sections. However, research indicates that there are many factors affecting retention. For example, Astin (2005) showed that students who tend to be more engaged are more likely to persist; further, well over half of the variation between institutions on a measure of "student engagement" can be attributed to characteristics present *prior to* entering college. Fostering a spirit of engagement in students who may not show that propensity may increase students' chances for success, and intervention program(s) designed to increase student engagement are certainly feasible from an institution during the first year of study.

Perhaps more importantly, the mention of modeling to discuss admissions policies elicits strong concern that profiling will result and will limit admissions to certain populations. Weinstein, et. al, (2001) acknowledge this modeling controversy and relate it to being a misconception that "the role of models is to establish truth rather than to guide clinical and policy decisions" (pg. 348). These authors provide examples of public policy domains from areas such as environmental protection or defense strategy that involve human life and health where models are generally accepted as decision aids. We propose the same use of modeling in student retention to view admission policies in an advisory capacity.

The Student Attitudinal Success Instrument (SASI; Immekus, Imbrie & Maller, 2004; Immekus, Maller, Wu, Imbrie & McDermott, 2005; Reid & Imbrie, 2008), a 161-item survey assessing 13 specific noncognitive constructs was developed based largely on existing instruments. This instrument is designed to provide data on noncognitive characteristics for incoming engineering students (a) *prior to* the onset of the first year and (b) for which higher education institutions may have an influence during students' first year. Data collected from this instrument may be suitable for use in the development of predictive models of student retention and/or graduation, which is the definition of success in this model. In this study, modeling is completed for first year retention and then graduation after 4 years (8 semesters) and 5 years (10 semesters). Due to such factors as the number of credit hours to obtain an engineering degree or a student's participation in cooperative learning (one semester in school alternated with one semester in industry), average graduation rates in the US are just over 4 years thus the 5 year graduation interest.

The SASI is used to provide the College information about the academic preparation and affective characteristics of incoming first-year engineering students. Such systematically gathered information helps us assess the impact of University and programmatic decisions aimed at student recruitment, admission, retention, and ultimately the success of all students and, in particular, underrepresented students. Underrepresented students in the US in the field of engineering includes women, as well as race and ethnicity designations of African American, Hispanic/Latino American, Native American, Native Hawaiian and Pacific Islander for US domestic students only.

The current model of student success includes 13 self-reported affective factors (leadership, deep- vs. surface-learning types, team or individual orientation, academic self-efficacy, motivation, meta cognition, expectancy value, major decision, goal orientation, implicit beliefs, intent to persist, social climate, and self worth); and 11 academic preparation items from high school including overall GPA, core GPA, standardized test results by subarea [SAT/ACT], average grades in mathematics, science, and English, and the number of semesters completed of mathematics, science, and English. Table 4 provides details of the origins of each factor.

Tab. 4: References used during the development of the SASI.

- Motivation (Pintrich and Schunk, 1996), (French and Oakes, 2003)
- Metacognition (Pintrich and DeGroot, 1990), (O'Neil and Abedi, 2000)
- Deep learning and Surface learning (Biggs, Kember and Leung, 2001)
- Academic Self-efficacy* (Bandura ,1986), (Pajares, 1996)
- Leadership* (Hayden and Holloway, 1985)
- Team vs. Individual Orientation* (McMaster, 1996)
- Expectancy-Value (Wigfield and Eccles, 2000)
- Major Indecision (Osipow, 1999)

* Developed internally based upon the cited reference(s)

Figure 4 shows, by sex, the model's most important factors used to predict "success," where success is operationalized as "1 year retention," "8 semester graduation," or "10 semester graduation, respectively. The factor data (the independent variables) were collected just prior to students beginning their college experience. The importance of a particular factor towards predicting the outcome variable (success) is indicated by the radial distance from the center of the circle (center - low importance, perimeter of the circle – high importance). For example, in the "1 Year Retention" radial plot below, leadership is an important attribute for women's success (defined as retention) at the first-year level. For men, the semesters of high school mathematics is important. Semesters of science is a factor important to both men's and women's success. Since the cohort remains the same for all 3 graphs, the results indicate that factors important to predict success for women and men are not the same and that import factors change with the measure of success. Since the model is used for predictive purposes rather than an explanatory tool, the authors can offer no illuminating rationale as to why the important factors differ by sex.

Due to the legal environment in the United States, admissions policies can use a holistic mix of factors in directing admissions and scholarship decisions. However, different factors cannot be used for men and women, or majority and minority students, even if these factors were to be based on the success factor data for each population. We have used the success factor data in developing our admissions factor recommendations to future policies that place a higher emphasis on affective indicators.

Thus, based on this model and additional research done on admission factors, a policy change recommendation is that admission decisions be made using a set of priorities

that include cognitive factors such as SAT verbal and number of semesters of mathematics, science, and English while taking into account leadership, major decision, and academic motivation. In addition, based on reports such as the National Academy of Engineering's report, *Changing the Conversation* (2008), social relevance of engineering as a discipline has been added to the decision process.

2004 Cohort, 1 Year Retention and 8, 10 Semester Graduation

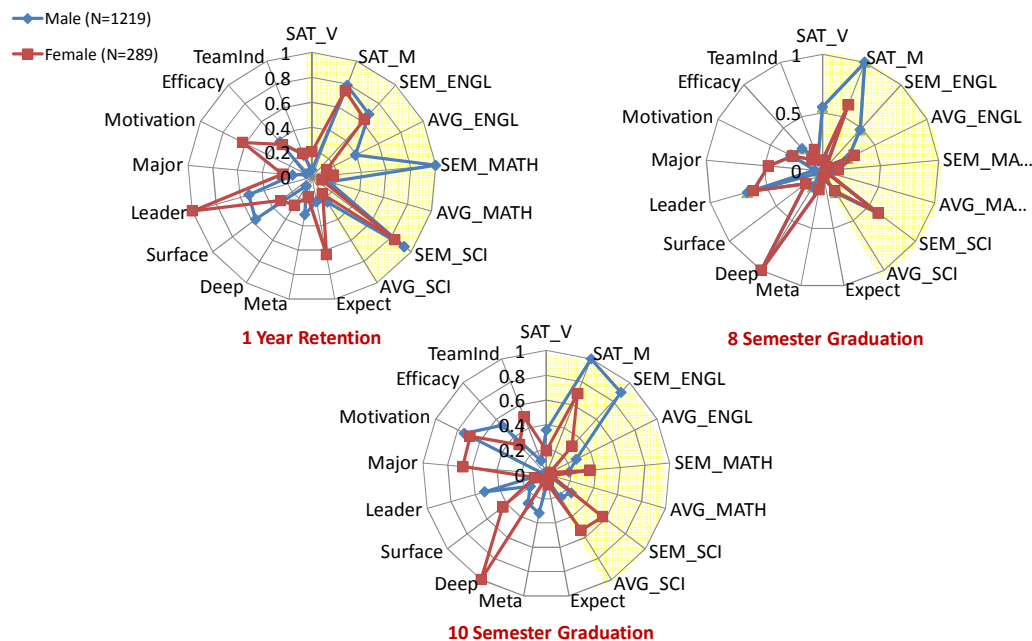


Fig. 4: SASI model of success factors by gender for the 2004 cohort.

FUTURE WORK

The resulting struggle is now the validity of the application to provide indicators of some of these attributes. Because of the data-based nature and the breadth of this work, these results have been used to inform changes in admissions practices on the studied campus. A more gender neutral set of admissions practices is essential for gender parity in engineering, particularly in light of recent research which suggests recruiting women into engineering is a larger issue than retaining women to graduation.

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STATISTICAL ANALYSIS OF SOME ACCURACY DEFINING PARAMETERS OF LOCATION BASED SERVICES OFFERED IN SOUTH AFRICA

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ABSTRACT

Location Based Service (LBS) enables mobile phone users to connect to points of interest at a particular geographical location providing real-time and personalized service based on location. These services are location information based on wireless technology and are accessible through mobile stations (mobile phones, Personal Digital Assistants (PDA), etc). This paper presents results from data on LBS collected at sixty (60) location points with nine hundred and thirty eight (938) LBS requests from two (2) LBS providers and mobile operators in South Africa. We report statistically how some parameters such as; time of the day, environment, geographical location, type of LBS request and mobile operators' network affect the accuracy of network based positioning offered by South African Mobile Operators to LBS registered users in South Africa. Our findings indicated that some parameters such as geographical location and environment of LBS request has a significantly high impact on accuracy provided by the LBS providers. It is therefore important to put into consideration such parameters when providing LBS to users for improved accuracy.

Keywords—location based services, accuracy, network based positioning, legacy mobile phone

INTRODUCTION

Mobile telephony without doubt recorded the largest development to have taken place in the telecommunication industry and its evolution has brought about unprecedented and explosive changes in services offered by mobile network operators all around the world and method of delivering the services to users. The world's poorest are carried along in the worldwide mobile evolution bringing the power of communication to all. Between 1998 and 2003 mobile subscribers in Africa increased by 1000% (ITU, 2004), this increase reiterates the fact that there is a rapid increase in the embrace for communication and value added services offered by mobile telephony. In rural areas where there is no electricity dwellers can boast of mobile phones and demand is driven by voice rather than data (Scott *et al*, 2004). There are affordable mobile phones with basic capabilities for example mobile phones with no Geographical Positioning System (GPS); these are affordable to underprivileged and low income earners. It is therefore important to increase services offered to users in order to optimize the mobile network and for improved user satisfaction.

Geographical location finding capability is one of such value added feature of mobile networks which makes it successful, attractive and optimized. Location Based Services (LBS) enables mobile phone users to connect to points of interest at a particular

geographical location providing real-time and personalized service based on location. These location based services are dependent on wireless technology and are accessible through mobile stations (mobile phones, Personal Digital Assistants (PDA), etc) (Gipsy, 2004; Turkyilmaz *et al*, 2008).

LBS gives mobile phone users access to LBS anywhere and anytime and it is of particular importance in a situation where the caller cannot indicate her location due to a medical condition or unawareness of the present location; for example emergencies and rescue operation, others includes locating friends, family and assets, disaster alert and other location services (Steiniger *et al*, 2006; Gipsy, 2004). LBS enable Mobile operators' to provide value-added services and generate revenues from other services other than voice and data (Gipsy, 2004; Turkyilmaz *et al*, 2008).

DEPENDABILITY FACTOR

LBSs assist in performing user task i.e in an emergency situation, LBS locates the MS and the emergency service provider performs the task of rescuing the owner of the MS who made the request. The user is dependent quality of service offered by the LBS for making an informed decision. Therefore a failure in the accuracy of the LBS translates to a failure by the emergency service provider in the rescue operation. This reiterates the importance of good service delivery to LBS users (Katasonov, 2004).

Accuracy is one of the parameters that define the quality of a LBS which is a measure that defines how close estimated location is to the actual location of the MS (Adusei, 2002). It is worth noting that different degree of accuracy is needed for different services; this is shown in Table 1.

Tab.1: Examples of LBS accuracy requirement (3GPP, 2007; Gipsy, 2004)

Accuracy Requirement	Location Based Service
Regional (up to 200km)	Weather report, traffic information, localized weather warnings
District (up to 200km)	Local news, traffic reports
Up to 1km	Vehicle asset management, congestion avoidance advice
500m – 1km	Rural and suburban emergency service, information service
100m (67%)-300m (95%)	U.S. FCC mandate (99-245) for wireless emergency service using network based positioning technology
75m-125m	Asset tracking, localized advertisement, information service, route guide
50m (67%) - 150m (95%)	U.S. FCC mandate (99-245) for wireless emergency service using MS based positioning technology
10m-50m	Asset location, route guidance, resource location, fieldwork support, field measurement.

This requirement is a guide line to enhance quality of service delivery for LBS. A failure to meet this requirement makes the LBS user perform sub optimally in other tasks the LBS information is used for (Katasonov, 2004).

Accuracy is the major measure of quality of service measurement used in this paper. An increase in the numerical values indicates a decrease in accuracy because accuracy is a measure of error obtained. An increase in error implies a decrease in accuracy and a decrease in error implies an increase in accuracy.

SURVEY MOTIVATION

Quality of service (QoS) offered to LBS is dependent on the amount the mobile network operators and mobile phone users are willing to invest (Gipsy, 2004). With feature-rich modern smart phone users gets better accuracy using the Geographical Positioning

System (GPS) or assisted GPS (AGPS) location method but unfortunately most users in developing countries are not able to invest in these high-end devices. It is important to ensure that services provided via mobile phones work optimally with legacy mobile phones. Unfortunately, this is proving challenging because present research in the field of LBS is mainly focused on the availability of smart phones and advanced infrastructure which are suited for developed countries. This is because mobile phones (Smart phones) designed today are geared to meet Western needs while mobile subscribers in developing countries are increasing explosively daily (EPROM, 2009).

To ensure improved quality of service delivery to mobile phones with no GPS, the accuracy of what is available need to be studied. This will help give a more informed decision about methods of improving the accuracy and ways to go about it. This paper investigates the accuracy of LBS delivered to LBS subscribers and makes suggestions on ways to improve this.

MATERIALS AND METHODS

The purpose of this research is to determine statistically the difference in predicted accuracy as given by the mobile operators and accuracy provided to LBS subscribers and factors affecting them. Survey data was collected from three types of environments in South Africa: a densely population suburban environment, a sparsely populated suburban environment and an urban environment which will be referred to as (Suburban Type A - A), (Suburban Type B - B) (Urban - C). Two types of LBS: "Distress request" service and "person locator" services were registered for with two separate mobile location providers.

A smart phone with assisted GPS was used to measure the actual/true coordinates of geographical locations and to locate points of interest during data collection. Six legacy mobile phones were registered for the two LBS each on the two location providers' network. Legacy phone were used in order to access the services rendered to the average man/woman on the street. Also due to the fact that the larger population of mobile subscribers in developing countries use legacy mobile phones (EPROM, 2009).

Six LBS requests named LBS1, LBS2, LBS3, LBS4, LBS5 and LBS6 were sent from sixty (60) geographical locations in the environments under consideration. These variables are summarized in Table 2. Survey data were collected over five days from the geographical locations. Data was collected twice a day; the first between 7:30AM and 11:00AM in the morning and the second between 7:30 PM and 9:00 PM in the evening.

Accuracy predicted by mobile location provider is estimated accuracy provided by the location provider when delivering the location information this is called Accuracy One. The location estimated by the LBS provider is given relative to the closest road to the true location of the mobile phone where the LBS request was made. The accuracy provided was calculated based on the distance from true location of MS to the road estimated by location providers as the crow flies and it is called Accuracy Two. When the length of the road specified by the location provider is put into consideration; this is used to calculate Accuracy Three. Accuracy Three is given by Accuracy Two in addition to length of specified road. This is due to the fact that LBS user can be located at any point on the road specified. If the road is 1km long then the Accuracy Three is given by Accuracy Two $\pm$ 1km. Length of the roads were extracted using Geographical Information System (GIS) from geospatial data collected from Gauteng City-Region Observatory (GCRO) (Municipal Demarcation Board, 2009). Other geospatial analysis

was carried out on the data collected. Table 2 summarizes the variables used for the collected data and explains them further.

Tab.2: Defining the variables used for collected data

Variable	Variable name	Type of variable	More information
Time of day	Morning Evening	Categorical and Dependent	Morning Night/Evening
Environment	Urban - C Suburban Type A -A Suburban Type B -B	Categorical and Dependent	There are three main types of environment
LBS Provider	LBS Provider 1 LBS Provider 2	Categorical and Dependent	There were two LBS providers registered to
LBS request	LBS1, LBS2, LBS3, LBS4, LBS4, LBS5 and LBS6	Categorical and Dependent	LBS1 = Povider1's response to distress request from a MS on its network LBS2 = Povider1's response to person location request from a MS on its network LBS3 = Povider1's response to location request from a MS on Povider2's network LBS4 = Povider1's response to location request from a MS on Povider2's network LBS5 = Povider2's distress request from a MS on its network. LBS6 = Povider2's person location request from a MS on its network.
Accuracy One	Accuracy One	Continuous and independent	Accuracy Predicted
Accuracy Two	Accuracy Two	Continuous and independent	Accuracy Provided to nearest point on the road specified
Accuracy Three	Accuracy Three	Continuous and independent	Accuracy Provided to nearest point on the road specified + Length of specified road

RESULTS

Over one thousand (1,000) LBS requests were made but only nine hundred and thirty eight (938) location response were received from the Mobile location providers. An average of 93.8% reliability and success rate was recorded. 11.3% of data was collected from an urban environment, 42.2% of the responses were from the Suburban Type A which is a densely populated with very little trees/ shrubs suburban environment. 46.5% of data was collected from Suburban Type B which is a sparely populated suburban environment with relatively many trees/shrubs. Due to error in data only data collected from fifty one (51) geographical locations were used for this analysis.

Data Analysis

Statistical Package for Social Sciences (SPSS) software was used for manipulation and statistical analysis of data collected. There were four independent variables (time of day, type of environment, mobile location provider, LBS request) and three dependent variables (Accuracy One, Accuracy Two and Accuracy Three) which were considered.

The various analysis carried out includes descriptive, parametric, paired sample t-test, one-way between-groups ANOVA (ANalysis of Variance) and MANOVA (Multiple ANalysis of Variance) statistical analysis. T-test is used to compare the mean score in continuous variables. One-way ANOVA involves one independent variable which has various groups/levels. Repeated measures analysis of variance was used for "time of day" independent variable and between-group analysis of variance was used for the other independent variables (Pallant, 2005).

MANOVA (Multiple ANalysis of Variance) statistical analysis is an extension of analysis of variance for use with more than one dependent variable. These variables should be related in some way, or there should be some reason for considering them together because MANOVA compares the groups. All the variables considered are related with the independent variables. MANOVA is based on separate one-way ANOVAs of dependent variable, this type of analysis is used instead of several ANOVAs to reduce the risk of Type 1 error which gives a false output; finding a significant result when in fact there isn't one (Pallant, 2005).

Interpretation of statistical analysis

Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. The descriptive statistics for the analysis was cross-checked and confirmed that correct information was analyzed.

Accuracy

A paired-sample t-test was conducted to evaluate the difference in accuracy predicted and accuracy provided for survey data. It was discovered that there was a statistically significant decrease in Accuracy One ($M = 720.76$, $SD = 433.09$) to Accuracy Two [$M = 586.02$, $SD = 702.63$, $t(937) = 5.967$, $p < .0005$], eta squared statistic (0.04) indicated a small effect size. There was a statistically significant decrease in the accuracy from Accuracy One to Accuracy Three [$M = 2165.47$, $SD = 2286.98$, $t(937) = -19.248$, $p < .0005$], eta squared statistic (0.28) indicated a large effect size.

The mean of Accuracy Two is less than Accuracy One but the standard deviation is much larger. This implies that there is a significant variance in Accuracy Two. Accuracy Two provided by the location providers gives a better picture of Accuracy One but the correct accuracy provided which is Accuracy Three is significantly different from Accuracy One. The mean of Accuracy One is 721, Accuracy Two is 586 and Accuracy Three is 2166. Accuracy Three is about three times more than Accuracy One. This implies that actual accuracy provided by the location provider is 3 times more than the predicted accuracy as observed from the statistics analysis result in the previous paragraph.

Geographical location

There were three dependent variables: Accuracy One, Accuracy Two, Accuracy Three and two independent variables: type of environment and geographical location from where LBS request were sent by mobile phone user.

A two-way MANOVA was conducted to explore the difference in accuracy predicted by location providers (Accuracy One) and accuracy provided (Accuracy Two and Accuracy Three). The analysis indicated there was statistically significant difference between urban, suburban type A and type B on the combined dependent variables: $F(6,1856) = 35.89$, $P < 0.0001$; Wilk's Lambda = 0.803; partial eta squared = 0.104. The dependent variables to reach statistical significance are only Accuracy One and Two. Accuracy One: $F(2,930) = 101.857$, $p < 0.0001$, partial eta squared = 0.180 and Accuracy Two: $F(2,930) = 12.625$, $p < 0.0001$, partial eta squared = 0.026. The environment has a large effect and a small effect on Accuracy One and Two respectively. The mean plots of Accuracy One, Accuracy Two and Accuracy Three are as shown in Figure 1.

There was also a statistically significant difference between location points where the data was collected on the combined dependent variables: $F(150, 2513) = 4.26$, $P < 0.0001$; Wilk's Lambda = 0.507; partial eta squared = 0.203. When considered separately, dependent variables to reach statistical significance are Accuracy One, Two and Three. Accuracy One: $F(50, 840) = 6.740$, $p < 0.0001$, partial eta squared = 0.286, Accuracy Two: $F(50, 840) = 3.649$, $p < 0.0001$, partial eta squared = 0.178 and Accuracy Three: $F(50, 840) = 3.489$, $p < 0.0001$, partial eta squared = 0.172. The geographical locations where the LBS requests were made all had very large effects on the dependent variable. Checking out the partial eta squared for independent variables these represents a moderate effect of about 29% for Accuracy One, large effects of 18% and 17% for Accuracy Two and Three.

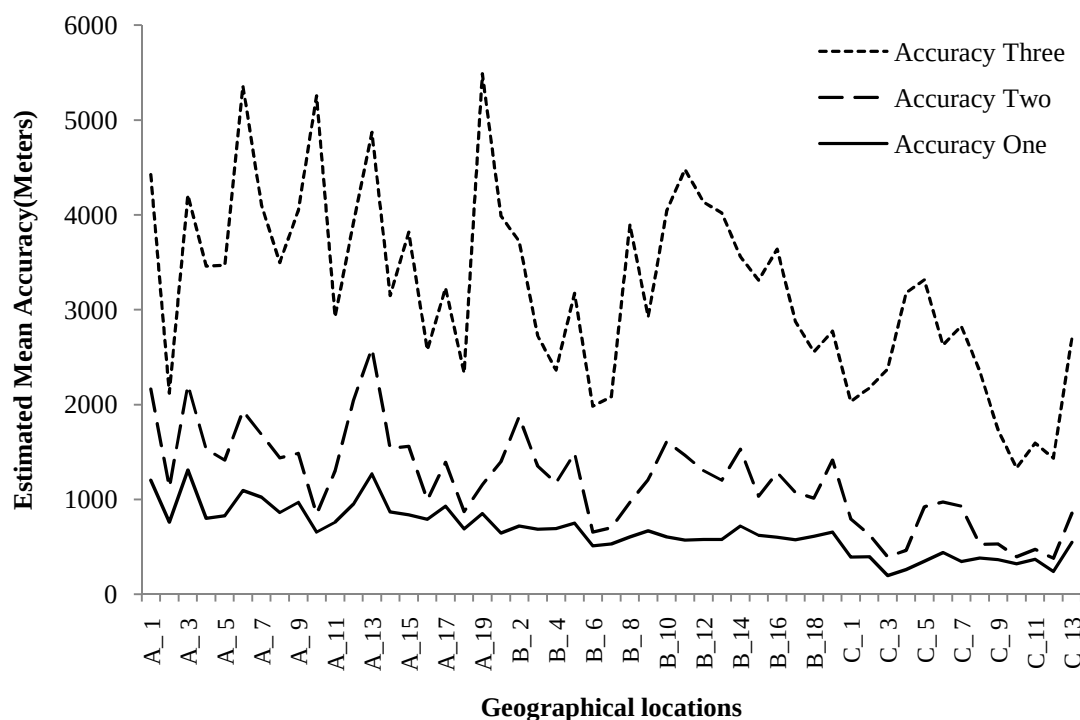


Fig.1: Mean plot for accuracy showing LBS request sent from different environments.

Data survey in urban (C) environment gave the best accuracy followed by the Suburban Type B (B) and the Suburban Type A (A). This might be due to the fact that base stations are more closely spaced in urban environments. Since, location providers use geometric algorithms in calculating the mobile phone, the accuracy provided is dependent on the geometry of the base stations.

LBS Request

A two-way MANOVA was conducted to explore the impact the types of LBS request have on accuracy. From analysis carried out, there was significant statistical difference between the accuracies provided by LBS1, LBS2, LBS3, LBS4, LBS5 and LBS6: and $F(15, 2530) = 11.048$, $P < 0.0001$; Wilk's Lambda = 0.839; partial eta squared = 0.057. Considering the dependent variables individually, Accuracy One and Two were more statistically significant with Accuracy One: $F(5, 918) = 28.743$, $p < 0.0001$, partial eta squared = 0.135 and Accuracy Two: $F(5, 918) = 7.709$, $p < 0.0001$, partial eta squared = 0.040. Partial eta squared for dependent variables Accuracy One and Accuracy Two are 0.135 and 0.040 respectively. This represents 13.5% and 4% of variance in dependent variables explained by LBS request.

Figure 2 show mean plots of Accuracy One, Accuracy Two, Accuracy Three and LBS requested for by mobile phone user. LBS requests LBS*_A, LBS*_B, LBS*_C, are in the Suburban type A, Suburban type B and Urban environments respectively. The type of LBS requested for by the mobile phone user had a moderate effect on the accuracy predicted, is has a smaller effect on Accuracy Two and very little effect on Accuracy Three.

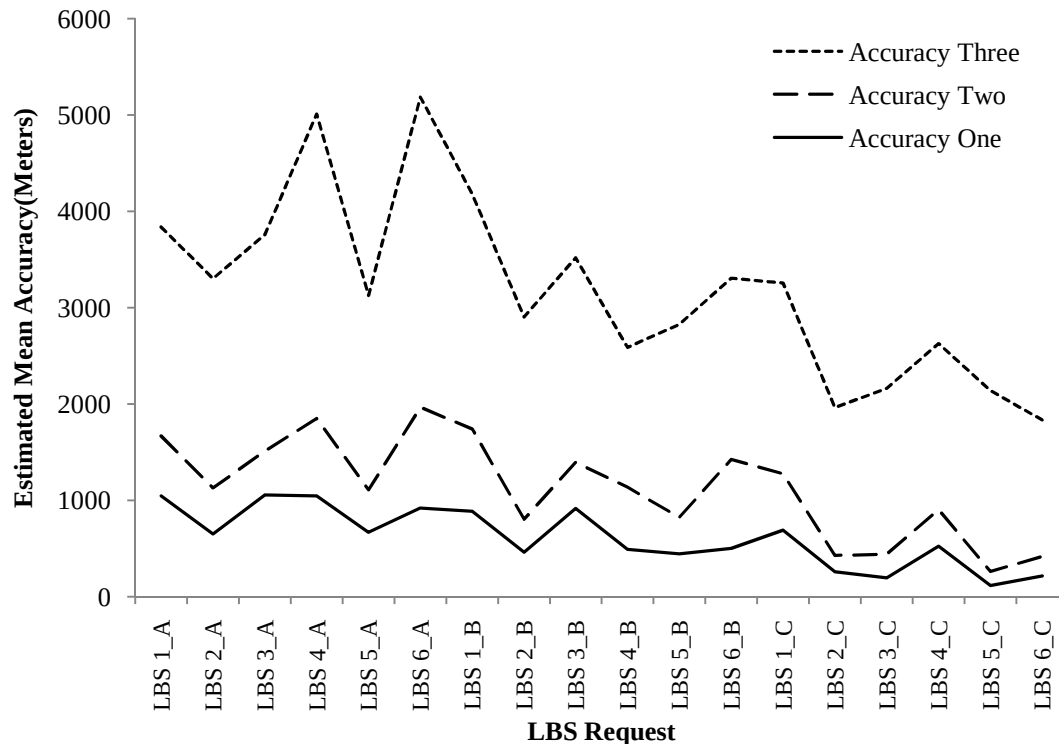


Fig.2: Mean plot for accuracy showing LBS request sent from different environments.

Overall analysis of type LBS requested for by the user shows that there is no significant difference between the accuracy provided by the location provider for each request. There is only a significant change in the accuracy for all types of request for the different environments. All LBS requested for gave the best accuracy at the urban areas and the worst at Suburban Type A.

Time of day

A two-way MANOVA was conducted to explore the impact of time of day has on accuracy at the geographical locations where LBS requests were sent from. Three dependent variables were used: Accuracy One, Accuracy Two, Accuracy Three and independent variables: time of day and geographical location of LBS request sent by the mobile phone user. The mean plots of Accuracy One, Accuracy Two and Accuracy Three in the morning and evening are as shown in Figure 3 and 4 respectively.

There was a statistically significant difference between data collected in the Morning and Night on all the dependent variables: $F(3,838) = 1.81$, $P = 0.144$; Wilk's Lambda = 0.994; partial eta squared = 0.006. Although of significant statistical importance, it is of very little practical importance which is about 0.6% of the total variance. Therefore, when the results for the dependent variables were considered separately, there were no dependent variables that reached a statistical significance.

Dependent variables: Accuracy One, Accuracy Two, Accuracy Three are not affected by the time of day in which LBS requests are made. The reliability of LBS (probability of receiving the location information requested for from the location providers) requests

made on Provider 2's network reduced by about 5% and about 2% of all requests made on the network in the evening had to be repeated twice or thrice before there was a response from the mobile operator. Provider1's LBS response were more reliable than provider2' LBS response.

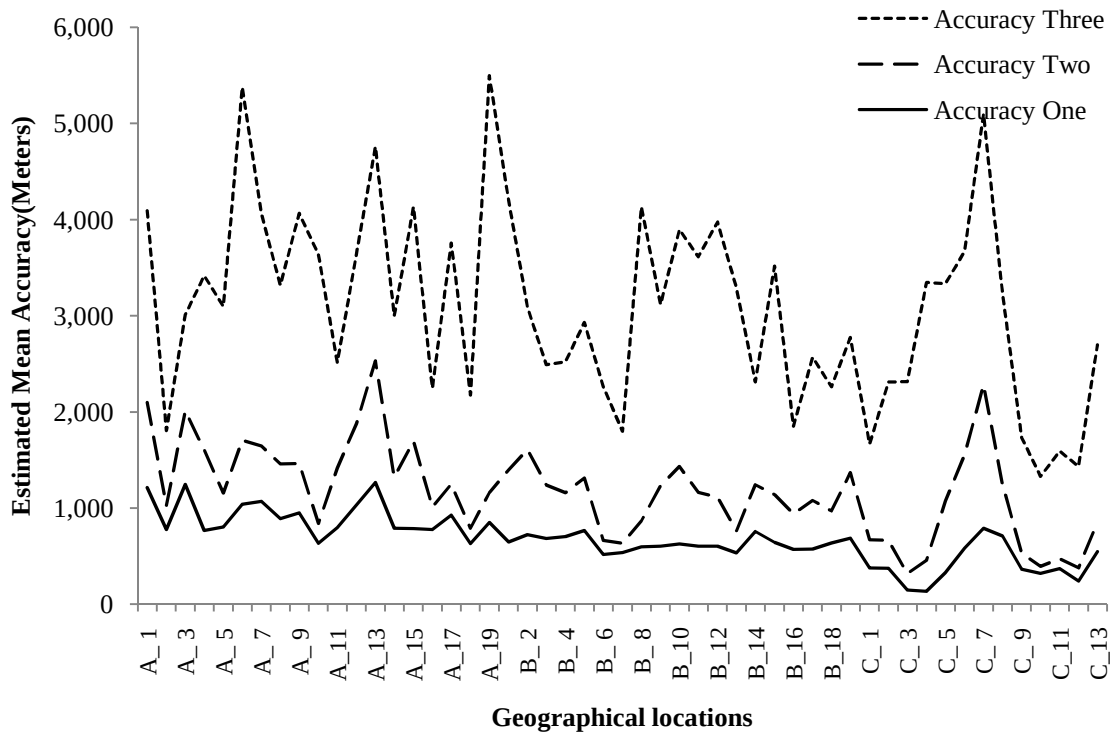


Fig.3: Mean plot for accuracy taken in the morning at different geographical locations

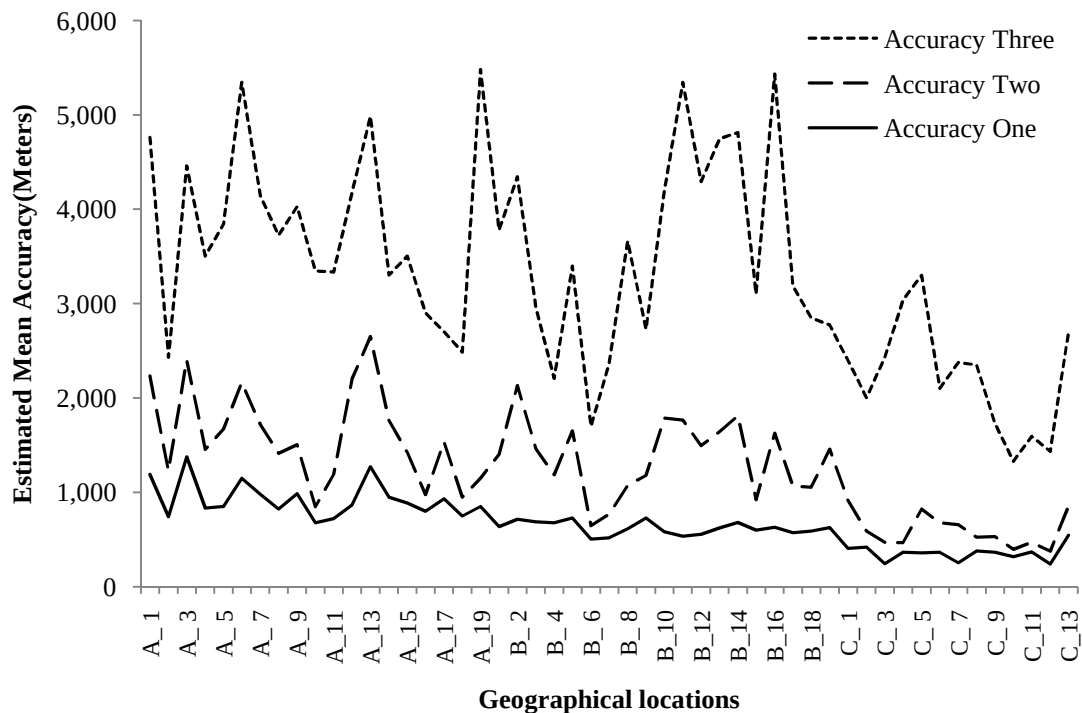


Fig.4: Mean plot for accuracy taken in the evening at different geographical locations

LBS Providers

A two-way MANOVA was conducted to explore the accuracy provided by LBS providers at different environments as given by the survey data. Three dependent variables were used: Accuracy One, Accuracy Two, Accuracy Three and independent variables: type of environment and LBS provider. The mean plots of the dependent variables with LBS providers are shown in Figure 5.

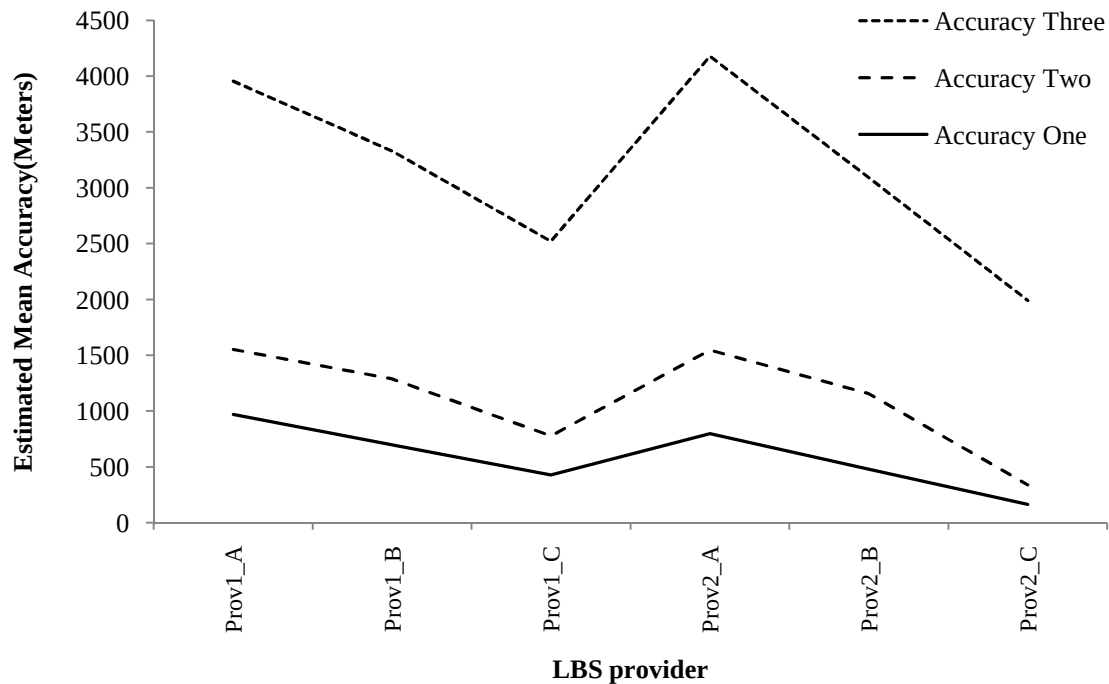


Fig.5: Mean plot for accuracy showing LBS Providers at different environments.

There was statistically a significant difference between the accuracies provided by Provider 1 and Provider 2 on the combined dependent variables: $F(3,928) = 16.26$, $P < 0.0001$; Wilk's Lambda = 0.950; partial eta squared = 0.050. Considering the dependent variables separately, the variable to reach statistical significance using a Bonferroni adjusted alpha level of 0.003 when the independent variable is LBS provider is only Accuracy One. Accuracy One: $F(1,930) = 44.037$, $p < 0.0001$, partial eta squared = 0.045. This signifies a small effect by the LBS provider on Accuracy One.

The LBS provider does not have a significant practical importance on the accuracy obtained from them, it can be seen from Figure 5 that it is the environment that has the most significant an impact on accuracies.

CONCLUSION

In conclusion, the dependent variables Accuracy One, Accuracy Two and Accuracy Three are affected by the environment and the geographical location of LBS request. They are not affected significantly by the time of day, LBS providers and the type or method of request.

LBS is used to support an activity the user is about to embark on. A small error in the accuracy predicted may turn out to make a large difference in the activity it is applied to (Katasonov, 2004). Failures in LBS translate to a failure in the user being able to accomplish the activity the LBS were used for. It is therefore of utmost importance to put into consideration the geographical location and environment the LBS request is made from in the algorithms used by the Location providers.

Algorithms which calculates the predicted accuracy needs to be changed and updated because it is significantly different from the provided accuracy.

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FOR FEMALE ENGINEERS: HOW TO IMPROVE YOUR CAREER PROSPECTS IN MALE-DOMINATED ORGANISATIONS

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ABSTRACT

Women continue to be disadvantaged in male-dominated organisations. Female engineers will invariably work for organisations run by men, and therefore could be disadvantaged in their careers. This paper presents a new approach for female engineers (and scientists) to enhance their career prospects in such organisations.

A key element of this approach is the concept that employees are playing a corporate game whether they realise it or not. It is a game because they are working to rules set by their organisation and from a career point of view there are winners and losers. To call it a game is not to trivialise its importance. Female engineers can enhance their careers by observing the way the game is played, understanding the rules (written and unwritten) and then deciding if they want to be willing participants.

To simply argue that corporate cultures need to change is correct in principle but does not bring about the necessary changes. The approach described here is to assist women with the skills they need to give themselves better choices for the types of work they could do. With this approach, more women will do more appropriate and satisfying work and reach higher levels of authority in their organisations, which by itself will effect change. Some of these women will then proactively introduce further change.

INTRODUCTION

In Australia and elsewhere, women continue to be disadvantaged in male-dominated organisations. Engineering and some parts of science remain male-dominated, and so female engineers and scientists will invariably work for organisations run by men, where some cultures and practices may disadvantage them in their careers.

There are four excellent reasons for having much greater gender balance in professions like engineering, *viz.* equity, excellence, efficacy, and efficiency (ETAN, 2000), and Toner (2006) published a new argument for more women in engineering based on personality types. But increasing the number of women attracted to engineering and science is just the start of the process; once women are trained and working within these professions, they are being challenged by workplace cultures and practices which favour men, alienate women, and cause women to leave their positions (Mills et al., 2008).

To simply argue that corporate cultures need to change is absolutely correct in principle but does not bring about the necessary changes. The aim of this paper is to present to women a new approach to enhancing their career prospects. This will allow women to have better career options and have more control over their professional lives. It does not mean they should strive to get to the highest levels of an organisation; rather, their

aim should be to use their skills and experience to get to a position and to do the type of work that gives them the most satisfaction and an appropriate return on their efforts.

With this approach, more women will be able to do more appropriate and satisfying work and reach higher levels of authority in their organisations, which by itself will effect change. Some of these women will then proactively introduce further change.

A secondary aim of this paper is to change the attitudes and behaviours of those men (and women) who deliberately or unwittingly make life difficult for female employees.

THE PROBLEM

Australia's female engineers and scientists, and women in business generally, face many issues which can inhibit the development of their careers and their enjoyment of their work. These issues are described below.

Lack of women in senior positions

In Australia, there is an unacceptably low number of women in line management, senior management and on boards. In 2010, women in Australia comprised (EOWA, 2011) 53% of all professionals, and 45% of the Australian workforce, but in the top 200 Australian listed companies ("ASX200"), women comprised only:

- 10% of executive managers (and 8% across all listed companies)
- 3% of chief executives
- 8% of board directors, and
- 3% of "Chairmen".

Almost half of these companies have no women board members. Yet a recent report (Insync Surveys, 2010) reviewing past research into women on corporate boards found that gender-diverse boards are more effective, not because women on boards behave differently from men, but because the boards as a whole operated differently.

In addition, there is considerable evidence that organisations which employ women at senior levels are more effective and produce greater financial returns than organisations which don't (Catalyst, 2007; Burrowes, 2009). Goldman Sachs JB Were (2009) estimated that closing the gap between male and female employment rates and boosting female productivity in the workplace would increase Australia's GDP by 11%.

Lack of women in engineering

There continues to be a national shortage of engineers in Australia (ANET, 2010) and other countries. The current number of domestic females commencing engineering is approximately 2,500 (17% of the total) and those completing degrees is approximately 1,300 (16%) (Kaspura, 2010). These figures have not varied by more than a few percent over the last decade. A similar story is evident in the workforce, with approximately 25,800 women (10%) in the engineering labour force (Kaspura, 2006).

Attraction of women into engineering and retention of them as practising engineers is a continuing problem and the subject of research (Hunt, 2010; ParisTech, 2010; Mills et al., 2008; Burrowes, 2007). A shortage of engineers is not a valid argument for a greater number of female engineers, as that implies that female engineers are reservists and only to be used when the more capable male engineers are not available.

In engineering and construction globally, women comprise 21% of total employees but only 3% of chief executives (World Economic Forum, 2010).

There is an often-used “pipeline” argument that as more women join the profession the shortage problem will be resolved. But this has not happened to date and is unlikely to happen in the future due to the low numbers of women enrolling in engineering and staying in the profession. A new approach focused on changing the culture is therefore needed, and both men and women need to change their attitudes and become role models in words and actions (Burrowes, 2009).

Discrimination, Harassment and Bullying

A recent study by APESMA (2010) of 1,100 women respondents in engineering, science and management reported that nearly 40% had been bullied and 38% discriminated against in the course of their professional employment, and nearly 20% reported sexual harassment. Not surprisingly, figures for sexual harassment and discrimination were higher in male-dominated industries.

Engineers Australia's second Careers Review of Engineering Women (Mills et al., 2008) found that 28% of women and 19% of men had experienced bullying by their manager or co-workers, 42% of female engineers had experienced discrimination (cf. 36% in 1999) and 22% had experienced sexual harassment (cf. 27% in 1999).

These are appalling statistics and not appropriate for an advanced country like Australia.

Pay gaps

There is a significant pay gap between men and women in engineering and other industries in Australia, and this continues to be a negative factor in women being attracted to, and remaining in, their preferred careers. Across the workforce, Australian female graduates earn \$2,000 less than male graduates, full-time women earn 17% less than men, and female executive managers in the ASX200 earn 28% less than male executives (EOWA, 2011).

Engineering in Australia follows the same pattern, with a pay gap for new female engineering graduates \$3,700 or 6% less on average than their male counterparts, and for female engineers with 20+ years experience, \$23,000 or 18% less (APESMA, 2007).

THE WORKPLACE FOR WOMEN TODAY

Women in Business

The many issues which women in business (and engineering) continue to face have a number of major causes. For business, Piterman (2008) describes these in four broad categories. There are short-term business drivers demanding immediate financial performances which force a results-oriented, competitive organisational culture. This “macho” environment encourages a 24/7 work culture which leads to poor work/life balance and difficulty in returning to, and staying in, the workforce due to lack of flexible working hours, high childcare costs, etc.

The next category of causes comprises gender biases that exist within workplaces, e.g. widely-held beliefs that women are numerically less competent than men, that women's communication and decision-making styles are incompatible with desired leadership traits, and that women lack ambition.

The last two categories relate to the male construct of masculine organisational cultures and relationship-building within the workplace, based on “mateship”, and the “heroic” masculine leadership model. In this model, leaders are assumed to be decisive, assertive or aggressive, competitive, self-confident, individualistic, advocating, controlling and dominating – but interestingly, these are not the characteristics of true leadership. Unfortunately but not surprisingly, the ideal of heroic leadership is rarely questioned in corporate circles and is an inappropriate leadership model (Sinclair, 1998).

The Australian Human Resources Institute has identified five common causes underlying the suppression of employment potential and widespread exposure to sexual harassment (Wilson, 2010):

- a predominant male work culture
- older male business leaders insecure in the presence of women at work
- an elite male group which feels entitled to the most powerful jobs in business, treasured for their alignment with the prevailing adult male persona and ego
- women who do not always replicate mutually supportive behaviour to other women, whom they see as competitors, and
- women tolerating sexual harassment because they fear for their jobs, reputations, futures and family livelihoods.

There is also the problem of biased HR systems in male-run organisations: “Talent management systems are frequently vulnerable to pro-male biases that inevitably result in less diverse employee pools” (Catalyst, 2010: 1). Gender bias can be overt or covert, and can be based on “unrecognised assumptions and habits of mind that disadvantage women without conscious intent” (Bailyn, 2010).

Women in Engineering

In engineering, unfortunately, there are additional problems (Simard, 2008; Jolly 2007). Engineering remains one of the last traditionally male-dominated professions and the industrial workplace has an even more widespread dominant male culture than in business. Men continue to occupy far more positions of authority than women. In some organisations gender bias is entrenched with men recruiting and promoting other men as a consequence. Although there is a natural tendency for people to recruit and promote others with similar personality types to themselves, in the engineering profession this occurs more frequently because there are far more men in authority.

Male sexist attitudes in these workplaces hold that men make better engineers than women and that women in general are complex, unpredictable, and hard to understand and communicate with. Engineers Australia (2007) has published a useful guide for engineering organisations to counter such attitudes. It contains theory, case studies and checklists for managing diversity in the workplace.

Career Progression for Women

In addition to the above descriptions of the working environment for women, various approaches have been developed for women to progress their careers in a male-dominated workplace. Sinclair (1998) presents a novel and useful view of women’s leadership by including the subject of sexual identity. She plots the level of personal power of a female employee against her level of sexual awareness and describes how these issues interact as she progresses in her career.

THE CORPORATE GAME

Women in business, and female engineers and scientists in particular, will continue to be disadvantaged in male-dominated organisations. Despite recognition of these problems in recent decades, progress has been far too slow. A new approach is needed.

The solution to the problem outlined above is firstly to attract and retain more women in engineering, the “hard” sciences and in business generally, and secondly to change the culture of the engineering profession and business to value gender diversity.

The thesis of this paper is that employees are playing a corporate game, whether they realise it or not, and that women can enhance their career prospects by understanding the game. It is a game because all employees are working to rules set by their organisation and from a career point of view there are winners and losers. To call it a game is not to trivialise its importance. Female engineers can enhance their careers by observing the way the game is played, understanding the rules (both written and unwritten) and then deciding if, and how much, they want to be willing participants.

As a prerequisite, female engineers need to understand a number of relevant issues (discussed below) and they will probably need to develop some new skills.

The previously outlined business models of Piterman (2008) and Sinclair (1998) describe aspects of the corporate game being played willingly or unwillingly by all employees. Some do not recognise the game, nor that it was established and is being run by male managers. The World Economic Forum (2010) finding that the greatest barrier to women rising to senior positions in engineering and construction world-wide is the prevalence of masculine and patriarchal corporate cultures is testament to the game being a male one. Because it is a male game, it is harder for women than men to recognise, and even if they do recognise it, it is even harder for them to participate in it.

RECOGNISING THE GAME

In order to recognise the game and participate in it, all employees, especially women, need to “read” the game being played and understand a number of relevant issues. To read the game, an employee needs to observe and decide *inter alia*:

- what are the rules of the game
- who are the people with power (official and unofficial)
- what are all the relevant relationships
- which men are sexist or uncomfortable with women, and
- who is likely to be promoted by management?

The Rules: Written and Unwritten

Catalyst (2008) researched the unwritten rules of corporate games in the USA and published its findings. Its first report states in its introduction:

Advancing in today's business world is often as much about learning and playing by the rules as it is about talent and results. Some rules are explicitly stated in organisational handbooks, ... procedures, or by senior leadership. But other rules are left implicit – unwritten – for employees to decipher on their own. Those who do not have the tools to access this maze of “unwritten rules” and the important knowledge these rules provide remain left out, no matter how competent they are...Many talented women may not have the

same access to their organisation's unwritten rules as their colleagues, to the detriment of their career advancement.

Results will vary in any organisation. As an example, from interviews with 65 women and men from a variety of industries, Catalyst (2008) found the most popular unwritten rules for workplace behaviours and actions for employees to be the following:

- network and build relationships within and outside the organisation
- find ways to become visible
- play politics and lobby for yourself and your work
- communicate effectively and ask for lots of feedback
- perform well, produce results.

Power

French & Raven (1960) described five different types of personal power, all of which are relevant to employees:

- reward power: the ability to provide monetary, social, political or psychological rewards to others for compliance
- coercive power: the ability to provide monetary or other punishments for non-compliance
- attraction power: the ability to elicit compliance from others because they like you
- expert power: the ability to elicit compliance because of technical expertise, either actual or reputed
- status power: compliance-gaining ability derived from a legitimate position of power in an organization

It is worthwhile for all employees to consider, firstly, which types of power they hold and how much, and secondly, what types and how much is held by the following: their manager's manager, their manager, their peers and their subordinates.

Male/Female Personality Differences

Some fundamental differences in the way men and women behave are discussed below.

Leadership

The prevailing common view of leadership is the heroic model, which fits the behaviour of men far more easily than it fits women. There are many models of leadership, but leadership is primarily about the leader having a vision, enrolling others in it and motivating them to work with the leader to achieve the vision or objective. In a frequently cited paper "Leadership That Gets Results", Goleman (2000) outlined six distinctive leadership styles based on the principles of emotional intelligence, which do not conform to the heroic model in any way.

When different genders are involved, the situation is more complex. A recent review of gender and culture factors in various leadership models concluded:

When women leaders adopt stereotypically masculine leadership behaviours, are in male-dominated settings or are evaluated by men, they are particularly susceptible to being rated negatively. This illustrates some of the additional barriers that women encounter as they attempt to negotiate their way through the labyrinth.

Ayman & Korabik (2010: 165)

Cheung & Halpern (2010) cite evidence that “women generally have a more democratic, participative and collaborative style of leading” than men, and that “high-achieving women tend to adopt a relational leadership style”, with a strong sense of conviction and self-worth. They state that “femininity and leadership are no longer considered incompatible”, a view which needs to be more widely held.

Barsh et al. (2008) studied successful women in business and distilled a *Centered Leadership* model with five broad elements: meaning, managing energy, positive framing, connecting and engaging. Their model explains how talented women thrive in business and gives women useful approaches for becoming more effective leaders.

Decision-Making

In his seminal work on personality types (later extended by Briggs and Myers), Jung established three dimensions of personality, with gender affecting only the *Thinking/Feeling* dimension. Jung held that people make decisions and judgements either through *thinking* (a logical and impersonal approach), or through *feeling* (based on personal and social values). In Western countries, the thinking/feeling (T/F) ratio for men is approximately 60/40 and for women it is typically 30/70 to 40/60. Hence women are more likely to make decisions in a feeling way.

Engineering and the “hard” sciences appeal far more to thinking types. With male engineers in Australia having a T/F ratio of approximately 88/12 (Toner, 2006) and insufficient data for Australian female engineers (but more like 50/50), male and female engineers and scientists are likely to sometimes make decisions very differently.

Communication

Berens (2008) has shown that people prefer to communicate in either an informing way (e.g. “we’re out of milk”) or a directing way (e.g. “please get some milk”), and that a person’s Myers Briggs personality type will generally determine which of these is the usual style. Overall, feeling types are more likely to use an informing style and thinking types are more likely to use a directing style. Hence in general, women are more likely to use an informing style. If not understood, this difference in communication styles can cause misunderstandings, distrust and conflict at work and at home.

Assertiveness

Assertiveness means communicating your needs, wants, feelings, beliefs and opinions to others in a direct and honest manner while being receptive to their needs and trying not to hurt their feelings. In general, females are less assertive than males for a number of reasons, including cultural influence from childhood (girls are brought up to be less aggressive and more consensual) and natural preference from personality type (feeling types prefer harmony and are less assertive). Women need to understand why they are generally less assertive than men, and how this affects them in the workplace.

Competitiveness

Similarly, it is generally accepted that, in the presence of men, women are slightly less competitive than men (Leigh, 2010), and an understanding of this difference and how to make use of it is a useful skill for women.

Career Management

Why is it that only 15% of highly qualified women aspire to positions of power against an average of 27% for men? Why is it that 70% of females rate their own performance as equivalent to that of their co-workers, whereas 70% of men rate themselves better than their peers? A lot of it is

about having the confidence to articulate a vision for the future and go after it. Men do that. Women don't to the same extent.

Nugent (2010: 52)

There is considerable evidence that men have more self-confidence and are more assertive in the workplace. Prepared to take greater risks, men will put themselves forward for promotion when they have only some of the required skills and experience, whereas women tend to do this only when they believe they have almost all the required attributes. And if males fail to get promoted, they are more likely to blame external factors, e.g. poor decision-making by others, rather than themselves (Schulman, 2010).

PLAYING THE GAME

With the ability to read the game, an employee has to decide how much she/he wishes to play it. To play it actively, the following checklist should be useful:

- decide the organisation's unwritten rules (and write them down)
- be fun at work (i.e. develop your attraction power)
- work hard and keep learning
- make the most of your professional institution (e.g. Engineers Australia) and continuing professional development training (i.e. increase your expert power)
- improve your leadership skills by increasing your emotional intelligence
- try to understand how your organisation rewards its staff, i.e. understand the management culture
- develop internal and external professional contacts to assist your organisation and personal contacts to assist your career
- create opportunities to show your manager and senior management that you are:
 - conscientious, responsible and respectful
 - trying to make the organisation more successful
 - creative (both technically and commercially)
 - confident and ambitious
 - uncomplicated as a person, i.e. low maintenance for your management
- don't accept bullying, harassment or discrimination, i.e. make your position clear
- ask for coaching or mentoring from internal or external people
- read self-improvement and management literature (Templar, 2003; Grose, 2010)
- raise your visibility in the organisation by taking on new roles internally or externally, i.e. be proactive rather than reactive, and
- regularly plan your career: what do you want to be doing in 10, 5 and therefore 2 years time? Keep a written record of your plans.

CONCLUSION

With the right skills, women can recognize the corporate game that is typically played in male-dominated organisations and give themselves the option of whether to engage in the game and if so, how much to play it to advance their careers.

However, the real issue is how the game can be changed to allow for gender-neutral workplace cultures and true gender equity across organisations. Bailyn (2010) described a series of successful intervention projects to increase gender equity in organisations and to better reconcile work and family needs. Achievement of this objective in Australia and elsewhere will only happen when progressively minded men (and women) have the knowledge, power and commitment to effect such major change.

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A CASE STUDY ON THE ENGINEERING PROFESSION: DIVERSIFYING TO SUCCESS

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ABSTRACT

Statistics continue to show that the engineering profession remains male dominated. Surveys show that women are not staying in the engineering profession or reaching senior positions within engineering organisations proportionate to their overall participation. One quarter of respondents to the Women in the Professions survey carried out by the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) 2009–10 indicated that they would leave their profession within five years. The research highlights that engineering organisations have to implement significant workplace cultural change to ensure the retention and promotion of talented women.

The first part of this paper presents a brief overview of the current statistics and research related to female progression and lack of retention within the engineering profession. The second part of the paper discusses how this current research has been used to formulate a diversity strategy for engineering organisation Kellogg Brown & Root Pty Ltd (KBR I&M)

Using current research, a working group within KBR I&M has developed a draft diversity strategy; with the goal of enabling KBR to become even more inclusive organisation, with a strong commitment to actively respecting, promoting and fostering each individual's unique background, characteristics and abilities.

This paper will discuss the implementation of the strategy and, in particular, what appears to be working, the challenges faced in rolling out the plan, and how we might measure success.

Introduction

The engineering profession remains male dominated and women are generally not staying in or reaching senior positions within Australian organisations. Research shows that women in developed economies have made significant contributions to the workplace and the lack of women in leadership positions means that organisations are missing out on an important and measurable advantage. Despite this, there is a considerable under-representation of women in our industry.

Women make up over half of Australia's total population and more women than men complete secondary and tertiary level education. However, women remain an overwhelming minority in top corporate positions in ASX200 companies in Australia, and levels are deteriorating rather than improving. The Careers Review of Engineering Women (CREW) survey indicates that while women have made considerable inroads into the profession, workplace culture has been slow to catch up, especially in the engineering industry. The cultures of many engineering workplaces are female and family unfriendly. Women remain generally more dissatisfied than their male counterparts, in particular with their opportunities for promotion and recognition.

This paper considers this issue, explores the reasons behind it, and suggests some solutions and actions that may help improve the situation.

A diversity strategy being developed at KBR to improve diversity is discussed to give a practical example of an approach to the challenge. (It should be noted that although the proposed KBR strategy covers both cultural and gender diversity, the focus of this paper is mainly on gender diversity.)

The Issues

Males and females in the engineering industry received the CREW survey and results were collated from responses received from 767 female engineers and 122 male engineers. Over 50% of men and women surveyed were between the 20-40 age group, 20% falling in the 40-50 while the rest in the above 50 age group.

The CREW report results reveal some of the many factors that affect women in a male-dominated industry.. These include:

- *Discrimination and Harassment:* A third of the women surveyed reported that they experienced discrimination while working as engineers and a few said they were sexually harassed.
- *Gender-based discrimination:* Managers and clients expressed views that women are not suited to being engineers and managers. This was worsened by racist attitudes towards women from other cultures, in particular women from non-English speaking backgrounds.
- *Fewer opportunities and rewards than male colleagues:* The expectation exists that women undertake administrative and tedious tasks.
- *'Boys club' culture and exclusion from mentoring and social networks:* Networking opportunities were male oriented.
- *Family responsibility and pregnancy (actual and potential):* Women experienced discrimination as their opportunities for interesting work were reduced when they became pregnant or took on carer responsibilities. Similarly, younger women were also discriminated against as it was assumed that most women would have children.

- *Workplace satisfaction*: The conditions that women found most dissatisfactory were opportunities and recognition for promotion, and poor salaries compared to male counterparts.
- *Workplace culture*: Men are more likely to describe their workplace as comfortable and supportive, compared to women, who describe it as competitive.

A study undertaken by the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) revealed that women engineers thought taking maternal/parental leave was disadvantageous to their career and that maintaining a work-life balance had hindered their career development. The APESMA study focused on the experiences and perceptions of female technical professionals and the results were derived from a survey of around 1,100 women respondents, the average age of respondents being 38. The industries that respondents worked in included- Research (25.7%), Consultancy and technical services (19.2%), Education (14.8%), Water, electricity and gas (11.5%). It was found that 77.9% respondents worked in a male-dominated industry. The majority of women indicated that they had left their profession within the first five years and that, generally, in a male-dominated industry women had to prove themselves, where men were assumed more capable.

During the ‘Year of Women in Engineering’ promoted by Engineers Australia in 2007, campaigns were run across Australia with the aim of improving the recruitment and retention of female engineers. One of these campaigns was the ‘Girl Talk’ program, targeted at high school-age females. Evidence shows that education about engineering as a career and about what subjects to choose at high school level is essential for women so that they select the prerequisite Maths and Science subjects that will enable them to gain entrance to engineering degrees. This program builds awareness in high school-aged women of the potential career paths for female engineers.

Although the Engineers Australia campaigns have had some successes in recent years, women continue to remain a minority in the engineering industry due to several limiting factors, some of which include:

- inadequate counselling prior to starting university degrees
- early differential socialisation of men and women
- lack of support from family, friends and professional engineers
- cultural and occupational barriers.

Consideration of the issues above within diversity forums at KBR has led to the development of a diversity strategy. The purpose of the diversity strategy is to enable KBR to become a more inclusive organisation that respects, promotes and fosters each individual’s background, characteristics and abilities. This strategy is still being developed but it is hoped it will be rolled out in the coming months. The challenges faced in the roll-out of this strategy are discussed in further detail below.

Recruitment and Retention

From discussions within its diversity forums, KBR has determined that one of the biggest challenges faced by engineering companies is to attract and retain women in the profession. Often women are attracted to companies that have successful female role models, as this demonstrates that there are good career paths, a receptive, friendly culture, and flexibility. Where this is not the case, recruitment will be a challenge.

A recent survey conducted at KBR sought views from some staff within the KBR Adelaide office, with some input from KBR's Melbourne and Brisbane offices. The survey posed questions relating to the most important attributes that an organisation needs to have to attract new staff. The first question staff were asked was: 'What do you need to know about an organisation before accepting a job offer?' The results to this question are displayed below in Figure 1. Out of the 102 staff surveyed (59 men and 43 women), the highest-rated attribute for future staff was the offer of training opportunities and potential for growth. The second-highest attribute was a family-friendly workplace and work-life balance. Some of the other aspects that men and women wanted to know before accepting a job offer were the reputation of the company in the market, salary and the type of projects the company had undertaken in the past.

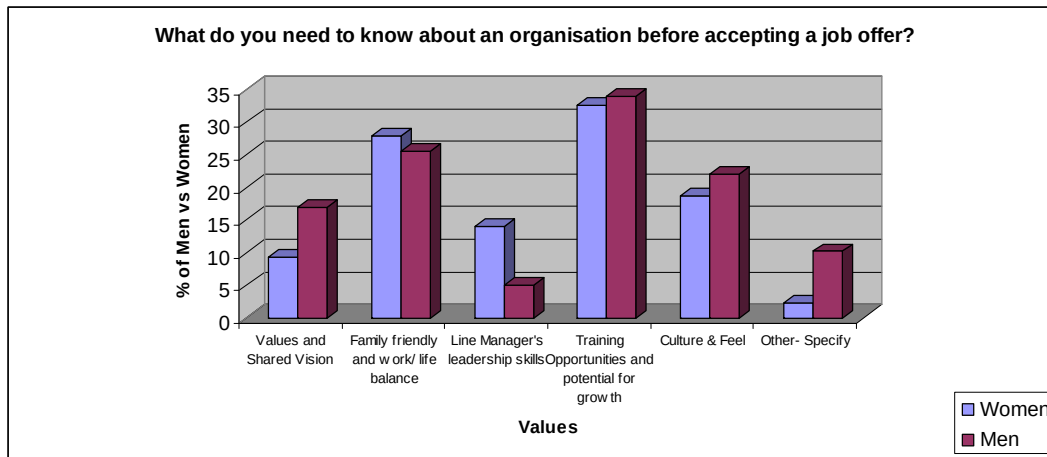


Fig. 1: Survey Results – Recruitment

The second survey question was: 'What is your reason for staying at a job?', the results of which are shown in Figure 2 below. It can be seen from the graph that a good working relationship with managers and co-workers was more important than career advancement for most women, the opposite to that chosen by men. It is interesting to note that 'desirable working hours' was rated less by women than 'relationship with co-workers' and 'career advancement'. This indicates that the culture of an organisation and career progression are important to women and that they would sacrifice desirable working hours (an attribute expected to be desired by most working mums) as long as a good working relationship with their co-workers and managers was maintained. Other reasons staff stated for staying at a job included job satisfaction, interesting work and experience on large projects.

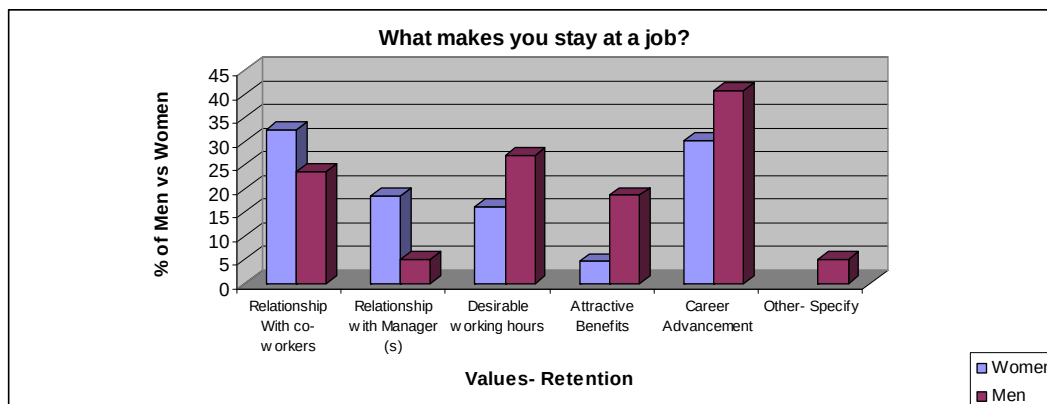


Fig. 2: Survey results – Retention

Poor female representation in the engineering profession is sometimes a result of women giving up their careers to raise a family; however; the primary reason for lack of retention has been shown to be a workplace culture that is not friendly to women. These results were evident in the CREW survey. As a result of a working environment that does not suit them, many women choose to leave the engineering profession. This is a significant loss to the engineering industry and ways need to be explored to change the culture of workplaces so that women are retained and attracted back to the workplace.

Diversity: The Advantages

A company that employs a diverse workforce is better able to understand the demographics of the marketplace it serves and is thus better equipped to thrive in that marketplace than a company that has a more limited range of employee demographics.

It is well known that there is a shortage of good engineers, with many organisations citing lack of good personnel and recruits being the main limiting factors to their growth. Over the next five years, significantly more people are predicted to leave the engineering profession, through retirement of baby boomers, than will be graduating with engineering qualifications.

It has been found that diversity in a workplace brings differing opinions and contradictory arguments. This encourages debate and consequently promotes creativity, which may in turn lead to improved decision-making. Findings from Robbins et al. (2004) demonstrate that heterogeneous organisations generally outperform homogenous ones. It is generally acknowledged that women make decisions based on different factors than men and this stimulates positive differences and vision. Hence, retaining women is not just about keeping up numbers or filling up lack of resources; the diversity itself is extremely important and leads on to the discussion of leadership traits that women possess.

Naturally, human beings have a tendency to hang around people who are like 'us'. Until the workplace is so diverse that 'us' doesn't exist, consideration needs to be given to how our behaviour affects people who aren't like 'us'. As mentioned above, having a workplace where different employees mesh and engage well is beneficial to a business organisation as it allows for a broad range of ideas. However, some gray areas might exist; for instance, a Muslim worker might want a morning off for Ramadan. Such a request if granted could upset other workers. One solution a business organisation could implement is a 'floating holiday'.

Women managers appear to create a work environment that is attractive to other women Smith et al. (1994) as well to men, and this helps in recruiting the best possible staff. Having high-profile women in executive positions or on the board in a company is of great benefit to female staff, who can aspire to follow in their footsteps.

Furthermore, greater gender diversity broadens the pool for recruitment of high-quality directors and employees, and is likely to support employee retention, encourage greater innovation and improve a company's corporate reputation.

Helgesen (1990) suggests that certain feminine characteristics give the woman leader an advantage. Characteristics described as essentially feminine are sharp communication skills, in particular good listening skills and empathy; advanced intermediary skills (for negotiation and conflict resolution); well-developed interpersonal skills; and a soft approach to handling people.

Moreover, maternity/parental leave is a time in which the carer grows as a person and as a leader. Pederson (2010) suggests that the skills learnt in parenting are extremely beneficial and directly applicable to management and leadership in the workplace. For instance, clear communication and emotional intelligence – two important characteristics for good leaders – are enhanced by parenting. To control one's emotions while managing the emotions of others, to behave rationally with self-confidence, to listen, to read between the lines, to understand a perspective, to act with empathy and to encourage and champion are qualities common to new parents and upcoming and good leaders. Why then does the profession lose parents, in particular women, coming out of parental leave with qualities such as these? More importantly, what can the profession do to increase the retention rate of women? A simple solution to this is the provision of an improved workplace culture including considering the re-structuring of senior and management positions. Research undertaken indicates that most women are not reaching senior positions when compared to the number of female graduates as a direct result of a lack of appropriate workplace structures and support. From past and current research and the results collated in KBR's survey, it can be concluded that measures such as providing a family-friendly workplace, along with provision for career progression can be undertaken to retain the best talent in the engineering industry. Some of these measures are discussed in more detail within the proposed KBR diversity strategy.

The KBR Infrastructure and Minerals Diversity Strategy

KBR is one of the world's largest engineering, procurement and construction companies. KBR delivers a wide range of services through a number of business segments including Infrastructure and Minerals, Power and Industrial, Downstream, Oil and Gas, Gas Monetization, and Government and Defence. The I&M business unit operates in three regions: Asia Pacific (APAC), Middle East/ Europe/Africa (MEEA) and the Americas.

As specialists in infrastructure, KBR's Infrastructure and Minerals (I&M) business unit offers a wide range of consulting engineering and project delivery services to private and public sector developments, in both urban and remote environments, in the following industry areas- Facilities, Minerals, Transport and Water.

KBR Infrastructure and Minerals (I&M) has developed a diversity strategy to improve gender (and other) diversity throughout all levels of the organisation. This strategy is still undergoing internal review and confirmation but the current proposal is discussed below:

KBR I&M's Diversity Vision is *'As a business unit delivering projects globally, we recognize that our people represent the diverse communities we serve and are committed to being an inclusive organisation that respects and fosters each individual's unique background, characteristics and abilities.'*

KBR I&M's purpose for developing this strategy is *'As an employer of technical, commercial and administrative talent, Infrastructure & Minerals believes that if it can provide a workplace that is more broadly inclusive than its competitors, it will enjoy a distinct advantage in the future.'*

There have been discussions within a diversity forum at KBR to lead a change over the next 12–18 months that will position KBR among the leaders, providing an inclusive workplace. KBR's methodology has four main themes:

1. *Committed Leadership*: This involves moving beyond compliance with policies and processes to a point of fully embracing the concepts and recognising the value that true diversity programs bring to the success of the business. Clear and consistent leadership is required to achieve the cultural change. Management at all levels is required to have a clear understanding of employee needs, critical diversity needs and the relationship between those and driving business success.

2. *Procedures and Processes*: Procedures and processes are required to be aligned with the desired organisational culture and diversity strategy. Areas such as recruitment and selection, career development, performance management, and compensation and benefits support the strategy. Furthermore, flexible working arrangements, for new parents in particular, are essential as they will provide significant alignment to the strategy.

3. *Communication*: Clear communication of our vision, strategy, company values and expectations in regard to diversity to all levels of the organisation. In addition, all employees will have available actions, plans and results to assist in achieving commitment and how all staff can all play a role in achieving the strategy/goals.

4. *Education/Training*: A key component in rolling out the strategy is educating the managers in regard to the benefits of the strategy, cultural values, legal obligations etc. To assist managers in embracing and implementing the strategy, methods need to be developed to raise their awareness and understanding.

KBR developed a cultural roadmap that helped identify some of the critical needs of current and potential employees. To assist with measuring success, KBR has proposed three strategic outcomes from the strategy:

Strategic Outcome 1: KBR I&M is seen as welcoming by job candidates from each gender as well as various cultural backgrounds and family circumstances.

The initiatives proposed to be implemented to drive the business towards this outcome:

- annual events for new employees from other countries and their families to meet location management staff
- annual office lunches in each location to celebrate diverse cultures where staff are encouraged to bring in cuisine from their own culture
- recruitment panels to comprise individuals from diverse backgrounds and gender balance, all with a solid understanding of job requirements and policy
- recruitment material, brochures, printed matter and related websites to strategically incorporate photos of culturally diverse people and different gender and ages
- promotion of flexible working hours and conditions as a viable option through whiteboard reminders and inclusion in employee information, e.g. four-day weeks on same pay, working from home etc.

Strategic Outcome 2: Return rate among people returning from paternal and maternity leave meets or is higher than industry average.

Some initiatives include:

- contemplating access to childcare services when determining office localities
- Investigating needs and if required providing additional storage space for prams, mobility support, and bicycles in offices.

Strategic Outcome 3: Existing employees do not perceive family circumstances or cultural and gender factors to be an inhibitor for internal advancement and progression, and feel supported by their employer.

Initiatives to achieve this outcome include:

- Conduct a survey to understand staff's cultural, gender, religious and other needs in terms of support
- Encourage a culture of scheduling reoccurring meetings and teleconferences in the core part of the day to enable parents to pick up/drop off kids
- Provide designated private multi-faith/multi-function 'quiet rooms'
- Make work, client and social functions more family-oriented and cognisant of out-of-work commitments; for example, holding KBR family days and staff functions during the day.

KBR believes that the above outcomes will be advantageous to the organisation. The proposed strategy is under review by senior management with the intention of rolling it out in 2011. As with any other new roll-out, there will be challenges. These, along with the management of these challenges are discussed below.

Diversity: The Challenges

With increasing attention directed to the importance of workplace diversity, Australian organisations are faced with the difficult task of the effective management of a diverse workforce. As KBR is a multi-national company, it is essential that it not only manages the diversity of the workforce across geographic regions, but that it does so with consideration to the history and traditions that are unique to each country within the corporate umbrella.

Various research studies have shown that organisations that emphasise collectivism in the work environment receive more benefits than organisations that emphasise individualism. An emphasis on teamwork enables the development of better relationships within an organisation.

KBR's forum discussions have concluded that having an organisational culture that encourages employee involvement and creates a sense of ownership and responsibility appears to be important for the management of workplace diversity. This implies that in this type of organisation all employees are being developed and empowered, not just those who contribute to diversity in the workplace.

At KBR, to effectively manage and maximise the benefits of diversity and successfully integrate a diverse workforce, the following initiatives will be implemented:

- frame the diversity management initiative as an opportunity for learning
- ensure senior management dedication and responsibility
- communicate how diversity is important to the overall functioning of the business
- highlight the value of diversity to all employees
- emphasise unity within the organisation
- evaluate the effectiveness of diversity management programs through established metrics.

Conclusion

KBR's proposed diversity strategy is currently being reviewed with the intention of implementing it in 2011. It is planned to monitor success by monthly reporting in diversity forums; through survey information studied by gender; review of exit interviews; and monitoring of staff reviews of female staff and their managers.

It is hoped that this proposed strategy will attract and retain women in the engineering industry. KBR's challenge is to successfully implement the strategy and to develop indicators against which success can be measured to enable refinement of the strategy as necessary.

Attracting women to the engineering industry, retaining them and helping them reach their full potential makes good business sense. Some of the key activities that may lead to improvement include:

- a female-friendly work environment
- opportunities available to all staff for training and potential for growth
- provision of opportunities for career progression
- desirable working hours.

Many of these activities apply equally to men and women, and introducing diversity to an organisation will help improve the performance of the business and the profession. In conclusion, employers will reap the benefits of diversity programs through increased employee effectiveness, attracting and retaining the best talent, improved morale and increased consumer and market responsiveness.

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MENTORING OF SENIOR WOMEN ENGINEERS - EXPERIENCES AND LESSONS LEARNT

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ABSTRACT

This paper looks at the success of the women at Aurecon establishing a Women's Initiative in 2008 and in particular a mentoring program. The program has assisted in raising Board awareness of both the issues facing senior female engineers and project managers and the talents that they have.

The Women's Initiative established a Mentoring Working Group and organised for the most senior female engineers and project managers to be mentored by a Board Member for the following 12 months. As this was the first program of its kind, there was initial feedback at the six month mark, with a final evaluation of the program at its completion. This evaluation included feedback on both the mentoring program and the mentors themselves, to assist in the development of the Leadership Team. One of key findings was that with the geographic spread of the mentors and mentees opportunities for face to face meetings were limited and that this made establishing a rapport difficult.

The final feedback in March 2010 was positive with the majority of participants wanting to continue the program. One of the main outcomes for the mentees was the opportunity for time and exposure with a Director. As a result it was agreed that there would be a change of mentor for each mentee to increase the exposure. The author is a civil engineer and mentee in this program.

This successful program has been expanded to all women Executives and a self-paced development program has also been adopted.

INTRODUCTION

The aim of this paper is to demonstrate how Aurecon established a mentoring program for its senior women Executives and to present the feedback from the program.

Aurecon's Culture Shift program, begun in 2008, indicated an existing management culture that was founded in traditional masculine values, such as having control and power as the primary tools of management. In light of the changes to Aurecon's goals and values, it was important to take a fresh look at this issue. The Board support for diversity and the establishment of the Diversity Leadership Team and structure led the way for change. To support Aurecon's value statement of respect for others by celebrating diversity and acting with integrity and honesty, it was recognised that there was a compelling argument for changing the organisation's culture, policies and procedures as they impact diversity. The first diversity issue to be investigated was the attraction and retention of women.

All Aurecon statistics in this paper refer to its Asia Pacific offices, unless otherwise noted.

Turnover

The turnover by gender as a percentage of staff was 19% of females as opposed 14% of males leaving the company in the 2008/2009 financial year. Whilst the organisation wanted to reduce all turnover, there was an economic argument that if the organisation could reduce the rate of turnover amongst females to the same rate as for males then it would save AUD1.8 million per annum from its bottom line.

Further, changes required by governments focussed attention on reporting diversity as part of tenders and in the consideration of awarding contracts. Companies are also increasingly scrutinising its providers' diversity policies. For instance in 2007 Microsoft UK stopped using a supplier due to its poor diversity practices (Pitcher 2007).

Original Female Executive Numbers

In mid 2009 females represent 23% of total staff and 21% of all professional staff. All staff in a business support function, eg. human capital and finance, fall outside the professional category. The break up by classification, both as a percentage of all staff and as represented in Professional staff, show that the distribution of female staff is skewed towards the junior Levels with 71% of females Level 4 or lower. A Level 4 professional staff member is fully competent and able to work independently, or as part of a team. They may lead a small team either on site or office based. They regularly interact with internal and external clients in completing projects. They are able to understand client requirements and are starting to be able to recognise client opportunities. Beyond this level it is expected that the professional will have gained chartered professional status with the relevant body.

Recruitment analysis indicated that 34% of Aurecon 2008/09 graduates were female, however, there was only 6% female representation at Executive Level. An Executive is Level 7 and above with an equity shareholder in the company.

Women's Initiative

To address these issues the Women's Initiative was established in June 2008. The Initiative was set up to address the needs and challenges of employees who are underrepresented within the company, and to ensure that the company celebrates the achievements and successes of women. Working Groups were established to focus on the key issues that were identified as important to women at Aurecon. The Working Groups were:

- Mentoring and leadership
- Flexible working practices
- Policies and benefits
- Communication

Senior female Executives led the Working Groups.

FEMALE EXECUTIVE MENTORING PROGRAM

The women of the Mentoring and Leadership Working Group developed a Female Executive Mentoring Program with the assistance of Aurecon's Human Capital team. The aim of the Program was to facilitate the mentoring of the organisation's female Executives within the Asia Pacific region by its Group Leadership Team and Market General Managers.

The mentoring program was to assist the Executive women in their development and provide an opportunity to increase their visibility with the senior leaders in the organisation. It was anticipated that this program would be a useful strategy to help women's advancement in the organisation.

Program Phases

The 12 month program was to be deliberately informal with the expectation that mentors would be fully trained and supported to initially drive the program. Human Capital was to prepare guidelines for participants in December 2008. The program was expected to have seven phases.

Phase 1 - A Diversity Leadership representative was to pair a senior leader with a female Executive.

Phase 2 - An invitation was to be sent to the five senior female Executives (Level 8 and 9) in March 2009 for the first meeting.

Phase 3 - Human Capital was to provide mentoring tips to the Directors (booklet or face-to-face meeting).

Phase 4 - The first meeting was to take place. The next meeting was to be identified collaboratively by the mentor and mentee.

Phase 5 - Monthly meetings were to continue for 12 months, or as agreed between mentor and mentee.

Phase 6 - Human Capital was to routinely gather feedback from mentors and mentees on the program's effectiveness. It was intended that on reviewing the feedback Human Capital would identify mentors for the Level 7 female Executives in May 2009. The program would be launched to the Level 7 female Executives in July 2009.

Phase 7 - The program was to be reviewed after 12 months. At this point it was expected that a final letter would be sent to each female Executive with thanks for participation and a final message from her mentor.

Roles and Attributes of Mentors and Mentees

Human Capital believed that if a mentoring program was to be successful, all parties must understand their part in the process. To this end Human Capital provided participants with details of the expectations of the program from both mentors and mentees.

No Fault Conclusions

Participants were to be made aware clearly and up-front that a No-Fault-Conclusion applied. A No-Fault Conclusion meant that either party was able to end the commitment with no blame for any negative experiences or results being placed. As a result of this it was hoped that the relationship would be more open and participants might feel less 'trapped' in a relationship which was not providing them with what they are looking for.

Personal Qualities of Mentors

When nominating people to undertake the role of mentor, consideration was to be given to the personal qualities displayed and the personal experience levels of the mentor. The program aimed to provide a very positive mentoring experience to participants and would do this by up-skilling mentors as needed.

Recommended Mentoring Guidelines

Further information was provided in relation to the program being:

- Private and confidential
- Impartial - The Mentor was to act without actual or perceived bias.
- Voluntary – The Mentee had the right to withdraw from relationship at any time. Mentors were able to withdraw at the direction of their management.
- Informal
- Neutral – Mentors were to be independent of politics or interests.
- Non-discriminatory

MENTORING

Professional Bodies

Aurecon's mentoring program for senior female Executives was based around the expectation that the Directors of the company, being more experienced in the business, could assist the women with career advancement.

There are various different aims that mentoring programs can be developed to achieve. They may have a very specific goal, eg attaining a particular skill level or qualification. Similarly, it may be more of a guidance role to have someone to assist when a need arises. Ones that are common in the engineering profession are aimed at obtaining recognition from the appropriate professional organisation, such as the Institute of Professional Engineers New Zealand (IPENZ). Male et al (2009) identified that engineers perceived technical, non-technical and attitudinal competencies as important. One of the non-technical competencies that was identified as important was the mentoring of co-workers.

IPENZ (2007) suggests that in addition to the traditional mentoring mentees could use peer mentoring or alternatively group mentoring to assist them in the process of becoming a Chartered Professional Engineer. Peer mentoring matches graduates within an organisation "the primary goal of peer mentoring is to reflect on the way people learn and to work with another through an observational model to improve them" (IPENZ 2007:4). Group mentoring has a senior engineer meeting with a group of graduates who meet in a structured session on a regular basis.

The Environment Institute of Australia and New Zealand (NSW Division) runs a mentoring program to help "environmental professionals achieve their potential". This program is based around a senior professional being matched with a less experienced member. The program runs for a fixed six month period. The Institute believes that this is enough time to assist one another. After this the mentee may choose to have a new mentor, no longer be mentored or to make an informal arrangement with the existing mentor. Institute of Professional Engineers New Zealand (IPENZ) has a similar fixed period, in this case 12 months (IPENZ Mentoring Guidelines 2007).

The IPENZ Mentoring Guidelines (2007) emphasis that mentors should be catalysts rather than leaders. The mentor has the experience to guide the mentee in analysing and reflecting on the mentee's situation. This could be used in the cross industry situation as the participants can make each other aware of the range of options from which they can choose. The participants can encourage each other to make their own decisions based on the options. Similarly the Auckland Women Lawyers' Association (AWLA) Mentoring Programme Guidelines propose that mentees should be allowed to make their own judgements and work at their own pace.

The professional institute models suggest that technical knowledge is only a part of mentoring process, even when a program is within an industry and aimed at assisting the mentee in achieving a professional qualification. This can go against the idea of a mentoring relationship based on the mentor having high level technical skills (Holland 2009). Technical skills were not a consideration in the Aurecon model due to the nature of the program.

Mentoring of Women

Stone (1998:328) specifically mentions that a mentor can be valuable in “helping women understand the culture of male-dominated business organisations”. However, he later suggests that women and minorities have fewer opportunities for informal mentoring because they lack the relationships within an organisation that would provide informal mentoring. This observation aligns with the nature of Aurecon’s program. Harper and Sawicka (2001) agree with this and go further in suggesting that women also have more demands on their time at work.

EXPECTED OUTCOMES

Harper and Sawicka (2001) identify a number of issues that can give rise to problems in a mentoring scheme. These are mainly around the participants not having a good understanding of the mentoring process that is being followed, for example vague or unarticulated expectation of the roles. With the provision of detailed information to the participants and the clear endorsement at the most senior level the Aurecon program expected to prevent many of the problems.

Stone (1998) suggests that mentors need to be trained and Holland (2009) goes further and suggests that ongoing training be provided. For this program there was no training given beyond providing information. A similar program by Victoria University of Wellington (VUW) provided extensive training for participants of its program, including a two hour pairing session (Harper and Sawicka 2001).

Within the professional institute models of mentoring, having more senior people as mentors, this program was well designed and it would be expected to achieve its objective of assisting Executive women in their development and providing an opportunity to increase their visibility to the senior leaders in the organisation. The only constraint on the program would appear to have been that the mentors were not selected for their interest in the program, rather for their position in the company. Stone (1998) suggests that mentors should be carefully selected for their interest in developing the mentees. For Aurecon’s situation this was not possible as within the Asia Pacific region there are only four Directors.

Sponsorship vs Mentoring

Stone (1998) uses the words sponsor and mentor interchangeably. Ibarra et al (2010) make the suggestion that whilst a mentor may guide a mentee a sponsor will actively advance the career of the protégé. This may be through nominating the protégé for promotion or membership of a high profile project team. The sponsor will use his or her influence with senior executives to advocate for the protégé. This was not the expectation of Aurecon’s program.

Analysis of Aurecon's Program

Phase 1

Whilst both mentors and mentees were not required to participate in the program there was visible support from both the Chief Executive Officer (CEO), who publicly announced the program, and the Chief Operating Officer (COO) who invited the mentors to an initial meeting.

A Human Capital representative, who had been involved in developing the program; the Global Leader of Human Capital; and a Director who had overall responsibility for the Diversity Initiative; assigned mentors. The matching was done by looking at location and market sector alignments to find an appropriate match. The two Level 9 female Executives were assigned to the CEO and COO. The Level 8 female Executives, including the author, were assigned to the remaining Directors.

Phase 2

An invitation was sent to each Level 8 and 9 female Executive in March 2009 for the first meeting. Four of the five invitations were accepted.

Phase 3

The mentors were provided with information on mentoring and suggestions on how to conduct the mentoring sessions. They were also provided with the expectations that the organisation had of the mentees and mentors.

The mentees were provided with information on mentoring and with the same information that the mentors received on the expectations that the organisation had of the mentees and mentors.

Phase 4 and 5

Meetings were held at the discretion of the mentor and mentee.

Phase 6

Human Capital gathered feedback from mentors and mentees on the program's effectiveness after six months, the results of which are discussed below. The feedback was obtained by a member of the Human Capital team. It consisted of a telephone call to each participant and asking the mentees:

- Has the program been of value to you personally? How?
- Would you like to continue with your mentor?
- What has been the major challenge in this program?
- Other comments

The mentors were asked:

- Do you believe the program was of value?
- Would you like to continue as a mentor?
- What has been the major challenge in this program?
- Other comments

For one of the mentors comments were provided by his Executive Assistant due to travel by the mentor. The same person made all the calls and then collated the results for

the Mentoring and Leadership Working Group, keeping individual feedback anonymous.

On reviewing the feedback Human Capital identified mentors for the Level 7 Executives in May 2009. The program was launched to the Level 7 female Executives in July 2009. The mentors in this case were selected from a wider pool of the Senior Leadership Team (Region Leads, Sector General Managers, etc).

Phase 7

The final feedback, at the end of 12 months, was obtained in the same way as previously. This feedback indicated that the program should continue.

OUTCOMES

Mid-Program Findings

At the midpoint in the program the Human Capital team contacted all the senior female Executive mentees to assess how the program was progressing. The clear result from the feedback was that all mentees had benefited from the program. The two main benefits that mentees saw were gaining exposure to the senior leader and being able to take a more strategic view of their career.

All mentees were able to easily connect with and relate to their mentor. However, most indicated that more face-to-face contact would be advantageous. A comment was also made that the mentors should participate in a Mentoring Executives workshop so that the standard of mentoring is consistently high.

End Program Findings

Mentees

In April 2010 the mentors and the mentees were canvassed for their opinions on the program. The mentees felt that the program had been of value to them in two main areas. Firstly, having someone other than their line manager to receive advice from and secondly, the opportunity to receive information directly as to the direction of the organisation. They were all happy to continue beyond the 12 months with their mentor.

The major challenge that was perceived with the program was maintaining a connection with the mentor.

In subsequent discussions it was agreed that a change of mentor would be an advantage. This would allow the senior female Executives exposure to a further Director, which would build on one of the main benefits that the mentees saw with the program.

Mentors

The four mentors agreed that the program was worthwhile and that they would be happy to continue with the program.

One of the mentors had concerns about having a program that provided special treatment for women. One of the Executive's had a similar concern.

Recommendations

From this feedback several recommendations were made, including:

- The mentors could participate in a 15 minute Mentoring Executive workshop so that the standard of mentoring is consistently high.

- The mentees could be trained as mentors and mentor other female Executives or high potential women/men.
- Provide tips for mentees so that they can get the most out of the program.

Female Executive Program

Under Phase 6 of the program, and with the positive outcomes from the mid review of the Senior Executive Program, the program was extended as planned to the remaining Female Executives.

Female Executives – Mid Review

At the midpoint in the program the Human Capital team contacted all the female Executive mentees to assess how the program was progressing. The results from this were less clear with mentees reporting that they had benefited in a limited way from the program. It appeared that some of the mentors had not been informed that they were to be mentors.

There was an apparent lack of communication as to the purpose and expected outcomes of the program.

A comment from both the mentoring programs was that it would be beneficial to meet with the other mentees as this would provide support for the mentees.

Female Executives – Final Review

In July 2010 feedback was obtained from both the mentees and mentors of the female Executive program. The outcome of this feedback was positive overall with the program being considered of value but there appeared to be much less commitment to the program than was found in the senior female Executive program. The following themes emerged from the feedback, both from the mentors and mentees:

- Time was a constraint in working this program effectively.
- The mentee experience and satisfaction relied greatly on the personal qualities of the mentor.
- In situations where meetings failed to occur, there was a general lack of ownership on initiating the meetings.

The issue, which was raised by the senior female Executives, of the lack of face to face meetings was not raised here. This is likely to be due to most of the mentors being in the same office as the mentee, although not in a line management role for the mentee. However, this may have manifested itself in the feedback that time was a constraint as the participants were relying on face to face meetings rather than telephone calls.

Additional Program

Under the Women's Initiative, local Aurecon Women Achieving Women (AW²) groups were established to act as a catalyst for female employees to meet and discuss issues, whilst also providing networking, mentoring and training opportunities for female staff.

As a further outcome of the Mentoring and Leadership Working Group the women of the AW² leadership team developed a program to assist women of all levels with career development and planning. Aspire is aimed at Levels 4 and 5. The program consists of seven modules that are run in local offices on a voluntary basis each week. There is preparation expected for each module and then a discussion of the results is facilitated during an hour long lunchtime session. This program gives a more structured approach

and is currently being rolled out by the AW² committees. It is a similar idea to the IPENZ group mentoring.

Summary of Findings and Lessons Learnt

At both the midpoint and the end of the senior Executive program the feedback from the mentees and mentors was positive, with both groups feeling they had benefited from the program.

There was a concern that the limited face-to-face contact between the mentor and mentee hampered the building of a relationship.

The findings of the Executive program were less clear with a lower level of commitment to the program by both mentors and mentees. The general findings were: the success of the program relied on personal qualities of the mentor; and lack of availability of the mentor and mentee to meet were a constraint on the program.

A lesson learnt from both programs was that the mentors needed to be sufficiently trained and committed to the program. In the case of the senior Executive women this assisted in the program's success but for the Executive women it was a failing of the program. From this Aurecon intends to use its "Mentoring for Success" training course to train all mentors.

A lesson from the senior Executive program was that mentoring gave the mentees better networking opportunities and that this became the focus of the program.

COMPARISON OF FEMALE NUMBERS

In January 2011 females represented 24% of total staff and 17% of all professional staff. The professional staff is dominated by Engineers, Surveyors and Planners. The distribution of female staff is no longer so heavily skewed towards the junior levels with 62% of all females Level 4 or lower.

Tab. 1: Comparison of Female Representation

	2009	2011
	Percentage	Percentage
Representation in overall organisation	23%	24%
Professional staff	21%	17%
Females Level 4 or lower	71%	62%

In 2011 there is 7.5% female representation at senior management, Level 7 and above, and 5.3% of Executives are female. Due to the small numbers of women involved any changes in percentage from 2009 should be treated with caution. It is difficult to draw any explicit conclusions from these figures in regards to the effectiveness of the mentoring program. The qualitative results from the questionnaires give a more useful indication as to the merit of the scheme. A comparison of both numbers and percentages are given in Table 2 to emphasise the small numbers involved. The four Senior

Executives, who participated in the mentoring, and the Board Members who were mentors, are included in both sets of figures.

Tab. 2: Senior Management Female Numbers

	2009		2011	
	Number	Percentage	Number	Percentage
Senior Management (includes Executives)	45	6.3%	57	7.5%
Executives	23	4.8%	24	5.3%

At the time of writing, the turnover by gender for 2010 was not available.

MUTUAL MENTORING FOR WOMEN

One of the skills that a female engineer learns early in her career, if she wants to advance, is to work in a male dominated environment. Once a female engineer reaches Level 5 her situation at Aurecon would be that only 20% of her peers, with various technical qualifications, would be female. This is similar across all engineering dominated companies.

Her counterparts in the New Zealand Public Service would have approximately equal male and female representation (State Services Commission 2010). The Public Service defines senior managers separately from the occupational category. This is similar to Aurecon's Executives who have that title no matter their profession. The Public Service senior management profile is based on a three tier system, with all organisations having a tier 1 manager (Chief Executive). Some smaller organisations may have only two tiers of management.

Tab. 3: Comparison of Female Representation in the NZ Public Service with Aurecon

	Public Service All Staff 2010	Aurecon Professionals 2011
Overall Organisation	58.7%	17.3%
Public Service - All Managers Aurecon Level 5 and above	47.4%	12.8%
Public Service – Senior Mgmt (CE+Tier 2 &3) Aurecon Level 7 and above	39.8%	7.2%
Public Service Chief Executive Aurecon Executive Level 9 and 10	16.1%	2.2%

This shows that a female Chief Executive (CE) in the public service is facing working in a male dominated position for the first time when she reaches CE level. It is suggested that the female CE has the business skills that would be advantageous for a female

Level 5 to have to progress her career to Executive Level. Likewise, the female Level 5 will have the skills to work in a male dominated organisation.

The State Services Commission (2010) recognises that mentoring is important but cautions that whilst it offers support women may require an advocate to successfully progress to the next level in their career. The Commission's Career Progression Survey 2005 shows that nearly all public servants, both male and female, who had mentors reported that it had assisted their career development.

There is a potential for a mutual mentoring scheme where each participant is both mentor and mentee. Within New Zealand the influence of Maori culture is seen through mentoring relationships that "are collaborative, open and equal, with 'expert' and 'learner' changing places, reflecting reciprocity" (Holland 2009:15). This mutual mentoring would be effective in professions where even numbers of men and women graduate but few are in Senior Management positions, such as Law and Accountancy.

Female Mentors

Women face different challenges to their male peers. For senior women engineers it is difficult to find a female mentor within the industry, either on a formal or informal basis. VUW recognised the important role that mentoring could play as "women staff members often experience the isolation and the competitive environment of higher education more intensely than their male colleagues" (Harper and Sawicka, 2001:3). A mutual mentoring scheme of women would help to alleviate the feelings of isolation. Barkham (2001) reported that Dame Sian Elias, the Chief Justice of New Zealand, was so isolated when she first started working as a lawyer in the early 1970s that for three years she lunched alone.

A mutual mentoring scheme could be one based around supporting women in male dominated industries. This would assist in retaining women in those industries. Neither party to the relationship would be in a position to advocate for the other within her own business. Therefore, the focus would not be on specific career advancement opportunities but more on coping strategies for the organisational positions that women have found themselves in.

CONCLUSION

Aurecon's mentoring of senior female executives has been well received and achieved its aim of giving senior women more exposure to the highest levels of the organisation. The program is continuing beyond its 12 month term with an expected re-pairing of mentors and mentees. The mentoring of the remaining female executives does not appear to have been so successful due to a lack of training of the mentors and an expectation of face to face meetings.

Providing mentoring is a well recognised tool for career advancement and assisting with skills transfer. The more traditional approach has been for the mentor to be more senior in some way than the mentee. However, there is an opportunity for more junior females in the engineering industry to assist those women in much less male dominated industries, once they reach a male dominated position. These senior women would be able to reciprocate by providing business and political skills required to reach senior management. Mutual mentoring should be considered by organisations looking to develop female mentoring programs.

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LESSONS LEARNED FROM THE FIRST YEARS OF MANAGING A MENTORING SCHEME FOR WOMEN IN SCIENCE, ENGINEERING AND TECHNOLOGY IN THE UK

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ABSTRACT

MentorSET is a mentoring scheme for women in science, engineering, technology (SET) in the UK. It is managed by the Women's Engineering Society (WES), a membership organisation. Funding comes almost entirely from the UK's Resource Centre for Women in SET, channeling money from the UK government and the EU.

Objectives: This study looks at the history of the scheme, and draws out useful lessons for managers of similar projects.

The scheme received its first funding in 2002, but this was the result of a lengthy process, which the paper will describe. There were few closely comparable schemes to help in the process of writing the guidelines for MentorSET. Some of the details of the project proposal and the subsequent contract had to be modified as things developed.

MentorSET mentoring has developed its own special flavour to meet the particular needs of professional women. There are interesting differences between the needs of the mentees in different disciplines. Adequate funding is always a problem. MentorSET delivers good value for money, but mentoring is expensive. Some of the scheme's administration is done by volunteers, and all the mentors are unpaid.

Evaluating the effectiveness of mentoring schemes is difficult, and different approaches are used.

Results: MentorSET is past the start-up phase and relatively stable, creating about 60 new mentoring pairs a year.

Conclusions: Mentoring is a powerful way to help people, but it is time-consuming to do it well. The effort involved in setting up and managing a scheme is high.

BODY OF PAPER

MentorSET is a national mentoring scheme for women in science, engineering and technology in the United Kingdom. Started in 2002, it has now reached one thousand women as either mentors or mentees. The scheme is run by the Women's Engineering Society on behalf of all women in the sector, it has been using government funding and thousands of volunteer hours. MentorSET is proud of its record of serving women, and a recent assessment was able to show its impact. It has been able to help so many women through the investment of many thousands of hours of volunteer work. The mentors are unpaid, and so are all of those involved with the administration of the scheme, with the exception of one part-time paid manager and some office help.

The Women's Engineering Society (WES) is a long-established association of working women engineers, based in the UK. Around the year 2000, key figures in the organisation decided that mentoring was so valuable for woman engineers that effort should be invested in designing and setting up a scheme to deliver it. At the same time, a sister UK organisation AWiSE, the Association for Women in Science and Engineering, was also interested in mentoring. A bid was made to the government's Department of Trade and Industry (DTI) for funding a joint scheme. Negotiating the details took some time, and funding was secured in 2002.

Several key factors led to the government funding, and its continuance until now. At the time of the original grant, DTI had a section called Promoting SET for Women which was led by a forward-thinking engineer and scientist, Jan Peter, who is now President of WES. She had come to the post from a government laboratory, not from a Whitehall (administrative civil service) post. There was a great deal of concern about the low representation of women in science, engineering and technology (SET) and the high proportion of qualified women leaving the sector. A government report was being prepared which would call for more investment in schemes to retain women, as well as help for recruiting and training new people. One of the concerns to be expressed in the report was the multiple small sources of help for women in SET and the need for more coordination, so a joint bid from WES and AWiSE was actively encouraged as a means of improving cooperation between the groups.

The aim of the scheme was to provide mentoring for women who would not have access to other suitable schemes. There are company mentoring schemes in some large companies, but most engineers work in small and medium enterprises (SMEs), with many UK companies employing only a handful of engineers. Some women engineers never meet another woman engineer in their normal working life. We feel that it is very important that women have access to a woman mentor, as some of their experiences are different from those of men. The professional institutions have mentoring schemes aimed at helping engineers get their professional chartered qualification. The mentors tend to be retired men engineers. These schemes are officially limited to that one purpose, and the mentors are anyway often unable to help women engineers with some of the wider aspects of being a woman in engineering. It is possible to buy coaching and mentoring, but many women cannot afford this, and SMEs usually do not have the money to help with such costs. And of course women not currently working in the sector are at even more of a disadvantage.

So MentorSET was set up to be "a friend of the friendless", helping women without other places to turn to for mentoring. The service was intended to be free and has remained so up till now, although this is likely to change with the changing economic climate. It covers women all across science, engineering and technology, and whether or not they are members of the formal women's networks which contribute to the scheme. There was a suggestion in the past that only women with the greatest needs should be helped, but we argued successfully that they were better served as part of a more general scheme where they mix with all sorts of women engineers and scientists. The scheme does not at present cover students, except those who are actively looking for work.

The areas that have attracted most official interest are "returners", retaining women in SET, SMEs, minority ethnic women and unemployment – we hit a wide selection of priority areas. "Returners" are women returning to work after having had a career break looking after small children. This problem varies between countries and between cultures. In the UK, the law provides for a year of maternity leave, but mothers often wish to delay their return to full-time paid work for longer. Many qualified women find

they are unable to return to the SET workforce in a job appropriate to their skill level if they have taken a longer break or want to work part-time, and many women leave SET at this point. There is widespread concern about this waste of talent and investment. In 2005 our funding source changed from being a government department directly, and since then we have received most of our money through the United Kingdom Resource Centre for Women in Science, Engineering and Technology (UKRC) created to handle all government funding for women in SET. The UKRC started off with a strong focus on returners. Over the years, returners have been a major group within the mentees, constituting between a third and one half of all mentees each year. Just recently, women who have lost their jobs and been unable to find a new one have started to outnumber the returners. Just at the end of 2010, the UKRC lost almost all its funding in a big round of government financial cuts, and at the time of writing MentorSET is having to look at other sources of funding.

MentorSET received its original funding in March 2002. It has been enough to pay a professional manager for the scheme, paid to work 3 days a week. (We were aware that her passion for the task meant that she often contributed more.) Our first round of hiring failed to find a suitable applicant, but we were eventually able to find an engineer with relevant experience, who remained MentorSET Manager into 2011. We had difficulty finding trainers to run the mentor trainings, and our manager took over this function. The difficulty in finding suitable people was related to the lack of any similar scheme aimed at professional women.

Because of the wide reach across SET, the team involved other women's groups in the design and delivery of the scheme. The main partner, AWiSE, collapsed after the death of its leader and WES became the sole owner of the project. MentorSET has had a management committee with wide representation from other groups. This has been valuable as a route to increased cooperation between groups.

MentorSET differs from most other mentoring schemes in several ways. One is that it is a low-bureaucracy system. We do not require form-filling about each interaction, or about very much at all. Clearly schemes involving vulnerable people need extensive records, but professional people do not need a high level of oversight, and do not wish to spend time on unnecessary form-filling. Also confidentiality is very important to our members. Our trainings build on the fact that these are intelligent and educated people and spend little time on obvious basics. What is found to be every valuable is training in listening to the mentee, with a strong message about not leaping in too early with possible solutions, which is an engineer's natural response to hearing a problem. The mentoring interactions are mentee-driven. Mentees are expected to take the initiative and to carry out actions such as researching sources of information themselves. Our guidelines for mentors were much smaller and more digestible than those issued on other schemes. We felt they were thus much more likely to be read. Our version has now been used as a basis for handbooks of other groups.

We have learned various things about matching mentors and mentees. We have found that we do not need extensive information to make a good match. The form used can be found on the MentorSET website. An age (or, more accurately, experience) gap of about 8 years is best. Not too close, and not so far away that the mentor has forgotten the details of life at that stage. We find that a match on job responsibilities is more important than an exact match on area of work, although we get as close as possible. Clearly, for returners, it is important to find someone who themselves returned to work after a break of a comparable length. Another major consideration is the ability to meet face-to-face on occasion. Much of the mentoring happens over the telephone or by

email, but a face-to-face meeting is important in establishing trust, and later meetings improve the relationship. The pair may live in the same geographical region, or sometimes one visits the city of the other regularly. We have arranged some “virtual” pairings, but they tend to break up more than those where the pair can meet.

The matching process works best when done in batches. Rather than doing an individual search on behalf of each mentee as they join, a better balance overall is found by considering several at once, and matching them against the currently available mentors. This is not a simple scoring process, but a careful weighing of different factors. The batch process fits well with the training of batches of mentors. All our mentors have received training, mostly from MentorSET but sometimes we accept suitable training from another scheme. It is not compulsory for mentees to attend training, but it is strongly encouraged. We find that this is valuable in giving them more realistic expectations of what mentoring can and cannot do.

We continue to believe that returners are best served by being part of a wider scheme. They benefit by mixing with women of various seniorities and wider experience, at the MentorSET trainings, at the personal development workshops also offered, and at other events to which they are invited such as the WES annual conference, a residential conference offering many opportunities for sharing stories of experiences. We are investigating delivering the initial mentor training online, on the grounds of cost and because of the difficulties caused by having only a few trainings a year, almost all in London. However, we would have to take action to provide other events to supply the valuable mixing with other people.

One regular group of our intake of mentees is the students of an Open University distance-learning course designed to help women to return to work in SET. (This course has now been opened up more widely and takes men as well.) These women have received instruction on such matters as researching information about jobs and writing CVs. They naturally are also told about the value of mentoring, and pointed to MentorSET. Take-up of this opportunity varies oddly between groups.

The scheme has run for almost 9 years now, with our yearly target recently being to create another 65 pairs, while delivering support to existing pairs and offering other activities. Assessment of mentoring schemes is notoriously difficult, as there are few objective measures that can be applied, beyond counting the numbers involved. Appraisal of projects seems a natural part of good practice, but has not really happened for MentorSET. This is partly because we were always operating with definite targets of numbers of successful mentoring partnerships and constructive events for each year, so there was a built-in measure of performance. There was more examination of the value of the scheme when the funding contract was renewed roughly every three years. Our internal processes were audited on occasion by members of WES. Permission for a full-dress appraisal was requested more than once, but there were always other calls on our parent organisation’s funding which took priority. It could have been useful to have been permitted to seek a grant just for this particular purpose.

At the end of 2009 MentorSET took part in a major effort which was held to appraise our funders and measure their impact, where phone interviews were used to talk to our members as beneficiaries of the government-derived spending. In-depth questioning revealed a solid record of women assisted into jobs, or retained in jobs they had thought to abandon, as well as promotions gained and new jobs found. Because of the way our funders were funded, there were also questions about the impact on family, colleagues and community – not an aspect with which we normally concern ourselves. However, the feedback on this did show valuable effects spreading outwards, as mentees applied

new skills and as they explained the source of their new competence and confidence. Unfortunately although we carried out the survey, we ourselves don't own the data!

At the time of writing, the future of MentorSET is unclear. Mentoring is a powerful way to aid women, but running a scheme needs the time of a professional manager, which is expensive. The UK government is attempting to "mainstream" spending on women in SET. We fear that they do not realise that gender mainstreaming is not code for "take away the money for women and let them scrape what they can from the ordinary budget" but should mean "add money for special efforts for women to the ordinary budget".

CAREER SUPPORT IN SCIENCE AND KNOWLEDGE MANAGEMENT – MENTORING AT NON-UNIVERSITY RESEARCH ORGANIZATIONS IN GERMANY

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ABSTRACT

Fraunhofer-Gesellschaft, Helmholtz Association and Max Planck Society are Germany's most important non-university research organizations with a staff of about 70.000 persons and a share of female scientific staff between 19 and 26 %. The aim of these organizations is to increase the proportion of women in science and management. An approach of this type has implications both for staff recruitment and as a basis for improving career opportunities for women throughout their term of employment.

Therefore, the three research organizations run several mentoring programs for supporting women's careers. These programs have been designed to be interdisciplinary and have a reach that extends to the whole of Germany and beyond. The mentoring programs encourage networking between individual institutes and considerably strengthen participants' identification with the sponsoring organization.

This win-win situation widens participants' circle of contacts and improves their career opportunities throughout the research organization. Inter-organizational networks are also forming: The three research organizations are already working closely together on the recruitment of mentors. This encourages additional networking between participants right across the scientific community.

The primary goal of the mentoring programs of all three research organizations is to enable women to catch up in the working world. Although the proportion of women in leading positions in science and industry has been slowly rising in recent years, there is still a need for pro-active measures in order to achieve genuine gender equality. The successful networking between the three research organisations may help to accelerate the dynamic in gender equality.

CAREER SUPPORT IN SCIENCE AND KNOWLEDGE MANAGEMENT

In recent years mentoring has become a very effective – and also cost-effective – tool in personnel development. This trend has invaluable qualities for the professionalization of the scientific sector in the light of current funding difficulties. The method originated in the USA as a formal counterpart to “old boys’ networks” with the aim of supporting otherwise disadvantaged groups of people. In the meantime, companies, political parties, clubs and trade associations in German-speaking countries have come to provide mentoring programs for a broad array of target groups. Numerous initiatives have also been started in the field of research, many of which have joined forces in

Germany's "Forum Mentoring e.V." association (<http://forum-mentoring.de>). This article focuses on mentoring programs geared to promoting young scientists and administrative academics and the specifics of these programs at non-university research facilities, with the programs of the Helmholtz Association, the Fraunhofer-Gesellschaft and the Max Planck Society serving as examples.

Examples of successful mentoring relationships can be found everywhere: It was in the law office where she worked that Michelle Obama met her husband when she was assigned as mentor to the trainee Barack. In the field of science, Max Planck and Albert Einstein as well as Max Planck and Lise Meitner are oft-cited examples of mentoring tandems. What is more, the reality at German universities is that many professors had powerful mentors backing them – further proof that mentoring programs blend organically into the prevailing scientific culture and are a suitable instrument for promoting young scientists.

Brandner (2005) describes mentoring as an invention of European education and a product of the Enlightenment. Yet the concept has been around for a long time in human history: The oldest documented tandem – that of Mentor and Telemachus, known from Greek mythology – gave the concept its name. Once the effectiveness of informal mentoring relationships had been established, mentoring programs were institutionalized, initially for the promotion of women (Haasen, 2001). Since then such programs have spread to a wide range of fields.

The principle of mentoring is based on a liaison between a (usually younger) person just setting out on a career and a person who, relatively-speaking, has achieved his or her career goals and who also possesses good social skills. As a personnel development tool, mentoring is defined as an activity whereby experienced mentors pass on their specialist knowledge or experience to less experienced people with the aim of supporting these "mentees" in both their personal and professional development. Mentoring relationships can consequently deal with areas from training, career planning and leisure through to personality development.

Mentoring promotes the personal and professional growth of mentees (Schermuly *et al*, 2009). But the concept also has distinct advantages for mentors. Haasen (2001) refers to mentoring as a winner's game. One cross-sectional study even reports a significant advancement in the careers of both mentees and mentors (Fisher, 2007). It is beyond doubt that mentoring promotes discourse between senior and junior staff, a circumstance that can help mentors "stay grounded" and can provide genuine insight into lower levels of the hierarchy. This awareness, which might otherwise get lost on a person's climb up the career ladder, can have a positive effect on leadership skills and thus on success as a manager. It is also an opportunity to reflect on one's own career and can provide stimulus for making future career plans.

Mentoring at non-university research organisations

The stated aim of the Helmholtz Association, Max Planck Society and Fraunhofer-Gesellschaft programs is to increase the proportion of women in management roles in science and industry, where they are currently still – sometimes markedly – underrepresented (She figures, 2009). An overriding goal such as this is best served by central coordination of programs. The programs discussed in this article are all coordinated by a central office at the various scientific organizations. These non-university programs differ in various ways from the more conventional mentoring programs to be found at many universities. While university programs usually only cover individual departments, universities or at most individual federal states, the

programs provided by non-university research facilities have been designed to be interdisciplinary and have a reach that extends to the whole of Germany and beyond. The Fraunhofer-Gesellschaft currently comprises 59 institutes and the Max Planck Society 80 institutes, while the Helmholtz Association consists of 17 research centers and over 30 branches, and altogether these three non-university research facilities have 17,000 (Fraunhofer-Gesellschaft), 30,000 (Helmholtz Association) and 21,200 (Max Planck Society) employees. The design and concept of the programs has to take into account the challenges of geography and the different specialisms of program participants that these figures represent.

Helmholtz mentoring program “In Führung gehen” (“Taking the lead”)

In adopting a comprehensive and coordinated strategy program (five points program) on equal opportunities in 2004, the Helmholtz Association established mentoring as an important talent management tool. “Helmholtz Network Mentoring” was originally managed by the German Aerospace Center (DLR) but the program was conceptually revised in 2009. Under the new name “In Führung gehen” (“Taking the lead”), comprehensive activities for the promotion of young scientists are now centrally coordinated and developed from the head office of the Helmholtz Association in cooperation with other centers.

The program addresses talented and highly qualified women at Helmholtz centers – scientists who obtained their doctorate about two to five years earlier, and women from administration and management at the start of their career who are aiming for a management position. Anyone interested may apply for a place on the program. Participants are selected by a steering committee headed by the Vice President of the Helmholtz Association, Prof. Dr. Eberhard Umbach (KIT). The first two courses of the program were in great demand, with a total of 67 and 61 applications respectively for the 30 available places.

Apart from forming and supporting mentoring relationships, the one-year program also offers starting and closing events as well as training workshops. The three two-day workshops take an in-depth look at topics such as performance reviews, conflict management and the change from ordinary staff member to supervisor, thus dealing with key issues facing women on the path to management positions. These are not just standard training courses. On the contrary, participants’ needs are ascertained at the start of the program and the workshop content is tailored to meet them. Furthermore, the program gives participants access to coaching. Issues which mentees consider important for their career (e.g. individual skills, preparation for new tasks, conflict situations, work-life balance) can be dealt with on a one-to-one basis in three two-hour coaching sessions. Mentors too have the opportunity to reflect on their mentoring tasks and/or receive counseling with a coach.

Senior staff at Helmholtz centers, other scientific organizations and in private enterprise are targeted as mentors to advise and support women in their career planning. This helps participants to build up a network in the scientific sector in general and within the Helmholtz Association in particular during the mentoring period. The annual networking meeting for participants, mentors and alumni helps to sustain relationships.

To control and analyze the impact of our mentoring programs, we conducted an evaluation of the program in summer 2010. Questionnaires were sent by e-mail to all participants of the first run of the program coordinated by the head office. As 31 mentees and 31 mentors were joining the first run, the population of my survey added up to 62. The rate of return was 45 % as 28 persons responded to the survey. Thus the

evaluation cannot claim to be representative, but it still allows an estimation of the acceptance of the program.

A high acceptance of the concept and an acclamation of the implementation of the program could be remarked. The mentees and participants took the high rejection rate as an honor to be chosen for the program. Only two of the respondents were not fully content with their participation in the program. Mentees report on enhanced communication skills and higher social skills. Another advantage they took from the program was an expansion of their professional network.

Max Planck Mentoring Program “Minerva FemmeNet“

The Minerva-FemmeNet mentoring program of the Max Planck Society grew out of one woman's initiative: At the beginning of 2001 the program was started by Barbara Legrum, who was at the time the women's representative at the Max Planck Institute of Biophysics in Frankfurt am Main. She enlisted 21 female graduates at the institute to each mentor a female doctoral student or post-doctoral student. Women's representatives at other institutes adopted the idea and also enlisted female graduates as mentors. Dr. Marlis Mirbach, the central equal opportunities officer of the Max Planck Society, also actively supported the idea and ensured that information on the developing network spread throughout the Max Planck Society.

Since 2009 the project has covered the whole Max Planck Society and is open to young female scientists of all institutes, from bachelor and master students to junior professors. The mentors are current or former Max Planck Society women scientists, some of whom have many years' experience in research or in business. Many can also pass on their experience of how to successfully combine work and family. Several institute directors support the project - some as active mentors, others as advisors. The Secretary General of the Max Planck Society, Dr. Barbara Bludau, is also a member of the network, acting as mentor in an advisory capacity.

One aim of the program is to encourage junior female scientists to pursue an academic career and another is to increase the percentage of women in leading positions in science and industry in the long term. In this connection the most important role is the one-to-one mentoring relationship between an experienced mentor and her mentee: A suitable mentor is sought for each mentee based on the main areas of research and the wishes of the mentees. If required, there are volunteers in the three sections of the Max Planck Society who help in the search for the “best match”. No tandems are established, within an institute, which ensures that discussions can be held in a spirit of trust and also avoids any conflicts of interests.

Since the program does not have any strict rules on the duration of a mentoring partnership or how it should be organized, each mentor/mentee pair can themselves decide on how they would like to arrange their cooperation. Usually, the mentoring teams start by assessing the mentee's situation, regardless of whether the mentee is a doctorate student or a “Privatdozent” (lecturer). The contact with a more experienced senior scientist is deemed to be very helpful, as a mentee concluded: “Some of her [i.e. the mentor's] advice took me by surprise, and I got to know a very different point of view on how to plan a career. Some of her advice was not applicable to my personal situation but on the whole I benefitted from our talk and began actively taking some steps toward my professional goals which I wouldn't have done otherwise.” Another mentee said: “When I started working as a group leader, my mentor gave me great advice on how to recruit people and on how to set up a working team. Furthermore, we have planned future conversations, and my mentor will have a look at my CV and

hopefully give me some advice on planning further steps in my scientific career.” And also mentors will get something out of a mentoring cooperation: “I really think that I benefitted from being a mentor with regard to my improved leadership qualities.”

In addition, mentors and mentees can take part in workshops and seminars organized by the coordination office or by other mentoring programs with which Minerva-FemmeNet cooperates (MentorinnenNetzwerk, SciMento-hessenweit and MuT – Mentoring und Training). In Berlin and in the Rhine Main area, mentors and mentees also have regular networking meetings to swap ideas and for informal counseling.

“Fraunhofer Mentoring Program”

The Fraunhofer Mentoring Program seeks to give life to the guiding principle of “more women in applied research”. The Fraunhofer-Gesellschaft is seeking to increase the proportion of female staff in all areas where women are underrepresented. The program helps participants of both sexes in planning their personal life and scientific career, thereby increasing their expertise and motivation. It is a key element of the Fraunhofer-Gesellschaft's systematic personnel development program, which also ensures that employees regularly undergo further training, giving them the potential to take up attractive positions - even outside the Fraunhofer-Gesellschaft.

Mentoring has already been going on for 15 years at Fraunhofer. The first internal pilot mentoring program for women only was carried out in 1996, unleashing a protracted debate on the pros and cons of special programs for women. In the years since, Fraunhofer has also been involved in external mentoring programs such as Cross-Mentoring München and TANDEMplus (in cooperation with RWTH Aachen and the University of Karlsruhe). Yet the centerpiece remained its internal mentoring program, which for the last five years has featured a women's quota whereby women should account for at least 65 percent of mentees. This has greatly increased acceptance of the program among female and male participants as well as among senior staff, with the result that the program is now carried out each year.

Young scientists can apply for one of the 20 places at the recommendation of their institute. Since the tandem relationship is at the heart of the mentoring program, the matching process is extremely important. Every “match” must meet the mentee's wishes. Mentees can choose to have a mentor from their own institute or from a different one. The program also allows for mentors from outside Fraunhofer, such as Fraunhofer alumni or even people working in industry and science. The tandem relationship is not subject to any strict rules, the idea being for mentees to drive the mentoring process. But for mentoring to be successful, the tandem relationship needs to be supplemented by a series of additional measures. Participants are familiarized with their respective roles at the kick-off event and receive extensive informational material. Half way through the program, i.e. after 6 months, the mentees gather for an advanced training seminar. Coaching is also offered to mentors. The mentees organize a closing workshop after one year, and all participants are asked in a telephone interview how their mentoring relationship developed. All these steps are monitored and evaluated by the program coordinator to allow the program's high standards to be maintained and built upon.

Conclusion

Provided that mentoring programs are conceived in a coordinated way, the design challenges specific to non-university research facilities described at the outset turn out to be a boon: The centrally coordinated mentoring programs encourage networking between individual institutes and centers and considerably strengthen participants' identification with the sponsoring organization. This win-win situation widens

participants' circle of contacts and improves their career opportunities throughout the research organization, whilst at the same time making the employer more attractive. And it gives the organization a whole new way to cultivate and retain its pool of talent – one that would be impossible without such inter-institute or inter-center measures.

A good indicator of the programs' success is the large number of mentees who themselves become mentors once their program is completed. As they say themselves, they have benefited from the programs and want to give something back. The involvement of these committed former mentees contributes to better networking between current and former participants and also to an even greater identification with the mentors' own research institute.

Inter-organizational networks are also forming: The three non-university research organizations are already working closely together on the recruitment of mentors. This encourages additional networking between participants right across the scientific community, and it enhances the appeal of the programs for mentors recruited from among university professors, senior scientists and leading figures from industry. Up to now, however, apart from the individual coaching sessions offered by the Helmholtz Association and the Fraunhofer-Gesellschaft, there has been very little program content aimed specifically at attracting mentors from this diverse group of people. To tackle this issue, the three research organizations are planning a joint advisory workshop for mentors in December 2010, with the aim of jointly developing attractive propositions and identifying future opportunities for collaboration.

The primary goal of the mentoring programs of all three research organizations is to enable women to catch up in the working world. Although the proportion of women in leading positions in science and industry has been slowly rising in recent years, there is still a need for pro-active measures in order to achieve genuine gender equality (She figures 2009). As a result, there has been little experience of opening the programs to men, although, where this has happened, it has seen the specific goal of improving the equality of men and women turn into the more general goal of advancing careers. This dilutes the effect with regard to improving equality between the sexes, but can be beneficial in terms of acceptance: A quota system that goes against the normal male-female ratio in science can encourage more diverse teams to form without excluding individuals from personnel development measures, and it can bring mentoring programs out of the sometimes still derided “women's corner”.

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CURTISS-WRIGHT ENGINEERING CADETTES: 21ST CENTURY QUESTIONS AND ISSUES

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ABSTRACT

The Curtiss-Wright Cadettes, sponsored by the Curtiss-Wright Corporation, was a U.S. World War II program to recruit women into engineering to fill in for men who had been drawn into the war effort. Curtiss-Wright was in the process of scaling up mass production of armaments and needed skilled workers. The Corporation thus requested that the Society for the Promotion of Engineering Education consult the engineering colleges to carry on a special program for preparing college women for responsibilities in engineering. 800 women were given accelerated training programs in major American universities and placed in engineering jobs at Curtiss-Wright facilities around the country. This paper examines the experiences of those women, based on documentary evidence and on a number of interviews with women who participated in the program. We explore the question of whether this program represented a breakthrough for women in engineering, demonstrating that women could serve well in that occupation and eventually leading to a growth in the numbers of women aspiring to engineering careers. Although many of the women who were recruited into the Cadettes had earlier technical education, few entered the program expecting to use it as a springboard to a technical career. Most saw it as a chance to do something enjoyable and to contribute to the war effort. When the war ended, the Cadettes were summarily let go by Curtiss-Wright; but, few of the participants seemed to expect anything different to happen. A few did go on to pursue professional careers in science and engineering, but most returned to more traditional roles after their wartime experience in engineering. The Cadettes program reveals the power of traditional gender expectations to limit women's ambitions and the ability of wartime conditions to define opportunities as momentary and exceptional.

INTRODUCTION

World War II completely disrupted the social and work fabric of the United States, and yet, this provided new opportunities for women, especially in science and engineering. Engineering, in particular, had major shortages. Twenty-nine engineering schools began admitting women during the war years. At the same time, while recruitment into specific programs designed to meet war needs was more temporary in nature, taken together these developments represent a possible beginning for significant numbers of women to enter the profession. Although their postwar prospects were unlikely from the very beginning, the war did present a potential opportunity for these young women. However, as historian Margaret Rossiter points out, these women's failure to adequately capitalize on their WWII experience was due primarily to the "prevailing public opinion about women's role in society." This "failure" is somewhat minimized by examining some of the founding members of SWE. Rossiter states that SWE was founded by two types of individuals: the pioneers, who had been trained before or during World War II, and those who after working as "aides" during had since returned to college to earn an engineering degree (Rossiter, 1995: 24; 51).

This account is based upon the published recollections of SWE's Elsie Eaves, who in 1927 was the first woman admitted to full membership in the American Society of Civil Engineers, and who worked for the *Engineering News-Record* until her retirement in

1963. This view does not fully acknowledge the role of the students at Drexel University, Cooper Union, and City University of New York. These women were too young to have been employed during WWII, but played a key role in establishing a national Society of Women Engineers (Eaves, 1976: 14).

The Curtiss-Wright Cadette program, founded in 1942, was a direct result of U.S. military needs during the Second World War. The program's purpose was to introduce qualified young women into an accelerated engineering curriculum at selected universities, with the ultimate goal of introducing them into the Curtiss-Wright Corporation, an airplane manufacturer. A total of 750 women participated in the program at seven institutions. Though it is unclear whether the program permanently impacted the engineering profession, the mere fact that it was conceived and successfully implemented represents a significant change for women engineers. While some former Cadettes express ambivalence about their Curtiss-Wright careers, the majority found the experience to be galvanizing and transformational in regards to their self-identity and personal confidence. Though the program's contribution may be unclear, it is nevertheless true that during the post-war years, women engineers felt an increasing need to organize (Rossiter, 1995: 339-342). Whether it was due to a new sense of identity or the tidal wave of veterans, women students organized at both Cornell and Iowa State, and other schools, which in many ways were the precursor to the creation of SWE in 1950. (Bix, 2004: 31).

In October 1942, the Curtiss-Wright Corporation, in collaboration with the Society for the Promotion of Engineering Education, consulted leaders in over 100 engineering colleges and universities regarding a plan for the emergency war training of college women to function as assistants in the Curtiss-Wright engineering departments. (Bix, 2004: 29) Interested institutions eventually signed contractual agreements with the company. Preliminary conferences were held in New York and St. Louis in December 1942 to establish the curriculum. A total of seven institutions were to train 750 women for the company, including Cornell (125 trainees), Penn State (125), Purdue (100), Minnesota (100), Texas (100), Rensselaer Polytechnic Institute (100), and Iowa State College (100).

Documentation of the Curtiss-Wright Engineering Cadette Program is scattered throughout the U.S., posing a challenge for those who might wish to assess the program's long-term implications. The majority of collections exist at the participating universities — specifically Cornell, Iowa State, Penn State, Purdue, Rensselaer Polytechnic, Minnesota, and Texas. These records range from published materials focusing on the program (such as *Life Magazine* and alumni magazines at Cornell), to subject files (Rensselaer) and official administrative records, photographs, and even film footage (Iowa State, Minnesota, Texas). Many collections include issues of the *Cadetter*, a newsletter published for the participants. Finally, there are collections of personal papers that include newsletters, scrapbooks, and oral histories, based on whatever the participant collected and saved.

In 1996, sociologist Peter Meiksins, with the assistance of Robert Hagen, a graduate student in the Cleveland State University sociology program, conducted 12 interviews with veterans of the Curtiss Wright Cadettes. The research was supported by a small grant from Cleveland State University's Research Foundation. Meiksins was given a copy of a list of attendees (including contact information) from the Cadettes 50th reunion, held in Columbus, Ohio in the early 1990s. Meiksins and Hagen then contacted individuals on the list who were within driving distance of Cleveland, OH. Respondents were asked whether they were willing to be interviewed and whether they were willing to allow the interview to be recorded. Twelve interviews were arranged and face-to-face interviews were conducted. Interviews were held in the respondents' homes; they lasted

about an hour and followed a semi-structured interview protocol developed by the investigators; three were conducted by Meiksins alone, eight by Hagen, and one jointly by both investigators. Most were Ohio residents, but one each resided in Michigan, New York, and Pennsylvania. Interviews were then transcribed verbatim by Hagen. Two oral history interviews were also conducted at Iowa State in the mid-2000s, focusing on donors in the central Iowa area, and also transcribed verbatim.

RECRUITMENT

The students were to be known as Engineering Cadettes, a quasi-military term most likely intended to convey its value, albeit secondary, to the war effort. Indeed, Curtiss-Wright wrote a recruiting booklet, *Engineering Cadettes*, which said:

You as the Curtiss-Wright Cadette will be a co-worker with the Soldier, the Sailor, and the Marine, and will share with them the responsibility of the war effort. This is your opportunity to add your name to the role of individual service, to give our valiant men the weapons to save America! (McIntire: 38).

Women were selected by interview from 44 states on the basis of academic ability, attitude, and interest. They were required to have completed two years of college, including one year of college mathematics or its equivalent. They were also required to be at least 18 years of age and to possess a better than average record in their overall college work. The average Cadette was 19.6 years of age, had 2.5 years of previous college work, and one year and three months of math.

The young women who joined the Curtiss-Wright Cadettes were, in many respects, among the most technically qualified young women in America. Most were in college before they began the program and a few had actually completed degrees. Many participants met the program's requirement of two years of college-level math education and quite a few were already taking science or engineering courses in university. Few of them could legitimately have expected to enter professional technical careers, given prevailing norms about women's roles in the workforce. In this context, the Curtiss-Wright Cadette program offered these young women an unusual opportunity to obtain significant technical education and, more importantly, to pursue professional-level work in a technical field. One might expect, then, that this was a real breakthrough for women in technical fields – an experience that transformed employers' views of women's potential as employees and that created both hope and ambition among technically competent women that they could pursue technical careers after the war was over. The reality of the Curtiss-Wright Cadettes was more complex, however, reflecting both the persistence of traditional gender roles and the participants' motivations for entering the program and their expectations of it. The young women who joined the Cadettes had multiple motivations for becoming involved: these included their interest in pursuing technical careers, but also a desire to continue their education; the perception that the experience would be fun and an adventure; and a desire to help out with the war effort.

Natalie McIntire, who studied participants in the University of Minnesota program, expressed some surprise when she discovered that patriotism was not the most commonly cited reason for joining (McIntire, 1993: 56-57). McIntire's thesis, *Curtiss-Wright Cadettes: A Case Study of the Effect of the World War II Labor Shortage on Women in Engineering*, focused on participants at the University of Minnesota. Her in-depth interviews with a dozen participants confirm that patriotism was important, but not the only motivation. Some had very personal connections to the war:

I had a serious man in my life who was missing in the south Pacific; later we found out died in the South Pacific, and that influenced my academic success at Kansas. Somewhere or other I picked up this program, and it seemed to me that it was the kind of program that could be considered a war effort. That it could be my contribution to getting those boys home again, if he was ever coming home, but he didn't. So, in the

fall of that year, this program just appealed to me as something I could do for the war effort (ISU Oral Histories, 2006, Goettsch: 1).

Others talked more generally about wanting to help out:

... when World War II began, we were all interested in doing something for the war effort. I was at Morningside College, and the best that I could think of to do would be to work the night shift on the defense plant downtown in Sioux City, which did not set well with the Dean of Women, nor with my mother. So they gave me an application to fill out for Curtiss-Wright Cadette Engineering Program. I filled it out thinking that nothing would happen with this, because that wasn't my talent. And in very short order I got an acceptance... (Meiksins Oral Histories, 1996, Logan: 1).

While patriotism figured prominently in the Cadettes accounts, even more important were two other factors: the desire to pursue their education and a sense that the experience would be enjoyable. Many of the Cadettes were already in college, but in a period when resources were limited, the chance for a free education (and even a stipend) was hard to resist. McIntire's thesis found this was the most commonly cited reason among the Minnesota alums (McIntire, 1993). Many of those interviewed by Meiksins were similar:

... I think a lot of us thought it might not be a career, but it would be something to help the war effort, also it helped us with our education, because we got a marvelous education. At least we did at RPI, and I'm sure the others did the same, and, uh, it was, we had top-notch professors (Meiksins Oral Histories, 1996, Hanley: 3).

Another Cadette, Ruth Miller, talked about being willing to interrupt her career at Miami of Ohio because joining the Cadettes offered a free year of education and took some economic pressure off her parents. She also noted that, for some participants, the Cadettes was their only chance to get an education:

One of my best friends was from Cuyahoga Falls then.... And that really boosted her, because she had no chance at all to go to college, and this gave her one-year of college. (Meiksins Oral Histories, 1996, Miller: 3)

Many of the Cadettes were drawn to the program by an interest in technical subjects, but more than a few said that they were not really interested in engineering. Arlene Hanley, for example, had actually entered Cornell as an engineering student before joining the Cadettes, but switched to a science major, saying that engineering just "wasn't her bag." (Meiksins Oral Histories, 1996, Hanley: 1). Mary Denton had studied geology in school and hadn't intended to be an engineer (Meiksins Oral Histories, 1996, Denton: 2). Ruth Miller had wanted to be an architect, but was told by a school counselor that that wasn't an appropriate career for a woman. The Cadettes program appeared to her as an alternative, although she found that engineering work "didn't appeal" to her (Meiksins Oral Histories, 1996, Miller: 1; 8).

Whether or not the Cadettes had ambitions to use the experience as a way to gain access to a professional career in engineering or science, they generally seemed aware of and accepted the fact that the program was temporary and offered no such promise. Several talked about their sense, both at the time and subsequently, of being pioneers. In Arlene Hanley's words, "I think we saw this as one way to break into a man's world." But, she continued:

"I think all of us knew that it wouldn't last.... I think most of us realized with the end of the war and with jets coming in we would have to learn a new technology (Meiksins Oral Histories, 1996, Hanley: 9).

The Cadettes program didn't promise women anything beyond a partial engineering education and work during the war. The participants were well aware of that and recognized, as well, that the training they were getting alone wasn't enough to qualify

them for real professional engineering work, particularly in the case of women whose academic backgrounds left them less prepared. This was the situation for Ruth Miller:

I felt totally inadequate. It wasn't enough, and we knew that. They were just trying to give us a smattering of this and a little bit of that to give us a background for doing the drafting. We took the math, and shop tools and practices, we learned how to weld, we umm, did aeronautical theory, worked with the wind tunnel, all that stuff was just to give us an idea of what was entailed in the drafting, drawing a picture of this thing. They went in depth with us as far as they could, we didn't have the high school background for some of those things (Meiksins Oral Histories, 1996, Miller: 8).

The Cadettes fully expected, "that as soon as the war was over, they would probably be gone" (ISU Oral Histories, 2006, Sweet: 9).

CURTISS-WRIGHT TRAINING

Actual course work began in February 1943. The Cadettes were housed separately from the traditional student population on their respective campuses, and attended class separately as well. As they were considered employees of the Curtiss-Wright Corporation, the company worked closely with counselors and faculty to ensure the success of the young women enrolled in such an intensive academic curriculum. College credit was given and the participants' tuition and board was provided. However, as "employees," they also received pay of \$10 per week. Courses were arranged in two semesters of approximately five months each so the complete curriculum was covered in a ten-month period and was completed by December 1943.

The course curriculum, according to a 1942 exploratory letter sent to potential colleges, focused on areas in which the Curtiss-Wright Corporation needed employees, namely the Airplane, Engine, and Propeller Divisions (Society for the Promotion of Engineering Education, 1942: 1-4). C. Wilson Cole (head of the Curtiss-Wright Engineering Personnel Bureau), later noted it was decided the Cadette program would only be used by the airframe and propeller divisions. The curriculum was based on fundamental concepts related to the airplane, aeronautical industrial organization, the function and operation of the Curtiss-Wright Engineering Department, and the aerodynamics and theory of flight. The Cadettes focused specifically on drawing and drafting skills, mechanics, the properties and processing of aircraft materials, and shop procedures. They also studied, at an accelerated pace, stress analysis, experimental testing, materials laboratory testing, lofting and template making, and technical analysis. Some of the courses taken by the Cadettes included Airplane Design and Construction, Elementary Engineering Mechanics, Aircraft Problems, Theory of Flight, Aircraft Drafting and Design, Strength of Materials and Aircraft Structural Analysis, and Aircraft Materials and Assembly. Cole notes in his final assessment report, that while the girls at a disadvantage due to their lack of exposure to mechanical things in everyday life and initially clumsy, "the Cadettes have mastered with a great deal of proficiency the handling of tools and operation of machines (Cole, 1943: 10).

When asked what was most memorable about the program, Betty Goettsch responded,

The long hours. Thirty-six hours of class a week and four hours of study hall and assignments outside of the 36 hours that had to be done. And the dedication of the other girls in the program. We were all very serious about what we were doing. It was not a fun and games, ever (ISU Oral Histories, 2006, Goettsch: 1).

She also described the accelerated coursework:

They gave us all of the physics of mechanics, how things worked, how motors worked. They gave us all of aeronautical information, and they crammed about 2 ½ years of aeronautical engineering, in a normal course, into 10 months (ISU Oral Histories, 2006, Goettsch: 2).

But for her, “It just emphasized what I believed, that women could be as good in science and math as anybody, but that people weren’t developing programs for us” (ISU Oral Histories, 2006, Goettsch: 4).

In reviewing the collected oral histories and reunion records, one consistent theme continually discussed by the Curtiss-Wright participants is a distinct sense of group identity. This was no doubt reinforced by separate housing and coursework. Specific references in the interviews include Goettsch describing the other Cadettes:

How sharp they were. How well they had chosen women that could be successful in whatever they wanted to do. They were just brain trusts. Each one of them outstanding in some individual way. But just really sharp, just sharp. And no sissies among us (ISU Oral Histories, 2006, Goettsch: 6).

Another said, “Because to me they were, as a group, a startlingly smart bunch of women.” (ISU Oral Histories, 2006, Sweet: 9). A number of Cadettes specifically mention their enhanced sense of self was one of the end results of the Cadette program. As Lois Brader Greenfield and Harried Talmage noted at the 1994 reunion held in Columbus, “The Curtiss-Wright Cadette Program was good to us, but we in turn used this experience to become prototypes for the young women today” (Patterson, RS 21/7/148).

THE CURTISS-WRIGHT WORK EXPERIENCE

Following training at one of the seven campuses, Curtiss Wright Cadettes were sent to plants in Buffalo, N.Y.; Caldwell, N.J.; Columbus, Ohio; Lexington, Ky., or St. Louis, Mo. Cadettes whose interviews are referenced for this paper either attended Purdue University and were sent to Columbus; the University of Minnesota, which also sent Cadettes to Columbus; Iowa State, whose participants were assigned to St. Louis or Columbus; and Rensselaer Polytechnic Institute, located in Troy, N.Y., which sent the women to the propeller division in Caldwell, N.J.

Lucy Lodge was recruited to the program mid-way during her final year at Akron University, where she was studying math. “When we signed up for the program, originally, the school we were sent to was determined by which plant we wanted to work in,” she said (Meiksins Oral History, 1996, Lodge: 5). She went to the University of Minnesota for her CW training and to Columbus to work, a desirable arrangement because her hometown was Akron, Ohio.

After completing the program, most of the women went on to work in the plants, although for some, confusing communications from Curtiss-Wright caused them to miss their assignments.

“The projected needs of each plant had changed in the year of planning and training, as had the job locations in which the Cadettes were needed most...Some of the women understood the shift in personnel to different plants to mean they were, in fact, no longer needed” (McIntire, 1993: 40).

Most of the responsibility for this confusion and resulting attrition was placed on those organizing the changes.

Because there was no obligation to continue, there was some additional attrition at this time, though the level was very low. One participant from the Minnesota program estimated it to be 10 percent or less. Other than missing one’s assignment due to poor communications, reasons for leaving at this juncture ranged from health issues to lack of interest, to marriage. Despite taking the program seriously and believing she benefitted greatly from the experience, Betty Claybourn Goettsch never worked in the St. Louis plant as she had expected to:

See, Curtiss-Wright Engineering Company did not have a lot of confidence in the fact that women could do this program. So they started about 800 ...a hundred at a time...and they graduated more than 700 of us. And that took them totally by surprise. They didn't have 700 necessary jobs at Curtiss-Wright. So any of us that had a reason not to go into the work immediately were just released from the program. And so since I had married, and my husband was in the service... the arrangement I had was a six-month break...so the six months became a year, and then just a total release from the program (ISU Oral Histories, 2006, Goettsch: 3).

Conditions in the Plants

Interviews indicate that while there were variations in individual experiences, and some differences between the facilities, overall there were several consistent themes that repeated from plant to plant and Cadette to Cadette. Consistent with Curtiss-Wright's recruiting message, the women's assignments were primarily in drafting, which included drawing, making copies, making changes, and checking finished drawings. Some women were assigned to work in "liaison" which consisted of drawing, checking, and making changes between several departments rather than working in the general drafting area or in a single department. In all of these scenarios there was no actual design work. A smaller number of women were assigned to other areas, which included testing labs or calculations. An even smaller number were assigned to positions such as librarian, based upon previous work experiences. Positions were entry level, though with time some women did advance.

For the first groups of women entering the plants, Curtiss-Wright may not have fully anticipated what it would mean to bring women in, but the company was quick to adapt. Of her experience in the Columbus facility, Lucy Lodge said:

They didn't know what to do with us when all these women descended upon them the first day...The people in the plant, the engineering department, I'm not sure that they were aware that all these women were coming in at the same time. But they got organized pretty quickly (Meiksins Oral History, 1996, Lodge: 6).

Cadettes working in the Columbus plant reported being generally accepted by coworkers and male supervisors. Their experience, however, was perhaps a bit more complicated. Wanda Nelcaup Hare addressed this ambiguity:

I think at first they...some of them I know resented it a little bit. Because they were the ones who...maybe had to end up going to the service and didn't have their status changed because they weren't as necessary as they were before, but that wasn't always true...They were all really very nice... I should not say that anybody was not nice. And I think that before we left, I could say they respected the girls. For what they could do...they thought what you were doing was worthwhile, and you weren't just there, just for decoration (Meiksins Oral Histories, 1996, Hare: 4).

Jeanette Tremlin Wickes had gone to Purdue and also worked at the Columbus plant. She said, "I saw myself as an engineer in training...I don't think the men felt that we were, but we felt that we were. Actually, we were probably better trained than some of the men in the department" (Meiksins Oral Histories, 1996, Wickes: 3). Wickes referred to the extensive coursework, particularly in drafting. Her point about training was echoed by other Cadettes. Many felt their training prepared them for more significant tasks than the low level work they were given, and eventually left the program because of the tedium.

At the New Jersey plant, Eunice Bray's experience in the drafting room was similar.

I was working on some rather complicated, not corrections, but re-dos, change orders...At one point I thought, why don't they scratch this whole thing and start from scratch, it gets too complicated to change orders on top of change orders on top of change orders. But it was modifying propeller design, and starting with what was there and reworking the drawings. Just propellers (Meiksins Oral Histories, 1996, Bray: 4).

After 10 months, Bray left the program, saying, “I cut out...it wasn’t my cup of tea. I was out before the war ended, before the rest of them left or got a pink slip” (Meiksins Oral Histories, 1996, Bray: 4).

When Cadettes arrived at the St. Louis plant, Mary Jean Logan Sweet said,

...there were a lot of women working in the plant, so women in Engineering (?!), too bad. In Engineering, there was more of a feeling that, ‘Who are these young women who think they’re engineers.’ So occasionally, you ran into some people whose feathers were ruffled (ISU Oral Histories, 2006, Sweet: 4).

Despite that, Sweet said, “The people that I worked with in my immediate office were very understanding and very kind” (ISU Oral Histories, 2006, Sweet: 5). She enjoyed writing, and was relieved when offered the choice between working in Engineering Change Orders or Materials and Processes, of which the latter included writing bulletins and specifications. Although the work could be tedious at times, Sweet counts as one of her accomplishments that a testing specification she wrote became a standard for the industry. “I was terribly proud of myself then” (ISU Oral Histories, 2006, Sweet: 4).

Somewhat different from the Columbus and St. Louis plants was the propeller division in New Jersey. The plant was located in a more isolated area, so “they already had car pools set up for use, they already were established. We knew where we were going, they had us in different areas, the drafting area, vibrations area...” (Meiksins Oral Histories, 1996, Hanley: 1).

Explaining that color-coded badges signified work location and access in the plant, Hanley said:

Our badges were color coded so we could only go in very small areas, to go down into the machine or manufacturing areas, where the men were, there were primarily men there, to be honest with you. I didn’t see any Rosie the Riveters or anything like that...the only times I went down there was to look at gauges on a propeller.” (Meiksins Oral Histories, 1996, Hanley: 10).

In addition, the badges were numbered, and Cadettes’ badge numbers were lower, because, “we got our badge numbers the day we started at RPI” (Meiksins Oral Histories, 1996, Hanley: 10). The badge numbers most likely contributed to an undertone of resentment toward some of the Cadettes on the part of some employees, at least for a while. Although she recalled that most of the people she worked with were quite decent to her, Hanley also said of her job placement:

Only three of us [from RPI] were doing the calculations and vibrations, the others had all been there...the others were all old hands, and there was animosity because we were not earning starting pay” (Meiksins Oral Histories, 1996, Hanley: 11).

Working in another section of the N.J. plant, Eunice Bray described her work area as being:

...interspersed with the 4-F people who didn’t go to war and the few managers who were excused because they were necessary...We were accepted, they needed us. I don’t remember any antagonism at all (Meiksins Oral Histories, 1996, Bray: 4).

As the program continued, attrition rates in the plants increased, and Curtiss-Wright did acknowledge the situation. By 1944, “43 percent of the women enrolled had left the program.” According to Curtiss-Wright, the primary reason for this loss of interest was “due to the fact the women were overtrained and not challenged by their jobs” (McIntire 1993: 41). While the company blamed the women for not recognizing the seriousness and importance of their contribution, the women generally felt that being given “these clerical, repetitious, and unchallenging jobs” meant they were not really needed. (McIntire 1993: 41).

Curtiss-Wright was not alone in having trained women for industrial jobs during the war that were initially met with enthusiasm and later abandoned. In a similar venture, a joint program between Goodyear and the University of Cincinnati trained young women “cadettes” or “aides” to work, paying them while in training and then placing them in plants. As Margaret Rossiter described the situation:

...these aides were both praised and blamed...a poll of one group of the women...found that 93 percent had liked their jobs most of the time, felt well paid, and found the experience worthwhile. Most also indicated, however, that the jobs they were given were so far beneath their level of training that they became bored with the work after two months and frequently left...The employers did not accept any responsibility for this situation but blamed the women (Rossiter, 1995: 15).

Although attrition rates at Curtiss-Wright do not appear to equal those described by Rossiter, mismatches between the level of training and the level of work, at least for some of the women, clearly contributed to their leaving the program. Other reasons women left included illness, deaths within a Cadette’s family, or marriage. Women who advanced into higher-level jobs or stayed at Curtiss-Wright for the duration of the program had a more satisfying experience. Mary Maggie Blaschak went to Minnesota in Feb. 1943 and from there to the Columbus plant, remaining for the duration of the war and several months afterward. She described her time at the plant:

I liked working there. I started working in the liaison group, where changes had to be made to the blue prints down on the factory floor, and they had to be changed to show the alterations. Almost everyone started in that group, and as time went on they needed people for various openings, we would move up. Some girls went to material testing, some to structure, weights. I went to the electrical design group...I was there for the rest of the time (Meiksins Oral Histories, 1996, Blaschak: 3).

The war ended in August, 1945, and Blaschak remained at the plant until December, along with another Cadette who was also part of the electrical group. Blaschak attributed the fact that she and her colleague were not given pink slips to being good on the job. Describing the decline in production that followed, she said:

All the government contracts were cancelled. They started working on an experimental plane at Curtiss, and I did a little work on that, but you could see the writing on the wall, there wasn’t going to be anything there, and so in December I decided to go back to my original plan, and in January I started a new semester at school (Meiksins Oral Histories, 1996, Blaschak: 3).

She returned home to Detroit to pursue her goal of becoming a science teacher. She taught general science and later received a master’s in library science, becoming a technical librarian.

Other Cadettes at Curtiss Wright in August 1945, such as Dorothy Wurster Rout, had only begun working that January. Rout had gone to Purdue in a second group of Cadettes and had worked in the Columbus plant for eight months when the war ended. She recalled receiving a pink slip over the radio. “...when the war was over, they announced it on the radio... ‘don’t report to work,’ and then the next day you were out of a job” (Meiksins Oral Histories, 1996, Rout: 6). Rout was pleased that all of her math credits from the program transferred to Ohio State University, where she went on to receive a degree in education and history with a minor in math. When asked if she still thought of herself an engineer, she said, “yes,” a testament to the enduring effect of the program personally, if not professionally.

During World War II, Curtiss-Wright had focused its efforts on the development and mass production of reciprocating (also known as piston) engines and propellers. At its wartime height, the Corporation produced 142,840 aircraft engines, 146,468 electric propellers, and 29,269 airplanes. After the war was over, the Corporation focused its efforts on commercial aviation. And as noted in their reunion biographies, the majority

of Curtiss-Wright Cadettes did not become engineers. Most, though certainly not all, ended up following a traditional path of marriage and family (Patterson, RS 21/7/148). In a way, this mirrored the company's original plan to fund a finite, war-based effort as opposed to a permanent job-training program.

CONCLUSION

Regardless, this "foot in the door" changed in a fundamental way the lives of the Cadettes and the perceptions of their families, friends, educators, and other students. Further studies could certainly examine the long-term impact of the program on children of the Cadettes as well as the careers of those who did remain in the field. It would also be of interest to examine their activity and involvement in the Society of Women Engineers.

Though it is unclear whether the program permanently impacted the engineering profession, the mere fact that it was conceived and successfully implemented represents a transformation for women engineers. For many of the participants, there was simply a return to the pre-war cultural norms. The emergence of a significant group of organized women actively seeking careers in engineering would have to wait until gender expectations changed and "normal" labor market conditions had been re-established. But, in many ways, the Curtiss-Wright Engineering Cadette Program represented something new and unique in American academia, and the doors would never again be shut quite so tightly against women engineers.

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WHY WOMEN AND MEN JOINED SWE OVER THE LAST 60 YEARS

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ABSTRACT

Why do women join the Society of Women Engineers (SWE)? Why do men join SWE? This paper will address these questions of membership throughout SWE's history (1950 to 2010), by membership type (student/professional) and related demographics of SWE membership. Of particular interest to participants in ICWES 15, this paper includes both an historical and current investigation of international members of the organization. Theoretical evidence supports information from the National Archives, to help us understand why women choose to join a "women's" engineering organization rather than, or in addition to, an organization focused on their engineering discipline. Details regarding the historical development of SWE's membership come from SWE's National Archives, where correspondence, founding organizational documents and other materials suggest the reasons that women formed the organization, why men supported the organization before male membership was accepted, and why women and men joined that organization over the last sixty years. Finally, a survey was distributed and the SWE website was studied to determine if the historic reasons women and men joined SWE are consistent with the reasons current members join the organization and remain members.

A THEORETICAL CONTEXT FOR WHY WOMEN JOIN SWE

The Society of Women Engineers (SWE) is an organization that empowers women to succeed and advance in the field of engineering, and to be recognized for their life-changing contributions as engineers and leaders. Over the past 60 years SWE has been an important network and resource, for both women and men, in all stages of academic and professional engineering pursuits. In turn SWE has had a significant impact on the engineering profession, engineering workplaces and other engineering organizations. The theories behind social and professional networks are explored to illustrate the importance of an organization such as SWE, and the positive impacts women (and men) experience through membership.

There has been a strong increase in the number of women joining the science and engineering workforce since SWE was founded; however, there are still issues that deter women from entering these fields and prevent women from advancing in their careers. Julia Stamm, assessed the role of networking in science careers, for both men and women, in her article "Women in Science – Why Networking Matters." (Stamm and Garoia, 2010). Stamm prefaces her research findings with a quotation from, *Waste of Talents: Turning Private Struggles into a Public Issue*, a publication released by the European Commission in 2003. Stamm emphasizes women's networks as a way "to

promote women in science [that] requires changing our own vision of science. It is about real commitment and imagination” (p. 121).

While there is no shortage of engineering networks among the professional societies, there are few that benefit women to the same extent as they do men. This is one reason the problems of leaky pipelines and glass ceilings have not been eliminated. Organizations, such as SWE, help to leverage members’ “personal capital” as well as “social capital” (p. 126). Stamm explains “people with strong networks are able to learn from others with different knowledge or experience, get more things done more effectively, and are able to use their network as they wish to move on in their careers” (p. 126). Through her engagement and research with different networking groups, Stamm has identified four beneficial aspects of networking groups for women, which include the “stimulation of exchange, cooperation, and new ideas; stimulation of research; stimulation of publications; and career advancement” (p. 127).

Although social networks have the potential to increase “personal” and “social capital” for women in engineering, the advantages are more numerous for those who more frequently, and more enthusiastically, participate in network activities. It may appear obvious that those who put forth more effort, reap larger benefits, but Florence Passy and Marco Giugni (2001) explore how and why networks may be more or less appealing to certain people in their study “Social Networks and Individual Perceptions: Explaining Differential Participation in Social Movements.”

Passy and Giugni believe that the “effectiveness of the action” (p. 125) is one indicator that may influence the intensity of one’s participation in a network or social group. In other words, the individual will most likely need to feel that their contribution will have an impact on the group, and on themselves, for it to be considered worthwhile. Second, Passy and Giugni hypothesize that any potential negative impact or risk involved with heavy participation in a group will create a barrier for the intensity of participation. Third, individuals taking part in a network or group have the need to feel legitimized. The more legitimate their activities and participation feels, the more likely they are to play an active role. And finally, if the network or group requires too much time, participation is less likely.

Networks are impacted by the above four hypothesis of participation because social networks spur activism. If women in engineering want to facilitate change, SWE becomes the formal mechanism used to initiate conversation and action. The more convenient and effective the network is, the more likely membership and activity will increase. The common outcome of joining a network, such as SWE, is that members experience an “embeddedness [that] places them in an interactive structure that allows them to define and redefine their framing in the social world” (p. 128). According to this definition, both women and men may use SWE as a network in order to define and redefine themselves as a unified group hoping to transform engineering into a discipline that engages and advances women and men equally. Furthermore, SWE as a formal social network increases the legitimacy of their cause, increases membership participation, and increases the potential effectiveness the organization’s goals.

Like Passy and Giugni, Forret and Dougherty explain that involvement in a network will result in building relationships and further developing a career. Forret and Dougherty believe that there are five types of behaviors related to networking, which include “maintaining contacts, socializing, engaging in professional activities, participating in community, and increasing internal visibility” (p. 421). These five behaviors are implemented differently among different people, in particular, by males and females.

While both males and females can potentially benefit from networking, Forret and Dougherty find that males typically benefit more than women. Because men's achievements tend to be valued more, because involvement in a networking group is done outside of the core working hours, and because women are typically held more responsible for their family and domestic responsibilities, women may engage less in networking activities because the outcome is not as positive as it is for their male counterparts. However, women's participation in social networks are beneficial due to the exposure to professional contacts, developing relationships, and mentoring resources, especially when participating in a network geared towards women's professional concerns and needs.

An important facet of being involved with an organization such as SWE, that has not yet been highlighted, is mentoring. Zellers, Howard, and Barcic (2008) explain that mentoring has "a wide variety of connotations" (p. 556). While there are clear benefits for mentees, mentors also benefit from this developmental relationship in multiple ways. Zellers et al. describe these benefits to include: a sense of contribution and accomplishment in addition to achieving personal satisfaction. Mentoring has also been "found to provide tangible benefits to a mentor's career by revitalizing his or her interest in work and contributing to professional and personal development through exposure to fresh ideas and new perspectives" (p. 558).

Many SWE members have expressed an interest in mentoring and helping to develop future generations of women engineers. Just as mentees seek out a mentor with whom they can identify and aspire to be, mentors too, "are more inclined to select or make themselves available to those with whom they identify" (p. 558). From this relationship, each party can share experiences, and the mentor can become a role model and a guide for a young woman's journey through the engineering pipeline.

Overall, SWE can provide female (and male) engineers with an opportunity to feel strength and belonging within their engineering community, while they may feel less engaged in the larger engineering context. SWE offers women engineers a chance to participate in a network of support that encourages women's success and advancement in a historically male-dominated field. Although there may be different intentions for each SWE member, SWE is a shared space for women to develop professional relationships, give back to the engineering community, and use these experiences as a way to leverage advancement in the discipline.

IN THE BEGINNING, WHY WOMEN JOINED SWE

Early documents indicate that interest in an organization of female engineers was developing in several locations simultaneously throughout the late 1940s. Two groups were particularly well organized — a group of students at Drexel University and a gathering of Cooper Union and City College of New York students with women engineers, who had already completed an engineering degree, in New York City. Additional gatherings of female engineers were taking place in Boston and in Washington, DC.

Evidence of the reasons why these women founded the national Society of Women Engineers (SWE), and were convinced other female engineers would join them, can be discerned from the written objectives as they appeared in the founding documents of the organization. On May 28, 1950 a meeting was held at Green Engineering Camp in Ridgefield, NJ. This facility was part of the Cooper Union for the Arts and Engineering, one of the founding colleges/universities. At the meeting the following objectives were listed for discussion:

- “To establish a Code of Ethics”
- “To foster congenial relationships between women engineers and industry”
- “To help undergraduates Find Their Place in Industry”
- “To foster Laws Favorable to Women Engineers”

The last bulleted item was later dropped, largely because SWE’s tax-exempt status did not allow lobbying.

The objectives of the fledgling SWE organization are clearly stated in the Certificate of Incorporation (SWE National Collection, 1950):

“That the particular objects for which said Corporation is formed are as follows: to make the public aware of the availability of women engineers; to foster congenial relationships between women engineers and industry; to help women engineers find their place in industry; to encourage all women who show an aptitude for, and a desire to study, engineering; to encourage membership in Engineering Societies and adherence to their codes of ethics; to encourage in every manner professional advancement among its members; to make available to women engineers such information as is not otherwise readily obtainable so that their full capabilities may be used for the advancement of engineering and science.”

A card dated 1958 aimed at student members, categorized the reasons students should join SWE into two areas: professional development and educational advantages. The reasons related to professional development included,

“1) opportunity for participation in organizational activities which develop the capacity for self-expression; 2) preparation through SWE activities for future participation in civic and professional groups; 3) direct participation in discussion of individual and group problems thereby often finding the solution for common problems; and 4) the availability of information about part time professional opportunities and summer employment.”

The educational advantages listed were,

“1) participation in technical meetings and field trips; 2) contact with women actively engaged in engineering and science; 3) opportunity to learn about the challenges and satisfactions of engineering work.”

(SWE National Collection, 1958)

It is interesting to know how, and to consider why, the Society’s objectives evolved over time. For example, in the second decade of SWE’s history, another version of the Society of Women Engineers (undated, probably early 1960s) listed these objectives:

- To inform young women, their parents, counselors and the general public of the qualifications and achievements of women engineers and of the opportunities open to them
- To assist women engineers in readying themselves for a return to active work after temporary retirement
- To serve as a center of information on women in engineering
- To encourage women engineers to attain high levels of education and professional achievement

These objectives remained unchanged for more than 25 years. It is curious that the objective of encouraging young women to “enter the engineering profession and to guide them in their educational programs” was no longer listed, as it was precisely during this period of time that engineering activities for young women in high school and college increased dramatically. Most SWE sections (student sections included) offered some type of career information programs, and many of them published brochures to encourage girls to consider engineering. SWE instituted career guidance awards during this period of time, recognizing sections for outreach activities. Career

information brochures were also developed by the Society, Engineering – a Goal for women (dated 12/80), High School Preparation for a Bachelor of Science Degree in Engineering (dated 1/81) and Women in Engineering (a career Info brochure aimed at young women dated 5/86). In an article published in U.S. Woman Engineer, (Wadsworth, LeBold and Daniels, 1992) describe the positive correlation between the increase in outreach activities that occurred in the 1980s and the subsequent increase in engineering enrollments and degrees. This finding is discussed relevant to the concurrent increase in SWE student members in the next section of this paper.

A brochure dated 3/83, Why You Should Join SWE, discusses multiple reasons for individuals to join the organization including the opportunities: for **professional and technical growth** through meetings, tours, and SWE Magazine; for **service to women in school** as role models; to “**practice management, organizational techniques, and leadership skills**” through committee work and by serving as officers; for **fellowship and networking**; to help their employer understand and accept women in the engineering profession, thereby building a **work environment “where all professionals, regardless of sex, are treated fairly and given the same opportunities for advancement.”** (SWE National Collection, 1983)

SWE MEMBERSHIP TRENDS IN AN HISTORICAL CONTEXT

In 1950 the membership of SWE was 61 growing to a high of 711 in its first decade of existence. This growth occurred during a decade when females represented less than 1% of the engineering workforce with a degree from an accredited engineering school—a situation that continued until 1971, when B.S. degrees earned by females (353) finally surpassed 1% of total degrees earned (CPST, 2008). Figure 1 shows the growth in SWE membership over the history of the organization and the relative number of student members compared to total membership (Society of Women Engineers, 2010). The increase of female engineering students that

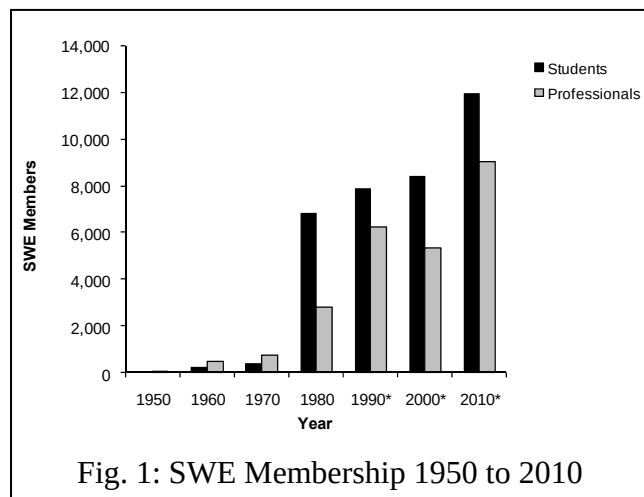


Fig. 1: SWE Membership 1950 to 2010

occurred in the mid-seventies and early eighties coincides with the dramatic growth in student membership during the same period (Figure 2). The growth in SWE senior and associate membership lagged by a decade, as student members graduated and then upgraded their SWE membership or re-joined the organization a few years after graduation.

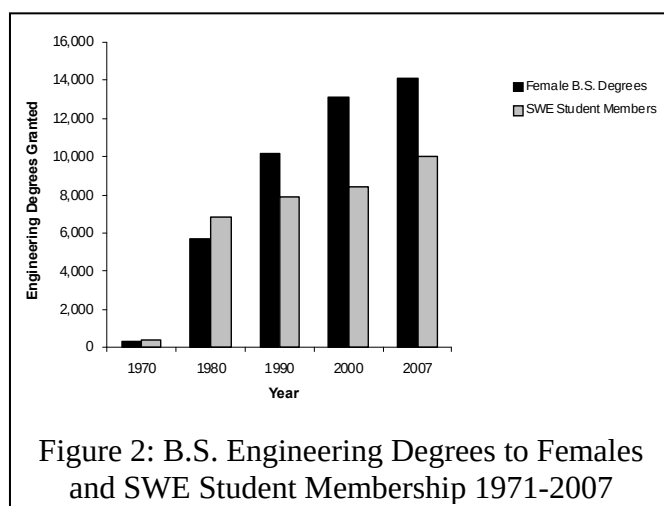


Figure 2: B.S. Engineering Degrees to Females and SWE Student Membership 1971-2007

degrees earned by females and the concurrent increase of the student membership in

SWE? One likely reason was the passage of the Women's Educational Equity Act (WEEA), part of the Elementary and Secondary Education Act of 1965, as amended, Title V, Part D, Subpart 21, 20 U.S.C 7231-7238 (Federal Grants Wire, 2010). Implementation of this act included the availability of funding to create programs for girls in elementary and secondary education. Several of the programs that received funding focused on the recruitment, retention and re-entry of girls and women into engineering education. Administrators of these programs were often serving as Faculty Advisors or Counselors of the student sections of SWE.

WHY MEN JOINED SWE

Only females were considered for membership for the first 25 years of SWE's existence. In these early years there was a "Men's Artillery", an informal group, mostly husbands of SWE members. In the 1970s these men decided to become a bit more formal, creating the Men's Auxiliary Society of Women Engineers (MASWE), to support the purposes of the Society of Women Engineers. While this may have been the written objective of the auxiliary, it is obvious from the correspondence between the men that they also wanted to show their respect and admiration for their wives, their daughters, their employees, and their friends. A letter welcoming a man to the MASWE, dated November 1, 1973, says, "SWE has a membership of over 1,700. I find it hard to believe there isn't at least one man (father, brother, husband, or friend) in the life of each of these women, who is willing to support women in engineering and female engineer students." (SWE National Collection, 1973)

The MASWE was created by a proposed amendment to SWE bylaws (Membership meeting June 25, 1967 voted to direct the Executive Committee to implement the suggested Men's Auxiliary), and stated:

A separate, autonomous organization known as the MEN'S AUXILIARY, SOCIETY OF WOMEN ENGINEERS, may be authorized by the Executive Committee, except that no activity or rule may be in conflict with these bylaws or with the established policies of the Society. Membership requirements and operating rules for the Men's Auxiliary must be approved by the Executive Committee.

A more contemporary view of why men join SWE can be derived from interviews with some of the Rodney D. Chipp Memorial Award recipients, who have contributed their voices to the Grassroots Interviews project, and the five men who responded to the member survey. The Rodney D. Chipp Memorial Award (named after the husband of the first national SWE president) celebrates and recognizes a man or company who has contributed significantly to the acceptance and advancement of women in the engineering field.

George Brewster (2010), Jim Porter (2007) and Walter McFall (2010) all learned about SWE because female engineers who worked for them encouraged them to get involved with the organization. All three of these men recognized the importance of SWE because of its value to female engineering students and female engineers and the challenges these women faced to succeed in such a male-dominated career. All three said they joined SWE to be supportive to women engineers and engineering students, particularly those who worked for them.

Brewster attended his first SWE National Conference in 1979 as a recruiter for Corning, Inc. What stood out in his mind was the large number of female students at the conference and how intelligently they could speak about their engineering coursework and what they were looking for in their careers. He was involved in several recruiting organizations whose members believed there were no females earning engineering

degrees, and therefore, the reason for the small number of female engineers working for their corporations. After seeing all of the bright, articulate female engineering students at the conference, Brewster said he could not understand why no one knew about them. He joined SWE and left the 1979 conference determined to make Corning an active participant in the organization.

Jim Porter served as a campus recruiter for DuPont engineering in the mid-60s, a time when there were no women in engineering with DuPont, or for that matter anywhere else. He admits that the work environment at his company and others were made for men and the way they did things. Porter began establishing a long-term commitment to women in engineering. He felt it was important that the environment change so that everyone had an opportunity and could be successful.

Walter McFall is now retired from his position as recruiting coordinator at Argonne National Laboratory. He was one of the earliest recipients of Rodney Chipp Award, receiving the award in 1997, when he was recognized for his tireless personal efforts to elevate the status of women in engineering. In addition to his commitment to women engineers working at Argonne and his focus on the recruitment of female engineering students, McFall was recognized for his outreach work to elementary and high girls to inform them about the work and career opportunities for engineers. For this pre-college work McFall received the WEPAN (Women in Engineering ProActive Network) distinguished service award in 2006.

All three men talked about the need for more women going forward and their thoughts match SWE's objectives very well. They believe girls need to be encouraged to see engineering as viable career path for them; and they believe that women must advance into high level positions in corporations so that they are role models for other women and have the power and authority to improve corporate policies and practices.

WHY WOMEN OUTSIDE THE UNITED STATES JOINED SWE

Historic documents show that the first woman to join SWE who was not a U.S. Citizen was Jacqueline Feyler Juillard. Juillard received her Master of Science in Chemical Engineering from the Ecole Polytechnique Federale de Lausanne, Switzerland in 1947. She was only the 11th woman to receive a degree from the institute. In 1955 she became a freelance scientific writer and spent the rest of her life's work serving to advance the public awareness of engineering as a profession for women. She provided career guidance for young women in Geneva and prompted the Swiss Society of Engineers and Architects to investigate programs which would advance the careers for women in those fields. Interesting to the participants in ICWES15 is this quote from a letter to SWE Headquarters from Juillard (Society of Women Engineers, 1984): "I shall be giving a small speech at the ICWES in Washington next June talking about the events which took place and the people involved in the first International Conference in New York. Many of them are unfortunately [sic] not any more with us." Juillard goes on to request photos which she wishes to turn into slides for her presentation.

Additional information about why women outside the United States joined SWE is included in the next section, Why Women and Men Join SWE Now.

WHY WOMEN AND MEN JOIN SWE NOW

The SWE website (Society of Women Engineers, 2010b) indicates that women and men might join the organization to:

"Aspire ▪ Advance ▪ Achieve at Every Stage of Your Career", stating
SWE is: "...a not-for-profit educational and service organization that

empowers women to succeed and advance in the field of engineering, and to be recognized for their life-changing contributions as engineers and leaders. Founded in 1950, SWE is the driving force that establishes engineering as a highly desirable career for women through an exciting array of training and development programs, networking opportunities, scholarships, outreach and advocacy activities, and much more.”

Another page of the SWE website outlines “Why Join SWE”:

When you join SWE you’re joining more than an organization—you’re joining a movement toward equality and opportunity for women in engineering. Our mission is focused but our impact is vast. We provide the resources you need whether you are beginning, resuming, or building your career. We also encourage creative and intelligent girls at an early age to explore the field of engineering. Through such career development and awareness, we are making significant strides—together.

Finally, the website discusses membership benefits around four topics: Community of Support, Education and Development, Resources and Information, and Leadership.

To better understand the reasons women and men currently join SWE and remain members, the authors created a survey based on the SWE website, historic materials and related theoretical concepts. Survey availability was announced to all SWE Sections via e-mail and was made available in paper format or on line. Respondents could select from nine responses (one of them being open ended) and could select multiple reasons. Two hundred fifty responses were received. Seven men responded to the survey, as did six women who are international members. Eighty-three percent of the respondents joined SWE as student members and 49% of the respondents are still student members.

If all respondents were grouped together, the top reason these members joined SWE originally (most of them joining as students) was **“to be in an organization with like-minded women.”** The next most frequently chosen response was **“as a source of encouragement for myself.”** The least common response for all categories of members was, **“to be in an organization where my voice could be heard.”** Less than 12% of both students and professionals chose this response as a reason they joined SWE. However, this proportion increased to 15% of the professional members and almost 30% of the student members, when asked why they remain members of SWE. Interestingly enough, none of the international members chose this response.

There was a noteworthy difference in responses from those who joined SWE as a student vs. those who joined SWE as a professional member. The top response to the statement, “Why I joined SWE originally” among members who joined SWE as a student was, **“to be in an organization with like-minded women”** (74%). This response could be expected from young women who are embarking on an educational and career path that is non-traditional. Undergraduate female engineering enrollments have never surpassed 21% (CPST, 2008) and female students often found themselves alone in a lab group or small class. When female students returned to their dorm room to study their engineering courses, do homework or prepare for an exam, it was, and still is, unlikely that there would be another female student on the floor where they live who was in the same class. The top two responses selected by members who originally joined SWE as a professional were, **“to support female engineers”** (61%) and **“to support female engineering students”** (55%).

CONCLUSION

Theoretical evidence presented by several researchers suggests that networking promotes the professional development of network members while advancing the issues important to them within their profession, as well as among the general public. Others

describe how mentoring has multiple benefits for both the mentee and the mentor. These theoretical understandings are consistent with the founding objectives of SWE to encourage professional advancement of their members, to encourage membership in Engineering Societies, to encourage women to study engineering, to foster congenial relationships between women engineers and industry and to increase public awareness of women engineers. Over time additional reasons to join SWE developed such as assisting women engineers to return to active work after temporary retirement and informing young women, their parents, and counselors of the qualifications and achievements of women engineers and of the opportunities open to them. In recent years new values of membership have been highlighted (Society of Women Engineers, 2010): "When you join SWE you're joining more than an organization—you're joining a movement toward equality and opportunity for women in engineering. Our mission is focused but our impact is vast. We provide the resources you need whether you are beginning, resuming, or building your career. We also encourage creative and intelligent girls at an early age to explore the field of engineering." Finally, 2010 survey responses from both student and professional members of SWE indicate that the founding objectives and historic reasons for joining SWE are still important to female and male members today—to be in an organization with like-minded women, to support female engineering students, to support female engineers and to support their own education/career. Current SWE members and leaders can trust that the objectives and values of the organization which have persisted for six decades will continue to attract new members, assuring a vital organization for many years into the future.

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UNDERGRADUATE RESEARCH PROGRAM AT A COMMUNITY COLLEGE

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ABSTRACT

An initiative by the National Research Council [USA] has charged Community Colleges to consider instituting a foundation program to introduce students to science research. A team of four women has begun formalization of this process. They include a reference librarian, a Teaching in Community Specialist, a civil engineer, and a physics faculty member. Initial focus will be a community of faculty "Research in Community" to promote test-bed implementation and assessment as well as foster faculty buy-in across the campus. The plan will be coordinated with the existing Honors Program and current independent faculty / student research projects. The major goals are to enhance overall student experience, improving student performance and preparation, supporting student transfer opportunities, and outreach to academic and community partners. This format is modeled on "Teaching in Community" specifically to provide better access for women in science to all aspects of the undergraduate experience.

INTRODUCTION

Springfield Technical Community College, a leader in technology and instructional innovation, transforms lives through educational opportunities that promote personal and professional success. To this end, the College is committed to fostering inquiry; embracing diversity; respecting an open exchange of ideas; encouraging leadership; and inspiring creativity and serving the future with a caring faculty and staff.

STCC Mission Statement

In November 2010, a team of four faculty and administrators (the workshop team) from Springfield Technical Community College (STCC) attended a workshop conducted by The Council on Undergraduate Research in conjunction with the National Council of Institutional Administrators (CUR/NCIA). Funded by the National Science Foundation (NSF), CUR/NCIA is a "program to build a foundation of knowledge and the resources upon which a vision of undergraduate research at community colleges can be constructed" (Council on Undergraduate Research & National Council of Institutional

Administrators, 2010). To that end, the workshop was designed to “assist community colleges to develop effective and sustainable undergraduate research programs” (Council of Undergraduate Research & National Council on Institutional Administrators, 2010) given the unique academic environment of those institutions. The workshop team attended with the overall objective of envisaging an ideal undergraduate research environment and arriving at a realistic conclusion about the possibility of such a program at STCC, consistent with the College’s vision of “being the leading-edge educational solution for workforce, community, and innovation” (Springfield Technical Community College, 2011) and advancing student engagement, success, retention, internship and transfer opportunities, and job placement. Critical to this determination was clarification of the definition of undergraduate research and the identification of highly important issues relevant to the College’s mission, i.e., the impetus for the initiative, and of current activities on campus that could be considered undergraduate research. In addition, the STCC team hoped to identify existing institutional practices or policies exist that would encourage or support both faculty and student participation in undergraduate research along with obstacles and challenges to the same.

This paper presents an overview of STCC as an urban, diverse institution; a summary of the workshop team’s preliminary analysis and self-study; an analysis of goals, objectives, and strategies in light of institutional strengths and challenges, preliminary faculty input on the feasibility and direction of the program, and the groundwork for future implementation and design of the program.

BACKGROUND

Since the publication of *How People Learn* in 2000, the fundamental underlying goal of research and development in education has been having students develop deep understanding of what they are learning.

Learning research suggests that there are new ways to introduce students to traditional subjects, such as mathematics, science, history, and literature, and that these new approaches make it possible for a majority of individuals to develop a deep understanding of important subject matter.

(Bransford, 2000, pg. 6)

How People Learn places great emphasis on deep understanding because all the evidence points to the central role of understanding in determining whether knowledge is usable, transferable, can be employed to advance one’s knowledge, and can be used in the creation of new knowledge.

The Council on Undergraduate Research defines undergraduate research as “[a]n inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline.” (Council on Undergraduate Research & National Council of Institutional Administrators, 2010) “Authentic research represents a significant departure from typical undergraduate laboratory courses in which students complete predetermined activities in a rigid three- to four-hour block of time each week throughout a semester. In contrast, students engaged in authentic research work as a part of a larger team of investigators...” Sadler and Troy (2010) suggest. Sadler and Troy also note that “[a]dvocates for undergraduate research in the

sciences have suggested that these experiences produce a variety of benefits including more sophisticated understandings of science and the nature of science, improved attitudes toward science, promotion of careers in science, enhanced critical thinking, and improved self-efficacy.” (Sadler and Troy, 2010) According to Nagda, Gregerman, Jonides, von Hippel, and Learner, the goal of a program established at the University of Michigan was to “broker intellectual relationships between faculty and first-year and sophomore undergraduates through research partnership.” (1998, p. 58). The project elements were similar to what is being proposed here. The program went through two standard semesters, rather than the summer. Faculty came from all departments and programs on the campus, and it was not an honors program. In fact, underrepresented minority students, women and even ‘marginal’ students were recruited. (Nagda, Gregerman, Jonides, van Hippel and Learner, 1998) They reported on retention statistics, and looked for evidence of persistence.

Dolan (2010) notes that national movements are under way to reform introductory biology education and integrate research experiences into undergraduate courses for majors and non-majors alike. This reform effort faces institutional and cultural barriers that prevent widespread employment of effective instructional practices. A goal of this project is to overcome those barriers that Dolan discusses, especially for traditionally underrepresented student populations. From Karukstis’ (2010) article, it is evident that there is existing or available NSF funding that supports this process. This is not community college focused. In 2007, she posits the importance of this kind of activity for a successful United States in the twenty-first century. Examples of previous work include that in 2008 reported by Mojock, Keefer and Summer. Their project was designed to provide a community college undergraduate an authentic research opportunity in a science discipline. They recruited students who had completed a two-semester sequence in chemistry or physics to explore the technical aspects of producing economically viable bio-diesel fuel from donated discarded restaurant cooking oils.

Springfield Technical Community College

Located in the Knowledge Corridor^{®1} of Western Massachusetts and Northern Connecticut, STCC (www.stcc.edu) in Springfield, Massachusetts, arose 40 years ago from the looming threat of a devastating economic blow to the region – the closing of the United States Armory. Today the institution – the only technical college in the Commonwealth of Massachusetts – is a powerful economic engine in its own right, providing businesses throughout Western Massachusetts with trained employees and encouraging business to grow and thrive. The only community college in the nation with a Technology Park², STCC offers 86 programs for approximately 7,000 (~ 4100 FTE) students (57% female, 43% male) and has given the community over 29,000

¹ So named because of its “dense population of elite colleges and universities (29 total) and over 100,000 college students”; colleges/universities include Amherst, Williams, Smith, University of Massachusetts Amherst. (The Economic Development Council of Western Massachusetts, 2011).

² In 2001, STCC was selected by the U.S. Department of Commerce, Economic Development Administration as the sole national winner of the Award for Excellence in Urban Economic Development. In 2002, the International Economic Development Council recognized the Technology Park with its Economic Development Award for a Revitalization Program. (STCC, 2011)

alumni. By race, current enrollment is 50% White, 19% Hispanic, 14% African American, and 4% Other Minorities.

Community colleges are generally two-year colleges, though students often take more than two-years to complete their programs. While many states do offer housing, Massachusetts' community colleges are not residential. STCC serves multiple missions. One is to prepare students for the workforce, often in response to local employer demands. Another is to prepare students to transfer to four-year colleges to continue studies in the sciences, liberal arts or pre-professional programs. The last is remedial, primarily in mathematics and English. This mission supports both native speakers of English and English language learners. Both a degree- and certificate-granting institution, STCC awarded 794 Associate Degrees and 204 Certificates in 2009-2010. Areas of study included Liberal Arts/General Studies Transfer (54%), Business & Information Technologies (14%), Engineering Technologies (14%), Arts, Humanities & Social Sciences (7%), Health Sciences (5%), Nursing (3%), and Mathematics, Science & Engineering Transfer (3%). By enrollment, the top five majors were Pre-Health Sciences, Liberal Arts/General Studies/Liberal Arts Transfer, Law Enforcement, Bilingual Core, and Nursing. There are currently 827 students in STCC's Engineering Technology programs and 60 in the Engineering Transfer program. STCC is an Achieving the Dream College, a major national initiative for student success and retention.

The College currently holds articulation agreements with twenty institutions, including Boston University College of Engineering, Rensselaer Polytechnic Institute, Rochester Institute of Technology, and the University of Massachusetts Amherst. In addition to its highly-regarded transfer programs, STCC offers a variety of high-demand career programs, such as Biotechnology, IT Security, Laser Electro-Optics, Nursing, and Sonography. The College offers academic remediation for entering students, Adult/Continuing Education programs, Advanced Placement credit, cooperative education, distance learning, English as a Second Language, Honors Program, independent study, internships, and services for learning-disabled students. Many STCC programs, degree or certificate, require a rigid application process.

Since 1990, the College's Commonwealth Honors Program has been a selective program offering a challenging academic experience for qualified students who desire unique study and research contact in their field of study. Honors students are required to enroll in two colloquia and a Library Research Methods course. Additionally, students may work independently with faculty to design an honors add-on component in an approved course, equivalent to an extra twenty percent of class work, subject to oversight and approval by the Honors Program committee.

Faculty – 425 total, including adjuncts – are required to hold a Masters Degree in their respective field. The College is supportive of faculty conference travel and encourages off-campus professional development events. Major professional development initiatives on-campus include the New Faculty Seminar, Emerging Technologies, and Writing across the Curriculum programs. In addition, a strengths-based sharing of best practices called Teaching in Community (TIC) encourages and supports faculty in creative exploration of experimentation with and reflection on teaching and learning as

it relates to the diverse STCC community. TIC is designed to provide faculty with a new or renewed sense of vision and connection to teaching and learning.

Pre-Analysis and Self-Study

The workshop team performed a self-study prior to the CUR/NCIA workshop. Fundamental to the process was the discussion and exploration of definitions of undergraduate research at the community college level, in general and in specific disciplines; the benefits and limitations of undergraduate research in a community college environment; the identification of institutional resources and support mechanisms; an overall methodology of development; student, faculty, and institutional expectations and responsibilities; and characteristics of successful programs.

The program as initially envisioned by the workshop team consisted of a dedicated core of students and faculty. Faculty directed student-centered projects as (1) individualized projects, (2) ongoing long-term projects through which students could “cycle”, (3) service learning projects designed to meet needs on campus or in the local community, or (4) student internships or practicum occurring in outside institutions – academic or business – which provided students with employment while satisfying academic requirements. Laboratory space, equipment, library services, and other resources were available. Faculty working with students received commensurate reduced workloads or other incentives. A central researchers’ space existed so that students, faculty, and guests could meet informally for discussion and networking. Annual presentations of activities occurred and a site hosting presentation materials was maintained. Student writing improved as thoughtful documentation and presentations of work ensued. Overall, participating students were better prepared for the four-year institution, more competitive in the scholarship and transfer application process, and better positioned for gaining employment. Further, students typically underrepresented in STEM fields – especially women and minorities – were attracted, engaged, and retained in these areas of study as research opportunities provided meaningful contextual and relevant methodologies for learning.

Students

A small number of STCC students currently conduct independent research projects under the guidance of faculty in varying degrees. Such projects are typically initiated when students approach faculty with an idea or topic they desire to pursue. These motivated students, however, face the same typical competing outside obligations of most community college students. Student schedules are restricted by job and family responsibilities, and many students are without access to computers or broadband Internet off campus. The workshop team agreed that those obligations must be acknowledged and validated. In addition, the lack of awareness about the definition and role of research, as well as a deficiency in research and pre-requisite skills, must be addressed. Demonstrating the value of student-centered research to students themselves is fundamental to the success of the program. Critical are strategies to ensure widespread opportunities for all interested students while maintaining satisfactory pre-requisite qualifications and skills. Further, determining effective recruitment and enrolment incentives as well as adequate support mechanisms to encourage, track, and document student progress is paramount to a sustainable model.

Faculty

Community colleges are teaching institutions and community college faculty are, first and foremost, teachers. Faculty endeavor to prepare students for selective program acceptance, transfer to four-year institutions, or entrance into the workplace. In general, faculty hope to foster lifelong learners with the skills to succeed in today's knowledge-based society. To that end, undergraduate research, in and of itself a powerful form of professional development for faculty, broadens knowledge in all teaching disciplines, strengthens collegiality between faculty, and enhances faculty/student relationships – all while elevating faculty professionally. It leads to potential grant opportunities and to the establishment of learning communities – proven pedagogy for increasing retention and student success – as well as drives outreach efforts to academic, business, and civic organizations. Service learning projects are an organic result of such outreach.

A perception exists on the part of faculty that undergraduate research is not valued or highly recognized in institutional culture. Involvement in undergraduate research is not a consideration for tenure, and, outside of a minimal amount within the Honors Program, scant resources exist to showcase research or support travel for students or faculty to present research. Contractual workloads, academic advising duties, and college service requirements present obstacles to faculty participation. Lack of incentives for faculty to undertake the commitment – additional compensation, release time, or tenure/promotion considerations – is at issue. Also critical is a lack of physical space and meeting time for students and faculty to collaborate. Strategies to effectively support and incentivize faculty in such a program are critical to the successful implementation of the program.

Institution

This program presents an opportunity for STCC to build upon its many strengths, including strong collegiality among faculty and staff, strong administrative support for faculty-initiated projects and programs, and a highly effective grants office. The institution must exhibit a willingness to meaningfully recognize the efforts of both students and faculty in an undergraduate research program and provide the necessary support for the program. In return, benefits to the institution would include increased grant funding, strengthened outreach to the academic, business, and civic communities, and an overall elevation of the College in the community. A heightened sense of faculty accomplishment and collegiately along with development of prestigious partnerships would further the mission of the College. Further, given the institution's challenge of an underprepared student body and consistent with its focus on student retention, an undergraduate research program promoting retention would place the College on the cutting edge of pedagogies for community college student success. These efforts would be especially significant if impactful on reaching traditionally underrepresented students in STEM fields.

ACTION PLAN

The workshop team formulated an action plan as the major outcome of the CUR/NCIA workshop. Pursuant to the overarching goals of the project, this plan outlines specific goals, strategies, objectives, and outcomes over a three year period in three phases with an ultimate outcome of full implementation of a successful and sustainable

undergraduate research program at STCC. Fundamental to the action plan is the clear articulation of the definition of undergraduate research, specific to the needs of the community college population at STCC, to the agreement of all disciplines and across all curricula, and to promote the participation of underrepresented and non-traditional students, especially women and minorities. Per CUR/NCIA, the term undergraduate research at the community college level does not imply publishable material but rather an experience to direct the student toward more formalized research. Therefore, the philosophy underlying this plan is that correctly applied student-centered research experiences enhance student engagement and understanding, thereby improving student success, preparation, retention, and inclusion. This experience will carry through to the four-year institution. In addition, meaningful student research experiences will enhance faculty teaching of all undergraduates while allowing faculty to pursue fields of interest and constructively reinforce student and professional relationships.

A faculty group modeled on the highly effective Teaching in Community program will be established and will serve as the faculty information and development “arm” of the project. Called “Research in Community for Excellence” (RICE), this group will serve as the faculty forum to facilitate enlargement of the knowledge base as input is drawn from the entire campus community. The formation of a support structure – a baseline system of accountability between faculty, students, and administration – will be designed. The current Honors Program, meeting teaching, learning, contractual, and institutional policy, will be the delivery mechanism for undergraduate research, extending research opportunities to all qualified students. The existing supervisory committee of the Honors Program, which makes academic decisions on what constitutes honors level work, will adjudicate the program parallel to a four-year institution. Current Honors faculty will guide and inform decisions until a working definition and program design are well-established.

Current research activities and independent projects will be inventoried and coalesced campus wide, allowing a balanced approach to designing student research experiences in all areas of study. Outreach to various STCC departments, such as Grants and Development, as well as to academic, business, and community organizations, will be a priority as the project nurtures research opportunities in the form of internships and community service projects.

Phase I: 2010 – 2011 Academic Year

Phase I begins the formalization of the program with informational sessions for faculty and initial reporting to administration.

Goal: To introduce and infuse a culture of undergraduate research at STCC

➤ Objectives

- Determine characteristics of successful undergraduate research program at STCC
- Determine how undergraduate research is compatible with a teaching institution and consistent with the teaching mission of the College
- Promote “buy-in” of faculty
- Identify methods to elevate participating faculty and students in the culture of the institution
- Assess existing and required resources and support

➤ Strategies

- Formulation of RICE group
- RICE meetings with STCC faculty
- Compilation of faculty feedback from RICE sessions
- Report to College President and Dean of Academic Affairs
- Research funding sources and begin funding process
- Outcomes
 - Preliminary working definition of undergraduate research at STCC
 - Preliminary formal articulation of program's philosophy
 - Preliminary draft of overall program characteristics and structure
 - RICE approved by College President and Academic Dean
 - Formalization of first full RICE faculty cohort

Phase II: 2011 – 2012 Academic Year

Phase II represents the specific formalization of the program. The program will eventually fit within the Shared Governance structure as a standing committee, which also serves as a free standing authority for future funding requests.

Goal: To design a sustainable undergraduate research program

- Objectives
 - Compile and analyze faculty feedback from RICE meetings
 - Evaluate existing library services and identify gaps
 - Inventory existing Honors projects and independent faculty research projects
 - Identify “test-bed” faculty and courses for pilot projects and faculty mentors
 - Set thresholds, pre-requisites, and criteria for participation
 - Identify realistic, sustainable incentives for faculty
 - Develop effective support structure for program
 - Determine satisfactory faculty incentives and adequate support
- Strategies
 - Exploration of existing and planned learning communities to further program
 - Present definition of undergraduate research to Shared Governance
 - Outreach to Grants/Development and other sources for funding; initialization of contacts in academic/business/civic communities
 - Review, compilation, and presentation to College President and Dean of Academic Affairs
- Outcomes
 - Formal definition of undergraduate research as approved by Shared Governance
 - Clarification of connection between undergraduate research and Honors Program
 - RICE becomes standing committee under Shared Governance
 - Fully-designed undergraduate research program at STCC approved by College President and Dean of Academic Affairs
 - Approval by Academic Curriculum Committee

Phase III: 2012 – 2013 Academic Year

The STCC definition for undergraduate research will be finalized and a working program design will be fully implemented.

Goal: To implement fully-designed undergraduate research program

- Objectives
 - Recruit and enroll qualified students
 - Pursue funding sources and outside resources
 - Comply with union contractual obligations and limitations
- Strategies
 - Establish faculty mentors
 - Develop assessment and evaluation instruments to align with academic/industry standards (examples: ABET, Essential of Medical Technologies, Nursing)
 - Conduct outreach to other community colleges via reciprocal site visits
 - Conduct outreach to other campus and national organizations
 - Conduct outreach to local/state/national civic and business communities
- Outcomes
 - Sufficient numbers of qualified and interested students and faculty; satisfactory projected enrollment
 - Formal assessment and evaluation underway
 - Collaboration with other academic, business, and community organizations with appropriate facilities, research programs, and opportunities for students
 - Recognition by STCC Board of Trustees

First RICE Meeting – Preliminary Faculty Feedback

The workshop team introduced the concept of the undergraduate research program to approximately thirty attending faculty at the first RICE meeting. Underlying faculty issues and concerns were probed from a strengths-based perspective. Faculty related best experiences in terms of “high points” doing research at STCC or in another setting and were asked “what wishes, hopes, and ideas do you have for this initiative of RICE?” A cursory compilation of feedback on the benefits of such a program indicated recurring themes of teamwork, student empowerment, non-traditional student inclusion, students seeing the “big picture”, collaboration between courses and disciplines, ongoing service projects, creativity in terms of research outcomes, and a sense of community at a “commuter school”. Consistent with the workshop team’s pre-workshop self-study, faculty consistently identified obstacles to the success of the program as students’ fear of research and lack of research skills, contractual workload and time constraints on faculty, and lack of funding and overall institutional support. A follow-up Phase I RICE meeting will further identify and clarify issues related to the implementation and sustainability of the project.

ASSESSMENT

The program will evaluate its impact both quantitatively and qualitatively consistent with, but not limited to, the following indicators and outcomes. A formal assessment plan is under development.

Tab.1: Evaluative Indicators and Outcomes

Students	Faculty	Institution
# participants	# participants	Increased collaboration with local and peer institutions

Diversity of participants	Diversity of programs offered	Increased visibility in community
Retention	Retention	Increased appeal to potential students
Increased scores on faculty-designed content/skill rubrics	Increased grant activity	Increased grant funding
Number and quality of presentations and publications	Increased collaboration with faculty	Enhanced collegiality among faculty and administration
Scholarship and transfer success	New faculty researchers and increased research publication	
Better preparedness for four-year institutions	Faculty feedback	
Job and internship placement		
Increased interest in STEM		
Student feedback		

CONCLUSION

A team from Springfield Technical Community College (STCC) attended a workshop conducted by The Council on Undergraduate Research in conjunction with the National Council of Institutional Administrators (CUR/NCIA). The team's attendance precipitated the development of an undergraduate research program at STCC consistent with the unique student population and teaching mission of the institution. Guided by a preliminary self-study to define undergraduate research at the community college level and explore the feasibility of such a program, an action plan was developed to begin formalization and implementation of the program. Fundamental to the process is the identification of both highly important issues relevant to the College's mission and of current activities on campus that could be considered undergraduate research. In addition, the STCC team hopes to identify existing institutional practices or policies exist that would encourage or support both faculty and student participation in undergraduate research along with obstacles and challenges to the same.

The major goals of this initiative are to enhance the overall student experience; improve student engagement, performance, and preparation; support student transfer opportunities; recruit and retain traditionally underrepresented groups in areas of study such as STEM; and foster outreach to academic, community, and industry partners. In a clearly outlined three-year, three-phase process, the major goals of the initiative will be directed by the STCC definition of undergraduate research and characteristics of the successful program will be identified and tailored by input across the campus and the curriculum. The initial template will be an existing Honors Program in conjunction with a faculty cohort called "Research in Community for Excellence (RICE)". Effective support structures will be formulated and approved and a meaningful assessment process of outcomes and results will be developed. The overarching goal of a successful and sustainable student-centered undergraduate research program will be reached in the 2012-2013 academic year.

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A Spatially Gender-Disaggregated Database for Bursary Allocation to attract Women pursuing Science, Engineering and Technology (SET) in Kenya.

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ABSTRACT

Industrialization is largely dependent on human resources having appropriate skills particularly in Science, Engineering and Technology (SET). In this regard, Kenya adopted a bursary reform strategy in 2007 for 19 Technical Training Institutes with guidelines for its administration set where the ratios for beneficiaries are given as, for Poor Household 40%, Orphans 30%, Female 15%, and Special needs 15%. The objective of this study was to develop a Spatially Gender-Disaggregated Database that can be used for mainstreaming bursary allocation specifically for Women pursuing SET Programmes. GIS was used to develop this database which contained the location of Technical Training Institutions and the amount of Bursary allocated. To establish compliance with Bursary Administration policy, Kitale Technical Training was selected and data captured on the students by gender, home district and courses (SET, Business and Others). The results obtained revealed a total student population of 406 comprising 270 Males and 136 Females spatially distributed countrywide. A comparison of the courses taken by gender Male to Female ratios showed that for Science (7:3), Engineering (9:1), Technology (4:5), Business (5:5) and others (3:7). The total enrolment for Women in SET was found to be 50 (21%) which is very low. In addition, the bursary allocated to this particular institution benefited 9% of the total Female population. Using trace analysis it was established that 28 of the 50 Female students came from areas that are economically disadvantaged. Such information is useful in streamlining bursary administration leading to attraction of Women in SET programmes.

Study Background

A country that recognizes and invests in its human resource increases an individual's organizations and a country's human capital resource pool (McIntyre, 2004; Olaniyan & Okemakinde, 2008). Indeed through appropriate education and training, one acquires knowledge, skills and abilities which subsequently enhance productivity and performance at work and life in general. Some of the challenges facing developing countries include poverty, food security, energy, water, environmental degradation, climate change, among others. The need therefore to have home grown solutions are of utmost important. Various programmes have been initiated globally, regionally and nationally which include the MDGs and country specific initiatives to address these issues. The Government of Kenya introduced two initiatives namely The Economic Recovery Strategy for Wealth and Employment Creation (ERS) (GOK, 2003) and the Kenya Vision 2030 (GOK, 2007). The implementation of the ERS recorded remarkable success with the countrys GDP rising from 0.6% in 2002 to 6.1% in 2006. Vision 2030 seeks to make Kenya a newly industrialized middle economy country by providing quality life to its citizens by the year 2030. With the changes in the global economic, social, political, technological and natural environment, the country needs to have competitive, innovative and adaptive human resources (GOK, 2008). Science,

Engineering and Technology (SET) courses therefore have been recognized in their contribution to empowering and transforming people into useful members of the society enabling them to participate in social cohesion and technological development (Alam, 2008). New industrialised countries like Singapore and Malaysia have also embraced such programs for faster economic growth (Robert, 1991; Garba, 2002).

SET and Gender

Appreciating the gender dimension across a broad range of Science, Engineering and Technology activities reveal challenges and opportunities that can be exploited to shape a stronger science policy. Further a gendered lens approach at Science, Engineering and Technology implies understanding perceptions, practice, policy, impacts and beneficiaries. In general, the issue at hand is whether the perception of Science, Engineering and Technology results in gender biased practice and policy. There has also been concern on the impact of Science, Engineering and Technology policies and programs on the lives of women and men (IWTC, 1997).

Gender issues in SET have continued to elicit a lot of interests globally as evidenced in a number of international Forums (Appleton et.al., 1995). For instance, in 1979 at the first International Conference on Science and Technology, only one article referred explicitly to women in science and technology. In 1985 the Mid-Decade Nairobi World Conference on Women took up the issue of women in science and technology more seriously leading to the recognition of their inventions and technology knowledge. The United Nations Commission on Science and Technology (UNCSTD) set up in 1983 on appreciating the importance of the gender dimension purposed to have gender as one of its three themes. To facilitate articulation of gender issues a Gender Working Group was set up drawing members from Africa, Asia, South America and Europe. In addition, it borrowed heavily from the experience of an NGO umbrella organization of women working in science and technology fields namely Once and Future Action Network (OFAN). The outcome of this Working Group with inputs from 67 international experts included nine science themes in challenge papers resulting in a 'Declaration of Intent' approved by governments at the Economic and Social Council. This provided an input to the 1995 Beijing Fourth World Conference on Women, with an associated set of 'Seven Transformative Actions' which contained cross-cutting references to issues of gender in science and technology interspersed in its themes. During this conference, a parallel NGO Forum, the 'Once and Future Pavilion' celebrated women in science and technology internationally and offered a wide-ranging set of workshops (McGregor & Bazi, 2001).

The World Science Report by UNESCO 1996 committed one of its five chapters to the consideration of the 'Gender Dimension of Science and Technology'. The succeeding 1998 World Science Report contained a commentary on gender issues, whereas the 1999 World Science Conference of UNESCO and IUSCU, held in Budapest, had a full theme committed to women in science and technology. These benefited from four preparatory gender workshops held internationally.

At the NGO level, professional associations of women such as engineers, physicians, women veterinarians, women chemists and women in trades have been actively organising national, regional and international networks of support. Many of these networks have mounted websites. Increasingly, as economies reposition themselves to compete in the new knowledgebased global economy, the gender gap in entry, promotion, decision-making and attrition in fields of study and remunerated endeavour in science and technology has caught the attention of planners. In some instances, Heads of State have commissioned national assessments of women's participation in science

and technology based on calls to action by their Science Advisors or National Science and Technology Advisory Boards. This involved examining women's barriers in science engineering and technology thereby establishing special mechanisms for recruiting, retaining and mentoring top female talent. A good example is the establishment of Canada's five NSERC Chairs on Women in Engineering in Universities in 1996 through a unique public-private joint initiative on promoting women in science and technology with an investment of \$1.25 million (McGregor & Bazi, 2001).

At the local level the government of Kenya has had one bursary scheme for the education and training where the criteria for getting the bursary was pegged on performance in national examinations regardless of the social and economic conditions of the applicant. However, with time it was established that growing poverty levels impacted adversely on the ability of a large number of the Kenyan population to access education. It was estimated that up to 46% of Kenyan households were within the poor bracket where per capita earnings were less than U\$1 per day. Thus a new strategy based on equity was then introduced with two main objectives, one to ensure the needy cases are targeted and two to enhance accountability and transparency in bursary administration. In this regard, Kenya adopted a bursary reform strategy in 2007 for 19 Technical Training Institutes with guidelines for its administration set where the ratios for beneficiaries are given as, for Poor Household 40%, Orphans 30%, Female 15%, and Special needs 15%. Indeed the Government of Kenya through Vision 2030 and Sessional Paper No1 of 2005 on A Policy Framework for Education, Training and Research deliberately emphasize on development of skills in these areas (GOK-MoHest, 2007)

Gender-Disaggregated Data

Gender-disaggregated data implies cross-classified data by gender, where information is presented separately for women and men. This data highlights roles, real situations, general conditions of women and men in every aspects of the society for instance, literacy rate, business ownership, employment, wage differences, dependants, house and land ownership, loans and credit, debts among others. According to UNESCO, (1995) using Gender-disaggregated data revealed that Men dominated natural sciences, engineering and agriculture whereas women tended to pursue social and biological sciences. It also established that women generally account for significantly higher percentages of enrolment and training oriented towards commercial and service trades than industrial and engineering trades.

Gender-disaggregated data has been found to be one of tools that can be used to highlight differential impacts, the others being gender analysis to policy elaboration and seeking women's input into programme development (McGregor & Bazi, 2001). The tools that can be used to collect this data can include questionnaires, observation or other techniques that reveal the different roles and responsibilities of men and women.

Lack of Gender-disaggregated data, makes it very difficult to identify the real and potential contributions of half of the population thus exacerbating the challenge of development of effective policies. Such data can be used to consider and track the impacts of national activities on women and men; find out and further define the problems, and then develop options and choose the most effective and beneficial one for both genders. The incorporation of the spatial dimension to the gender-disaggregated data would add value since most of the issues are location specific. Some of the underlying influences to gender challenges include culture, social, economic and the political environments which vary from one place to another.

GIS in Gender-Disaggregated Databases for Bursary Administration

Gender issues vary in space and time making Geographic Information System (GIS) a valuable tool for application. Specifically, Bursary administration in terms of allocation and monitoring requires a tool like GIS that will be able to trace funds from the time it is allocated to an institution to when it reaches the beneficiary (Longley et.al, 2005). Students come from different backgrounds and most of the time administrators rely on what students say since they have no capacity of verifying information. A well-developed gender-disaggregated database including the spatial data will make it easier to trace and verify the student's background thus improving accountability and transparency in the administration of bursary (Hansen & Hansen, 2008). Within the context of bursary administration GIS can be used to capture and store the relevant data in a Gender-Disaggregated database. The data in the database can be subjected to analysis and modelling to generate and visualize the relevant information that is useful for decision making.

Methodology

This section describes in details the methodology adopted in this study. Specifically on the data used, the development of a spatially Gender-Disaggregated Database for SET programs and the application of the database for bursary allocation. Figure 1 shows an overview of the methodology.

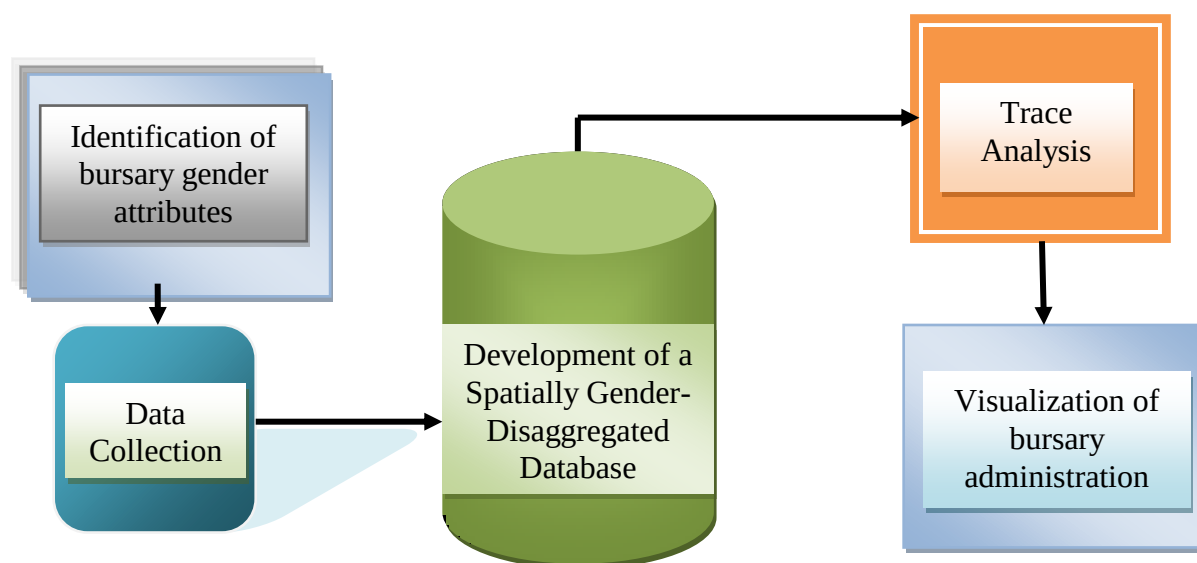


Fig.1: Bursary Administration Overview

Data

In order to effectively administer bursary to attract women taking SET programs, there is need for appropriate data. Within the context of this study both spatial and non-spatial data were collected. The spatial data included the location of the Technical Training Institutes, home location of the student and the Poverty Index Map. The non-spatial data considered included the student's name, gender and the program enrolled for. In addition, the amount of bursary allocated to the Institute was used to establish whether the policy on equity distribution was adhered to and how GIS can be used to add value in its administration.

Development of a Spatially Gender-Disaggregated Database for SET programs

In this study Kitale Technical Institute was used as a case study. Data collected on the students were designed and organized in a spatial database. The fields of interest considered included mainly the students name and their home location. In addition, attribute information on the gender and the programs being pursued were also captured in the database. The programs were categorized into two mainly SET and others. The database was developed in MS-ACCESS.

Trace Analysis

The main objective of trace analysis was done to establish the home location of the Kitale Student population by gender, the poverty levels of the students and how bursary was administered for the financial year 2007/2008. Using GIS, these locations were mapped and in addition based on the poverty index map it was possible to establish which of the students came from high poverty areas. On the basis of the government policy, Female students who came from poor areas were analysed to establish whether they obtained any bursary.

Results and Discussions

Results

This section gives a detailed account of the results obtained.

a) Technical Training Institutes

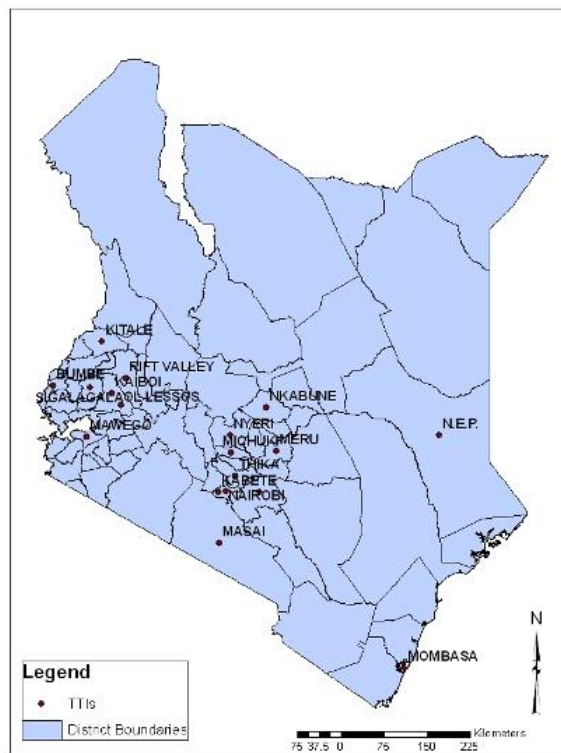


Fig.2: Distribution of the Technical Training Institutes in Kenya

There are a total of 19 Technical Training Institutes in Kenya as shown in figure 2. It is evident that most of the TTIs are concentrated in the Central/Southern and the Western part. There is only one to the Eastern part and none to the Northern. This information is useful in planning future TTIs particularly in the location optimization.

b) Student population in Kitale Technical Institute

Kitale Technical Institute is located in TransNzoia District. Figures 3 and 4 show the student population and those pursuing SET courses by gender respectively.

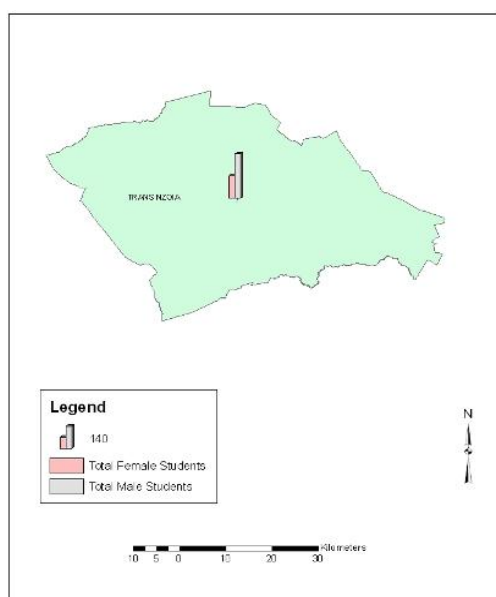


Fig.3: Student Population by Gender

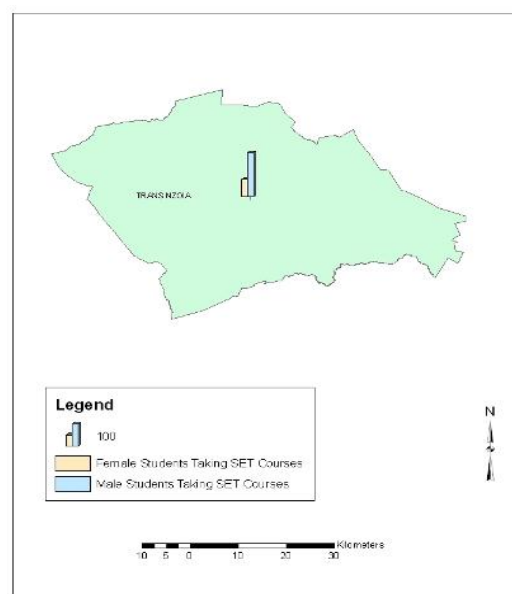


Fig.4: SET courses by Gender

It is evident that the male student population is almost double that of female as shown in figure 3, specifically it was found that the male were 270 whereas the female were 136 making a total population of 406. In addition to SET courses, the Institute offers business oriented courses for instance Accountancy, Business Administration and Marketing Management. The focus of this study was in SET courses and a comparison by gender also revealed disparity in enrolment. Indeed, a total of 186 male compared to 50 female enrolled for SET programs.

c) Tracing Analysis on the basis of Poverty Index

Kenya is divided into eight provinces namely Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley and Western. Technical Training Institutes being national Institutions are expected to enrol students countrywide. This section highlights the home location of each student by gender with special emphasis on those pursuing SET courses at the Kitale Technical Training Institute. From the data obtained, it was established that there were no students from North Eastern and therefore this province was not used in the study. The main objective is to try and trace the home location of Female students on the basis of Poverty Index Map per province for purposes of bursary allocation.

A summary of the student enrolment per province by gender is shown in Table 1, whereas Figures 5 to 11 are the maps showing spatial home location of the students on the basis of the level of poverty per province.

Tab.1: Enrolment per Province by Gender

Gender	Provinces							Total
	Central	Coast	Eastern	Nairobi	Nyanza	Rift Valley	Western	
F	3	1	0	0	3	30	13	50
M	4	1	1	1	9	60	110	186

Kitale Technical Training Institute is indeed a national institution as it draws its student population from almost all over the country as shown in Table 1. However, the Institute tends to attract more students from some provinces compared to others, for instance Rift Valley and Western provide the highest number of students whereas Nairobi, Coast and Eastern have the lowest namely 1 to 2. The enrolment by gender also reveals major disparities with a total of 50 (21%) female compared to 186 (79%) male students pursuing SET programs. Eastern and Nairobi have no female students whereas Rift Valley and Western have 30 and 13 female students respectively.

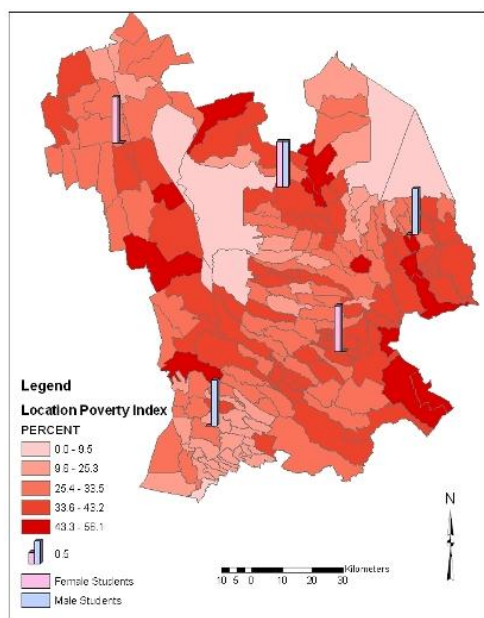


Fig.5: Central Province

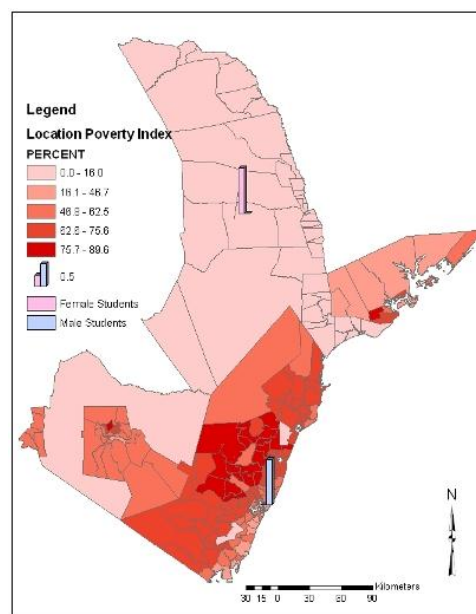


Fig.6 Coast Province

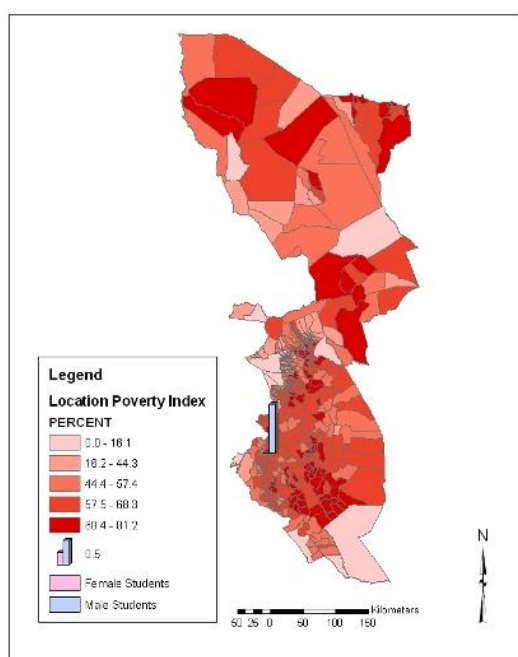


Fig.7: Eastern Province

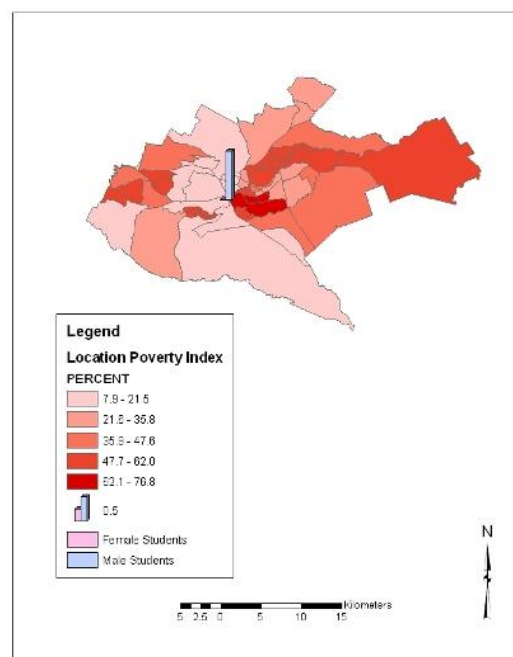


Fig.8: Nairobi Province

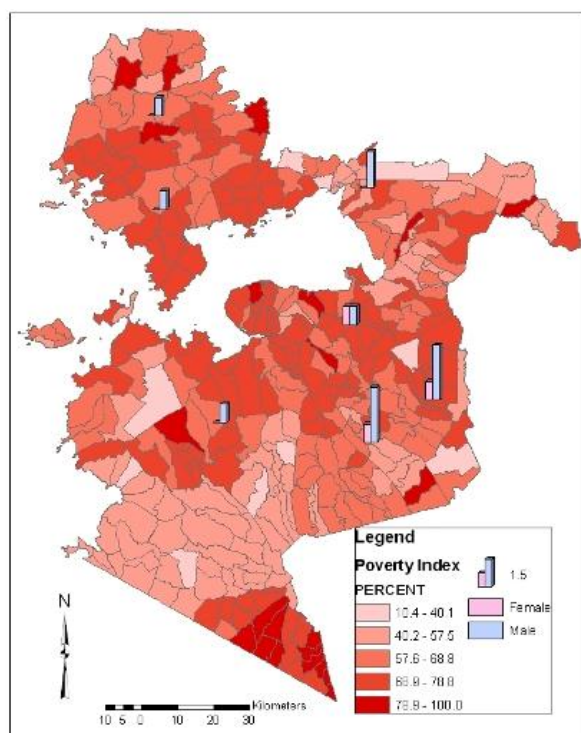


Fig.9: Nyanza Province

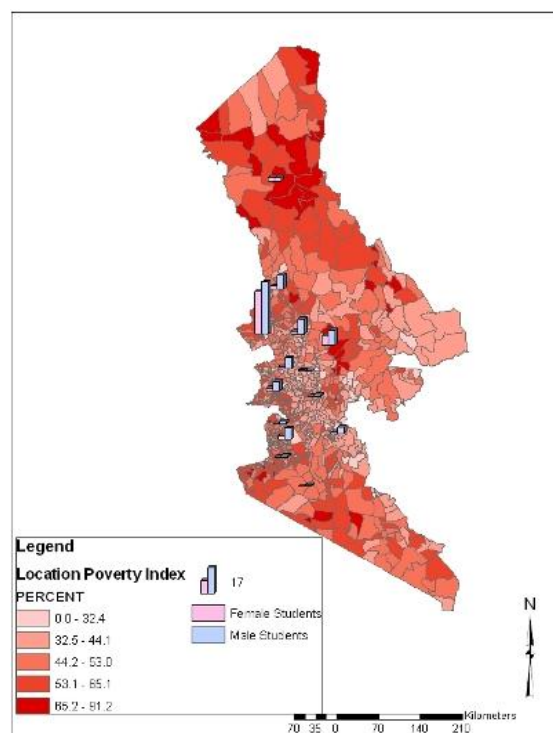


Fig.10: Rift Valley Province

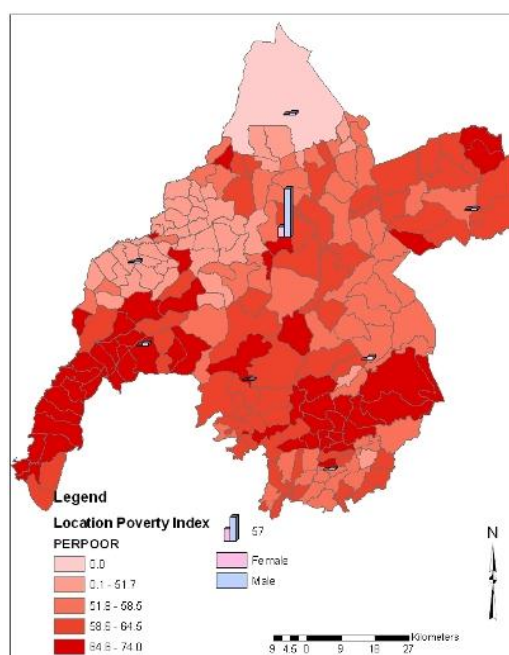


Fig.11: Western Province

In Kenya the level of poverty varies from one place to the other as shown in the figures 5 to 11. Central province is relatively better with highest poverty levels being 58% compared to Nyanza reporting 100%. The spatial unit is locational level and the students come from different parts varying in the levels of poverty. Thus, in allocating bursary this is an important consideration.

In Central Province, the 3 female students come from poor locations as shown in figure 5, with poverty levels of between 25%-58% whereas the one from Coast Province is from a relatively economically endowed location with a poverty index of between 0-

16% as depicted in figure 6. Eastern and Nairobi did not have any female student as evidenced in figures 7 and 8. Nyanza produced 3 female students who come from poor locations with poverty levels ranging from 57%-100% as shown in figure 9. Rift Valley province had the highest number of female students specifically 30 spread throughout the province. The home location of these students range from 32%-91% in terms of poverty levels with majority of them in the areas of highest poverty as shown in figure 10. Western Province had a total of 13 female students also spread out in different locations as depicted in figure 11. Evidently most of the female students are from poor locations with poverty levels as high as 74%.

Using trace analysis it was established that 28 of the 50 Female students came from areas that are economically disadvantaged.

Discussions of the Results

Bursary administration is a spatial problem that necessitates a spatial approach for transparency and accountability in allocation. This is even more critical when the aim is to attract Women pursuing SET programs. This study focussed on Technical Training Institutions specifically Kitale. Use of a spatially gender-disaggregated database formed the basis for demonstrating how GIS can be used as a tool to facilitate decision making on bursary allocation. Tracing the home location of the students on the basis of poverty maps provides a rough guide on whether a case deserves bursary or not. Consequently, this study based its trace analysis on two main inputs namely those female students pursuing SET programs and their home locations.

From the results obtained it revealed that Kitale Technical Institute has a national outlook by drawing the student population countrywide, specifically the 7 provinces and only North Eastern did not have any students. This made it a good sample for assessing the needs of students on the basis of the poverty levels. In terms of student enrolment the female students is 33% whereas the male are 67%. Further investigation revealed that those pursuing SET programs are 21% for the female and 79% male. In terms of poverty levels, Central Province registers the lowest level as 58% compared to a high of 100% for Nyanza. However, the bulk of the student population originated from Rift Valley and Western where the highest poverty index is 91% and 74% respectively. By spatially visualizing the home location of the female students on the basis of poverty index it was possible to establishing whether this is a deserving case for bursary consideration or not.

Conclusions

This study has demonstrated the power of spatially gender-disaggregated databases in tracing needy cases for bursary allocation. The emphasis has been on female students pursuing SET programs and how bursary can be allocated to attract them. This is possible since, using poverty index maps it is possible to identify the home location of the student before detailed analysis can be done. As a result, this study is meant to facilitate decision makers in establishing needy cases rapidly and therefore supporting their decision. This will lead to improved accountability and transparency in bursary allocation. It is well known that developing a policy is not the problem the issue is how to implement it. The need to have scientific justification especially involving taxpayer's money like bursary is of paramount importance. Spatially disaggregated databases are very useful in gender mainstreaming and ensuring equity distribution of resources. In order to improve on the results of this study, it is recommended that the profile of the Female Students be enhanced to include the economic activities of the parents or guardians since on the basis of poverty index map alone there is a possibility of misdiagnosis.

Acknowledgements

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COMBATING GLOBAL WARMING AND ITS EFFECTS ON SUSTAINABLE AGRICULTURE: CLIMATE CHANGE - RESPONSIVE AGRICULTURE EDUCATION APPROACH

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ABSTRACT

This paper reports on a survey to propose a more intensive Climate-Change-Responsive Agriculture Education (CCRAE) for Nigerian universities and presents the proposed CCRAE curriculum contents, with a view to make relevant input for combating Global warming (GW) and its effects on sustainable agriculture. This work is based on the philosophy of building a supper structure on well built foundation. Its pertinent to equip Agriculturists with the strategies to control and fight GW and its effects on agricultural environments via the educational system. The study was conducted in Akwa Ibom State of Nigeria, employing comparative research design. The population of the study comprised experts in a) Environmental Studies, b) Agriculture and c.) Curriculum. A sample size of 150 was drawn using Stratified Random Sampling Technique based on the three research groups. The research instruments employed included Focused Grouped Discussions (FDG) and validated four-point rated Questionnaire with the benchmark at 2.00 points. Research questions were answered and hypotheses tested at 0.05 level of significance. Statistical tools included Descriptive and Analysis of Variance. In the results, there were no significant differences in the mean responses of the research groups on 1) the need to proposed CCRAE and 2) the Selected Curriculum Content proposed for CCRAE. Summaries of the FGD re-affirmed the need for CCRAE curriculum contents. Recommendations were based on the findings to build more solid foundation to wrestle with GW.

INTRODUCTION

Education is a tool for individual development and a medium for knowledge and skills acquisition. Education aims at making an individual to appreciate cultural, social and physical structure of his/her society and prepares the individual for functionality and necessary adjustment

for survival within the society (Ugwu, 2003). The Nigerian philosophy of education is based on the integration of the individual into sound and effective citizenry (FRN, 2004a). Against this background, Agriculture education in Nigerian university strives to sufficiently equip the learners to offer solution to existing impediments to agricultural developments and its related discipline. The problems constituted by climate change and the anticipations of greater damages are not exclusive. The concept of the Climate-change Responsive Agriculture Education (CCARE) becomes highly relevant.

Agricultural education is offered at all levels of education in Nigeria. The climax of agriculture education is in tertiary institutions including the secular universities and universities of agriculture. Within the context of this study, agricultural education embraces all forms education and training in different specialties in agriculture including, agriculture teacher education, whose objective is training agriculture students for teaching agriculture. The aim of agriculture education at the tertiary level is to produce high level manpower in different areas of agricultural developments (FRN, 2004b).

CCRAE is a form of education in agriculture and related disciplines which provides general awareness and basic knowledge on climate change, its causes, effects on agriculture and its environments, as well as equip the learners with the necessary strategies, attitudes, skills and practices to combat Global Warming and its influences on agricultural developments

Okon et al,(2004) opines that, the curriculum, among other factors is a strong determinant of the extent to which the objectives of university education could be realized. Since the achievement of the aims and objectives of education is greatly determined by the curriculum the researchers therefore propose an upgrade of the agriculture education curriculum contents for CCRAE. Harvey (2004) defined curriculum as a systematic group of courses and planned experience required for graduation for certification of learner under the guidance of a teacher. Many other experts in more recent years see curriculum beyond the course content to all the school does. Mark and Smith (1996) define curriculum as programme of all activities undertaken by teachers and students.

The aim of the study was therefore to propose a more intensive Climate-Change-Responsive Agriculture Education for Nigerian universities (CCRAE) and presents the proposed CCRAE curriculum contents, with a view to make relevant input for combating Global warming (GW) and its effects on sustainable agriculture. The proposal for CCRAE is based on the philosophy of building a super structure on well built foundation. It is pertinent to equip Agriculturists with the strategies to control GW and its effects on agricultural environments via the educational system.

The research questions were 1.) Why is it needful to propose CCRAE for undergraduate students in Nigerian universities and 2. What are the proposed selected undergradute curriculum content (Courses) for CCRAE in Nigerian Universities?

Null Hypotheses Were H_0 1.) Responses of the three research groups do not significantly differ on the need for CCRAE. (H_0 2). Mean Responses of the three research groups do not significantly differ on relevant areas of curriculum content for CCRAE

It is anticipated the findings of this study would serve as relevant input for education policy making mechanism in policy formulation. It is expected that curriculum planners and developers in agriculture education would be sensitized to consider the integration of the recommended contents on climate change into agriculture education curriculum for undergraduates of

Nigerian Universities.

Climate Change and Agriculture in Nigeria

Climate Change phenomenon affects agriculture in a number of ways (BNRCC2008). For example, uncertainties in the onset of farming seasons, due to changes in rainfall characteristics, leads to an unusual sequence of crop planting and replanting which may result in food shortages due to harvest failure. Early rains may not be sustained, and crops planted at their instance may become smothered by heat waves. Extreme weather events such as thunderstorms, heavy winds, and floods, devastate farmlands which results in crop failure in several instances (IISD, 2007). Pests and crop and diseases migrate in response to Climate Changes and variations (e.g. the tsetse fly has extended its range northward and will potentially pose a threat to livestock in the drier northern areas. It is estimated that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4 % of GDP due to climate change. Parts of the country that experienced soil erosion and operate rain-fed agriculture could have decline in agricultural yield of up to 50 % between 2000 – 2020 due to increasing impact of climate change (IPCC, 2007).

The Principle of Dynamism and Flexibility in Agriculture Education.

Agriculture education emphasizes dynamism and flexibility in contents and delivery modes. Flexibility emphasizes its ability to adopt new situations and be changed according to societal circumstances (Umoh & Etuk, 2003). This is a philosophical theory which explains the dynamic power of force with which education influences societal occurrences. Agricultural education believes in learning situations which are designed from present life situations and work experiences. Based on this premise, learners identify problems and workable solutions for today and realize new solution for the future. The consistence of Agricultural education with agricultural development within the society is vital. It follows that if the Nigerian youths' experiences gained from the curriculum delivered in school are valid, the graduates would be motivated to further convert those experiences into valid and useful agricultural developments, combating the effects of climate change inclusive.

RESEARCH METHOD

Study Design and Site.

The study was a survey employing comparative research design. The comparisons were between groups of respondents. The study was conducted in Akwa Ibom State of Nigeria. The state is in the south east of Nigeria consisting of 31 Local Government Areas (LGA), with Uyo as the state capital. It is a location where climate change has directly or indirectly influenced agricultural activities. There are three universities in the state. Environmental studies, Agriculture or Education programmes are being offered in these Universities. Existing State Governmental

Agencies among many others includes; the Ministry of Environments, Ministry of Agriculture and Ministry of Education within which the Curriculum Unit operates.

Population, Sample Size and Sampling Technique.

The population of the study comprised professionals and experts in a) Environmental Studies, b) Agriculture and c.) Curriculum. A sample size of 150 was drawn using Stratified Random Sampling Technique based on the three research groups. Each research group consisted of 50 subjects, comprising 25 professionals drawn from members of academia from universities and 25 Experts drawn from the fields of the corresponding professions (a) Environmental Studies, b) Agriculture and c. Education) within the study area. The field experts included consultants and officers working under the Ministry of Environment, Agriculture and Education respectively.

Research Instruments

Two (2) validated instruments were used for data collection. The first was a validated and reliable structured questionnaire with a four points rating scale and the benchmark at 2.00 points. The instrument was divided into two parts. Part one of the questionnaire was structured to gather responses on the need for CCRAE. The items in part two were statements framed to address the proposed curriculum content of CCRAE for Nigerian universities undergraduate programmes. The second instrument was Focused Grouped Discussions (FDG) moderated by checklist on the need for CCRAE and selected curriculum content for CCRAE.

The instruments were subjected to content, context and construct validation by a team of professionals drawn from universities in the area of study. An average percentage of 92% was deemed high enough to confirm the instruments as valid in all respects. A test-retest reliability proof was used to establish the reliability of the instruments. In the test, the instruments were administered on 20 respondents including subjects drawn from the population but not the direct respondents within the research population. Pearson Product Moment Correlation Coefficient (r) was used for calculation of the reliability index which ranged from 0.7 to 0.8 for all the instruments. The indicated index justified the instruments as being reliable. Questionnaire instrument was administered individually and in groups to professionals and experts by the researcher. 100% return rate was achieved. The FGD sessions were conducted in groups of ten for each research group which were 1) Environmentalists, 2) Agriculturists and 3) Educationalists. Each session lasted for 30 minutes.

Research questions was answered using mean statistics and research hypotheses were tested at 95% probability level, in comparison of mean responses from the three research groups using One way Analysis of Variance (ANOVA).

PRESENTAION OF RESULTS AND DISCUSSION

Results: Data analysis was based on research questions and hypotheses.

Resarch Question 1. Why is it needful to propose CCRAE for undergraduate students in Nigerian universities?

Table 1: Mean Responses on the Need for CCRAE.

N= 150

S/N	Items of Need for CCRAE	Mean	Remark
1.	Creation of awareness for global warming in among future agriculturists	3.83	*
2.	Creation of awareness of the effects of global warming on agriculture	3.66	*
3.	The learners would further spread the awareness of GB in their immediate communities.	3.62	*
4.	Motivation of the learners to adopt agricultural practices that reduces green house emission in future.	3.96	*
5	Development of technologies that would reduce the effects of GW on agriculture	3.97	*
6.	Motivated future leaders to strengthen international co-operation for towards environmental safety.	3.73	*
7.	Facilitation of food security in the future	3.50	*
8	Reduction future land degradation land	3.49	*
9	Preservation of biodiversity	3.76	*

Source: Field Work. 2010.

*Accepted reasons for the need for CCRAE in Nigeria with cut-off point at 2.00.

The results in table 1 indicated that all items 1 to 9 were accepted as reasons to propose CCRAE in Nigerian Universities.

Research Question 2. What are the proposed relevant content for inclusion in the CCRAE curriculum for undergraduate students in Nigerian universities?

Table 2. Mean Responses on Proposed Selected Curriculum Content (Courses) for CCRAE in Nigerian Universities.

N=150

S/N	Proposed Selected Curriculum Content (Courses) for CCRAE in Nigerian Universities.	Mean	Remark
1.	Introduction to Global warming concept and Sources of Green house emission/ gases	3.54	*
2.	Effects of Climate change on Agriculture and agricultural environments	3.02	*
3.	Agricultural Climatology and Ecosystem Relations	3.71	*

4	Soil Management and Preservation Technology Education	3.43	*
5.	Farm waste Management and recycling and Use of Renewable Energy in Agriculture	3.61	*
6.	Climate Change and Crop waste/ disease Management	3.86	*
7.	Animal Diseases Control, Heat Stress Management and Temperature Regulation Strategies.	3.90	*
8 .	Water cycles and Water Resources Management in Agriculture	3.54	*
9.	International Co-operation for Environmental Policies and Protection Education	3.47	*

Source. Field work 2010

*Accepted proposed selected curriculum content for CCRAE with cut-off point at 2.00.

. Table 2 shows that all the selected content (items 1-12) were accepted as relevant areas for inclusion in the proposed CCRAE curriculum for Nigerian universities.

H₀:1. Mean Responses of the three research groups on the need for CCRAE in Nigerian Universities do not significantly differ

Table 3. One Way Analysis of Variance for Comparison of Mean Responses Between Research Groups on Need for CCRAE for Nigerian Universities.

S/N	Items of Need for CCRAE in Nigeria	Mean	F- ratio	P@< 0.05	Remark
1	Creation of awareness for global warming in among future agriculturists	3.83	1.183	2.906	NS
2	Creation of awareness of the effects of global warming on agriculture	3.66	1.914	3.568	NS
3	The learners would further spread the awareness of GB in their immediate communities.	3.62	1.732	3.011	NS
4	Motivation of the learners to adopt agricultural practices that reduces green house emission in future.	3.96	1.613	2.780	NS
5	Development of technologies that would reduce the effects of GW on agriculture	3.97	1.186	2.932	NS
6	Motivated future leaders to strengthen international co-operation for towards environmental safety.	3.73	1.609	2.455	NS
7	Facilitation of food security in the	3.50	1.032	2.710	NS

	future				
8	Reduction future land degradation land	3.49	1.168	2.223	NS
9	Preservation of biodiversity	3.76	1.735	2.440	NS

Source: Field Work. 2010. NS = Not significant. N=Significant

Table 3 shows that mean responses of the three research groups on the need for CCRAE in Nigeria do not significantly differ. The null hypothesis is thus upheld.

H₀: 2. Mean Responses of the three research groups on relevant areas of curriculum content for CCRAE in Nigerian Universities do not significantly differ

Table 4. One Way Analysis of Variance for Comparison of Mean Responses between Research Groups on Proposed Selected Curriculum Content (Courses) for CCRAE in Nigerian Universities

S/N	Proposed Selected Curriculum Content (Courses) for CCRAE in Nigerian Universities.	Mean	F- ratio	P@< 0.05	Remark
1.	Introduction to Global warming concept and Sources of Green house emission/ gases	3.54	1.520	2.803	NS
2.	Effects of Climate change on Agriculture and agricultural environments	3.02	1.304	3.841	NS
3.	Agricultural Climatology and Ecosystem Relations	3.71	1.365	3.206	NS
4.	Soil Management and Preservation Technology Education	3.43	1.652	3.854	NS
5.	Farm waste Management and recycling and Use of Renewable Energy in Agriculture	3.61	1..490	2.562	NS
6.	Climate Change and Crop paste/ disease Management	3.86	1.034	2.435	NS
7.	Animal Diseases Control, Heat Stress Management and Temperature Regulation Strategies.	3.90	2.531	3.984	NS
8.	Water cycles and Water Resources Management in Agriculture	3.54	1.417	2.930	NS
9.	International Co-operation for Environmental Policies and Protection Education	3.47	1.502	2.227	NS

Source: Field Work. 2010. NS = Not significant. N=Significant.

Table 4 indicates that there were no significant differences in the mean responses of the three research groups, on the proposed selected curriculum content for CCRAE for Nigerian universities. The null hypothesis is thus upheld.

Summary of Focus group Discussions (FGD)

Participants of the FGD re-affirmed the need for CCRAE. Creating awareness for Global Warming (GW) in the minds of the ones who would practice agriculture in future was needful. All the discussants noted that CCRAE would motivate the learners towards developing strategies and technologies that would reduce the effects of Climate change on agriculture. Being the future leaders of tomorrow, with the knowledge acquired in school to combat GW, they would seek to strengthen and promote international policy and co-operation against green house emissions. The participants also saw CCRAE as a way of sustaining future food security and preservation of biodiversity. The selected areas for the proposed curriculum content presented in the FGD for open discussion, were accepted as relevant contents for the CCRAE in Nigerian universities' undergraduate programmes in agricultural education.

Table 5. Proposed CCRAE Curriculum Content (Courses) and Goals

University Level	Curriculum Content (Course Titles)	Goal	Credits hr unit per week
100 Level (1 st year)	Introduction to Global Warming Concept and Sources of Green House emission/ gases	To Create awareness of GW and equip learners with Knowledge of Sources of Green house gasses	2
100 level	Effects of Climate change on Agriculture and agricultural environments	.To creates awareness in students of climate and seasons let learners acquire of skills in sustaible agricultural practices.	2
100 Level	Agricultural Climatology and Ecosystem Relations	To equip the students with knowledge of the effects Climate change on agricultural developments	2
200 Level	Soil Management and Preservation Technology Education	To expose students to soil management and preservation technologies	3
200 Level	Farm waste Management and recycling and Use of Renewable Energy in Agriculture	To expose students to waste management technology and waste recycling process.	3
300 level	Climate Change and Crop Paste/ Disease Management	To equip the students with knowledge and skills in Crop paste and disease	3

		management	
300 level	Animal Diseases Control, Heat Stress Management and Temperature Regulation Strategies.	To equip the students with knowledge and skills in Animal disease management and heat/ temperature regulation strategies.	2
400 level	Water cycles and Water Resources Management for Climate Change in Agriculture	To exposed students to acquire knowledge in Water cycles and water Resources Management for climate change in Agriculture	2
400 level	International Co-operation for Environmental Policies and Protection Education	To expose learners to acquire knowledge in International co-operation and policies for environmental Protection.	2

key. .The levels means the year of study in the undergraduate programme.

100 level = year 1, 200 level = Year 2,300 level= year 3, 400 level = year 4

Discussion.

The findings of this study is in consonance with that of IISD (2007) and BNRCC (2008) who realised the need for Nigeria to do everything within her power to be protected from the dangers of climate change and its effects on agriculture, for purposes of foods security, reduction of land degradation and preservation of wildlife and bio-diversity. Nigeria needs to be stronger in terms of reserves, if she has to survive effects of climate change. Our children will be worst hit in future if Nigeria does not make climate change a subject of concern. It is therefore pertinent to teach details of GW and climate change and its effects in schools from the early days to through secondary schools to universities.

The researcher hereby advocates for provision of CCRAE with the indicated proposed curriculum content reflected in table 5, for Nigerian university undergraduate in agricultural education. The Federal Government of Nigeria should consider adoption of CCRAE. The provision of appropriate learning experiences is required to achieve the stipulated goals of the curriculum.

In conclusion, the proposal for CCRAE emphasizes the employment of agricultural scientists, professionals and other related scientists, to use best analysis, cross comparison, syntheses and deductions more intensively within the educational system to combat Global Warming and its effects for future generations. Opera-djan(1990) affirms education is meaningful and purposeful if adequate consideration are given to the aims and values the members of the society hold dearly. Agriculture education needs to keep current with changes and practices in the concept of life long learning. Climate change in recent years has been a great concern, therefore the need CCRAE as one of the ways to fight it.

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THE METAKETTLE PROJECT: A JOURNEY TO THE HEART OF HIGHER EDUCATION

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ABSTRACT

Among the ways that universities can advance the participation of women in science and engineering is by adopting integrative pedagogies which set the technical foundations of educational programs within their wider economic, social, cultural, ethical, and personal contexts. This conclusion undergirds the MetaKettle Project, a practical and innovative follow-up to the recent NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (2004-2009). The MetaKettle Project offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education. Not only a hub for curricular development and pedagogical support but also an arena for transformative educational experiences, the MetaKettle Project brews big picture thinking about engineering and science education. This includes critically reflecting on the “what” and “how” of science and engineering, as well as the dynamic “who” and “why” of the person who aspires to be a scientist or engineer. The MetaKettle Project taps into the motivations and values which students bring to their study and work, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally. When situated within this larger context, our efforts to promote women in science and engineering expand to enabling change at the university, fostering increased engagement by our students and life-long sustainability for our graduates. Doing so requires re-engaging the “heart” of higher education, as well as its mind.

INTRODUCTION

This paper contends that universities can advance the participation of women in science and engineering by, among other approaches, adopting and developing integrative pedagogies which connect the person who is learning with the problems being solved, the content being learned, and their wider contexts. There are many pedagogies which have integrative elements, including experiential learning, dialogue-based learning, holistic education, service learning, student-centred learning, etc. In one way or another, each of these pedagogies addresses the student as a whole person, and hence not as only a student, but also a citizen, as well as potentially a future employee, employer, entrepreneur, policy maker, etc. The integrative approach is not new—indeed it has been the goal of the educational enterprise since Socrates in ancient Greece. As is the case with many human goals, integrated education can be difficult and elusive to attain. Yet, efforts to seek this goal can lead to highly transformative results, not only in the education of students, but also in their lives, through enhanced understanding, knowledge, efficacy as scientists or engineers, and potential to better meet human motivations, values, and life goals.

The times are right for a focus on pedagogy as a way to advance the participation and well-being of women in science and engineering. There is an emerging sea-change in

science and engineering education (and higher education more generally), due to the convergence of a wide set of drivers for change. Governments, industry, and universities recognize the need for engineers and scientists to exercise leadership in complex projects which require not only technical competence but also demand an understanding of the social, cultural, economic, environmental, or ethical dimensions of the issues (Grasso and Burkins, 2010b). Industry increasingly seeks employees with “T” shaped expertise, i.e. deep expertise in one discipline, together with the ability to collaborate effectively across a breadth of areas (Institute of Electrical and Electronics Engineers, 2010). Professional licensing associations, such as the Canadian Engineering Accreditation Board, now require that university graduates demonstrate their technical and process skills in terms of outcomes-based measurements (Canadian Engineering Accreditation Board, 2010). And, finally, there is a vital and energetic driver coming from students of the millennial generation who are seeking relevance in their education, not just for immediate career opportunities but for consistency with their life aspirations, including a sense of meaning and connection with their inner values and motivations, and with the global community (MacDonald, 2010; Moloney, 2008).

Our home institution, Memorial University, is engaged in the development and implementation of a Teaching and Learning Strategy (Memorial University, 2011a). At Memorial University, we have initiated a pedagogy project, called the MetaKettle Project, as a legacy from the recent (2004-2009) NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (Rosales and Moloney, 2010).

This paper summarizes and organizes the scholarship which supports our claim that universities can advance the participation of women (and men) in science and engineering by changing the way we educate scientists and engineers. We demonstrate our approach with the MetaKettle Project at Memorial University. To underscore the difference between the conventional approach or status quo of undergraduate education and the approach advocated by the MetaKettle Project, we employ the metaphor of “journey” into the “heart” of higher education.

THE CWSEA, A CHAIR FOR WOMEN IN SCIENCE AND ENGINEERING

Despite many advances over the past 30 years and more, the participation by women continues to lag behind that by men in many fields of science and engineering, in Canada as well as in other countries. For example, the percentage enrolment by women in full-time accredited undergraduate engineering programs in Canada peaked at just over 20% in 2001, and has fallen below 20% since then (Engineers Canada, 2010). Such continuing and surprising under-representation of women was the impetus for the establishment in 1997 of the unique Canadian program of regional Chairs for Women in Science and Engineering by the Natural Sciences and Engineering Research Council of Canada (NSERC). The key mandate for these NSERC Chairs is that each Chair develop, implement, and communicate strategies to raise the level of participation of women in science and engineering as students and professionals (NSERC, 2011).

Over 2004-2009, the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region (CWSEA) was held at Memorial University in St. John's, Canada. During the five years of its term, the CWSEA developed and conducted a program of activities and research towards fulfilling the NSERC mandate. Worth noting for its importance to the entire CWSEA program and to its legacy in the MetaKettle Project is a key theme which ran through the initiatives and research of the CWSEA. This theme started from the CWSEA vision for the development of the talents of individual women and girls and the realization of their dreams; it grew into an ethos and concern for the whole person who is or who aspires to be a scientist or engineer; it led

to numerous research results and operational elements about the person who is the scientist or engineer, including her motivations and how she thinks and learns.

Among the CWSEA results were a better understanding of the person who is the scientist or engineer, as thinker and agent (Moloney, 2005), and how she (or he) learns, especially abstract course material (Moloney, 2010). Based on Rogoff's (1995) three-plane model of sociocultural activity, we developed the model that a student becomes a scientist or engineer through thinking, feeling, and acting like a scientist or engineer in workshops and courses (Moloney, 2010). Since thinking and acting are always accompanied by feelings based on values, we also investigated the range and significance of the values and motivations of young women, and generated strategies to better meet these values and motivations in presenting them with the possibility of studying and having careers in science or engineering (Moloney, 2008). These results from the CWSEA are carried forward into the MetaKettle Project.

THE METAKETTLE PROJECT: A CWSEA PEDAGOGY LEGACY

Although the CWSEA's mandate was specifically about women, it became clear that many of the lessons we learned about increasing the participation of women in science and engineering could benefit a larger population. The wider significance of CWSEA initiatives and findings together with the specific insights obtained into the person who is the scientist or engineer in her (or his) full human dimensionality (Moloney, 2008) led to a key conclusion that among the ways that universities, together with their community and professional partners, can advance the participation and engagement of women (and men) in science and engineering is by adopting and further developing integrative pedagogies. Further, we recommended that a project consistent with this conclusion be initiated at Memorial University to realize the potential within the conclusion.

The result is a practical and innovative follow-up pedagogy project to the CWSEA, called the MetaKettle Project, which offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education. The activities of the MetaKettle Project seek to engage the motivations and values which students bring to their study and work in engineering, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally.

When situated within this larger context, the efforts of the CWSEA to promote women in science and engineering is now expanding to the larger goal of enabling change at the university, by adopting a perspective and implementing methods to foster increased engagement in our students and to promote their life-long learning and growth as graduates and throughout their careers. The MetaKettle Project thus becomes one of the most significant outcomes of the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, 2004-2009 (CWSEA).

Integrative Pedagogy for Science and Engineering

In this section, we outline the scholarly argument for using a range of pedagogies, or ways of teaching and learning, in science and engineering. In particular, we focus on integrative pedagogies which aim to connect the person who is learning with the material being learned and its wider context, and thus make positive learning experiences and results more likely. Our focus is on university level education, as that is the domain of our expertise and influence; however, we acknowledge the need and applicability of the ideas proposed here for all levels of education.

Science and engineering education researchers and practitioners have started to argue that the traditional or established undergraduate curricula in science and engineering programs do not respond adequately to the needs of the present world, much less to the needs of a future which is expected to be defined by rapid change, increasing complexity, and global consequences (Colgoni and Eyles, 2010; Felder, 2006; Grasso and Burkins, 2010a; Jaschik, 2010; MacDonald, 2010; Moloney, 2010; National Academy of Engineering, 2005; Reeve, 2010; Rugarcia et al, 2000; Sheppard, Pellegrino and Olds, 2008; Somerville et al, 2005; Williams, 2003). For example, engineering programs established since the 1950s have educated students to be specialized within disciplines, many of which are traditionally defined, and to be technical problem-solvers. However, the 21st century context of engineering, as well as much of current engineering practice, points to benefits to be realized when engineers are problem-definers as well as problem-solvers (Grasso and Martinelli, 2010; Somerville et al, 2005), and more significantly, are able to engage in socially responsible and interdisciplinary collaboration (Goldberg, 2010).

Similarly, the scientific enterprise benefits from cross-disciplinary collaboration and from scientific inquiry situated within a wider context which extends beyond the strictly scientific domain (Colgoni and Eyles, 2010). From a civic perspective, our national and global communities need citizens who are scientifically literate at the level of our times and global issues. In addition, governments, industry, and scientific research institutions have begun to acknowledge the benefits when scientists, as well as engineers, are involved in collaborative, multidisciplinary projects (Brint, Marcey and Shaw, 2009). From a pedagogical perspective, science education thus needs to provide experiential opportunities in which the relevance of the science is clear (Jaschik, 2010; MacDonald, 2010). Further, concerns with better engaging students in science can be extended to the sphere of public policy, where experiments in deliberative democracy show promising developments in engaging the public with social and ethical issues in science and technology (Franklin, 1999). In other words, how to think about science in its full context, i.e. historical, economic, philosophical, etc., is proving to be just as important to the future of science as the processes by which scientific inquiry is conducted (*How to Think About Science*, 2009).

In examining the role of the university in narrowing the gaps identified above, we note the statement of Ursula Franklin, eminent Canadian physicist, public scholar and humanitarian, that “the purpose of a university is not only to be a place where knowledge and understanding find a home, but also to provide a bridge for interaction with the larger community.” (Franklin, 2006, pg.139). Although Canadian universities strive to provide bridges through interdisciplinary programs and community engagement initiatives, gaps remain between the wider context and aspirations of a 21st century university and the remnants within it of a “cold War curriculum” (Goldberg, 2010). More significantly and positively, we can consider what we stand to gain when our universities’ curricula catch up with both the 21st century and our full humanity. This is the challenge that universities face today around the globe, and in a special way due to their focus on objective content, that science and engineering faculties and schools face.

What is needed is a systemic transformation of science and engineering education within the university, with a shift towards frameworks and perspectives that are more holistic or integrative in scope (Grasso and Burkins, 2010b; Colgoni and Eyles, 2010; Somerville et al, 2005). Such a systemic transformation would include not only an integration across the science and engineering disciplines but also greater emphasis on building teams and on teamwork, on the development of more effective

communications skills, on cross-disciplinary dialogue and on dialogue between humans and their objects of study, on increased awareness of the social, political, environmental, commercial and government contexts of engineering and science (Brint, Marcey and Shaw, 2009; IEEE, 2010; Somerville et al, 2005) and on methods to heighten awareness of self (Lonergan, 1993; Moloney, 2010).

Leaders in science and engineering are taking stock. In Canada, the leaders of the engineering profession organized a summit in Montreal in 2009 at which they issued a declaration which recognized that engineers are “enablers of dreams” (Canadian Engineering Leadership Forum, 2010) who play a significant role in society’s development. To this end, the Summit participants committed themselves to transforming engineering education and practice in order to foster greater collaboration, a culture of sustainability, and the best quality of life for Canadians (Canadian Engineering Leadership Forum, 2010). In addition, the Canadian Engineering Accreditation Board has recently adopted guidelines which recognize the need for engineers to relate their work to the wider economic, social, health, safety, legal and cultural contexts (Canadian Engineering Accreditation Board, 2010).

Research into and the practice of integrated or holistic science and engineering education are demonstrated in nascent programs: in Canada, the University of Toronto’s Leaders of Tomorrow in the Faculty of Applied Science and Engineering (Reeve 2010), McMaster University’s iSci Interdisciplinary Science program (Colgoni and Eyles, 2010), and our MetaKettle Project at Memorial University, among others; in the United States, at Smith College (Koshland, 2010), Princeton University (Jaschik, 2010), and Olin College (Somerville et al, 2005), among others. In addition, programs in other disciplines, such as the Undergraduate Semester in Dialogue at Simon Fraser University in Vancouver, Canada (Gunnlaugson and Moore, 2009) demonstrate successful program elements which provide inspiration for programs in science and engineering.

These initiatives are moving beyond the big picture thinking which emerged in the 20th century (for example in systems engineering) towards even more broadly-based education in engineering and science in the 21st century. Such a move represents a profound response to the world, one not narrowly concerned with keeping up with the global marketplace, but cognizant of the need for the solution of highly complex and multidimensional problems, and, behind all these needs, the human desire for meaningful work (Franklin, 2006; Moloney, 2008; Schumacher, 1979).

To counter criticism that this approach is inefficient, unproductive, or too costly, advocates of integrative or holistic education argue that such broad-based education is both attractive and personally empowering for students, and globally-competitive for industry and governments (Grasso and Burkins, 2010b).

In summary, science and engineering education is being challenged to address both the human side and the content or technical side by setting the technical foundations within a wider context that accounts for historical, social, cultural, ecological and personal frameworks. While conventional science and engineering programs do attempt to expose students to these types of opportunities, the established curricula still tend to focus on delivering technical content rather than on integrating other skills throughout. Although science and engineering education will always need to be technically and scientifically rigorous, the development and implementation of holistic or integrated curricula will tend to broaden students’ experiences with a range of subjects, and to cultivate the “soft” or process skills of management, communications, creativity and entrepreneurship.

Journey to the Heart of Higher Education in Science and Engineering

In the previous subsection, we outlined the arguments for integrative education in science and engineering, and pointed to approaches which are now being implemented. However, more can be asked of educational programs in science and engineering. We can ask that educational programs help students (and faculty) to cultivate habits of self-awareness and thought which will help them to become not only well-rounded professionals, but also attentive, intelligent, reasonable and responsible human beings (Lonergan, 1993; Palmer, Zajonc and Scribner, 2010; Zajonc, 2006).

It is the latter and more ambitious challenge to which the MetaKettle Project responds. While we are adopting holistic and integrative approaches for their ability to facilitate more effective retention and application of knowledge, we are also attracted by their potential to transform the knower. In contrast to conventional or youth-oriented pedagogical methods, transformative learning is “the essence of adult education” (Mezirow, 1997, p.11), intending the education of autonomous thinkers, who reflect critically both on their own values, beliefs and meanings, and on those of others (Cranton, 2006; Mezirow, 2000). In a similar way, the theoretical and practical approaches which inform holistic or integrative education in science and engineering not only attempt to engage the whole person, but also focus on changing habits of mind and attention, such as exercising flexibility in problem solving, nurturing the creative dimension of thought and fostering a sense of accountability for one’s actions (Sheppard, Pellegrino and Olds, 2008; Somerville et al, 2005; Zajonc, 2006).

A key source of inspiration and validation of our approach is found in the work of Zajonc (2006) and of Zajonc with Palmer in (Palmer, Zajonc and Scribner, 2010). The latter 2010 book, titled *The Heart of Higher Education: A Call to Renewal*, is not so much a guide to integrative pedagogies as a philosophical framework to provide coherence for the emerging field of methods in integrative education. This work is not only theoretical but also uses poetry and metaphor to connect to feelings in the reader. Of note is their use of the word “heart” as a central metaphor for their vision of higher education, where “heart” is used with its older meaning, “not just as the seat of the emotions, but as the core place in the human self where all our capacities converge: intellect, senses, emotions, imagination, intuition, will, spirit, soul.” (Palmer, Zajonc and Scribner, 2010, p.20) In addition, their philosophical framework is woven together by the everyday word “community,” understood in the usual way as the basic human orientation towards being in relationship, with self, with others, with the globe, with a subject of study, etc. The connection between theoretical framework and positive human action becomes explicit in the following statement:

“We believe that ethical thinking and action are supported by integrative teaching and learning. Compassionate action is fostered in students when they learn not only with the intellect but also with the heart. As I have attempted to show, an epistemology of love bridges the divide between intellect and feelings, between objectivity and participation. Once knowing activates our feelings, we are moved to action.” (Palmer, Zajonc and Scribner, 2010, p. 98)

We recognize and value the approach of Palmer, Zajonc and Scribner (2010), as it connects with our past approach of seeking the philosophical ground upon which to build our initiatives (Moloney 2005, 2010). Although more work is still needed to fully work out, explain, and apply the philosophical framework of integrative education for science and engineering, we endorse the approach of Palmer, Zajonc and Scribner (2010), and are intentionally using it in our development of operational programs within the MetaKettle Project at Memorial University.

The MetaKettle Project at Memorial University

The MetaKettle Project (Rosales and Moloney, 2010) was initiated in 2010 as a legacy of the NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, 2004-2009 (CWSEA). The impetus behind the MetaKettle Project was to build on the work of the CWSEA and to continue to contribute to its mandate of increasing the participation of women in science and engineering. However, by its setting in a co-educational university, the MetaKettle Project extends the CWSEA goals. Thus, the MetaKettle Project aims to increase the diversity of students studying science and engineering, while enhancing the long-term sustainability of graduates over their careers and lives. We are actively working on growing the MetaKettle Project as a centre for curricular development and pedagogical support as well as a cross-disciplinary arena for transformative educational experiences.

The project's name, MetaKettle, comes from the simple, everyday kettle, an enduring design and artefact from antiquity, symbolic of human productivity and ingenuity and of the natural bent of human beings towards discovery. Moreover, kettles are eminently practical for producing the steaming mugs of tea or coffee over which ideas are discussed and relationships formed within a community. While kettles represent the work of science or engineering, i.e. the product of engineering and the content of science, the MetaKettle is the whole in the Kettle, i.e. the person who is the engineer or scientist. Thus, the MetaKettle Project is intent upon brewing big picture thinking about science and engineering education. This includes critically reflecting on the "what" and "how" of engineering and science, as well as the dynamic "who" and "why" of the person who aspires to be an engineer or scientist.

The MetaKettle Project started in 2010 by adopting a conversational strategy similar to that outlined by Palmer, Zajonc and Scribner (2010, Chapter 5) who demonstrate how institutional change can happen from the grassroots up, conversation by conversation. The initial conversations of the MetaKettle Project were about visions and plans, about how to foster community, etc. They have become an ongoing series of conversations, with individuals and small groups, which have grown our network of supporters and participants. We anticipated—and are beginning to see the results—that our smaller conversations would connect with others, and thus contribute to fostering wider change in the University's conversation. Doing so has started us on a journey to the heart of higher education.

In addition, we engage in conversations to further the MetaKettle Project and to lead to its continuance and growth as a well-funded project within the university. We also develop and run operational programming. The MetaKettle Project has a primary focus on dialogue-based education, which we have developed based on the Undergraduate Semester in Dialogue at Simon Fraser University in Vancouver, Canada (Gunnlaugson and Moore, 2009), although with a specific orientation towards what works best for engineering and science (Rosales and Montano, 2011). In addition to our primary orientation towards dialogue education and the development of a dialogue institute, we are assisting the Faculty of Engineering and Applied Science in preparing for the switch to outcomes-based evaluation measures which will be required for accreditation of the engineering programs as of 2013. We are developing module materials on leadership for graduate students, on how to think about science, and on engineering ethics for courses in the engineering profession stream which will be offered in the upcoming academic year, Fall 2011 to Spring 2012. We are collaborating with colleagues in the Faculties of Arts and Education on a research project on creative methods to foster research writing for graduate students in the humanities and in engineering.

We now situate our work within the recently-adopted Teaching and Learning Framework of Memorial University. We contributed to the consultation process which led to the development of the recent Framework documents (Memorial University, 2011a). The MetaKettle Project is identified as a strength of Memorial University, both for its support of educators and for its interdisciplinarity (Memorial University, 2011b).

CONCLUSIONS

The MetaKettle Project offers a pragmatic response to a rapidly changing world and an integrative perspective on higher education for science and engineering. It offers programming which seeks to engage the motivations and values which students bring to their study and work in engineering, including an emerging sense of themselves as citizens engaged in understanding and meeting the complex challenges of our times, both locally and globally. While the MetaKettle Project is a work in progress, with much development and research to be done (as well as fund-raising to make its future more secure), it is a strong outcome from the recent NSERC/Petro-Canada Chair for Women in Science and Engineering, Atlantic Region, and contribution to the NSERC mandate, as well as an example of the leading edge of integrative education for university-level science and engineering.

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CHALLENGES FACING FEMALE ENGINEERING STUDENTS IN AFRICA-OUR EXPERIENCE

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ABSTRACT

Engineering and science are the backbone to the industrial development of nations all over the globe. Africa as a developing continent is in dire need of engineers and scientists to support its industrial development. Universities in Africa have steadily increased intakes into these programmes, but the percentage of female engineering students in Ghana is less than 20%. The aim of our study was to ascertain the reasons for the low participation of girls in engineering with the objective to create awareness of the challenges of the female engineering student (FES) and advocate for change. Fifty female engineering students of KNUST, Kumasi were interviewed to list their 3 worst and 3 best experiences and 50 non engineering male and female students on their perception of FES. Results indicated that for the worst experiences, fear of stigmatization was 100%, partial or total exclusion in some class activities 92% and cultural belief and stereotyping was 85%. In the case of best experiences 78% of them indicated being acknowledged for good performance, 74% said family pride, while 65% said some of their best experiences were during industrial attachment. 98% of others students perceive FES as brave and 'boyish' among others. In conclusion, these findings reiterated our fears and threw more light on the reasons why females are not drawn to pursue programmes in engineering. There is the need to break these barriers to attract more girls into engineering in Africa and efforts must be made to make engineering more interesting especially for females.

INTRODUCTION

In this twenty first century where technology is the engine that drives national economies and industrial development, the importance of engineering cannot be over emphasised. Engineering has gone through a lot of changes over the decade and has brought about massive development in the world. From tiny microchips, which control all kinds of devices, to towering sky scrapers, which beautify and serve the needs of city, are all based on engineering principles. As such every aspect of life makes use of engineering. In spite of these advancements, there are very few females in science and engineering. Women are sidelined when it comes to certain professions and top-notch

positions in the corporate world. Realising this imbalance, in recent years, a lot of countries have put measures and strategies, especially the developed ones to bridge the gap between men and women. This is however not the case in Africa where most of its workforce is predominantly men with very few women up the corporate ladder (Global Gender Gap Report, 2010). In Ghana there is less than 30% female enrolment in universities. The statistics is even worse when it comes to women in science and engineering. For example, data from the Kwame Nkrumah University of Science and Technology indicates that girls in engineering make up only 1.9% of the total students population. The case is even worse in University of Mines and Technology the second technological university in Ghana.

A close study of percentages of female engineers in countries of various continents revealed that female engineers make up 11% of the total number of engineers in the USA (Chattanooga E.S., 2010). In Australia, similarly a rate of 11% was recorded for women engineers in 2010, with China and Russia having the highest percentages of 40% and 58% respectively, according to a survey conducted in 2010 (ParisTech Review/Editors 2010). Women engineers in Tanzania in East Africa represented 3.7% (Engineers Registration Board of Tanzania, 2009). The low numbers in female engineers is also reflected in low numbers of female engineering students in the various institutions of study all over the world. Although this trend runs through all the nations of the world, the lowest percentages were recorded in African countries. The overall low participation of women in top-level jobs has raised concern about whether African countries can meet the Millennium Development Goals 3 of gender equality and empowerment of women by 2015 (UN Millennium Project, 2005).

Many of these studies were designed to find out the reason for the low participation of female in engineering with varied reasons including child bearing, stereotyping and cultural beliefs. There were however very few published data on women engineering and their challenges they face in Africa and how to solve them. Being young female engineering students in a predominately male programme confronted with several challenges and wanting to ascertain why, what can be done and how these can be solved. Therefore the aim of this study was to conduct a baseline survey to ascertain the challenges of female engineering students in KNUST and create awareness about them so as to advocate for change

Methodology

Description of study area

The study was conducted on the campus of KNUST, which is Ghana's oldest Science and Technological University. It is situated in the middle forest belt of Ghana with a population of about 26,000 (KNUST, statistics, 2010). The University comprises of six colleges namely the College of Engineering, College of Health Sciences, College of Science, College of Agriculture and Institute of Renewable Natural Resources, College of Architecture and Planning and College of Art and Social Sciences. Statistics from these Colleges and the University were analysed to determine if there were any trends with the baseline study.

Subjects and method

A total of 100 consented students, between the ages of 16-30 were randomly recruited into the study, of which 50 were female engineering students and the remaining 50 were male and female students from other disciplines including engineering. Two pre-tested questionnaires, one tailored to suit each group of 50, were administered to students to seek the following demographic and perception information:

- i. Age, name of high school, type of high school, region of residence, ethnic group and course being pursued and;
- ii. Thoughts of how family and peers perceive female engineering students and whether they would recommend engineering to female students. The questionnaire for the FES also included people who influenced their decision to do engineering, how much they enjoy engineering, whether there were any regrets, opinions on how engineering could be made more interesting, opinions on how various people perceived FES and their best and worst experiences of being a FES.

Statistical Analysis

Statistical Package for Social Scientists (SPSS) version 19 was used for statistical analysis to determine frequency of distribution, mean, median and correlations.

Results

Background and characteristics of subjects

A total of 50 female engineering students, and another 50 students comprising of; (i) male engineering students, (ii) male non engineering students and (iii) female non engineering students, between the ages of 16 and 30 were assessed. The median age group was 19-21. Of the 100 students, 82% came from single sex schools with the remaining 18% coming from mixed schools. Of the 50 FES, only 24% came from mixed schools.

In assessing their residential status, half of the number of students surveyed (50%) reside in the Greater Accra region, followed by Ashanti with 24% and the remaining 24% were from other regions. There were no students from Northern and Upper East regions and 2% were foreign students. (Fig. 1)

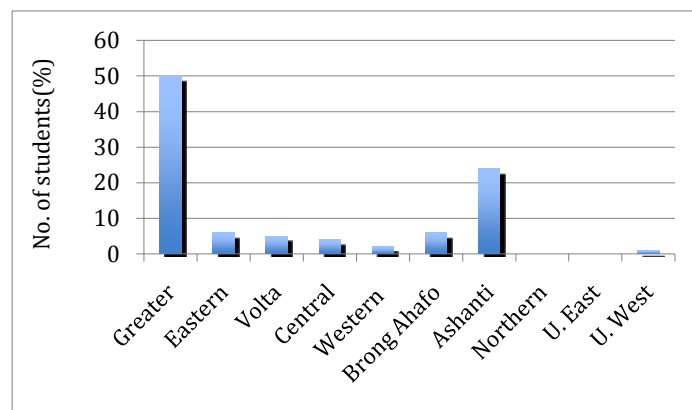


Fig. 1: Percentage of students living in the 10 regions of Ghana

The most dominant ethnic group of student respondents was Akan (63%) followed by Ewes (13%) with Ga/Adangbe being the third highest (11%), with only 1% from the Dagaaba and Guan ethnic groups as shown in Figure 3. Six percent of the respondents did not state their ethnicity. (Fig. 3)

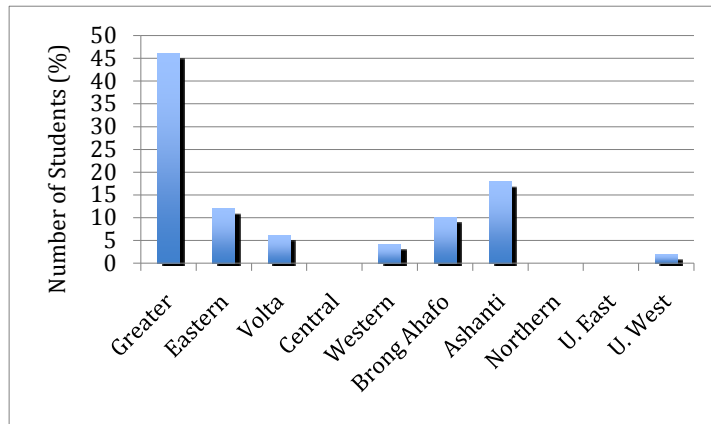


Fig. 2: Percentage of FES living in the various regions

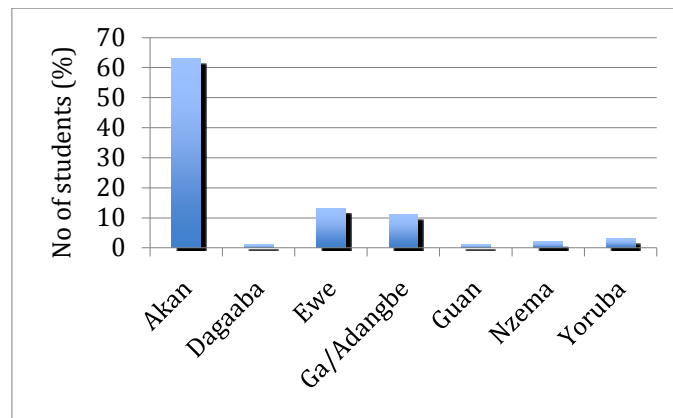


Fig 3: Percentages of students and their ethnicity

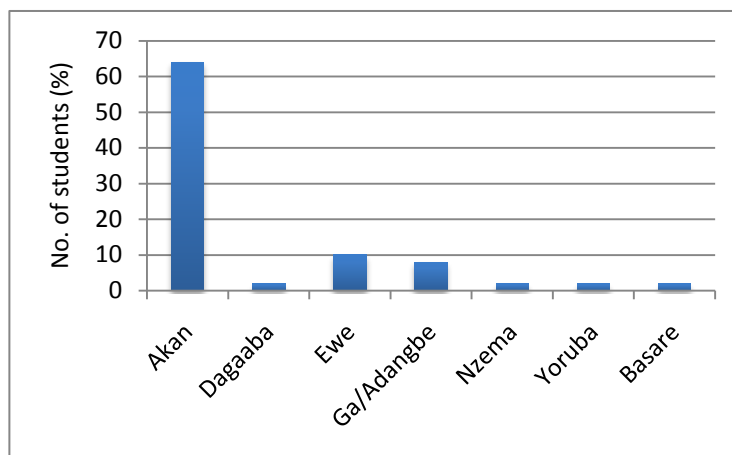


Fig. 4: Percentages of FES and their ethnicity

Perception

Student respondents were asked how they thought FES were perceived by two categories of people; peers and family. In addition, FES were asked how their colleagues male engineering students perceived them. For perception by peers, 98 % of students thought FES were perceived as brave and boyish, 54% intelligent, 19% 'know all', and 26% competitive. For perception by family, 19% of students thought FES were perceived as brave and boyish, 79% intelligent, none 'know all', and 7% competitive. On how FES thought their male counterparts perceived them, 50% of said they were brave and boyish, 20% intelligent, 20% 'know all' and 28% of their colleague male competitive (Fig. 5)

Whether they enjoyed engineering and would recommend it

Out of the 100 student respondents interviewed, 90% would recommend engineering to their female friends and relatives. Eighty-two percent of the FES also said the same. Forty percent of FES said they enjoy engineering very much, and 58% found it ok while the rest said they do not enjoy it at all (Fig 6).

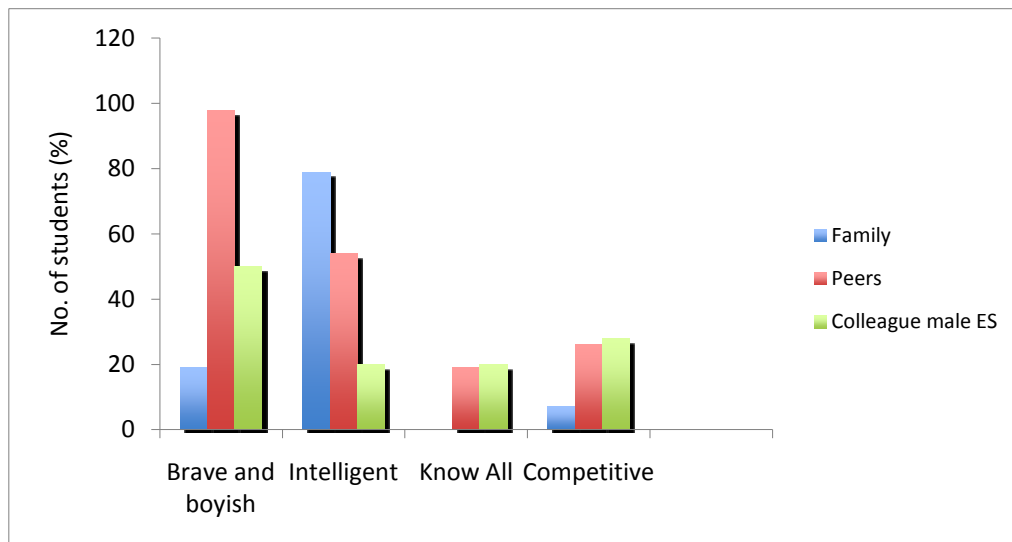


Fig. 5: Percentages of perceptions of FES

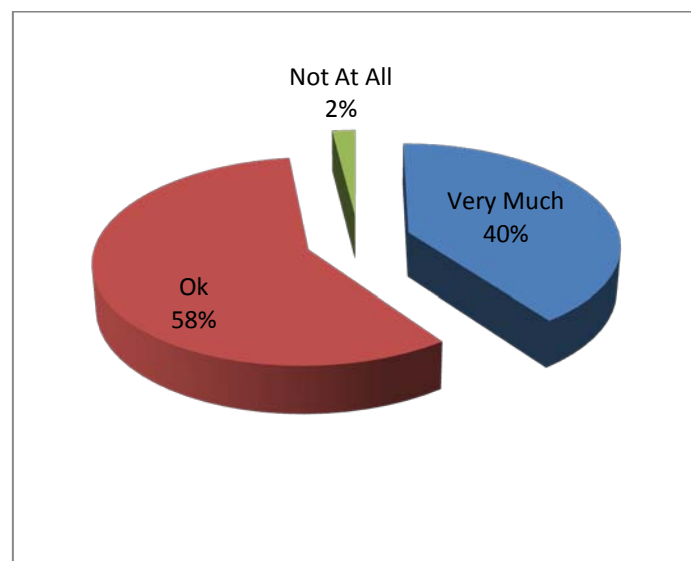


Fig. 6: Percentages of how much FES enjoy engineering

Majority of FES (88%) said they do not regret doing engineering with 6% regretting pursuing a degree in engineering and the remaining 6% with no answer.

Experiences

FES were asked to grade 6 experiences and of these 6, results indicated that for the worst experiences, fear of stigmatization was 100%, partial or total exclusion in some class activities 92%, and cultural belief and stereotyping was 86% (Figure 7). In the case of best experiences 78% of them indicated being acknowledged for good performance, 74% said family pride while 66% said some of their best experiences were during industrial attachment. (Figure 8)

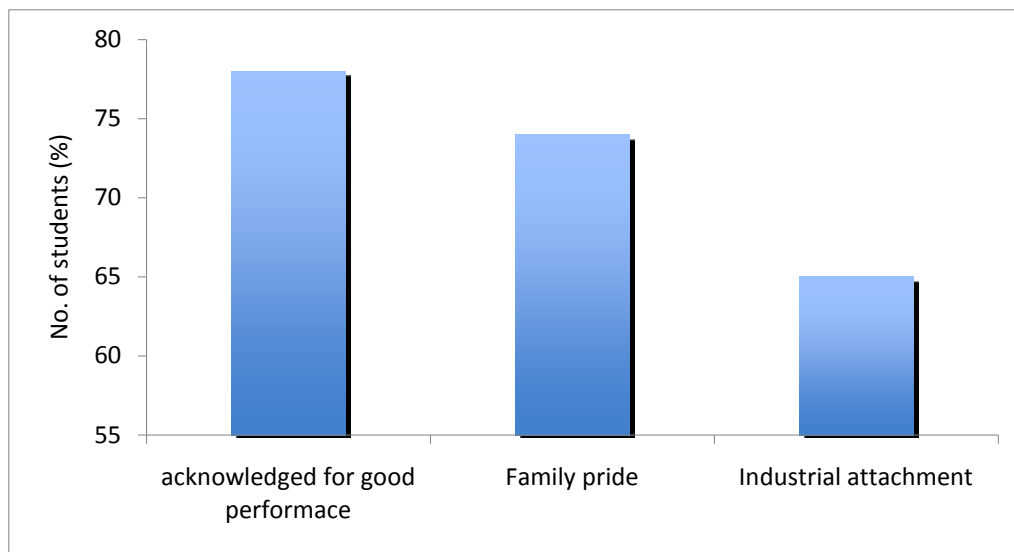


Fig. 7: Percentages of best experiences of FES

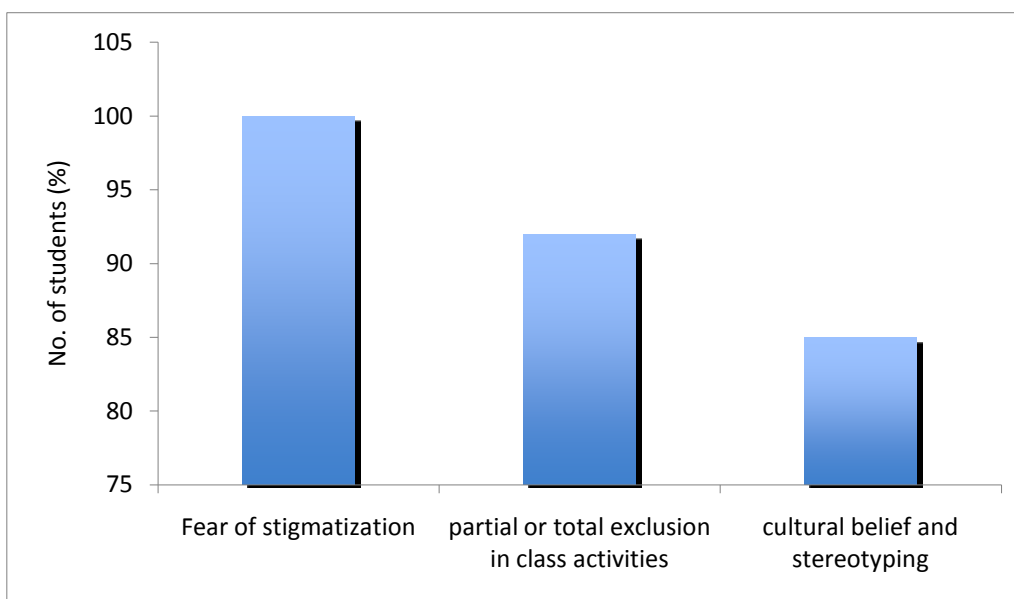


Fig. 8: Percentages of worst experiences of FES

Advisors

FES were asked who advised them to pursue an engineering degree. Self came up the highest with 40%, 12% relatives, 10% their fathers the other 2% stated that their mothers advised them, 2% others, 10% said more than one of these categories advised them. Surprisingly none mentioned teachers while 24% on the other hand did not answer the question. (Fig. 9)

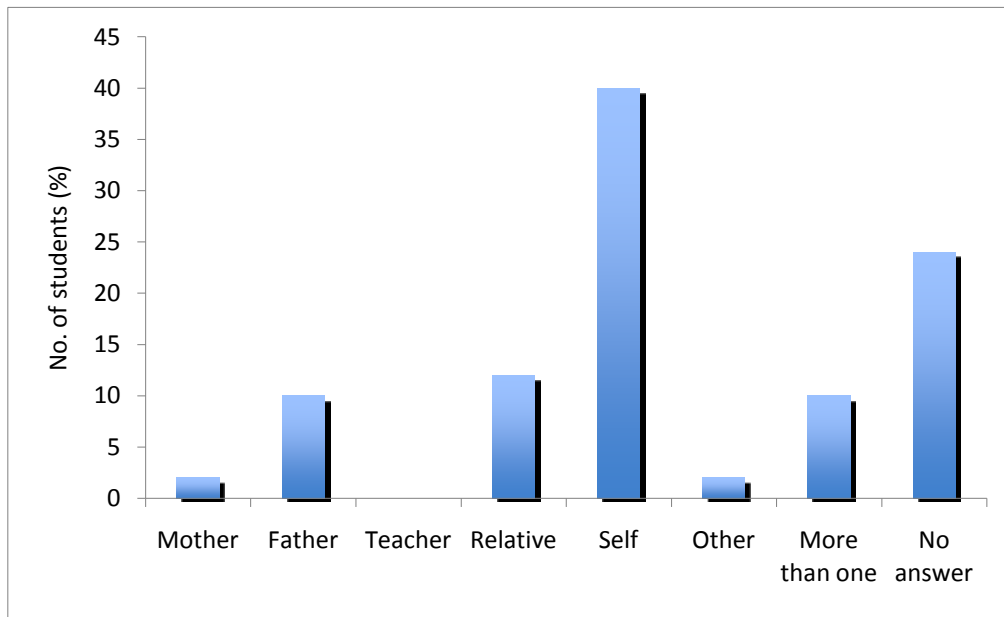


Fig. 9: Percentages of people who advised FES to pursue engineering

Tab. 1: Relationship between variables

Relationship between variables	Pearsons Correlation	pValue
Partial exclusion and perception by male engineering students	0.328	<0.05
Cultural belief and perception by male engineering students	0.388	<0.05
Partial exclusion and academic excellence	0.753	<0.01
Cultural belief and academic excellence	0.601	<0.01
Enjoy engineering and partial exclusion	-0.388	<0.05
Partial exclusion and stereotyping	0.675	<0.01
Academic excellence and family pride	0.551	<0.01
Academic excellence and industrial attachment	0.528	<0.01
First choice and industrial attachment	0.372	<0.05
Stigmatization and partial exclusion	0.644	<0.01
Stigmatization and cultural belief	0.517	<0.01
Type of high school and cultural belief	0.380	<0.05
Partial exclusion and stigmatization	0.644	<0.01
Academic excellence and stigmatization	0.670	<0.01
Academic excellence and type of high school	0.409	<0.01

Table 1 shows the various variables which has significant correlations. Most of them had positive correlation except the relationship between enjoying engineering and partial exclusion which had negative relationship.

University Data

KNUST in the 2008/09 academic year for instance, admitted 9298 students as freshmen and women. Of this number, 2513, representing 27%, were female. The college of engineering received 1187 students of which 167 were female. This represents 14% of the total number of freshmen admitted to pursue a degree in engineering, making only 1.8% of the total number of students being female engineering students admitted into KNUST.

A look at the other colleges clearly shows that females were more likely to be found in non-engineering programmes. It was also noticed that, apart from the College of Health Sciences, which had a relatively high female ratio, other colleges in which science related courses are pursued also had a low female numbers. The College of Art (CoA) alone had 1118 females out of the 2974 students admitted into the college, representing 37.6%. Thus the females in the CoA made up 44.5% of the 2513 females admitted into the university and 12% of the total number of freshmen admitted (Fig. 10).

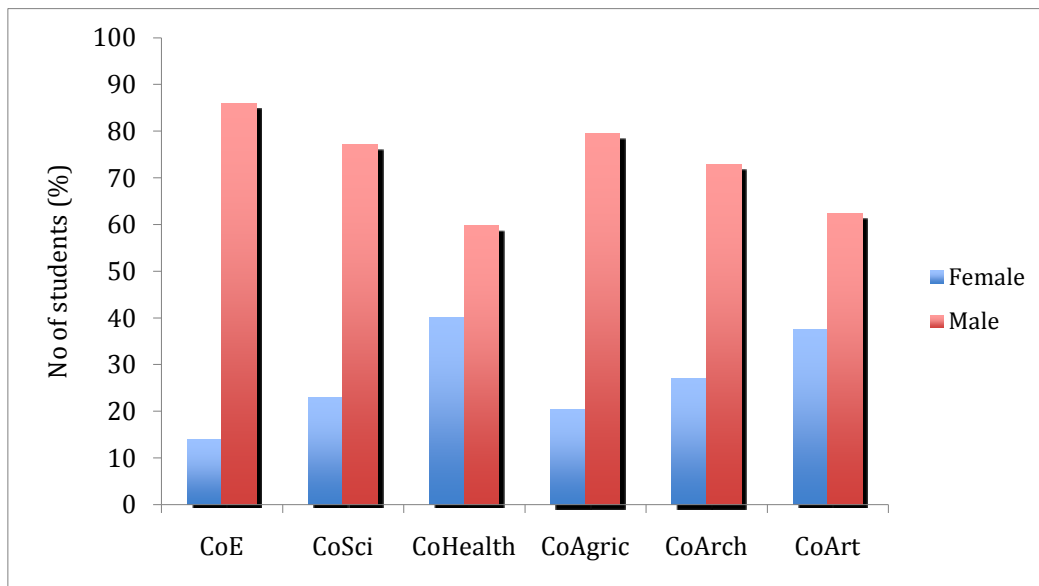


Fig. 10 Percentages of males and females in colleges

Between 1990 and 2009, the number of females admitted into the university has steadily increased but generally the percentage of females in a class in the CoE has been undulating but is usually on average of about 12%. (Fig 11)

From the university statistics it is also realized that girls in engineering also tend to favour certain disciplines or branches of engineering more than others. Out of the 12 branches of engineering offered in KNUST, those with the highest percentage of girls in class over a four year period, are chemical engineering with an average of 21%, computer engineering 19.3%, telecom engineering 17.5%, petroleum engineering 11.5% civil engineering 11.4% and electrical/electronic engineering 10.0%. The disciplines with lower than 10% are geomatic engineering 7.7%, mechanical engineering 8.75% and materials engineering 9.7% and (Fig. 12) (Basic Statistics 43rd Congregation, 2009).

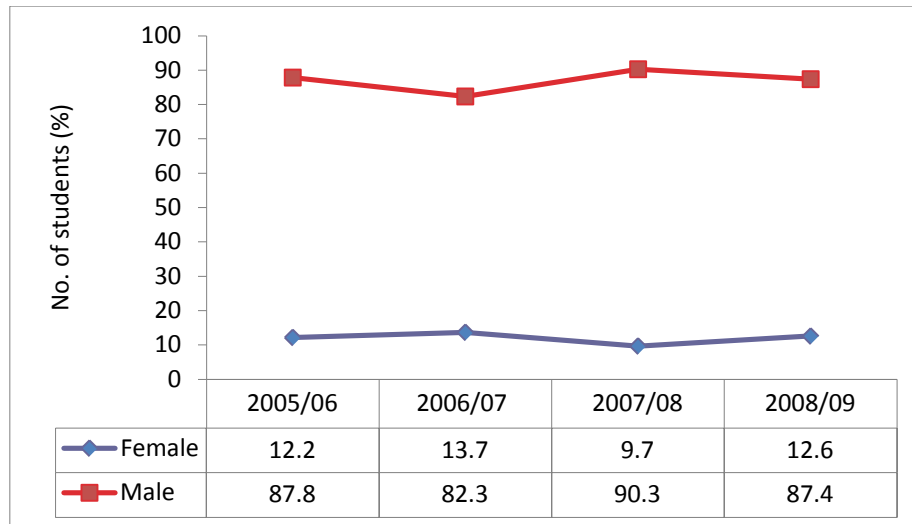


Fig. 11: Percentages of males and females admitted into the CoE over four years

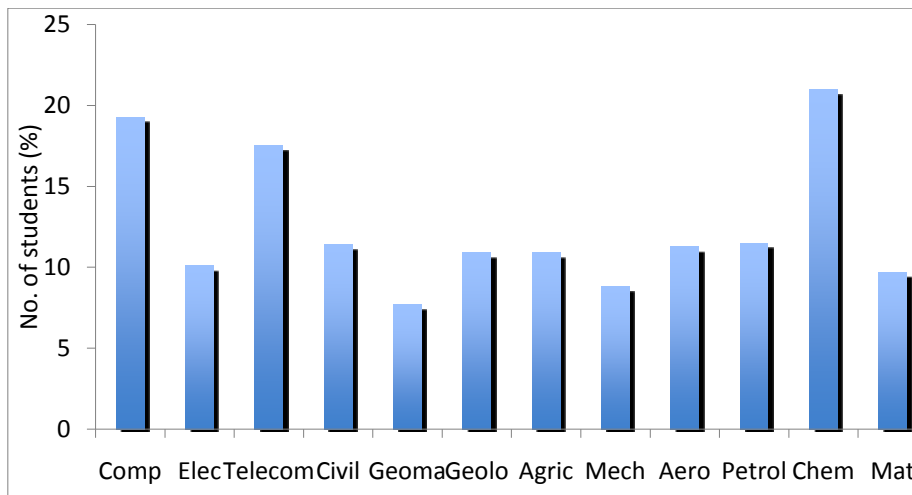


Fig. 12: Percentages of females in the various engineering programmes

Discussion

In all 100 students, comprising of 66 females and 34 males from KNUST, took part in the survey. It was realized that most students including the female engineering ones resided in the Greater Accra region followed by the Ashanti Region (Fig.1). These two regions have the two main metropolitan cities in Ghana and populous (Ghana Statistical Service Report, 2009). The urbanism of these regions probably has a very strong bearing on their residents who are more enlightened and are more aware of the importance of engineering in the country. This could account for such a high number of FES who live in these two cities.

The percentage ethnicity of female engineering students followed a similar pattern to the female population in Ghana with the Akans dominating by over 60% followed by the Ewes (10%) and Ga/Ga Adangbe with 8%. This probably stems from the culture of these ethnic groups. From history till now, women from these particular ethnic groups are very involved in decision-making and leadership and are known to be brave and not quitters. This data correlates with those from the Ghana Statistical Service, 2009. As such girls from these ethnic groups would probably be encouraged more to pursue a career in engineering and given equal opportunity than other ethnic groups. There was

only 1% of the female engineering students from Northern Ghana where there are fewer girls in school than boys.

Girls who attend single sex schools are more likely to offer engineering than those from mixed schools. This can be attributed to girls being encouraged to believe in themselves and build self esteem to compete in apparently male dominated programmes. In the mixed schools because of our cultural belief, it is more likely for boys to be encouraged to pursue the likes of engineering and other so called 'male courses' at the expense of the girls. The self esteem in girls is also seen in their response to who advised them to pursue engineering. Majority of these FES (40%) made their own decisions to pursue engineering and were perceived by peers as brave and boyish and family as intelligent (Fig. 5).

Even though these female engineering students are happy with their choice of engineering (88%) (fig 9) and have not regretted it, they are however faced with challenges of partial or total exclusion by peers, fear of stigmatisation and stereotyping as a result of the entrenched cultural belief in Africa. These have been the challenges of many female engineers all over the world and must be addressed in this 21st century. The KNUST FES also indicated that family pride played a lot of influence on their academic performance. This motivates them to excel. It is also vice versa in the sense that, when females excel in the field, their parents are very proud not only because of their grades but because of the fact that they are excelling in such a male dominated field.

Conclusion

Engineering in Ghana is still perceived as a male course and even though efforts are being made to increase enrolment, cultural beliefs and practices exclude female participation in science and engineering. Engineering curriculum needs revamping to make it more interesting, relevant, engendered, interactive and more practical. Many of the female students feel isolated because of the numbers and need to be developed to increase female enrolment in engineering.

General education of the public on engineering and its importance with emphasis on female engineers and their contributions should be done. This would encourage parents to allow their daughters to pursue careers in engineering. Scholarships should also be instituted to cater for the needs of needy but brilliant girls whose dreams are to become engineers.

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RECLAMATION OF OILFIELD PRODUCED WATER USING HYDROPHILIC PERVAPORATIVE MEMBRANES

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ABSTRACT

The suitability and application of a novel hydrophilic polymer pervaporation based irrigation technology for energy efficient, cost effective and environmentally friendly treatment and reuse of oilfield produced water is being investigated. Mass transport across the membrane occurs as a result of diffusive transport of water under the influence of humidity gradient. Selectivity of water versus dissolved contaminants is due to hydrogen-bonding interaction of water and molecular size differences. Varying concentrations of sodium chloride (salinity), magnesium chloride, and humic acid solutions have been selected as model contaminants. Methods used to evaluate the diffusion, solubility and partitioning coefficients of model contaminants are immersion/sorption tests to measure the rate at which the permeant/contaminant is absorbed by the polymer and permeation/diffusion tests to evaluate the rate of solvent transport across the membrane. Results show the average water uptake by the membrane is $4.51 \times 10^{-4} \text{ m}^3/\text{m}^2/\text{hr}$ at room temperature. The diffusion coefficient D for water is $3.3 \times 10^{-3} \text{ m}^2/\text{d}$ at room temperature. The dominance of Fickian diffusion kinetics is confirmed by the initial linearity of amount of water absorbed with time in the sorption curve pattern plotted for water and contaminants which is representative of a solution-diffusion process. It was further observed that water uptake and diffusivity decreased with increased salts concentration due to ionic effects. These initial bench-scale tests have shown promising results for implementation of this system to provide reclaimed oilfield produced water for microirrigation at pilot-scale phase; future work will examine the removal of oil components (e.g. benzene, toluene).

Keywords: Produced water, Reclamation, Hydrophilic, Pervaporation, Solution-Diffusion

INTRODUCTION

Oilfield produced water is the water that comes along with crude oil and gas during exploration and drilling (Reis, 1996, Tellez et al., 2002, Veil et al., 2004). It is trapped within the geological formations. Water production rates are five times or more (up to hundreds) compared to the oil production rates making it by far the largest volume by-product associated with oil and gas production (Tellez et al., 2002). In the US, produced water accounts for about 99% of the total waste stream (Reis, 1996, Veil et al., 2004, Neff, 2002). It is a very saline waste stream containing heavy metals, dissolved or suspended hydrocarbons, aromatic hydrocarbons, volatile organic compounds and is oxygen deficient (Røe Utvik, 1999, Neff, 2002). The predominant inorganic components are dissolved salts which many times exceed that of seawater (Reis, 1996, Neff, 2002, Tellez et al., 2002). Total dissolved solids (TDS) concentrations range from 100 mg/l to as high as 300,000 mg/l and while the large majority of these salts consist of sodium chloride (approx. 80% of the TDS), the ionic composition of these waters

may vary considerably (Tellez et al., 2002, Neff, 2002). Major cations include sodium, calcium, magnesium and potassium while anions include chloride, sulphate and bicarbonate. The most abundant hydrocarbons in produced water are the one-ring aromatic hydrocarbons, benzene, toluene, ethylbenzene, and xylenes (BTEX) (Tellez et al., 2002, Neff, 2002).

Currently, 91% of produced water is reinjected: 70% injected for oil recovery and 21% injected for disposal (Veil et al., 2004). For near-shore/inland discharges in shallow water, there is less opportunity for mixing and dilution resulting in a toxic plume of high-saline, oxygen-deficient brine (Reis, 1996) which have caused severe environmental contamination of surface and coastal waterways as well as coastal wetlands (Tellez et al., 2002). Saline soil contains excess dissolved salts which affect the ability of plants to absorb water and nutrients from soil making plants to consequently dehydrate; it alters the mechanical structure of the soil by disrupting the transport of air and water to root systems (Reis, 1996).

It is very important to reuse the reclaimed oilfield produced water for other beneficial purpose especially as freshwater demand and agricultural production requirements are ever increasing in the world. Moreover, with the growing global concern on climate change and other environmental issues, there is a need to remediate existing waste streams by developing and using cleaner technologies for pollution prevention, recycling and reuse (Veil et al., 2004). Design Technology and Irrigation Ltd (DTI-r) are currently using a hydrophilic pervaporative polymer pipe that is laid in the ground and can be used for irrigation using highly saline starting waters (Tonkin et al., 2004). Even though the ability of this technology to treat oilfield produced water is unknown, it has been successfully used for the effective treatment of brackish waters in desert regions which have similar composition and chemistry to those of many produced waters (Tonkin et al., 2004). Similar PV systems have also been tested on micro-irrigation using desert aquifer water (Korngold et al., 1996), on wastewater (Quiñones-Bolaños et al., 2005a, Quiñones-Bolanos et al., 2005b), brackish waters and synthetic model waters (Korin et al., 1996, Quiñones-Bolaños et al., 2005a). The treatment of produced water will introduce new challenges due to the high TDS concentrations and hazardous organic contaminants (i.e. BTEX) that characterise these waters. The main aim of the present initial study was to determine the sorption and permeation characteristics of the PV membrane using deionised water, sodium chloride and magnesium chloride salts and humic acid as a model organic mixture.

SOLUTION-DIFFUSION MECHANISM

Pervaporation is a separation process in which a multi-component liquid is passed across a membrane that preferentially permeates one or more of the components (Reiss, 1996). Most pervaporation membranes use nonporous, dense membranes through which permeates are transported by diffusion under the driving force of a pressure, concentration or electrical potential gradient (Jonquieres et al., 2002, Baker, 2004). The separation of the various components of a mixture is related directly to their relative transport rate within the membrane, which is determined by their diffusivity and solubility in the membrane material (Baker, 2004). Hydrogen-bonding interaction is also another dominant factor controlling the selectivity toward water in hydrophilic pervaporation process (Flory, 1975, Hopfenberg et al., 1981, Semenova et al., 1997, Hansen, 2004).

Transport of liquids by pervaporation takes place by a solution-diffusion mechanism (Mulder et al., 1985, Wijmans and Baker, 1995, Mulder, 1996, Baker, 2004, Shao and Huang, 2007). The three key steps involved in the process of permeation in the solution-diffusion model are *adsorption* (partition of contaminant between inner surface of membrane and solvent), *diffusion* of the permeant through the membrane, and

desorption (partition between the outer surface of the membrane and the outer medium). These steps are accounted for using the transport coefficients of diffusion, solubility and partitioning coefficients (Wijmans and Baker, 1995, Vane, 1998, Baker, 2004, Shao and Huang, 2007).

Currently, the best quantitative description of permeation uses phenomenological equations, particularly Fick's law which outlines the mathematical basis of the solution-diffusion model (Wijmans and Baker, 1995, Baker, 2004). Thus, the flux J_i (g/cm².s) of a component i with concentration c_i (g/cm³) is

$$J_i = -D_i \frac{dc_i}{dx} \quad (1)$$

The diffusion coefficient D_i (cm²/s) is a measure of the mobility of the individual molecules and the minus sign shows that the direction of diffusion is down the concentration gradient (Wijmans and Baker, 1995, Baker, 2004).

For membranes in which transport is best described by the solution-diffusion model and Fick's law, the free-volume elements in the membrane are tiny spaces between polymer chains caused by thermal motion of the polymer molecules (Baker, 2004). These volume elements appear and disappear on about the same timescale as the motions of the permeants traversing the membrane (Mullerplathe, 1994, Baker, 2004). The rate limiting step for penetrant diffusion can be the creation of transient voids in the polymer matrix via local scale polymer segmental dynamics involving several polymer chains (Mullerplathe, 1994, Park et al., 1996, Katoch et al., 2010). Molecular transport, as perceived by current free-volume theory, is consequently governed by the probable occurrence of two events: (i) a hole of sufficient size appears adjacent to a molecule and (ii) the molecule will then possess enough energy to jump into the void (Zielinski and Duda, 1992). Park and Nibras (1993), Sangam and Rowe (2001) and Joo et al (2004) have all observed that diffusion coefficients tend to decrease with increasing contaminant molecular volume. The reason for the lower diffusion coefficient to be the higher activation energy required for diffusion of larger molecules (Sangam and Rowe, 2001, Joo et al., 2004).

METHODS

The methods used for evaluation of diffusion, solubility and partitioning coefficients for membrane characterisation are (i) *immersion/sorption tests* (Hopfenberg et al., 1981, Berens, 1989, Park et al., 1991, Islam and Rowe, 2009, Katoch et al., 2010) which are bottle tests where the membrane material is immersed in a container filled with the solvent e.g. deionised water, salt solution or humic acid in this case. It is used to measure the rate at which the permeant/contaminant is absorbed by the polymer. The polymer was immersed in an excess amount of deionised water and various concentrations of saline solutions and humic acid. The polymer was removed, weighed and replaced over a period of time until swelling equilibrium was attained; (ii) *permeation/diffusion tests* (Buss et al., 1995, Park et al., 1996, Haxo and Lahey, 1988, Islam and Rowe, 2009) where the membrane is used to divide the two compartments of deionised water and salt/humic acid. This is used to evaluate the rate at which the penetrant travels through the polymer, i.e. solvent transport across the membrane. Either the permeation or sorption data can be used to establish whether transport in a given system obeys the ideal Fickian relationships, since the form of either kind of data can be calculated from the appropriate solution of Fick's law (Crank, 1975, Berens, 1985). Furthermore, if transport is Fickian, then the parameters obtained from sorption experiments, namely the diffusivity D and the equilibrium solubility S , can be used to predict the rate of permeation P through samples of any thickness as $P = SD$ (Berens, 1985, Katoch et al., 2010).

These tests were replicated four times and the standard deviation was found to be very low. Characterisation of the membrane using this immersion and partitioning methods with sodium chloride, magnesium chloride and humic acid as model contaminants have so far given an insight on the diffusive transport of water across the hydrophilic membrane and at what rate other contaminants will also be transported along.

RESULTS AND DISCUSSION

Sorption Curves

Because of its hydrophilic nature, the polymer membrane initially swelled quickly since it sorbed the water very fast. The sorption process lasted for 24 hours and the average water uptake of PV polymer using deionised water was $4.51 \times 10^{-4} \text{ m}^3/\text{m}^2/\text{hr}$ at room temperature. Fig. 1 presents the water sorption curve for deionised water and the trend over time indicating that transport is Fickian which is ideal for a solution-diffusion process. The dominance of Fickian diffusion kinetics was confirmed by the initial linearity of amount of water absorbed M_t vs $t^{1/2}$ plots for deionised water before flattening to a plateau.

The water uptake and sorption curves for deionised water, different NaCl and MgCl_2 concentrations as well as humic acids were similar in nature which showed the rate of swelling being high initially before flattening to a plateau when equilibrium was reached. The plateau regions of these curves give the maximum sorption values after attainment of equilibrium sorption (Crank, 1975, Berens, 1989). Experiments were continued for longer times to ensure complete equilibration. The experimental diffusion results obtained for all experiments clearly represent a Fickian mode of transport. The diffusion coefficient D for deionised water was found to be $3.3 \times 10^{-3} \text{ m}^2/\text{d}$ at room temperature.

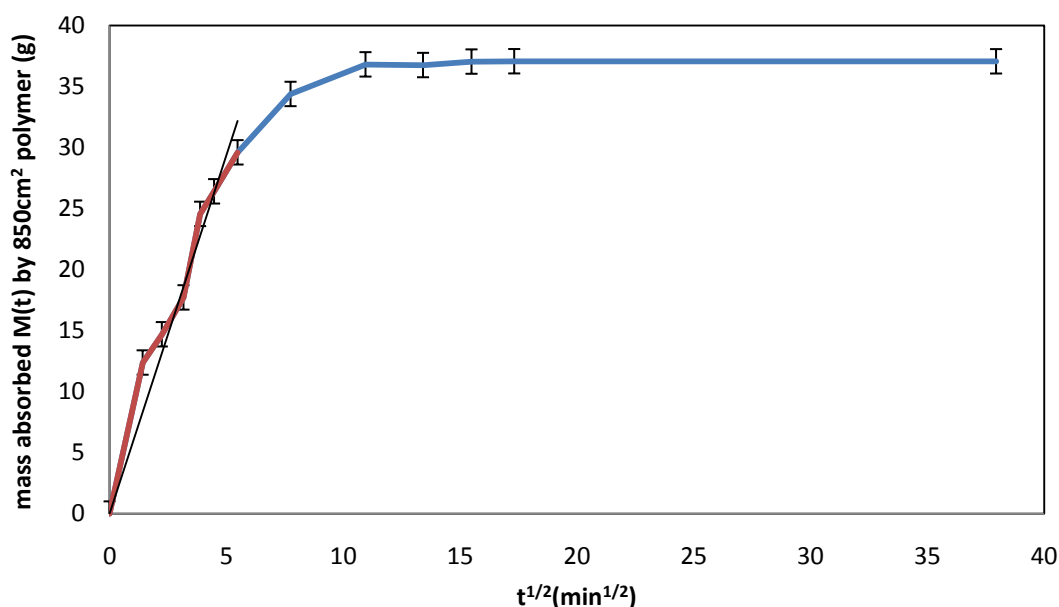


Fig. 1: Sorption curve for polymer membrane immersed in deionised water

Effect of Solute Concentration

The experiments for NaCl solution used varied concentrations of 30g/l, 50g/l, 100g/l and 150g/l. NaCl solutions with least concentrations exhibited the highest amount of water uptake and similarly that with the highest concentration showed the lowest amount of water uptake (Fig. 2). The volume of water sorbed increased with time for all

four concentrations. Similarly, the weight gained corresponded to the volume sorbed by having the highest weight gain at 30g/l. The electro-conductivity increased with increasing salt concentration as well.

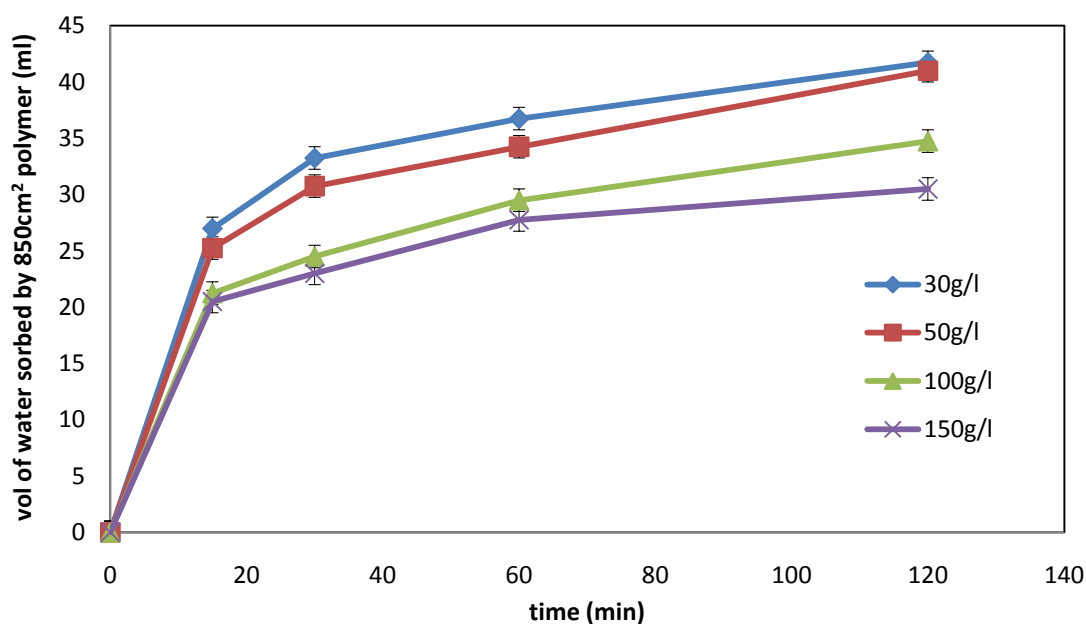


Fig. 2: Average water uptake by polymer membrane using NaCl solutions

To further verify the effect of charge, sorption tests using magnesium chloride MgCl_2 which has 2^+ charge was carried out in Fig.3. The results for the MgCl_2 also showed a decrease in water sorbed as the concentration increased like the NaCl. But comparing NaCl with MgCl_2 , there was no significant effect of the different ionic charge at these concentrations, i.e. 1^+ versus 2^+ charge had no effect.

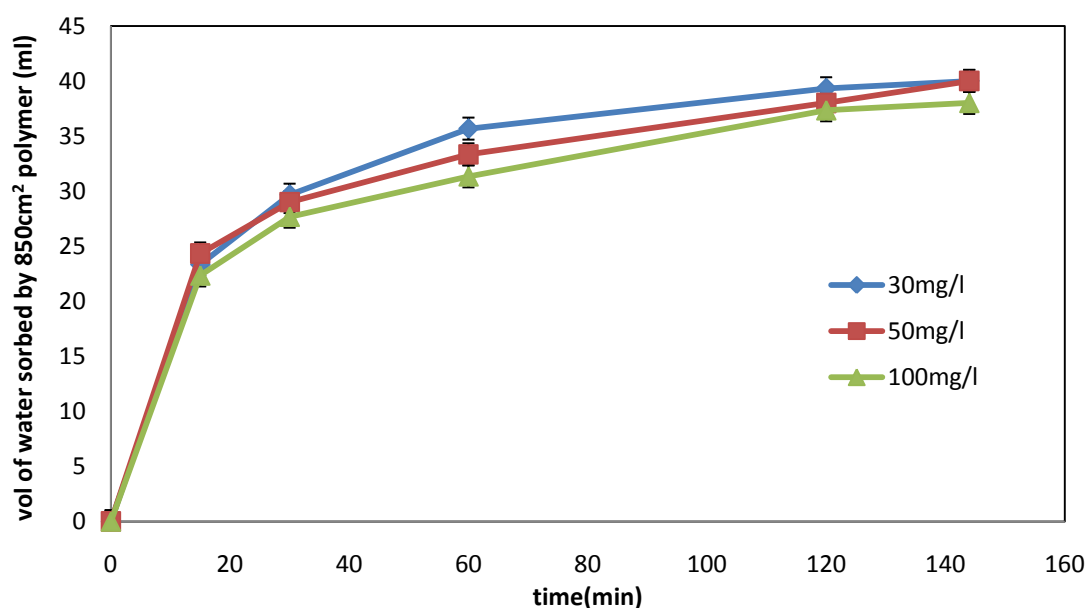


Fig. 3: Average water uptake by polymer membrane using MgCl_2 solutions

Salts dissolve in certain polymers and the conductivity is not only sensitive to the degree of crystallinity, temperature and the like but also very much to the salt concentration (Berthier et al., 1983, Watanabe and Ogata, 1988, Mullerplathe, 1994). Conductivities generally increase with temperature and salt concentration and as the concentration increases, the conductivity increases due to the availability of more

charge carriers (Watanabe et al., 1986, Watanabe and Ogata, 1988, Mullerplathe, 1994). At higher salt concentrations, the polymer becomes stiffer, due to effective crosslinking by the salt (Watanabe et al., 1986, Mullerplathe, 1994). Ions diffuse in a similar way to gas molecules, in that they hop between certain, favourable dwelling sites (Mullerplathe, 1994, Semenova et al., 1997, Baker, 2004). The presence of strong and specific interactions changes several aspects of the motion pattern (Mullerplathe, 1994). Anions, which are only weakly bound in a polymer like polyethylene oxide, diffuse almost completely like molecules (Mullerplathe, 1994). They are captured in cavities of free space, and they move as channels between those cavities become available (Watanabe and Ogata, 1988, Mullerplathe, 1994). For cations, however, there is less similarity with gas or liquid diffusion due to strong complexation by polymer thereby inducing major changes in the polymer and they also customise the binding sites to their needs, at least to some extent. Therefore, ions in large concentrations might change the transport and other properties of the host polymer to a much greater extent than gas or liquid molecules (Watanabe and Ogata, 1988, Mullerplathe, 1994). Hence the observed reduced water uptake observed for NaCl and $MgCl_2$ at higher concentrations.

On the other hand, it was observed that for the humic acid solutions there was no clear effect of increasing concentration on the water sorption and the weight gain by the polymer (Fig.4). These may be because of less ionic charge on humic acid compared to the salts and hence reduced influence on the stiffening of the polymer at different concentrations.

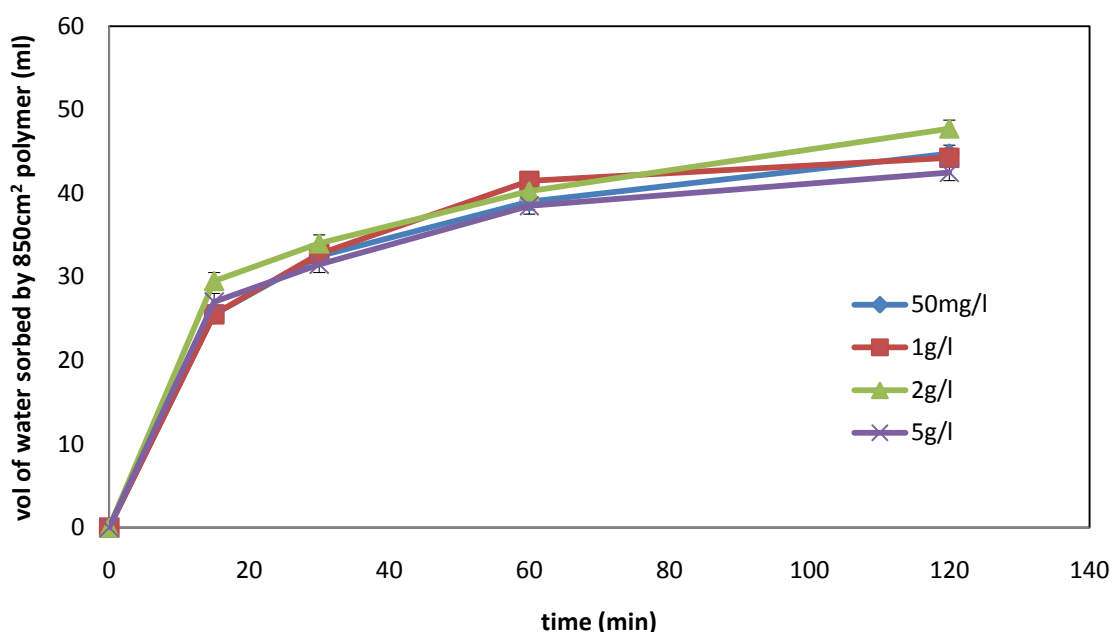


Fig. 4: Average water uptake by polymer membrane using humic acid solutions

CONCLUSIONS

Based on the experiments conducted so far, the hydrophilic polymer technology has promise in reclamation of oilfield produced water. It is clear from these initial trials that the concentration of certain contaminants (e.g. salt) has a direct effect on water sorption by the polymer. The next step will be to measure water flux of the polymer when surrounded by soil matrices and to assess the rejection of BTEX by the polymer.

Acknowledgements

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BRINGING SYSTEMATIC INNOVATION INTO PROJECT DELIVERY – THE PERSPECTIVE OF A WASTEWATER NETWORK PROJECT OFFICE.

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ABSTRACT

Systems thinking and systems innovation are popular tools to bring innovative, sustainable ideas into infrastructure development. However, the focus of these tools tends to be ‘big picture thinking’ such as a concept for a whole town, or a whole infrastructure system, where innovation will have ‘maximum’ impact on solutions.

Concepts are given to civil engineers and environmental scientists to turn into physical infrastructure. So, how do we ensure that systems thinking, consideration of broader effects and benefits, carries through into the construction of the infrastructure, when the focus tends to shift to programmes and budgets?

This paper covers the authors’ experience as a Project Office Manager and an Innovation Specialist, working together on the development of innovation tools focussed on infrastructure problem-solving, starting with feasibility studies, then developing into detailed design and construction. It discusses the use of a Project Management System to embed the innovation tools by systemising them to become business-as-usual, in the context of an existing innovative culture.

Measuring innovation from an infrastructure perspective is also challenging, partly because the benefit from the innovation may not be realised for several years, and partly because people don’t distinguish innovative ideas from ‘we do that anyway’. The paper discusses methodology to develop tools, case study experiences of trialling the tools developed, and the integration into Project Management Systems, both for the project office and for the client group.

The paper concludes with lessons learnt from the testing process, and notes how innovation was recorded and measured on the project, as an outcome of using the innovation tools.

INTRODUCTION

North Shore City Council (NSCC)’s Wastewater Network Strategic Improvement Project commenced in the year 2000 and is ongoing in the new Auckland Council (Watercare Services Ltd) – its aim is to achieve Network Consent by 2021, by reducing wastewater overflows to an acceptable minimum, through improving storage, increasing capacity in the network and treatment plant, reducing infiltration into the network and planning for growth. A 21 year programme of works was developed, initially to target major overflows along the main trunk through storage, then to improve catchments through rehabilitation of existing sewers and construction of new sewers and pump stations.

There are many challenges affecting the implementation of this ambitious city-wide improvement project in a densely populated, urban environment, with iconic beaches and reserves and amenity much valued by the residents. This has necessitated an innovative approach to problem solving from initial identification of solutions through

to implementation. The Council determined that to achieve design, consenting and construction of the programme, a Principal Consultant would be appointed to deliver all the new capital expenditure (CAPEX) works. SKM, with subconsultant Opus was appointed in 2000, initially based in a project office but later working in a co-located team in NSCC offices. SKM is an international Engineering and Science consultancy, as is Opus. SKM for the past few years has had a strategic focus on bringing holistic thinking into projects.

INITIAL INNOVATIONS AND MEASUREMENT

Initially, the project was awarded with a small bonus element of fee, to be payable on achievement of certain Key Performance Indicators (KPIs) which included Innovation/Technical Quality as one of 7 indicators. Initial measurement of the KPIs comprised a spreadsheet in which the team reported technical quality actions and innovation. In addition, an annual summary was written, which included identifying major cost savings arising from innovations.

The project's starting focus on technical quality led to some early innovations in itself – standard details for the project were produced early on, and a teamwork approach to solution development and sign off was developed between the Projects, Operational and Planning parts of Council. To improve decision making, multi criteria analysis and risk management tools were used, and as part of continuous improvement there was a formal lessons learnt process at the end of every scheme, or after a site safety incident. However, measurement remained essentially as a qualitative record.

NSCC had also started to explore innovation tools and methodologies and to consider how to apply them to projects as opportunities arose. In specimen projects innovation was used at an early stage to identify and find solutions for problems and issues that would not normally have been identified until much later in the design and construction process. Using large workshops, and tools such as strategic foresight (looking from the future back to the present), innovative and sustainable outcomes were developed for large projects such as Rosedale Effluent Tunnel & Outfall Project in 2005 (Total value \$116 M) and Birkdale Sewer Amplification Project (Total value \$19M.) in 2007. However, these were 'big picture thinking' workshops, of two days duration or longer, involving external facilitators.

There was therefore strong support for innovation from client and consultant, a reward system which sought to record and reward innovation, and a comprehensive project management system in which decision-making was embedded.

APPLYING INNOVATION TO INFRASTRUCTURE PROJECTS

In 2007 Council started the process of developing an innovation framework and in 2009 established a formal innovation programme, seeking out ideas and opportunities that would enable them to: reduce costs, improve customer satisfaction, provide better solutions, improve processes and ways of working together, improve project certainty (including consentability), and improve staff morale. They appointed an Innovation Specialist Ideas Accelerator (IA) to develop a number of programmes to embed innovation across council. Together NSCC and IA approached SKM to suggest that the scale of the wastewater network Project made it suitable to try and develop an innovation methodology for Infrastructure.

Innovation is officially defined, within the OECD, by the OECD Oslo Manual, (1997), and by Statistics NZ as:

1. The introduction of a new or significantly improved product or service to the market
2. The introduction of a new or significantly improved process within a business

For the purpose of this project innovation was defined as any activity that adds value to the organisation and its customers, through changes to systems, processes, or through the development of new engineering options.

Project Innovation objectives were identified by NSCC as:

- Continuous improvement
- Better, or more appropriate, solutions to problems
- Reduced cost of solutions
- Increased benefits from solutions
- Development of a process to enable these objectives to be achieved consistently.

While a great deal of creativity and innovation is embedded in the day to day management of infrastructure projects; managers and contractors naturally focus efforts on risk mitigation and delivery, after the preferred option is agreed. However, for innovation and sustainable thinking to occur, our challenge is to move away from “we’ve always done it like this” to developing ways to understand and solve problems better. So, engineers and designers need to be encouraged to think about project solutions in a wider context.

INTEGRATING INNOVATION TOOLS INTO THE PROJECT DEVELOPMENT PROCESS

As part of aligning the Quality Assurance (QA) processes of the Project Office towards NSCC’s own Quality System, SKM had been documenting the project processes and developing flow charts and templates to add a project-specific level of detail to North Shore’s project management processes. To ensure consistency of approaches, from questions asked at project start up through to deliverables, Project Management Templates were developed for the various project stages, which meant that a comprehensive system existed on which tools could be superimposed.

The projects undertaken by the project office had been separated into 3 key stages:

1. **Concept and Preliminary Design;** where choices of different concepts to solve wastewater network problems, such as increasing storage, augmenting existing pipelines, or diverting/transferring flows, or where choices of initial decisions in implementing a concept, such as location and route, are identified and a preferred option chosen. This phase tends to concentrate on idea generation and comparison.
2. **Detailed Design;** where the details of how an improvement project is going to be built and operated are identified and resolved with end users, often including stages of consenting, and of preparing tender documents to enable the improvement projects to be tendered and built. This phase tends to focus on risk management to achieve construction targets.

3. **Construction;** where the asset is constructed under the supervision of the Council and its agents. The focus at this stage is on a high level of scrutiny involving many routine tasks on a daily, weekly or monthly basis. However the principal challenge at this stage is the quick resolution of problems when they arise on site, so as not to affect programmes or outturn costs with time delays.

DEVELOPING AND SELECTING TOOLS

The first stage of the innovation project was for SKM and Ideas Accelerator to discuss and refine each project stage; to define the purpose, outcomes and challenges and to look for opportunities to formally introduce innovation tools and techniques. It was agreed that we would start by trialling innovation processes in the concept and preliminary design stage, based on the idea of having maximum innovation impact early on in projects.

From an engineering or project perspective; innovation can be maximised anywhere solutions are to be identified and weighed up. As engineering of infrastructure comprises defining and solving a problem, innovation tools could theoretically be applied at each problem solving stage of 'idea generation' or 'idea testing' where a preferred solution is selected. Using the established process flow charts as a basis for further development, the team determined that the **decision-making meetings** ie start-up, option generation and option identification meetings were the most suitable parts of the project to introduce formal innovation processes; largely because these meetings are focussed on exploring ideas with key stakeholders, to ensure ultimate agreement to the processes used and the options chosen.

Based on seven years experience of applying innovation tools and techniques to processes and systems within large organisations, Ideas Accelerator chose to utilise and adapt two innovation tools; **Scamper** (Mindtools 2009) that assists in the generation of ideas – divergent thinking and **De Bono's Six Thinking Hats** (De Bono 1999) that assists with the assessment or analysis of ideas – convergent thinking. Both of the selected tools allowed for easy adaptation to fit an infrastructure context, whilst still ensuring that a range of different perspectives were applied. They were also easy to use and require little training in order for them to be effective.

TRIZ, also known as the Theory of Inventive Problem Solving (TIPS), a Russian acronym, was developed by Genrich S. Altshuller in the 1950s (Trizworks 2010). TRIZ theory holds that there are two types of problems people face: Problems with generally known solutions and problems with unknown solutions – it also operates using a set of questions to develop, assess and evaluate, problems, ideas and opportunities. This structured methodology gave us the idea of presenting the innovation tools as a series of questions to be asked at the decision-making meetings.

It was agreed that the existing templated project management system would be used, with the intention of integrating innovation and making the innovation process so easy to use that it would be easier to use it than not use it; ideally, the innovation tools should be able to be used in a standard project context, without a facilitator.

Option Generation Tools

Scamper (Mindtools 2009) is used as a check list of questions to spur ideas and help solve problems. It helps to open our minds to new possibilities by assisting us to think of changes that could be made to an idea and thus helps us to generate new ideas. Developed by Bob Eberle, the changes SCAMPER stands for are;

- **S - Substitute** - components, materials, people, methods
- **C - Combine** - combine or integrate ideas, service, methods, technologies
- **A - Adapt** - alter, change function, change processes
- **M – Modify / Magnify** - increase or reduce in scale, dimensions change shape, volume, pressure?
- **P - Put to another use** – additional or subsequent uses
- **E - Eliminate / Escape** - remove or reduce elements, reduce costs or time, condense.
- **R - Reverse / Rearrange** change the construction sequence, programme, pace

This method is used to challenge ideas, and gather more information for future research and subsequent implementation. . As the wastewater project was dealing with a defined starting point (ie improve the wastewater network), this tool was considered appropriate to generate options.

SKM and Ideas Accelerator brainstormed the overall ideas of SCAMPER – substitute, combine, adapt, which was merged with modify/magnify, put to other uses, eliminate/escape and reverse/rearrange. Structured (TRIZ style) questions were drafted, turning the SCAMPER concepts into engineering terms and ideas. Terminology was kept as broad as possible, with a view to being able to adopt the ideas across Council projects if the trial was successful, e.g flows could be taken to mean fluid flows, or traffic flows.

The questions were then grouped into the following themes to assist with structure:

- How can we change the resources used, or future-proof the option for changes in resources or conditions?
- How can we change the problem – by changing flows etc?
- How can we change the solution, by changing layout etc?
- How can we add value to the solution we have?

The questions above were turned into a Generate Concepts Guide to be used at the ‘generate options’ workshop. The Generate Concepts Guide (based on the Scamper concept) was integrated into concept design and preliminary design process phases and was listed for use as part of the meeting and workshop template process.

Option Appraisal Tools

De Bono’s Six Thinking Hats; Six Thinking Hats is used to develop and assess ideas and opportunities; by using parallel thinking to help us to analyse ideas from six different perspectives. Parallel thinking is when our thinking focus is split into specific directions, thus avoiding potential adversarial situations (when different ‘perspectives’ are being applied to one idea at one time). The method is attributed to Dr. Edward de Bono and is the subject of his book, *Six Thinking Hats* (de Bono, 1999).

The premise of the method is that the human brain thinks in six distinct ways. Each of these ways is represented by a coloured hat, that indicates the thinking style that you should adopt when thinking from that mode. De Bono's Six Thinking Hats is a structured process used to ensure that an idea is evaluated and developed from a range of perspectives in order to improve the outcome or solution.

- **White Hat;** what information, fact and figures are available or needed
- **Black Hat;** Risks, opposition, downsides
- **Red Hat;** Emotions, feelings and instinctive gut reaction.
- **Yellow Hat;** Benefits, supporters
- **Green Hat;** Creativity, improvements, creative thinking
- **Blue Hat;** Strategy, blue sky thinking and next steps.

SKM Opus and Ideas Accelerator reviewed the criteria required by NSCC's Quadruple Bottom Line analysis, and the criteria used in SKM's multi-criteria analysis, as well as the option agreement workshop agenda and meeting objectives. We determined that for preliminary and concept design, the meeting had six stages, which could be developed into a series of questions based on the Six Hats principles. These stages are;

- Weighing up each option in terms of the multi- criteria analysis, ie summing the relevant facts for each option (White hat). The options would be scored.
- Considering whether the option meets NSCC objectives, and whether it has any additional benefits or reasons for supporting it, outside the multi-criteria analysis and the objectives (yellow hat).
- Considering the risks associated with the option, including reasons for the option not gathering council or community support (black hat).

At this stage, the meeting leader would adjust the scores, to identify the preferred option and any close runners up to be considered further. The attendees would then brainstorm to check the outcome, as follows:

- Reviewing whether the option could be improved, and how it could be improved (green hat)
- Checking that everyone is happy, and in agreement (red hat)

The final stage, to close the meeting, is to agree on future work stages.

An Evaluate Options Guide was developed as a meeting format to challenge thinking, but without incorporating role play. It was integrated into concept and prelim design processes and was listed for use as part of the meeting and workshop templates. The Project Guidelines were designed so all resources; process flow maps, planning guides and meeting and workshop templates, were available for use in one place.

TRIALLING TOOLS AT CONCEPT DESIGN STAGE – OUTCOMES AND LESSONS

A key lesson in identifying innovation tools was that we were missing the opportunity to bring stakeholders into the project at ideas generation stage. A consequence of that was that potentially, stakeholders would be dissatisfied at a later stage with the range of options considered, which could impact on selecting a preferred option, or even on likelihood of attaining Landowner or Resource Management Act (RMA) consent for the

option implementation; the RMA being New Zealand's legislation for managing environmental effects.

The project team had just commenced concept design for a new pumping station to service a major growth area in the north of North Shore City. Preliminary assessments in the early 1990's had identified a potential site within a recreational reserve, and some geotechnical investigation had been undertaken, but no agreements had been reached with NSCC Parks as landowner. In addition, the area was developing significantly, and NSCC roading were planning several transport initiatives in the area, including developing a 'park and ride' facility.

The team agreed that we would modify our option generation meeting to include potential in-Council stakeholders from Roothing and Parks, as well as NSCC's Water stakeholders from Wastewater Planning, Projects and Operations, and Stormwater Planning. To cater for a varying extent of familiarity with the area, we agreed that the option generation meeting should be held on site. This would enable everyone to see elements such as local topography, extent of tree cover and other potential constraints to options.

We agreed that the site meeting should comprise an initial briefing stage, to establish the problem to be solved and summarise the work done to date on identifying a solution, and to encourage the others to talk about their plans for the area. This would be followed by a tour of potential sites identified by the project team, and any other sites identified by the team and the stakeholders whilst on site. The meeting would then reconvene to consider the idea generation concepts in the Innovation Toolkit. Briefing documents were prepared, comprising aerial photographs of the area, with existing wastewater network and potential sites identified so far overlaid, and an explanation of the option generation and option appraisal process.

Prior to the meeting, four areas had been identified as potential sites, some with two potential locations within a site. The group identified nine specific sites in total, and discussed the advantages and disadvantages of each site and specific issues as they went along.

The Generate Concepts Guide was used on site to generate ideas such as combining a toilet block into the pumping station if it was located on the reserve, and there was much discussion about community uses or benefits, and opportunities for different council departments to work together. However, the ELIMINATE aspect helped the project team to review whether a pump station was required, or whether capacity issues could be resolved by bypassing some of the flow to further downstream with a new gravity sewer. This bypass option was added to the option list, and subsequently chosen as the preferred option, reducing the \$13M estimated construction cost by about 8%, and reducing the consenting and construction programme by approximately 1 year.

Prior to this, the success of the trial in improving innovation and engagement meant that NSCC commissioned SKM and Ideas Accelerator to develop innovation tools for the project stages of Detailed Design and Construction. Lessons learned from undertaking the new option generation process and using the new innovation tool were fed back into the process, and will be discussed on presentation of the paper.

DEVELOPING TOOLS FOR DETAILED DESIGN AND CONSTRUCTION

Detailed design proved to be more risk-focussed, and as such relied on the Project Management template risk documents as the basis for brainstorming ideas to mitigate risk and facilitate delivery. The team's focus moved to construction problem solving with the intention of developing a tool that could be used for rapid problem solving at detailed design stage or on site.

Construction innovation is a well-developed science from the Contractor's perspective, to increase competitiveness and add value. From the Client and Consultant perspective, we therefore concentrated on the times when the whole project team comes together on site to troubleshoot specific problems. This process is very tightly focussed on solving a perceived problem in a defined time frame at minimum cost. Three processes were identified as being necessary to get a good outcome:

- Define and understand the problem
- Find solutions to the problem
- Evaluate the preferred option, and assess risks to implementation.

Ideas Accelerator suggested using Root Cause Analysis as a way of developing a simple tool that helps to define the real problem to be addressed. The team developed a tool which used '5 stages of why' (Mindtools 2009) to drill down to understanding of the problem to be solved. This was developed as part of a meeting Agenda, with an example built into the tool to make it easier for the people using the tool to understand what was being sought.

As brainstorming was agreed to be the most appropriate way of developing solutions to the problem once defined, the tool incorporated a brainstorming stage. This was deemed to be the best way to leave the ideas generation as unconstrained as possible. It directed users towards the Idea Development Resource Kit as containing useful brainstorming tools and techniques.

To assess the options, the Evaluate Options Guide was identified to still be a suitable tool, however the list of questions was abbreviated and the tool redeveloped. This was presented as a **beermat**, to introduce a sense of fun.

TRIALLING DESIGN AND CONSTRUCTION INNOVATION TOOLS

The tools were trialled on a real site problem for a NSCC project that SKM was not involved in. NSCC staff led the meeting, and SKM staff were invited to attend to contribute ideas.

The site problem was a very deep manhole. A large shaft 30m deep was excavated and de-watered to construct the manhole in. Once the manhole was in place, there was only 600mm to 1 metre of working room left around it. The Contractor needed to backfill around the manhole, to give a flat ground surface and allow the water table to recover. Initially, this had been designed to be done with flowable fill because there was no access to compact it, and it needed to be something that was watertight. However, this flowable fill was expensive and a workshop was held to seek a lower cost solution.

The use of the root cause analysis tool identified two separate problems: backfilling a constrained space, and making the manhole impermeable. The group brainstormed solutions to the two problems separately. Lots of options were defined for each solution, including elements of material reuse, such as sealing the manhole with waterseal paint, then using inert waste to fill the shaft.

The beer mat - evaluation tool was used to start assessing the options, but found that we stopped on item one – the cost and other implications of the different solutions were not known, because the solutions identified with were not what was anticipated. As there was insufficient data to analyse further, the ideas were taken back to the design and construction team. Due to time constraints and performance queries about water sealing, ultimately the flowable fill option was still used, however the tools had been successfully deployed.

The main lesson learnt from trialling this tool was that cost data is unlikely to be readily to hand, so two meetings, or a meeting plus further investigation may be needed to establish a solution. For site problems, it is therefore important to establish a collaborative problem sharing approach early on.

MEASURING AND RECORDING INNOVATION

The final stage of implementing a systemised innovation system was to develop a consistent means of recording and evaluating innovations, as part of the Project Management System. At project feasibility stage, the options are costed and an assessment made of construction risks and programme, so the effect of innovation can be quantified. However, there may be iterative or step changes in the design through the detailed design and consenting process, and there may be unexpected site conditions or other risks which when they eventuate change the cost or programme. Therefore, recognising the actual value of innovation requires some analysis.

An Innovation Register was developed to record the innovative ideas arising from the programme of works. This records the assessed savings in cost, programme or other (such as ease of consenting), at the time of the option workshop. The register also records the actual cost, programme, or other saving during construction. The register also requires commentary, and this is made up from a larger questionnaire about the implementation of the option, the risks, and how the option would have compared to other options considered.

The first project which had a significant innovation recorded through a specialist innovation workshop (prior to the tools) is currently being completed on site – the lead author will present actual outcomes at the Conference.

CONCLUSIONS

Subjecting the Project's QA processes to scrutiny by explaining them to a third party has identified some improvements, and has reinforced the value of developing a process-based system aligned with NSCC's processes.

The tools that have been developed are easy to use, and enable the project team to incorporate innovation tools into meetings easily as they have now been integrated as part of a 'business as usual' process. There are many approaches for assessing options in infrastructure design, but far fewer are in use for ideas generation. These tools are novel, in that they have been specifically designed with infrastructure problems and outcomes

in mind, and bring a structure for innovation across design and site problems as well as the traditional area where innovation is focussed, which is concept design.

Our experience to date has been that the tools and processes encourage buy in, and provide a good framework for encouraging divergent thinking in option identification and assessment. Innovation has already proven to deliver significant value to the council, its contractors and staff; through project cost reductions, increased efficiency and planning for better use of resources on site.

The innovation tools have been designed for wastewater, but would also be relevant to other water, and to transportation. With minor amendments they would be applicable to other infrastructure problems. We therefore believe they would be useful to other councils and infrastructure authorities in New Zealand, and the concepts would also be applicable elsewhere. In general, the authors believe that a structured approach to innovation has benefits in terms of both innovation and project management, and would encourage other authorities to identify and focus on key times for innovation within their projects.

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PHOSPHORUS, QUALITY AND ENERGY: CHALLENGES FOR THE WASTEWATER INDUSTRY

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ABSTRACT

At a time when the global community seeks to combat climate change through lower energy technologies and reduced natural resources consumption, improvements demanded in the quality of wastewater discharged to the environment necessitate ever increasing energy inputs.

Are these advances required in wastewater treatment coming at too high a cost in power and chemicals consumption? This paper provides an overview of wastewater treatment technologies, their development in response to water quality objectives and relative energy impacts with a focus on European practice in phosphorus removal.

The resulting nexus and potential conflict between improving water quality and combating global climate change is discussed. Key opportunities exist for participation by the wastewater industry in achieving water quality objectives within the European Union and for setting a socially and environmentally responsible example for others to follow. This will require improved participation and communication by an industry otherwise focused on science and engineering end of pipe solutions.

INTRODUCTION

Phosphorus is vital for human and plant life and has helped transform our society through modern agriculture. Most recently focus has been on its negative impacts in eutrophication of water bodies and the European Union (EU) has enacted legislation to combat this at a catchment level via the Water Framework Directive (WFD).

The UK Water Industry has predicted an increase in greenhouse gas emissions of up to ninety percent if water quality objectives under the WFD are to be achieved - primarily due to increased energy usage, chemical usage and sludge production. Yet, in order to meet challenging emissions targets, the industry must substantially reduce its carbon emissions.

This paper provides an overview of the origins and fate of phosphorus against the background of the WFD approach with a focus on the UK and Scotland. Its purpose is to provide a policy background and to challenge the reader and water industry practitioners to appreciate the wider issues - to consider the catchment approach intended and to realise opportunities for efficiencies in their support of and participation in the basin planning process. With this appreciation and a technical understanding of the key carbon impacts associated with phosphorus removal in sewage treatment, it is hoped that effective prioritisation of measures to address phosphorus can be developed with less reliance on more energy intensive end of pipe solutions.

PHOSPHORUS ORIGINS

Historically phosphorus required for animal and plant growth was available in soil structures and returned to these in the application of human and animal wastes. Modern day agriculture has broken this cycle and requires phosphorus to be added as fertilizer.

Forty percent of the world's phosphate rock resources lie in Morocco and Western Sahara; China has the second largest reserves and is the second largest world producer after the United States of America (U.S. Geological Survey, 2011). An estimated 90 years of viable resources remain based on current extraction rates and the potential for 'peak phosphorus' is increasingly recognised (Vaccari, 2009; Soil Association, 2010).

Phosphorus use is primarily in fertilizers and household detergents. UK domestic inputs by mass are illustrated in Fig. 1 below. Point source human phosphorus inputs comprise some fifty percent of total inputs to EU water bodies – the remainder is diffuse – though apportionment between sources is highly catchment specific (EEA, 2005).

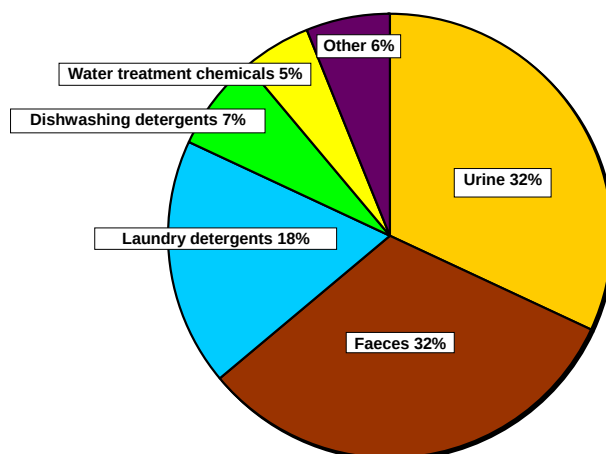


Fig. 1: Domestic phosphorus inputs by mass (Source: UKWIR, 2009)

Food related phosphorus intake, primarily through meat and dairy products, is estimated at 1244 mg/d per person - of which fifty to seventy percent is absorbed into the body (Food Standards Agency, 2003). Nutritional phosphorus requirements are estimated at 550mg/day (British Nutrition Foundation, 2009). As food additives¹ phosphorus compounds are increasingly added to 'improve functionality' in restructured meats, processed cheeses, instant and refrigerated bakery products (Jones, 2009; Uribarri & Calvo, 2003).

Definitive estimates of phosphorus apportionment between sources in catchments are lacking. These are highly catchment specific and characterised by poorly understood diffuse inputs. A recent study in Scotland suggests phosphorus loads from often poorly maintained rural septic tanks are likely to be a significantly underestimated source of diffuse pollution UK wide (Dudley & May, 2007).

IMPACTS ON WATER QUALITY

Phosphorus from fertilizer or slurries in excess of plant nutrient needs runs off with soil into watercourses due following rainfall. Septic tanks and sewage treatment discharge phosphorus in effluents during wet and dry weather. Resulting elevated phosphorus concentrations can lead to eutrophication - the enrichment of water bodies by nutrients causing an accelerated growth of algae and higher forms of plant life which causes undesirable disturbances and which can result in loss of aquatic life (OJ L, 1991).

Recent focus on seasonal river concentrations has suggested that, in the UK, soluble reactive phosphorus from sewage pollution (STW and septic tank effluent) represents a

¹ With some sixteen phosphorus containing 'E numbers' to be counted at <http://www.food.gov.uk/>.

more significant issue than agricultural pollution phosphorus which tends to be less bio-available and more prevalent as a result of high rainfall storm runoff when eutrophication is less of a risk (Jarvie et al., 2006).

THE EU LEGISLATIVE RESPONSE

The issue of eutrophication from phosphorus is addressed by EU Member Countries through various legislative controls focused on source reduction and treatment. Once transposed by Member States, these are binding under EU law.

Source Reduction

While a number of member states had already banned phosphates in laundry detergents², the EC has recently proposed a ban on phosphates in laundry detergents from 2013 (EC, 2010). In the UK phosphate containing detergents have a seventeen percent market share and while consultation for their phase out is ongoing it seems unlikely to bring any imminent result. Neither the EC ban nor UK proposals concern dishwashing detergents which include dishwasher tablets and comprise an estimated seven percent of phosphorus in domestic sewage – with dishwasher use also predicted to increase (UKWIR, 2009).

Although increasing attention is being given to dietary phosphate intake and the health effects of an increasing number of phosphorus containing food additives, evidence suggests intake will further increase due to increasing consumption of meat and fast foods (Uribarri & Calvo, 2003).

Diffuse Pollution from Agriculture

EU member states have instigated various mechanisms for control of diffuse pollution from agriculture. Within Scotland, General Binding Rules have been developed under the Water Environment (Diffuse Pollution) (Scotland) Regulations 2008 and cover activities which may result in diffuse pollution including agriculture.

The Scottish Environmental Protection Agency (SEPA) has proposed a two tier approach for enforcement - a national awareness campaign and identification of priority sub-catchments to be targeted in the first basin planning cycle (2009 – 2015). SEPA are presently³ assessing the extent of diffuse pollution through measures such as on-the-ground river walks but it is clear that diffuse pollution identification and management - despite likely to be contributing significant phosphorus loads - is in its formative stages.

Sewage Treatment

End of pipe phosphorus reduction is achieved through the Urban Wastewater Treatment Directive (1991/271/EEC). This sets nutrient limits on STW discharges for works greater than 10,000 population equivalent⁴ (PE) discharging into sensitive areas subject to eutrophication, requiring a 2mgP/l total phosphorus concentration on an annual

² EU Member States Belgium, Germany, Ireland, Italy, Luxembourg, Netherlands and Austria have all banned phosphates in laundry detergents.

³ See <http://www.thecourier.co.uk/Living/Outdoors/article/5350/perthshire-s-waterways-under-scrutiny-from-sepa.html> - though one to one discussions with landowners found to be in breach of general binding rules on diffuse pollution have been delayed in this catchment until late 2011.

⁴ With one PE equivalent to 60g BOD per person per in day raw sewage in UK design standards.

average basis or a minimum eighty percent reduction in incoming load. For STWs of greater than 100,000 PE, a 1mgP/l limit is applied (OJ L, 1991).

Since the Directive's introduction in 1991, UK Water Companies have implemented significant reduction of phosphorus loads; effluent phosphorus discharges to the Thames have reduced almost ten fold in the last twenty years (Colin Neal et al., 2010).

WFD – A River Basin Approach

The Water Framework Directive (2000/60/EC), introduced in 2000, is considered the most significant international water legislative instrument to be introduced to date. It establishes a framework for the protection and improvement of water bodies, promoting sustainable use and protective management measures and is novel in its requirement for economic analysis of water and for full public participation in the development of river basin management plans (OJ L, 2000). Member countries are required by 2015, through river basin planning, to achieve 'good' status in all surface water bodies – unless this is disproportionately expensive⁵.

Perhaps the most important concept of the WFD for the water industry is that, following data gathering and assessment, it requires the prioritisation of key measures to address pressures on water quality status at a river basin and sub-catchment level and it requires stakeholder participation.

In the EU, eutrophication from phosphorus emissions is identified as a key catchment pressure and river basin management plans (RBMPs) require its reduction from point and diffuse sources. While there is evidence that regulators are developing the means to apportion and assess the relative contribution of phosphorus from point and diffuse catchment sources, this process is in its formative stages and a significant impact of the WFD has been new or tightened phosphorus standards for STWs. In England and Wales, the WFD is expected to require some thirty percent of STWs to introduce phosphorus removal (EA, 2009).

PHOSPHORUS REDUCTION IN WASTEWATER TREATMENT

Where an end of pipe solution is required, phosphorus removal at STWs is enabled with a combination of biological, chemical and physical removal processes.

Enhanced Biological Phosphorous Removal (EBPR) uses selection of specialised microbial populations capable of storing phosphorus in excess of their metabolic requirements, with the resulting captured phosphorus wasted as sludge (WEF, 2011). This is achieved through the provision of anaerobic and aerated aerobic treatment zones. There are no EBPR plants in Scotland though there are elsewhere in the UK – however biological removal remains challenged by dilution through infiltration and inflow resulting low organic loads and by winter sewage temperatures (Black & Veatch, 2009). Where installed, combined biological and chemical phosphorus removal may be required as well as supplemental carbon dosing to enable sufficient carbon for treatment.

While historically, UK catchments have transported combined storm and sewage flows to treatment, new developments do have separate storm and foul sewers and increasing focus is for removal of storm flows. Infiltration problems remain, however, and in

⁵ There is plenty of UK discussion concerning disproportionate costs in the WFD but no examples of determining this in practice. See Proceedings of the 4th European Water and Wastewater Management Conference, edited by Horan, N.J. Aqua Enviro, September 2010.

Scotland infiltration flows in combined sewer systems can account for many times the volume of foul sewage to be treated. For this reason chemical phosphorus reduction remains the only option for phosphorus removal throughout Scotland and is widely used throughout the UK.

Chemical phosphorus removal occurs through precipitation, surface complexation and solid-liquid separation due to dosing with hydrous metal oxides – commonly iron or aluminium (WEF, 2011). Iron is most widely used in the UK. The reaction consumes alkalinity and in addition to removing phosphorus, enhances removal of solids as sludge in settlement stages.

The requirement for metal salts dosing for phosphorus removal and as a coagulant in drinking water treatment applications has resulted in metals effluent standards being introduced and these alone may introduce a requirement for tertiary filtration to at some STWs. Phosphorus consents below 1 mg/l may also require tertiary filtration and such tertiary treatment stages retrofitted to existing STWs typically require re-lift pumping of all flows with substantial operating cost impacts.

PHOSPHORUS REMOVAL AND THE GREENHOUSE CHALLENGE

Chemical phosphorus removal, widely used in the UK, increases energy and material requirements at STWs. The net increase in carbon emissions due to phosphorus reduction for WFD compliance is estimated at between twenty five to fifty percent in work by the Environment Agency (2009) though is highly dependent on the size of STW.

Yet in the face of WFD compliance, and corresponding emissions increase, the UK Water Industry is expected to achieve reduced carbon emissions.

The WFD makes no explicit mention of climate change and while future 2015 basin plans require ‘climate proofing’ the focus is on climate change impacts on water quality rather than the WFD impact on climate change. However, WFD objectives are to be met at least economic cost by taking into account the economic valuation and uses of water. Within the UK water industry, carbon accounting and trade has recently been introduced - with authorities required under the Government’s compulsory CRC Energy Efficiency Scheme to report on and purchase permits for their expected emissions annually (DECC, 2010).

EU member states have also committed to a twenty percent reduction in greenhouse gases below 1990 levels by 2020 and are required to meet renewables targets. With considerable renewables potential, the Scottish Government have recently revised their national target from fifty percent renewable energy to eighty percent by 2020.

UK Industry response

Scotland’s RBMPs developed under the WFD do not quantitatively consider climate change impacts of planned measures and the likely process for future prioritisation of planned measures considering economic (and carbon) costs is far from clear.

The Environmental Agency of England and Wales (EA) in a recent report *Transforming Wastewater Treatment to Reduce Carbon Emissions* outlines five key strategies to mitigate increases in emissions due to WFD compliance:

- Source control – recognising the greatest carbon savings but also the lack of control Water Companies have here.

- Low carbon process solutions – continued end of pipe treatment but at lowest carbon cost possible.
- Greater operational efficiencies –improved aeration control, reduced treatment of storm waters, reduced infiltration through catchment intervention.
- Redevelopment of existing treatment processes – to less conventional lower energy technologies.
- Renewable energy generation – increased adoption of anaerobic digestion, other on-site generation opportunities such as hydroelectricity.

In considering compliance with the WFD and two scenarios of varying emissions reduction, the EA concludes that net emissions can be reduced - but only with a catchment based approach (EA, 2009).

Recycling phosphates

A further possibility to offset of carbon emissions when considering phosphorus is its recovery through recycling as fertiliser. There is no EU requirement for P recycling other than for general beneficial reuse of sludges and wastewaters where possible (EC, 2006; OJ L, 1991). This section provides a broad overview of considerations only.

Recovery could be as urine, as sewage sludges or in effluent reuse. Agricultural slurries are already widely spread on land in the UK, increasingly regulated through diffuse pollution policies. An issue with sewage derived sludges is the availability of local land banks for spreading given potential competition with farmers' spreading (Scottish Water, 2006). In addition, while balancing soil nutrient needs is relatively straight forward for inorganic fertilizers, it is more complicated for organic P in sludges where application of sufficient N may result in consequent build up of excess P in soil due to nutrient ratios if not managed correctly (Boesche et al., 2001).

With fifty percent of total household phosphorus excreted in urine in just one percent of waste volume, separation of urine at source as fertilizer has been adopted in Sweden. Studies conclude that, though not without its social challenges, urine separation and direct application as fertiliser is a lower energy alternative to sewage treatment and conventional fertilizers (Jonsson, 2001).

Once incorporated into sewage, phosphorus can still be recycled as struvite through sidestream processes or recycled to land as fertilizing biosolids. Struvite production at a UK works recently began in Slough – however the process can only be adopted where biological and not chemical phosphorus removal is undertaken (Thames Water 2010). The agricultural benefits of chemical P sludge application to land are yet to be confirmed – with precipitated phosphorus less bioavailable to plants (Hislop, 2008).

While unplanned indirect potable reuse has been widely practised in the UK⁶ no agricultural irrigation schemes exist – though reuse is an increasingly hot topic in water stressed Southern England.

The great sludge debate

Scottish Water's carbon footprint, somewhat higher than the rest of the water industry, shows thirty five percent of all emissions as a result of sludge transport, treatment and disposal – sixty six percent of this in electricity (Scottish Water, 2010). With chemical

⁶ As the River Thames Alliance remind visitors, a drop of rain falling in the Cotswolds will be drunk by 8 people before it reaches in the sea.

phosphorus removal increasing sludge production, this has considerable implications for sludge management and carbon footprints.

Sewage sludges in the UK are mainly disposed of through recycling to land following anaerobic digestion (AD) or incineration (Water UK, 2010). While incineration of sewage sludges is widespread, increasing attention is being given to digestion for enhanced power generation – identified by the EA as essential for emissions reduction in achieving WFD compliance (EA, 2009).

In addition to issues surrounding sewage sludges management and reuse⁷, key carbon impacts are summarised in Table 1 below assuming chemical phosphorus removal. The degree of interactions and importance of site specific treatment and disposal routes is evident; meaningful options evaluation and emissions assessment has to be site specific.

Tab.1: Relative carbon impacts of increased chemical phosphorus sludges

Increased ↑ GHG emissions	Reduced ↓ GHG emissions
Increased volume of sludge to be managed – associated embodied, opex carbon including transport	Potential for on site anaerobic digestion (AD) increases with increased sludge volume.
Reduced thickening capabilities of chemically dosed sludge – even larger volumes to manage	Increased removal of organics during primary settlement = enhanced biogas potential in AD
Increased percentage of inert solids in primary and secondary sludges = increased aeration costs, lower energy potential in AD or incineration	Increased removal of organics during primary settlement = reduced aeration costs.
Reduced fertilizer value of chemical sludge – requires more artificial fertilizer use than with non chemical sludges.	

CHALLENGES FOR THE WASTEWATER INDUSTRY

From the preceding discussion, it seems clear the Water Industry has commitments to reduce its carbon footprint while increasing the levels of phosphorus removal and that it has a role to play in economic analysis of treatment alternatives for prioritisation of planned measures: the resulting measures must enable *improved water quality*. This will be challenging for the industry because:

- Significant catchment pressures are from sources the industry has had little historical interaction with - diffuse pollution, human consumption and detergents.
- While significant diffuse agricultural phosphorus pressures will be identified and should be prioritised in WFD planning, this process will be slow and point source sewage discharge will remain a concern.
- Little is understood of the proportion of diffuse pollution from septic tanks yet this information is required on a catchment basis for prioritisation of measures.
- Nutrient balances on a catchment basis will be required to prioritise measures to improve water quality at least cost.

⁷ Including health impacts, heavy metal residuals, hormones and other emerging pollutants of concern.

- The lowest emissions solution to phosphorus in watercourses is reduction at source; the highest emissions solution is in complying with end of pipe phosphorus removal in STWs.
- The implications of chemical rather than biological phosphorus removal are worse from an emissions and reuse perspective but remain the reality for countries like Scotland with weak sewage strength.
- There is significant scope for reduction of STW energy consumption through improved process operation and control, heat and power generation from AD.
- There is scope for beneficial agricultural use at various stages of P removal from sewage. This could in part replace artificial fertilizers and fossil fuels reliance.

Given the above the industry's role in the effective reduction of phosphorus pollution in watercourses for the water industry is, perhaps, less clear. Significant phosphorus inputs appear beyond their control; the most obvious solutions appear to be upstream of STWs. Yet the catchment approach afforded by the WFD offers key opportunities for participation in delivering the most effective methods of nutrient reduction.

Source reduction through WFD basin planning

The water industry acknowledges a lack of control over source reduction (EA, 2009). While this may be the case it is suggested that only with the knowledge of the industry, its treatment costs and wider sludge issues, can the WFD assess on a catchment basis the relative importance of measures to best achieve required water quality objectives.

In England water regulator OFWAT has on rare occasion allowed funding for catchment management schemes proposed by Water Companies (Hislop 2007). With such participation and action by the water industry, meaningful catchment projects can be developed in place of, or to compare with, end of pipe phosphorus reduction solutions.

The process must be iterative - apportionment of emissions between diffuse and point sources is largely a balance of diffuse versus sewage emissions and, as focus on point source sewage pollution continues to reduce P emissions, the net relative importance of diffuse sources increases (EEA, 2005). Only by participation will the Water Industry ensure the Regulator has the information required to achieve such adaptive management.

Catchment based phosphorus balances

Watercourse nutrient loads are assessed regularly in the licensing of discharges; there is a need to extend this to catchment based nutrient assessment by considering diffuse source pollution. With significant monitoring and data collection required under the WFD and the resultant development of interactive water quality mapping tools, the makings of a catchment scale nutrient assessment exist already and must be developed to enable the required prioritising of planned measures to improve water quality at least cost.

Challenge the need for treatment

When faced with the requirement for a STW improvement, current practice would see a solution promoted by the designers after whole life cost assessment of alternative treatment options. During this stage, an opportunity has to be recognised for a better informed assessment of options including a no-action option or a re-allocation of funds elsewhere to a more effective catchment water quality solution. Only when sufficient

information becomes available in project development is this assessment likely to be possible and there must then be a forum for challenge of the catchment solution.

Challenge the process solution

To succeed as a lower carbon wastewater industry and mitigate the impacts of phosphorus reduction and WFD compliance, significant efficiencies must be made at STWs. This must include challenge of the degree of treatment required, flexibility in licenses, and the pursuit of low energy construction and operational solutions. Lack of data should not drive a risk adverse approach in design and the designer must take responsibility for challenging design norms and adopting new technologies to enable emissions reductions. With carbon accounting now entrenched in the UK Water Industry, carbon assessment of treatment options and specific plant options including low carbon alternatives must be undertaken to justify all elements of design. The industry must develop necessary tools for designers to have at their disposal for this purpose.

Process design for nutrient and energy recovery

Identification of suitable reuse options for biosolids, effluents and energy will allow more informed design choices to be made. A catchment level approach in line with biosolids strategies will help enable the consideration of nutrient recycling. However, the scale of treatment possible, available land bank, competition from farm slurries and lack of effluent reuse options may remain barriers to nutrient recycling (SW, 2006).

CONCLUSION

The human relationship with phosphorus is interesting. As a non-renewable resource, our major phosphorus use in fertilizers is heavily reliant on fossil fuels, is set to increase to meet global food needs – and yet significant excess amounts applied to soils are lost at the expense of diffuse agricultural pollution. At the same time, humans consume and excrete increasing amounts of phosphorus through changing diet and additives – with this also set to increase with development.

Unfortunately, we have identified a key water quality issue the result of our phosphorus emissions and we are now attempting to address this – the net impact of which will be increased carbon emissions with a number of interdependent impacts on wastewater treatment, energy generation and sewage sludge management.

This paper has attempted a broad discussion on the phosphorus issue, the EU legislative response and the resulting challenges for the UK water industry. To participate in effective management of our anthropogenic phosphorus problem without further contributing to climate change, water industry practitioners must bravely step outside their site boundaries, understand phosphorus inputs and interactions, appreciate the catchment approach and engage effectively with regulators and customers to allow most effective management of sewage, nutrients and water quality.

Opinions herein are the author's and not necessarily views of Jacobs Engineering.

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CONNECTING THE DOTS: THE VALUE OF SYSTEMS THINKING IN SUSTAINABLE OUTCOMES

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ABSTRACT

Achieving sustainable outcomes on projects increasingly requires a holistic, integrated view of its context risks and challenges. Applying systems thinking is an effective approach that encourages the full context and wider environment to be understood, and recognises the inter-dependencies between the elements of the project. Such an approach fosters sustainable outcomes through more integrated solutions with multiple benefits. This particularly applies to complex, multi-faceted engineering projects.

This paper will present a series of practical tools for applying a systems approach coupled with case studies of how they have been applied to a range of projects, including mining, highway design, power stations and water pipelines.

The impacts from applying the tools and structured process include re-thinking the project boundary, recognising inter-dependencies and relationships between issues that at first did not appear to be closely connected, and understanding the multiple dimensions (social, environmental, economic, legal, technological) of key issues that can influence our approach to resolving them. Many of the examples demonstrate the link to innovative thinking that was only identified by taking a broad view, challenging existing assumptions, and looking for more holistic solutions that deliver multiple benefits

Why the need of Systems Thinking?

A system can be defined as a “set of interacting units or elements that form an integrated whole intended to perform some function” (Skyttner, 2001). Systems thinking is a holistic approach to analysis that focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems (Miller-Williams and Kritsonis, 2010). In world of increasing complexity and interconnectedness the traditional singular and linear approach to analysis (common to a range of disciplines including engineering and sciences) are no longer adequate to understand and to conceive of approaches to deliver sustainable outcomes for our environment, our society and our economies. Systems thinking is an approach that enables humans to understand complexity and identify the potential leverage points that will enable positive change.

Within the context of engineering planning, design and delivery, understanding the systems and context in which a project is operating is pivotal to understanding of what is possible and informing decisions and what can be done to achieve these goals and aspirations. Systems thinking and the tools discussed in this paper enable dialogue between and across different technical disciplines, enables a broader range of perspectives to be taken into account including end users, affected community stakeholders, asset owners, funders and operators.

How does Systems Thinking enable sustainable outcomes?

The commonly used definition of sustainable development was first described in the report for the Brundtland Commission (World Commission on Environment and Development), *Our Common Future* (1987) “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 43). This definition highlights some of the key considerations in determining a pathway for sustainable development including the consideration of needs of both the present and future generations, and by extension of the limitations of the environment to support economic growth and consumption. This definition and the concept of triple bottom line sustainability includes consideration and integration of the complex environmental, social and economic systems. Thereby by definition the identification of deployment of sustainable action requires an application of systems thinking.

Sinclair Knight Merz (SKM) a leading projects firm with global capability in engineering, sciences, strategic consulting, design and delivery has developed a number of simple applied systems thinking tools as part of the Sustainability by Design© toolkit. The following describes the tools, how they are applied and provide details of the insights and lessons learned during practical application of these tools.

The Systems Mapping Tool

The systems mapping enables a group of stakeholder to develop a shared and deepened understanding of a project. The exercise involves determining the key elements of a system and the different forces and influences at play within that system and enables understanding the current project context.

Consideration of Scale

Understanding the different scales and hierarchies of systems helps to build understanding of context. Thinking about a particular problem or issue at a single scale for instance within the boundary of a site, cannot provide a full understanding of the context, because the system will always sit within an larger set of forces and influences. A new piece of infrastructure for example does not start and stop at the site boundary. Connections to adjacent infrastructure need to be made, planning and consultation will be required within the local region, state and federal laws may apply and so on. Not taking into account the impacts from and to different parts of the system at different scales may prevent a full picture of the system and may lead to different decisions being made.

The systems mapping activity provides a systematic review of influences at different spatial scales to ensure that a fuller understanding of the potentially shaping forces on the project and the ramifications of the project are understood and taken into account. The systems mapping tool was applied by SKM to a new geothermal energy project in Olkaria, Kenya. SKM was commissioned by our client KenGen to oversee the engineering, procurement and construction management for a new geothermal power plant exploiting the geothermal resources of Kenyas Rift Valley. As part of the initiation of activities for the project a systems mapping exercise was undertaken with the project and client team to draw out and communicate the full knowledge of the project context from the group. The exercise allowed the participating group to understand the local system associated with the project including the key pieces of infrastructure required, the impacts to local communities including the nomadic Masai and the environment

including nearby Hells Gate national park and waste water discharge to Lake Navaisa. At a regional scale the impact of new additional supporting infrastructure such as roads and power connections provided potential opportunities for development for the local community, at a national/international level the opportunity for energy security and not being beholden to international resource prices and to sell energy to neighbouring Tanzania and Uganda. Although the systems mapping exercise is about understanding the current state of play, understanding the full context helps the teams to conceive what the full suite of opportunities and influences that might be available in identifying key scoping and design solutions. Experience suggests that solutions to many project challenges lie outside the ‘traditional’ project boundary. Examining connections across a wider scale, and understanding upstream and downstream connections to the project provides additional options for developing more sustainable solutions.

Enabling direct team dialogue and diversity of thought

The “mapping” of key elements and influences as part of the systems mapping approach also enables direct dialogue between team members, to share their perspectives and knowledge. Drawing together a diverse range of skills and perspectives enables a fuller understanding of the context for a project and deepens the collective and individual knowledge of the participants. Developing the “systems map” using “white hat” thinking as described in DeBono (1985) (which encourages facts rather than options or suppositions), allows rapid parallel processing and capturing of information as it is not about debating or challenging what is said, but encouraging questions which unearth the knowledge of the group and capturing what is known in a visual “map” of the key elements of the system. The systems mapping exercise for the Olkaria project which included a range of engineers, scientists, accountants, financiers, project sponsors and environmental and social scientists. Statements such as “I hadn’t realised we’d need to build roads for construction” (by a financier) or “I can see that the project will have significant impact on local communities” (by an electrical engineer) are often heard during a group discussion of the systems map.

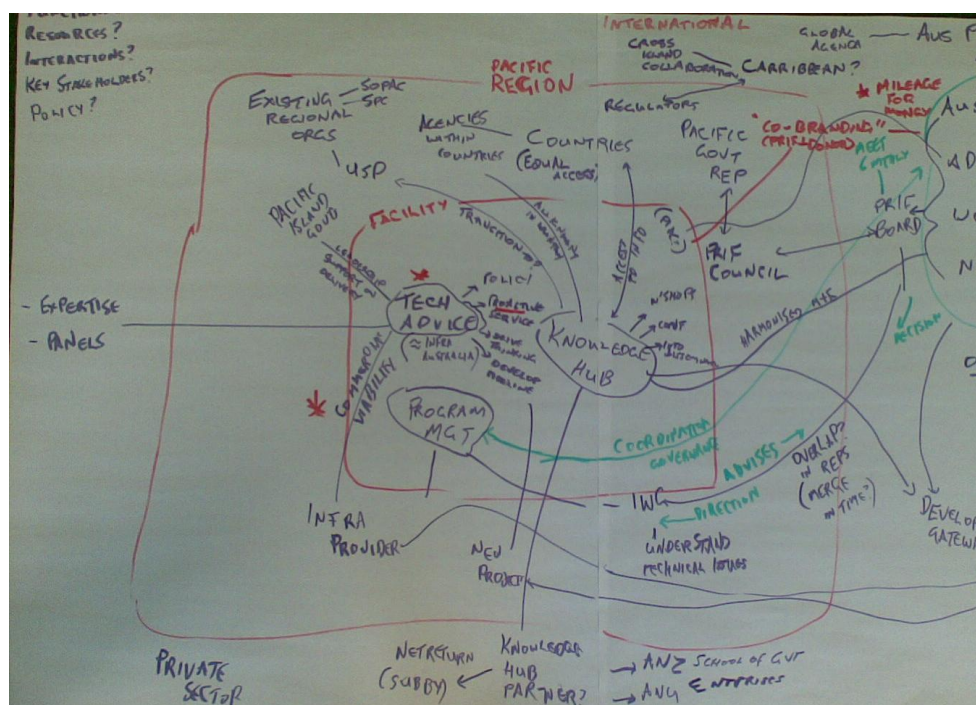


Fig. 1: Image of Systems Map – developed in 15 mins by group of 8 people

The systems map and utilisation of systems thinking enables the project team to take a step back from the (technical) details of a project to have a look at the big picture and see the full range of opportunities and challenges, the interconnections between seemingly disparate elements of a project, an example of a systems map generated by a group of group of 8 people in the space of 15mins is show in Figure 1. This exercise is a systematic approach that helps to overcome three often observed biases within the scientific and engineering professions. They are the bias towards jumping into technical detail, to working in ‘silos’ with similar disciplines, and the bias towards going straight to solutions.

The Issues Wheel Tool

Another systems thinking tool used by SKM as part of our Sustainability by Design© toolkit is the issues wheel. This tool looks at developing a causal relationship map of the potential issues and opportunities associated with a project. Figure 2 shows a blank template that promotes thinking across issues and across time, the adjacent image in Figure 2 shows a completed issues wheel with connections across categories. The Issues Wheel requires the project team to think about what might be, and builds on what is already known about the project.

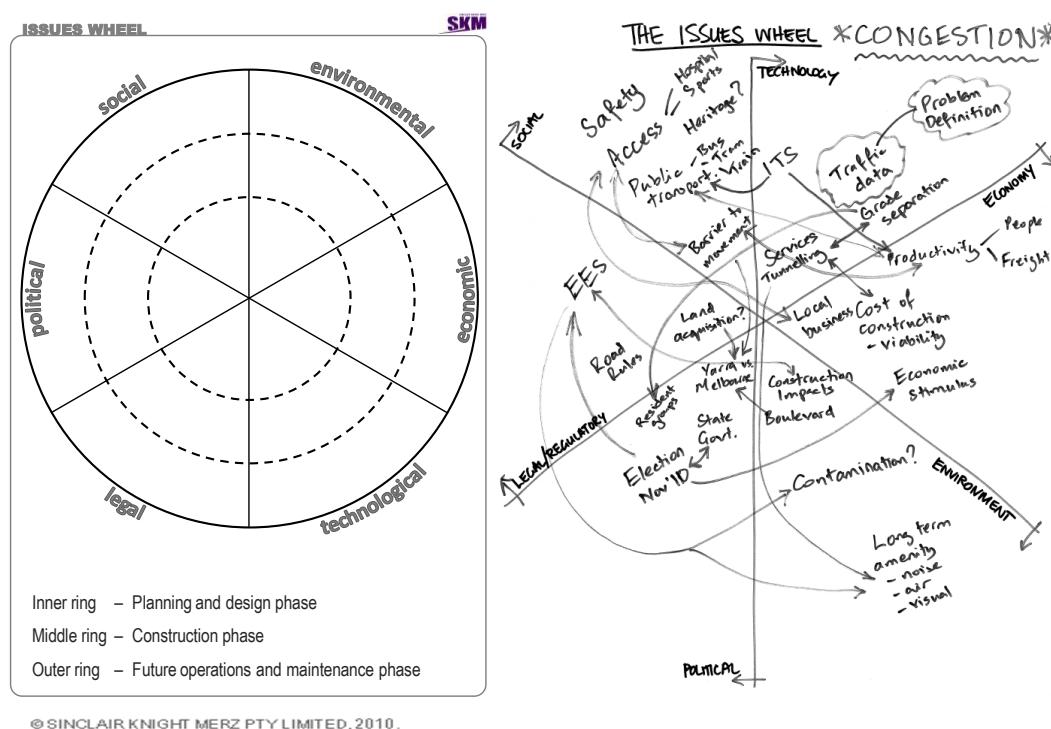


Fig. 2: Issues Wheel Template and Completed Issues Wheel

Simultaneously identifying risk and opportunity

The issues wheel requires the use of a certain amount of green hat and black hat thinking, as described in the DeBono (1985) six-hat thinking terminology. This means that project teams are encouraged to optimistically to identify opportunities (green hat), and to also consider the risks or what might go wrong (black hat). This enables the team to identify new and unforeseen opportunities along with the unforeseen risks and challenges. Using these opposing perspectives in combination helps to bring a balanced perspective in the evaluating the project opportunities, whereas traditional approaches to

risk assessment exhibit a bias towards risk and an inherently defensive way of engaging with a project. Think for example about a common risk matrix which includes axes of “consequence” and “likelihood”, although consequence can be positive it is most often expressed in terms of number of deaths, injuries, cost, loss of species and other equally negative consequences. Outcomes of the issues wheel may identify potential “stretch” goals for the project along with key risks and challenges.

Another advantage of thinking about risk and opportunities simultaneously is the opportunity to translate potential risks into opportunities for the project, as opportunities can be the flip side of risk. For example in a power transmission project in Western Australia, applying the systems thinking approach to the project identified the ‘risk’ of community opposition to the new transmission line. However, through thinking about how the communities could be engaged and potentially turned into a supportive asset for the project and client organisation, an approach was conceived which not only informed communities about plans but engaged them in planning and design. This approach led to better decision making with respect to environmental and social assets for the community, identified new potential routes which were acceptable to the community, generated a great deal of good will between the project proponent and helped the project process without objection without a lengthy EIA process due to the unprecedented local community support.

This example of how a risk can be turned into an asset for a project is also part of systematic approach that SKM is applying through the sustainability by design toolkit. In coaching project teams at the outset of a project to think about how to work their way up the hierarchy of “making a problem worse”, “improving a problem”, “eliminate a problem” or “turning a problem into an asset” through design, can help shift thinking from risk to opportunity and help project teams to see what might be possible.

Multi-dimensional thinking is required

The issues wheel is comprised of social, technological, environmental, economic, political and legal dimensions. Explicitly identifying these dimensions and using them as a stimulus for identifying key issues and opportunities helps to generate a diversity of thinking and identify perspectives of various project stakeholders. For example issues and opportunities relating to the social dimension might identify the needs of end-users, local communities or other segments of society. Understanding the views of these stakeholders (and what a successful project might look like for them) enables a more holistic understanding of the opportunities and can not only help deliver the primary benefit which is being sought by the project proponent, but deliver ancillary benefits including brand and reputational benefits, community, environmental and economic benefits. Additionally, by tracking how the issues identified relate to other dimensions additional benefits can be identified, and assumptions challenged. For example, de-watering was a significant issue for a major uranium mine, where

The process of systematically reviewing the issues and opportunities across the different domains also ensures we draw upon thinking that is outside the range of our traditional core areas of expertise. For example, involvement of a waste specialist in a mining and rail project in Africa scoping session identified a waste from nearby cities to energy opportunity as a reliable and long term energy source for the port infrastructure. This would contribute to regional development, as well as result in multiple environmental and cost benefits. Many participants in such activities indicate the value

gained from working with diverse expertise and disciplines, and the rich perspectives they bring.

Identifying the causal relationships

A key element of developing a complete issues wheel and utilising a systems thinking approach is understanding the causal relationship between different opportunities and issues i.e looking back at the root causes of particular issue and forward through to the flow on consequences. This approach enables a deeper understanding of issues and opportunities and enables an understanding of not just the symptoms, but the root cause. It also enables a review of potentially perverse consequences which may result from actions.

Identifying the relationship between various issues and opportunities enables solutions which tackle the root causes and not just the symptoms, but it can also identify positive feedback loops, or when a particular activity or issue might have multiple benefits. An example of where the root cause was identified and tackled in this way relates to a waste water (sewage) pumping station in Western Australia, which was required to pump the treated effluent up over land and out to sea. The pump station was at capacity and becoming unreliable with occasional break downs, and there was a real risk of increased wastewater spills and overflows. Part of the issue was that pumps require ‘compensation basins’; a basin that holds any overflow and spills to prevent pollution reaching nearby residences.

These occupied significant area of the plant site, but were only required in emergency situations. The plant and pipeline are surrounded by sensitive land uses – including significant bushland with active community groups, hospitals, nursing homes, schools, day care centres and a University that had taken legal action in recent years against the water authority for spills and odour. The site was also located in an urban, fully developed catchment, where land prices are high, and with no opportunity to acquire additional land for future expansion. The systems thinking tools encouraged the team to ask the questions: What will improve the long term operational efficiency? How can this project contribute to improving the plant’s function into the future? The assumption was challenged that simply increasing the size and number of the pumps was the best solution.

Instead of the traditional approach of pumping treated effluent to the coast, a gravity fed process was identified that would deliver:

- No energy consumption, or Greenhouse Gas emissions - pumps are not required
- No need for large areas for the compensation basins to accommodate spills – which results in a more efficient site footprint and land available for future plant expansion
- Highly reliable – gravity does not ‘fail’ (ie no electricity ‘outages’ or failures), therefore very low risk of any effluent spills, and

A simple solution – simple to operate and maintain.

Our solution had greater flexibility to adapt to changing water treatment technologies by occupying a fraction of the site area compared with other design options.

Incorporating the dimension of time

The ability to project forward and think about how things will change over time is also a critical aspect of understanding systems and determining the actions which will contribute to sustainable outcomes. The issues wheel tool uses multiple time scales as

lenses in which to think about how issues and opportunities change over time. Time scale can be selected including design, construction and operations or now, 10 year time, 30 years+, this enables not only potential future outcomes to be thought about but also to identify the drivers of change which will influence a project over time.

This thinking was applied to a road rail grade separation, which aims to remove a local level crossing and which intended to build a new bridge over an existing set of tracks. A key question identified was “what will the rail corridor look like in 50 years time?” The timeframe was well within the design life of the proposed structure and hence was a very relevant question. Through group discussion, key issues such as population growth, future passenger rail expansion and the role of freight transport in the corridor were identified. Given the potential and anticipated growth in these areas, the design team realised it was important to design in future flexibility into the design, to prevent potentially costly (financially, environmentally, and socially due to road and rail service disruption) reconstruction and redundancy of the proposed structure or without “locking out” the future expansion of rail in the corridor. The subsequent design allowed provision for additional track width, and excavation of the rail corridor as required, and put in place structures that would support a large span. All this was done against a backdrop of reducing the capital cost of the bridge so as to not make the project financially unviable and to provide a high level of function both now and in the future. By taking a systems thinking approach, incorporating the dimension of time and how things were likely to change in the future, a road project catered for future expansion of population, passenger and freight services without compromising the viability and functionality of a current project.

This thinking can equally be applied to the time dimension within a project lifecycle. As part of the expansion of a defence force facility located in a residential neighbourhood, concerns over operational noise impacts from the base lead to design of a noise-wall to reduce noise. In thinking through the key issues and opportunities across the project lifecycle, including design and planning, construction and operation it was identified that the same noise wall could be used to reduce nuisance noise to residents during construction, which in turn lead to a change in project sequencing with the noise wall being first infrastructure built. This simple change in programming, stimulated by thinking about impacts during different project phases, helped substantially reduce noise to adjacent residents.

Challenging the project boundary

The use of systems thinking tools at the outset of a new project enables a project team to understand the broad context. By taking a “step back” from the detail before going to potential solutions, the full suite of opportunities start to emerge. It is common that many of the solutions lay outside the normal boundary of the project. By reviewing the “cross-boundary” interactions a range of new opportunities can start to emerge. A factory in suburban Melbourne was looking to reduce the water consumption of its plant, and a number of water efficiency measures were introduced to enable some substantial savings of water. One opportunity identified was to utilise the 4 hectares of roof space on site to harvest water. However on first glance it was considered not possible due to the lack of storage space and the quality of water required to make its products. The team took a step back and examined the broader system. This identified the potential to capture rain water for storage and use by the adjacent school, where ample space was available and the water could be used for flushing toilets and irrigation of playing fields. Although the capture of rainwater did not lead to substantial direct savings for the manufacturer, the total net saving of water for the school and the

manufacturer combined provided a substantial saving at low capital cost (significantly outweighing the efficiency measures in terms of return on investment) and provided an educational opportunity for students at the adjacent school. This example also demonstrates how a systems thinking approach can help facilitate outcomes which are effective as well as efficient.

Outcomes of application of the tools through workshops

Group application of tools and systems thinking approach has a range of benefits over a traditional meeting or reflection by an individual. The process enables a collective sharing of information, brings different perspectives and enables group problem solving.

Visualisation of Discussion

The building of the systems map and the issues wheel usually occurs on whiteboards or flipcharts. The drawing of these maps by facilitators and group members allows a live capture of thoughts and visual representation of the discussion. This ensures both an accurate portrayal of the groups thinking (as it can be seen where someone feels like their point was not captured accurately) and can represent the complex interplay of systems, in a way that language (which is linear form of communication) or text alone cannot. This approach not only helps the participants to remember discussion, but to take in complexity.

Giving every participant a voice

Another effective technique to implementing the system thinking tools is to use small breakout groups to develop the systems maps. Working in small groups of 2, 3 or 4 enables (and compels) participation in the discussion. This approach ensures that every workshop participant has the opportunity to contribute. This can be particularly useful where hierarchy and perceived power differentials (derived from gender, seniority or culture) are apparent, or where groups have a number of introverted personality types (as can often be the case in engineering and scientific professions). Participants may not contribute for fear of contradicting senior figures. Recent workshops where the tools were applied in Kuala Lumpur with a team comprised of SKM staff from Australia, the UK, Thailand and Malaysia, highlighted the value of this approach. In plenary discussions many of the participants were quiet and reserved in voicing their opinions. However, in break-out sessions the discussions and opinions flowed more easily. When reporting back to the group on the outcomes of the break-out session, the group representative could report back on behalf of the group, rather than represent their individual opinion.

Synthesis of information

In discussion the key issues in breakout groups and collectively, information can be collected from a number of disciplines and perspectives. The conversations, the visual recording of information and the filtering of key connections and outcomes enables all this information to come together, it enables the group to safely shift their ideas to a new common ground and also builds ownership of the discussion, the outcomes and actions coming out from that session.

Conclusions

The impacts from applying the tools and structured process include re-thinking the project boundary, recognising inter-dependencies and relationships between issues that at first did not appear to be closely connected, and understanding the multiple

dimensions (social, environmental, economic, legal, technological) of key issues that can influence our approach to resolving them. Many of the examples demonstrate the link to innovative thinking that was only identified by taking a broad view, challenging existing assumptions, and looking for more holistic solutions that deliver multiple benefits

The word “Sustainability”, which is often misunderstood and frequently misused, and some audiences can struggle to see its relevance to project challenges and risk. However, it is worth noting that without even without deliberately steering towards “sustainable” solutions, or using the word project teams will come up with new, valuable and sustainable solutions simply by encouraging systems thinking, includes multi-scale, long term thinking across a range of domains including environmental, social and economic.

Not only can systems thinking tools help to identify new and innovative solutions for individual projects, the deliberate and consist application of this approach by sustainability and engineering professionals helps to build a competency in systems thinking. A competency which will be required to understand and deliver the engineering and scientific approach of the future.

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CAPACITY BUILDING IN SCIENCE TECHNOLOGY AND INNOVATION (STI) POLICY FOR SUSTAINABLE DEVELOPMENT IN WEST AFRICA-THE ROLE OF WOMEN ENGINEERS AND SCIENTISTS

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ABSTRACT

The link between Science, Technology and Innovation (STI) for development is amply illustrated in the socio-economic advancement of new and emerging economies. Building the future through STI and higher education training for women presents major challenges for many African countries. These include: i) understanding and managing the intricacy of science, engineering and technology for increased competitiveness; ii) limited capacity in STI policy development; iii) gender education and social demands that require reorientation and; iv) engaging all stakeholders. The aim of a UNESCO-funded workshop was to assist regional ECOWAS countries to harness STI for sustainable development, and develop a monitoring and evaluation system to assess its impact. The objective was to create requisite capacity in STI policy formulation, implementation, monitoring and evaluation and enhance its application for sustainable development. A three day workshop was organised for scientists, engineers, social scientists, policy makers, private sector and development partners from ten ECOWAS countries to assess the policy environment for application and development of STI; provide a framework for STI policy training; capacity building in STI policy development, monitoring and review with emphasis on women and; develop in-country action plans/road maps. The result was the creation of a critical mass of scientists, engineers and decision makers in STI policy to assist/inform national STI policy development and drive the STI agenda to support productive activities for sustainable socio-economic development and increase global competitiveness of ECOWAS countries. In conclusion, strategies for regional cooperation and STI policy framework that have been developed for ECOWAS are worth adapting elsewhere.

Introduction

Decades ago, African countries realised that science and technology was crucial to economic development, so many institutions were established to enhance the national capacities for the development and application of Science, Technology and Innovation (STI). In the 1960s STI institutions were newly built for scientific human resource development, research and development (R&D) as African countries gained independence. In the Lagos Plan of Action of 1980 - the first African continental development plan - African heads of states committed themselves to invest 1% of GDP in R&D. In spite of this political will, progress in this area has not been appreciable compared to those of South East Asian countries like Malaysia, Korea or China. Today, the challenge is how to enhance capacity for sustainable development on the continent.

One of the key issues identified by many African countries was the slow pace at which appropriate technological innovations are used for social, economic and industrial development as well as how these are working for women and the poor. Several policy papers including Africa's Science and Technology Consolidated Plan of Action (NEPAD, 2005), National Vision documents and Growth and Poverty Reduction Strategies (GPRS) treated science and technology fairly but were not explicit on the use of science, technology and innovation for modernising production of goods and services and wealth creation. Conspicuously absent were the strategies for enhancing women's capacity in science and engineering.

The important linkage between Science, Technology and Innovation (STI) and development is amply illustrated by the socio-economic advancement in the industrialised and newly industrialising countries in Europe (EU Science and Technology, 2010). Their strong scientific and technological research in health, transport, ICT, nanoscience, nanotechnologies and new materials, environment, energy, transport (including aeronautics) and new production technologies and equal participation of women have supported productive activities. These have given them competitive advantage on global markets and facilitated development in the respective countries. These science and technology and innovation bases and participation of women in STI are however missing in Africa and there is the need to address the cultural biases prevalent in most African countries to harness the potential of women.

The Millennium Development Goals (MDGs) have become the ultimate global development agenda covering almost all aspects of human life. These MDGs cannot be achieved without a framework of action that places science, technology, and innovation at the centre of the development process (UN Millennium Project, 2005). UNESCO's Biennium Sectoral Priority 1 for 2010-2011 (UNESCO Report, 2009) is to step up its STI policy advice, capacity building and monitoring. The recent Science with Africa Conference II hosted by the Economic Commission for Africa (ECA) in Addis Ababa in June, 2010 and Economic Community of West African States (ECOWAS) Science and Technology Expert group meeting in Abidjan, July, 2010 reiterated the need for member states to harness science technology and innovation for sustainable development of the region and put a monitoring and evaluation system in place to access its impact on improving Africa's competitiveness.

These strategies call for the development of astute and dynamic scientific, technological and innovative capacity which must be deliberately planned and built within a policy framework. STI capacity building is vital for enhancing the needed engineering and

scientific skills to solve the prevailing socio-economic problems, transform the society and have a positive impact on the standards of living of the society (Watkins and Ehst, 2008). Despite this, many African countries do not have the capacity to develop and implement a comprehensive STI policy for accelerated socio-economic development. Many of these forums have acknowledged these challenges and there was an urgent need to address them at regional and national levels.

Realising these needs, the UNESCO Regional Office for Science and Technology for Africa (UNESCO-ROSTA) organised a three day training of trainers' workshop aimed at building the requisite STI policy development capacity and capability in the West African sub-region with the ultimate goal to assist ECOWAS countries to develop effective and realistic STI policies to enhance sustainable socio-economic development and increased global competitiveness. The specific objectives of the workshop were to:

1. assess the policy environment for application and development of the STI in the selected countries;
2. identify gender participation and equality gaps in science and technology
3. provide a methodological framework for STI policy training and monitoring and evaluation
4. provide training for trainers of STI policy formulation, implementation, monitoring and review;
5. develop in-country action plans/road maps for national STI policy implementation; and
6. ultimately establish a regional network to facilitate active collaboration among participants

The objective of this paper is to use this workshop as a case study of how to build the necessary capacity in STI policy development and implementation as well as to enhance the participation of women engineers and scientists in the development and application of STI for sustainable development in Africa.

Methodology

A three-day capacity development workshop was organised for policy makers, parliamentarians/ministers, academics, scientists, engineers, media practitioners, sociologists and NGOs responsible for civil societies, private sector and development partners. One each of these stakeholders was carefully selected from ten ECOWAS countries in recognition of their role in the policy development, implementation and monitoring and evaluation in their respective Francophone or Anglophone country. Special efforts were made to invite female participants and those from post-war countries. The World Bank, Washington and Accra Offices, ECOWAS Commission, UNESCO-ROSTA, STEPRI and the KNUST also participated as resource persons and collaborators in the ECOWAS STI policy development and implementation. The training took the form of lectures, role play, case study analysis, group dynamics and discussion.

Countries which participated in the workshop were The Gambia, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Togo and Benin. Nigeria was unable to participate at the last minute due to flight cancellation but sent in their country report. Each of these countries reflects the diverse developmental characteristics of West African countries. For

example, The Gambia is a small strip of country with a GNP tied to the export of primary commodities and to some extent tourism. Both Sierra Leone and Liberia are war-torn countries making efforts to build on the peace that comes after the devastation of the war has left the country with some of the highest poverty indices in the world. Nigeria is the largest sub-Saharan African country with a population of nearly 200 million and a huge resource of crude oil. However, the problem with multinational oil companies is very much in evidence leaving the country with enormous socio-economic challenges. Ghana is often touted as a beacon of hope to Africa given the relative peace and stability in a democratic environment and its recently discovered oil reserves, but the challenges in socio-economic development are frightening and necessitate effective STI capacity building. Ghana's neighbours, Ivory Coast, Burkina Faso, Togo and Benin are no exception. These countries brought in diversity of purpose, experience and expertise but with unity of aspiration to harness their natural and human science, technology and innovation potentials for sustainable socio-economic development. The remaining five ECOWAS countries were unable to attend for various reasons while that for Cape Verde and Guinea was language problems and associated cost of logistical support for translation. Although efforts were made to invite women participants, only Ghana and Nigeria nominated women scientists and policy makers. In all there were seven women and nineteen men participants. The authors were resource persons.

Implementation Strategy

During the three days, each participant presented a paper on situational analysis of their various countries teasing out their strengths, challenges, threats and opportunities in integrating STI in national development agenda. Participants developed draft documents emanating from analyses of the policy environment of their country using the UNESCO policy mapping instrument (UNESCO, 2010). Assessment indicators include existing infrastructure for STI application and development, human resource development, commercialization of research outputs, investments, gender development and the country's competitive advantage among others. Gender equality and participation in science and technology was also assessed using the Global Gender Gap Index (GGGI) as an indication. The GGGR index assesses 134 countries on how well they divide resources and opportunities amongst male and female populations, regardless of the overall levels of these resources. This was modified to include participation in science, engineering and technology.

These country assessments were collated and analysed during the workshop and formed the basis for policy formulation, and plans for monitoring and review.

Key Findings

Reports presented by participants indicated varying levels of challenging development issues such as poor infrastructure, limited availability of critical mass of STI experts, limited documentation of commercialisation of research outputs and low participation of females in science technology and innovation. Countries like Liberia and Sierra Leone had no gender disaggregated data. With regards to availability of a national STI Policy, only Ghana out of the ten countries had a national STI policy while Nigeria was at the final stage of developing one. Report from a previous ECOWAS meeting of Experts in Science and Technology in June 2010 corroborated this finding that only Ghana out of 16 countries in the West African had a national STI policy explicitly linked to national development agenda.. The reason for lack of this document, in these countries, was the limited capacity and methodological framework within which to

develop this policy (ECOWAS, 2010). This made it imperative to have guidelines for the development of a framework which takes into account ECOWAS and individual national developmental agenda.

In the area of gender and STI, all ECOWAS countries were above 70 on the Global Gender Gap Index (GGGI) 2010 rankings, with Ghana ranking 70 compared to Lesotho, the highest ranking African country at 8 and South Africa at 12 (World Economic Forum Global Gender Gap Report, 2010). The GGGI ranking takes into account equality between men and women in education, health, science and technology capability. Many of the ECOWAS countries despite their economic potential did very poorly on the GGGI ranking. The Gambia was 75, Nigeria 118, Cote d'Ivoire 130 while others were well below and not listed. The Nordic countries like Iceland (1), Norway (2), Finland (3) and Sweden (4) remain on top and continue to demonstrate the greatest equality between men and women in education, health, science and technology etc. Studies have shown that there is no tool for development more effective than empowerment of women (Annan, pers. comm, 2005), especially women in science, engineering and education thus making it imperative for African countries to make gender equality in science, technology and innovation at the heart of economic and social progress. It must be a critical component of effort/policy to reduce poverty and enhance global competitiveness and democratic governance and achieve sustainable development. ECOWAS countries must make this as an overarching principle in addressing gender equality and invest in equal participation of women in science technology and innovation for accelerated development.

Lessons Learnt

The lessons learnt were categorised into challenges, strategic action and opportunities.

Challenges

There were numerous challenges identified by many of the countries. Countries like Liberia and Sierra Leone are emerging from many years of war with devastating effect on human and natural capital which are the backbone for any effective STI policy for development. Both the system of governance and infrastructure have been destroyed and have to be built from scratch. Cote d'Ivoire would face similar challenges if the current impasse continues. Togo and Benin have structures to build an effective STI policy but would need to amend or develop new regulatory laws devoid of French laws or adapt those laws to local aspiration. Nigeria on the other hand has enormous capability and capacity but needs to take advantage of its human and natural capital resources for sustainable development.

The major challenge common to all these ECOWAS countries is the absence of STI policy or ineffective implementation of national STI policies. This can be attributed to the limited or absence of evidence-based data for decision making, regulatory instruments and institutional framework within which to operationalise these policies. Another challenge is working with various partners to strengthen their capacity to implement and monitor gender equality and participation in STI. Ameliorating some of these would require local capacity development at all levels of governance as well as government commitment to make progress in implementing their priorities for development and gender equality. The fundamental imbalance in STI capacity and demand for harnessing these capacity and capability for sustainable development

defines the overall challenge West African countries must overcome. These will require evidence-based approach to policy making where scientific evidence is integrated into decision making.

Capacity building in STI through Strategic actions

It was evident from the various country assessments that there was the need to develop a methodological framework for STI policy training and monitoring. A tool on methodological approach to facilitate training in STI policy development, implementation and monitoring was developed as one of the outputs of the workshop through participatory action as follows:

Training for STI Policy Formulation, Monitoring and Evaluation:- the formulation of STI Policy requires some expertise and competence. There is also the need for an effective monitoring and evaluation (M&E) system to be put in place to ensure effective implementation. Key steps in policy development identified were; ideation and the decision, review of existing national and international policies, first drafting, stakeholders participation, ‘nationalisation’ of policy and the final policy document.

- *Ideation and the decision:* - this is the conceptualization state which requires national ‘driver(s)’ with passion and vision to work out the various linkages for an effective science, technology and innovation for sustainable development. It also requires institutional commitment and engagement of experts to carry out the process. Participants were confident that from the training they could serve as trainers for others in their country.

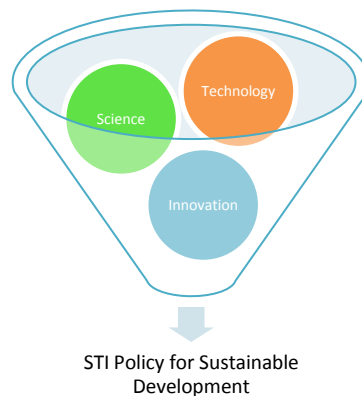


Figure 1: Linkages of an effective ideation of STI policy

- *Review of existing STI policy:* - it is essential to build on existing national STI policy or adapting other countries’ of national interest than to reinvent it. Sectoral policies such as agricultural, industrial, trade, energy, health, education and other sectors of national interest and other publications must be reviewed. This will not only save scarce resources but will also enhance the policy documents by building on the strengths and opportunities in existing ones while safeguarding against the challenges.
- *First draft:* - revision of existing policy or writing of a new one requires the dedication of a team of drafters from varied backgrounds and expertise and wide

consultation with stakeholders. This draft policy must have some governance structure/principles to ensure good governance.

- *Stakeholders' participation:* - this step is crucial to ensure that the policy is owned by all stakeholders with inputs addressing all aspects of the national development agenda. Women scientists, engineers and policy makers should particularly be involved in this process as pertains in Nordic countries with high GGGI ranking. This will require capacity building of women scientists and engineers in STI policy formulation and innovative communication strategies using various means such as mass media, posting on the internet, public forums, advertising, etc. Science, engineering and technology must be demystified into simple everyday appreciation of science. This leads to the second and enriched final draft document.
- *Nationalisation of the policy:* - this must be a national document owned by the citizenry. The consultative process may vary from country to country, but it is essential to present the final draft document to cabinet to be adopted with an implementation/action and M&E plan by parliament.
- *Final document:* - the content of the STI document should include an introduction with a situational analysis of the country and justification of policy, vision, goals, objectives and principles, sector specific linkages, organisational framework for policy implementation and funding mechanisms. Trainees were taken through how to write effective STI policy. It was emphasised that STI was key to national development, however the extent to which it is key, depended entirely on how effectively STI policy is formulated and implemented detailing the strategies and programmes for its application in the respective countries. Each trainee was able to develop a sketch draft of STI policy taking into accounts their country's vision and competitive advantage for sustainable development. Institutional and regulatory framework within which to operate the policy was also discussed.
- *Monitoring and evaluation:* - is a systematic collection of data to help provide developmental interventions or to gauge the extent of progress or achievement made. The stakeholders of monitoring should include the people whose lives could be affected positively or otherwise by the project or persons, groups interested in policy, planning or the change process. Monitoring can be classified according to the level of intervention: Impact, Effect/Outcome, Output, Process, Input, and Context.
In designing a monitoring system specific activities such as clarity of issues and objectives, analysis of process and determination of 'smart' (specific, measurable, attainable, realistic, and timely) indicators among others are important.

Analysis of gender participation and equality in STI: - this is important but there is no set formula. The GGGI was modified to measure the size of the gender inequality gap in four areas:

- i. Economic participation and opportunity – outcomes on salaries, participation levels and access to high-skilled employment such as engineering, science, technology
- ii. Educational attainment – outcomes on access to basic and higher level education with gender disaggregated data at all levels
- iii. Health and survival – outcomes on life expectancy and sex ratio
- iv. Political empowerment – outcomes on representation in decision-making structures

Provide Advocacy for National STI Policies:- there is the need to popularise the national STI policies in the respective countries as a way of winning public interest and support. Participants were trained on how to draw mass communication strategies to engage key actors in the print and electronic media to popularise STI policies. Some of these included talk shows, internet discussion, public forums at national, region and community levels to enhance the policy document. These would require national and institutional ‘champions’ to keep the momentum.

Establish/Strengthen Centre of Excellence of STI Policy:- to carry out the activities of the project on sustainable basis there is need the for lead a institution. The workshop trained trainers in how to harness multi-disciplinary human resource and institutions to strengthen centres/networks of excellence for STI Policy activities in the sub-region. This is to enable a competent institution to be built as a hub for present and future work in STI policy. It is also important for this institution to follow the progress of the policy to ensure accountability of decisions and transfer and accuracy of information in the implementation process.

Harnessing Opportunities in STI in West Africa

Participants acknowledged that opportunities in STI abound in West Africa and there was the need to harness them. For example, many ECOWAS countries are blessed with mineral resources such gold, diamond, oil and gas, large forest reserves, long coastline for marine products and salt production, solar energy and population of over 200 million. Transforming these resources into high value goods, services and processes require astute national STI policies that must guide the future while meeting the needs of today. For example, the oil and gas discovery in Ghana comes with a lot of responsibilities and opportunities which requires transformational development: where clear national development objectives are set; old regulatory instruments are revamped; regulatory agencies are strengthened to enhance consumer protection and education; research and development are enhanced particularly in oil and gas technology and ancillary industries; small and medium scale enterprises are retooled and re-skilled; communities are educated on environmental safety; environmental protection agencies are capitalised to perform to international standards and gender equality is pursued etc. It is only by developing strategies and programmes supported with adequate funding that STI policy would lead to sustainable and peaceful socio-economic development. National STI policy would need to address all these, taking into account the social and development impact of the country’s resources.

Participants acknowledged that science technology and innovation was essential to propel African countries to achieve their development goals. Africa must develop a critical mass in STI and look for new and emerging areas to enhance her global competitiveness. In particular, women who make up over 50% of the total population in West Africa must be engaged at all levels of policy for sustainable development. Technologies such as carbon sequestration are a big part of sustainable globalisation and Africa can create a niche in this area by producing alternative clean energy sources. For example, West Africa is endowed with solar energy with a big potential in bio-fuels if adequately harnessed. A new paradigm for ECOWAS countries is renewable energy in response to climate change mitigation and adaptation and she must develop the critical mass to take advantage of market-based mechanisms such as carbon trading and clean development mechanism (CDM). Climate change also poses a serious threat to food production, health and the environment which are all indicators of development and poverty reduction. Minimising the impacts of climate change by developing

innovative processes requires capacity development in climate science and technology and this must be addressed in any national STI policy. It is expected that a robust STI policy with clearly defined objectives, actions and guidelines with specific, measurable, attainable, realistic and time bound indicators in sectors with great socio-economic potentials must be developed at regional and national levels in West Africa.

Strengthening the ECOWAS economic block was also seen as an essential strategy for sustained economic development of the region. The region is endowed with arable fertile land and coastline which must be harnessed using science, technology and innovation in the value chain. Well coordinated national and regional food production linked to value addition, through processing, packaging, certification, marketing and distribution can increase access to food and reduce poverty while enhancing ECOWAS global competitiveness.

The region's knowledge-base in plant medicine was also identified as a great potential and women have been custodians of this indigenous knowledge. Application of biotechnology, nanotechnology and 'nutriceautics' in transforming rare flora into niche products, has the potential to improve health and nutrition as well as generate wealth. In view of the fact that countries are at different levels of scientific and engineering capability, one of the strategies to enhance R&D and innovation is to create a critical mass for a coordinated ECOWAS 'internal market', where researchers, technology and knowledge freely circulate.

Conclusion

Pursuance of gender equality was reiterated as a critical component of efforts to reduce poverty and enhance economic growth. Evidence from the Global Competitive index, 2011 clearly showed that Nordic countries like Sweden (2) Finland (7), Denmark (9) and Norway countries (14) had excellent gender participation and also ranked very high on the Global Gender Gap Index (World Economic Forum Gender Gap Report, 2011). The ability for a country to harness the benefits of equal participation of women in science engineering and technology is imperative in driving innovation to enhance its competitiveness. Since there was no set formula for analysing gender participation and equality in science and engineering, the GGGI was modified to be used for future analyses. It was recommended to pilot this assessment tool in other countries in Africa to come up with a tool for gender participation and equality in STI assessment. ECOWAS countries must compete by transforming her natural endowment into products, processes and markets for sustainable socio-economic development. This was articulated in the Communiqué produced at the end of the workshop to governments, ECOWAS Commission, development partners and a commitment to a common cause. One of the key recommendations was strengthening or creating Centres of Excellence in STI Policy formulation, implementation, monitoring and evaluation to drive the STI agenda for sustainable development of the region.

Developing capacity in science technology and innovation policy formulation, implementation, monitoring and evaluation is essential to the sustainable development of ECOWAS. The creation of a critical mass in STI policy to better understand global challenges, emerging trends and the engendering of these processes is crucial for enhancing ECOWAS's global competitiveness. This requires the effective use of science, technology and innovation as well as the enhancement of the unique role of women scientists and engineers as equal partners in this transformational change. This case study of how to build capacity in STI policy formulation, implementation,

monitoring and evaluation and how to differently build capacity in female scientific and engineering community in ECOWAS countries are worth adapting elsewhere. At the end of the workshop participants developed in-country road map for implementation.

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WOMEN ENGINEERING DEANS IN THE UNITED STATES: A NEW MODEL FOR ACADEMIC LEADERSHIP

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ABSTRACT

Women in the United States have made significant gains in doctoral degrees and participation in academic careers over the past 25 years, but remain significantly underrepresented in engineering (Burrelli, 2008). In 2009, women earned 21.3% of engineering PhDs, and comprised 12.7% of engineering faculty and 7.7% of full professors (Gibbons, 2010). Almost 400 institutions in the U.S. have accredited engineering programs, and 38 were led by a female dean of engineering or equivalent in the spring of 2010. Thirty-one other women have served as dean at some point in the past 20 years. (ASEE, personal communication) Deans play an important role in defining the work environment and establishing the climate for faculty as well as students. A deanship is also a common stepping-stone to higher academic leadership roles, such as provost and president (Wolverton *et al.*, 2001).

Eleanor Baum became the first female dean of engineering in the U.S. in 1984. She retired in 2010, but women engineering leaders in academe are still few and far between. What can we learn from the women who have successfully navigated the path to leadership in engineering education? How did they get where they are today? How has their career impacted their personal life, and vice versa? And what impact are they having on engineering and engineering education? Interviews with women deans over the past ten years illustrate the diversity of their career paths, their approaches to work/life balance, and how they are changing engineering education.

INTRODUCTION

During the 1960s, less than 0.5% of engineering degrees in the United States were earned by women. Beginning in the 1970s, the *numbers* of women pursuing engineering degrees increased dramatically through the mid-1980s but then stayed relatively stable for the next 20 years. The *percentage* of engineering degrees awarded to women had reached 10% by 1980 and then grew more slowly to 20% in 2000, but the increased percentage of women during the 1990s was largely a result of fewer men pursuing degrees in engineering – the total number of U.S. engineering bachelor's degrees dropped from a historic high of more than 77,000 in 1985 to a low of just over 59,000 in 2001 (Di Fabio *et al.*, 2008). Since the turn of the 21st century, the *numbers* of both men and women studying engineering in the U.S. has increased, but the *percent* of degrees earned by women has actually begun to decline, to just 17.8% in 2009 (Gibbons, 2010). Looked at in a different way, only 3% of all bachelor's degrees earned by women in the U.S. are in engineering or computer science fields, while 15.2% of all bachelor's degrees earned by men are in engineering or computer science (Su, 2010).

For a different perspective, from 1997-98 to 2007-08 women earned between 56% and 58% of all bachelor's degrees in the U.S. (NCES, 2010), including 50% of all

bachelor's degrees in science and engineering fields (including physical, biological, social, and psychological sciences and engineering). The proportion of degrees in physical and earth sciences earned by women increased from 23.9% in 1980 to 42.2% in 2006. In biological and agricultural sciences, women earned 39.1% of bachelor's degrees in 1980 and 59.8% in 2006, with their numbers more than doubling from just over 25,000 to almost 54,000 in that time frame. Conversely, while the number of bachelor's degrees awarded in math and computer science tripled from 1980 to 2003, the percentage of degrees in those fields earned by women decreased from 36.4% in 1980 to 26.8% in 2006 (Di Fabio *et al.*, 2008).

A doctoral degree is a pre-requisite for most faculty positions in engineering in the U.S. today. The proportion of doctoral degrees earned by women in all science and engineering fields has increased from 9.3% in 1980 to 40.2% in 2006, with engineering again lagging behind other disciplines. Going back to 1970, women earned 0.5% of U.S. engineering doctoral degrees. Women's share of engineering doctorates increased slowly, to 3.6% in 1980, 8.5% in 1990, 15.7% in 2000, and 21.1% in 2008 (Burrelli, 2008).

Faculty ranks in the U.S. begin with assistant professor, with promotion to associate professor (usually with tenure) after a probationary period of 6 to 8 years, and a final promotion to the rank of professor (sometimes referred to as "full professor") at an unspecified time, based on performance. While women are the majority of students on U.S. university campuses, they remain underrepresented on the faculty, especially at the more senior ranks and at more prestigious institutions. Among full time faculty across all disciplines, women make up 52% of lecturers and 51% of instructors (positions not generally granted tenure in U.S. universities), 45% of assistant professors, 33% of associate professors, and 24% of professors (Dean, 2009).

Within the ranks of engineering faculty, women remained less than 10% of full-time tenured or tenure-track faculty at U.S. engineering schools until 2006 (Burrelli, 2008), and currently comprise 12.7% of all engineering faculty. Women engineers are also concentrated in the lower rungs of the faculty career ladder, constituting 21.6% of assistant professors and 14.5% of associate professors. While associate professors sometimes serve as department head or chair, candidates for higher administrative positions such as dean, vice-president, provost, or president generally are expected to have achieved the rank of professor. In 2009, only 7.7% of U.S. engineering faculty members at the rank of professor were female (Gibbons, 2010).

Women are now at the helm of several high profile universities in the U.S., including Harvard, Massachusetts Institute of Technology (MIT), Rensselaer Polytechnic Institute (RPI), and the University of Michigan, but overall women remain underrepresented in senior leadership roles in academe. Data from the American Council on Education (ACE) show that some progress is being made. Women were 9.5% of college presidents in 1986, increasing to 23% in 2007. More than a third (38%) of provosts or chief academic officers are now women. However, senior women leaders are still more likely to be found in community colleges (2-year associate degree granting institutions) and baccalaureate institutions than at research-intensive doctoral-degree granting institutions (Madsen, 2010).

Occupying a position between department heads and senior administrators, deans are key academic leaders in U.S. universities, responsible for faculty recruitment, hiring,

and development, as well as setting priorities and allocating resources for their college. They play an important role in defining the work environment and establishing the climate for faculty as well as students. A deanship is also a common stepping-stone to higher academic leadership roles, such as provost and president. (Wolverton *et al.*, 2001, Montez *et al.*, 2002, Del Favero, 2005) It is therefore worth exploring the careers and experiences of women who have served in the role of dean.

Of the almost 400 institutions in the U.S. with accredited engineering programs, 38 had women in the role of dean of engineering or director of the engineering program in the spring of 2010, according to the American Society for Engineering Education (ASEE). At least thirty-one additional women have served as dean of engineering at some point in the past 20 years, for a total of 69. (Records prior to 2000 are incomplete.) Several of these women served as acting or interim deans, and others led small programs consisting of a single department. Six have served as dean at bachelor's degree granting institutions, 28 at master's level schools, and 34 at institutions that grant doctoral degrees (ASEE personal communication, 2010). Of the 31 former deans, half have gone on to other academic leadership roles, including provost, vice-president, chancellor, and president.

METHODOLOGY

The author interviewed 21 of the known women engineering deans for profiles published in the Society of Women Engineers magazine annually since 2002. Two or three deans were selected each year to represent different types of academic institutions, different geographic regions of the U.S., and different engineering disciplines. They were asked to describe their role and accomplishments as dean, their career path, their leadership style, and the interactions of their career and personal life. At the time of their interviews, the women had been in the role of dean for varying lengths of time, ranging from one to 18 years. Ten had been in their position for 3 to 5 years, 7 for less than 3 years, and 4 for more than 5 years.

The deans were given the option of responding to the open-ended questions by email or in a telephone interview, and in some cases the author supplemented the email responses with telephone conversations. The telephone interviews were not recorded but careful notes of the discussions were kept. The deans were also asked to provide biographical information such as a curriculum vitae.

After the profiles were published, the author compiled all of the interview responses and reviewed them in depth to identify similarities and differences that emerged across the interviews. Analyses of the deans' career paths, people and events that influenced them along the way, and perspectives on gender and leadership have been discussed elsewhere (Layne, 2010, Layne, 2011b, Layne, 2011a). This paper reviews the deans' preparation for leadership, their experiences balancing the demands of work and family, and their impact on the institutions they lead.

Since the interviews were explicitly intended for magazine profiles, there was no promise of confidentiality, and potentially sensitive issues were not explored in depth. The deans may also have censored some of their responses, knowing that the interviews were intended for publication. No comparable dataset on male engineering deans is available for comparison. Nevertheless, the deans' own descriptions of their career paths and accomplishments provide some insight into how they view the role of dean and how

their leadership is impacting the institutions they lead and engineering education more broadly.

FINDINGS

The women deans interviewed represent 14 research-intensive doctoral-granting institutions, 6 master's level institutions, and one bachelor's degree granting school. Five were born outside the U.S., and one in Puerto Rico. One is Asian-American, while the rest are Caucasian. Nine of the deans received their degrees in electrical engineering, 3 in chemical engineering, 3 in biomedical engineering, 2 each in civil and mechanical engineering, one is an industrial engineer and one has a PhD in statistics.

Twelve of the 21 deans interviewed were still serving in that position in fall 2010, while 9 are no longer deans. Of the former deans, one is retired, one has moved to a non-academic position at a policy-related non-profit, three moved directly to positions as president or chancellor, and four moved to provost or chief academic officer positions. Three of the provosts have since moved on, one to become a chancellor and one to a politically-appointed position in the U.S. Department of Energy.

Preparation for Leadership

A study of academic deans in the U.S. in the mid-1990s found that two-thirds of the male deans but only slightly more than half of the female deans had experience as a department head or chair prior to becoming dean (Wolverton and Gonzales, 2000). While that study did not include deans of engineering, it does provide a general benchmark for comparison. Less than half (only 9) of the 21 women engineering deans interviewed had previously served as department head. Those who had experience as department head valued that experience highly when moving into the deanship. For example, two of the deans spoke emphatically about the importance of serving as department chair prior to becoming dean:

When I became chair, I was glad I had been through the research grant process so that I knew what faculty go through. Being chair helped prepare me for the dean position [...] going through the academic career ladder gives me more confidence and credibility.

and

Experience as a department chair is so valuable. The department is the critical unit, deciding about hiring, promotion, workload, curriculum, accreditation [...] I would not want to be dean without that experience.

Others had experience as associate deans, directors of major research centers, program officers at the U.S. National Science Foundation (NSF, the government agency that funds much basic research in science and engineering), as leaders in professional societies, and sometimes in several such roles. One of these deans observed that "becoming director of an NSF funded Engineering Research Center led to connections across universities and got me thinking broader."

Few deans receive any formal training or preparation for their role (Wolverton and Gmelch, 2002). Only one of the women deans in this study had participated in a leadership development program specifically designed to develop academic leadership:

When I was still an assistant professor at [...] University, I applied for a position called "Faculty Associate to the Provost." [...] This was a rotating one-year position created to help increase the number of women in higher education

administration. The individual in that role reported directly to the provost, was mentored by him, attended meetings of the President's Cabinet and Deans' Council, and was responsible for several special projects.

Another dean was inspired to look for new opportunities after attending a conference designed to encourage women faculty to move into leadership roles:

I attended the WELI Leadership Summit at the University of Connecticut with a wonderful group of women who were department chairs and deans. I looked at and listened to these women and thought, "I can do this!"

Eleven of the deans interviewed had some non-academic work experience, in most cases a year or two working in industry after completing their bachelor's degree and prior to graduate study, but two deans spent more than five years in the chemical industry before going back to school. Two other deans earned their first degree in a non-engineering field and worked as pre-college teachers before pursuing graduate work in engineering. Only a few of the deans interviewed took what is generally considered to be a "typical" academic career path, going directly to college after high school, straight from a bachelor's degree to graduate school, then to an academic appointment, a department head position, and a deanship.

While a minority of the female engineering deans interviewed had served in the role of department head prior to becoming dean, and only one had participated in a specific academic leadership development program, the deans gained experience as administrators and leaders in a variety of ways. It is important to note that all of the deans served as faculty members for varying lengths of time before moving into academic administration. Whether as a volunteer leader in a professional society, as director of a major research center, as a program officer in a government agency, or as an assistant or associate dean, these women developed skills and made contacts that prepared them for a dean's position.

Work and Family

Several studies have documented the effect of family formation on the careers of academic women in the U.S. Married women and women with children are less likely than men to enter a tenure-track position upon completion of the Ph.D., and women are less likely than their male colleagues to achieve tenure. Single women who enter tenure-track positions are less likely than their male peers to marry, and women who are married when they obtain their first tenure-track job are more likely than their male peers to divorce. Women faculty are also more likely than men faculty to say that they had fewer children than they wanted (Armenti, 2004, Mason *et al.*, 2006, Ward and Wolf-Wendel, 2004).

At least 14 of the 21 deans interviewed have children. (Deans were asked how their career has impacted their personal life and vice versa, but not specifically whether they have children, so unless the interviewee brought up the subject no explicit attempt was made to determine their family status.) Some of the deans were very clear that they had made a conscious choice to combine parenthood with a faculty career:

I decided that there is more to life than work. My life has been far richer for sharing it with a loving spouse, two wonderful daughters, a couple of dogs, and an assortment of friends and family. Life is hectic, complicated, fun, and always tiring, but never, never boring (unless you count the endless meetings I attend).

In some cases the future dean made a choice to change jobs or work part-time for a period in order to accommodate other demands on their time:

Certainly, there have been times when it has been difficult to balance my career and family life. I have been fortunate because my husband [...] and I have worked hard to share responsibilities for our two sons throughout our 23 year marriage. This partnership with my husband is what allowed me to have a successful career and raise two extraordinary sons. But I also have made deliberate choices that have been less than ideal for my career, but were the right choices for my family.

and

I was committed to building a successful career AND having a rich, fulfilling personal life. I suppose one would say that I wanted to “have it all” in that I did not want to make sacrifices either in my professional development or in having a family. Now, there were *compromises* along the way, to be sure, but sacrifices? Not really. I feel that I have achieved a great deal professionally, and my life has been indescribably enriched by the experience of being a mother.

Several volunteered comments on how their experience as a mother has informed their leadership style, for example:

My survival skills in the workplace include humor, pragmatism, and experience in managing family dynamics as a mother.

and

Good parenting is related to being a good manager: understanding people, supporting people, having clear and transparent expectations and limitations on behavior. I would not be as good a dean if I had not been a mother.

In some cases the deans were explicit about how their experience as a parent shapes specific policy decisions related to work/life balance for their faculty. For example:

My own personal experience has caused me to take this very seriously. [...] We have implemented liberal family leave policies within the College of Engineering, modified teaching schedules, and we routinely offer faculty the choice to extend their tenure clock for the birth or adoption of a child. I have made it clear to faculty and department heads that important choices that faculty make about their family should not be dependent on teaching schedules or tenure. In addition to being the right thing to do, these policies have had a positive impact on our college and faculty morale and has contributed to doubling the number of female faculty in the College of Engineering over the last five years.

Two thirds of the women deans interviewed found ways to combine children with the demands of a faculty career. In some cases, they started their families before embarking on their first faculty position, while others waited until after achieving the security of tenure to have children. Some changed institutions or positions in order to make more time for their families. Many expressed the belief that motherhood has made them better leaders, forcing them to prioritize and honing their people skills. Their life experience also informs their approach to university policies and procedures. Some of these women are using their positions to actively change the work environment for current and future generations of faculty, both male and female.

Accomplishments

It is beyond the scope of this study to examine external indicators of institutional change that may be attributed to the actions of these deans, but it is interesting to examine how the deans themselves describe their accomplishments in the context of

recent changes in engineering education in the U.S. In 2000, ABET, the non-governmental organization that reviews engineering programs in the U.S. for quality, changed from a prescriptive model that required engineering schools offer a certain number of credit hours in each of a given list of subject areas to an outcomes-based model, requiring engineering educators to assess the impact of their programs on students. Specific outcomes to be evaluated include professional skills in addition to engineering content knowledge:

- a: an ability to apply knowledge of mathematics, science, and engineering
- b: an ability to design and conduct experiments, as well as to analyze and interpret data
- c: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- d: an ability to function on multi-disciplinary teams
- e: an ability to identify, formulate, and solve engineering problems
- f: an understanding of professional and ethical responsibility
- g: an ability to communicate effectively
- h: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- i: a recognition of the need for, and an ability to engage in life-long learning
- j: a knowledge of contemporary issues
- k: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (www.abet.org)

In describing their accomplishments and impact on their institutions, in addition to listing achievements such as new academic programs, cutting-edge research, improved facilities, and growing enrollments, at least half of the deans interviewed mentioned integrating interdisciplinarity, collaboration, and social context into their research and education programs, skills specified in ABET criteria d and h. One dean spoke of “expand[ing] the vision of what engineering can be” at her institution by working with colleagues in the medical school and applied sciences. Another focused on “preparing students to thrive in a global economy [...] working with colleges of business and humanities on developing a global perspective”. Yet a third dean emphasized the importance of working across traditional boundaries:

This may be the single most important difference in the college today. Fundamentally, this ability to work collaboratively and develop interdisciplinary projects has allowed us to create new degree programs such as biomedical and systems engineering that cross department and college lines. It has allowed us to recruit and retain excellent faculty who work at the interface of multiple disciplines and it has allowed us to address important problems in a manner that no single investigator or department can address.

While one dean expressed a strong desire to expand interdisciplinary research in her college, she recognized some of the challenges inherent in that endeavor:

I would like to [...] make even larger inroads into interdisciplinary and multi-cultural research and education. Fantastic things are going on now in these areas. But we can do much more. In the profession now, the reward structure is not designed to encourage junior researchers and faculty to create collaborative interdisciplinary programs.

Another dean is forging ahead with major organizational changes to facilitate interdisciplinary research:

We reorganized from 10 traditional discipline-based departments to 5 schools focused on broad grand challenge themes. This is a revolutionary change in

engineering that has not happened in other engineering schools around the country.

In addition to comments about collaboration and working across disciplines, another common theme in these deans' accomplishments related to people. Since faculty members tend to stay at institutions for long periods of time, hiring new faculty has a major impact on a college. One dean commented that "We, like all universities, are only as good as our faculty." The deans frequently mentioned hiring faculty and providing faculty members with the resources they need to succeed as one of the ways they have influenced their institution:

I have worked very hard to make the College "people-centered". Colleges of engineering often focus on equipment, labs and buildings. These things are all very important, but the most important part of a college is the people. Success can only be achieved if you have outstanding individuals at all levels. We have built up a really strong program to recruit the very best students, staff and faculty. We also provide them with professional development opportunities so that they can grow on the job. As a result, the College is flourishing.

When asked to describe how their institutions are different as a result of their leadership, the women deans in this study mentioned the usual metrics of increased national recognition, new academic programs, more funding for research, improved facilities, rising enrollments and new faculty, but they also focused on some of the changes currently underway in engineering education. Specifically, they discussed finding ways to encourage their faculty and students to develop skills that enable them to work across disciplinary boundaries, to recognize and incorporate the local and global social context in their problem solving, and to take a more holistic approach to engineering as a field of study.

DISCUSSION

Conversations with 21 of the 69 known female engineering deans in the U.S., most of whom have been appointed in the past 10 years, hint at changes that may be occurring in engineering education and academe more broadly. Although some of these deans followed a traditional linear academic career path based on a male model of uninterrupted commitment to the workplace, many took less direct routes to their current positions, with detours for family and non-academic work. Two-thirds of the women have found ways to combine raising a family with the demands of an academic career. Many of them are actively working to expand the boundaries of possibility within engineering, both by making their colleges more interdisciplinary and people focused and by serving as mentors and role models for younger women. Almost half of the women interviewed have already moved into more senior leadership roles within the academy, where they have an even broader scope of influence. While these women remain a tiny minority in engineering and a somewhat larger minority in higher education, the fact that they have managed to succeed within the male culture of engineering and, more importantly, are actively working to change that culture from within, is an encouraging sign.

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FAMILY-FRIENDLY POLICIES AND WOMEN ENGINEERS' CAREERS

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ABSTRACT

The recent review of the *Equal Opportunity for Women in the Workplace Act 1999* reports that achieving equal opportunity requires removal of barriers to women's participation in the workforce and includes better management of work and family commitments by workers. Work-life balance is a particular concern for women engineers where professional norms and culture dictate working long hours. Human Resource (HR) policies for achieving work/life balance can create barriers for women engineers to achieve successful and satisfying careers, attain senior management positions and remain in engineering organisations. The role that organisational policies and practices have on women engineers' careers requires investigation. This qualitative study examines the effect that HR policies and practices for work/life balance have on the work experiences of the women engineers in three engineering consultancies. A critical social science approach, using document analysis of publicly available organisational documents is supplemented by interviews with the organisations' HR managers and women engineers.

The engineering consultancies in this research address family-friendly policies to differing degrees through publicly available sources. Equal Opportunity for Women in the Workplace Agency (EOWA) reports are difficult to locate and are at different stages of development in each organisation. Differences between the organisations are evident when comparing the policies and practices of the engineering consultancy awarded an Employer of Choice for Women Award with the other two organisations' policies and practices. Dissemination of relevant policies differs across the organisations. Improved career outcomes for women engineers require organisations to place greater consideration on family-friendly and practices.

INTRODUCTION

Programs and policies for managing diversity in the Australian public and private sector are important, not only for providing all workers with opportunities to take part in paid employment, but also for improving organisations' reputations and performance (Strachan, French & Burgess, 2010). Transparent, flexible working policies and practices, when adopted as part of organisation's diversity management plan, have resulted in higher levels of employee commitment, motivation and productivity and lower employee turnover for women (Wilkinson, 2008). Policies framed around balancing work and family to reduce the conflict experienced by employees, particularly women, who still bear the majority of the responsibility for care giving to children and family is an important issue facing Australian organisations and employees (Strachan & French, 2007). Work-life balance is a particular concern for women engineers in

companies where professional norms and culture dictate working long hours, making it difficult for employees to undertake other roles, such as primary caregiver at home (Ballout, 2008; Lewis & Humbert, 2010). Balancing work and family is one of the career barriers for women engineers to achieve successful and satisfying careers and senior management positions within their organisations (Ranson, 2005).

Women engineers in Australia are more likely to occupy positions requiring lower levels of responsibility and lower pay than their male peers, and considerably more men are in higher pay brackets than women (Bell, 2009; Mills, Mehrtens, Smith, & Adams, 2008). Women engineers leave the profession after seven to ten years employment, without gaining the same senior levels as their male counterparts (APESMA, 2007). Therefore retention and career development of women engineers remain critical issues. Considering these issues a question arises: how do engineering consultancies HR policies and practices effect women engineers' careers? This question requires investigation using qualitative research with a critical social science approach to gain a rich and deep understanding of the issues and provide recommendations to enable women engineers to achieve a more balanced work/family life, more satisfying and longer lasting careers, and for engineering consultancies to retain their women engineers.

This study begins with a review of the literature identifying the issue of work-family "conflict" and organisations' response through family-friendly policies to address work-life balance in the case of women in engineering. The paper then describes the methodology and research design. Current workplace profiles are established for three engineering consultancies: GOGH, WARHOL and HART, which operate internationally and have offices in Brisbane, Australia. The companies' family-friendly policies and practices are described and compared. The Critical Research Document Analysis (CRDA) framework is applied to publicly available documents and interviews with HR managers and women engineers from the three companies. Findings are presented and discussed to identify future issues requiring investigation. Limitations to this study are identified.

LITERATURE REVIEW

The implementation of family-friendly policies and practices by organisations has enabled many single and dual-career parents to continue in the workforce (ABS, 2003; Ballout, 2008; Wilkinson 2008). Nevertheless, men and women continue to struggle with balancing paid work and family (Teicher & Spearitt, 1996). This struggle results in work-family conflicts (WFC) as well as family-work conflicts (FWC) (Ballout, 2008; Lingard, 2004). Netemeyer, Boles and McMurrian (1996) determined that WFC and FWC were both related to inter-role conflict, which is specific type of conflict associated when membership of one group (e.g. work organisation) conflicts with membership of other groups (e.g. family). When pressures from the family role are incompatible with the pressures from the work role, this can negatively impact on the quality of both work and family realms, and work-life balance (Ballout, 2008). Too much time at work prevents time being spent with family, resulting in personal and interpersonal conflict, stress, inter-role conflict and burnout (Lingard, 2004) which is experienced in professions such as engineering, where commitment is judged by working long hours and remaining totally available (Lewis & Humbert, 2010). Fig.1

shows that balancing work and family life is a major concern for professional women in Australia.

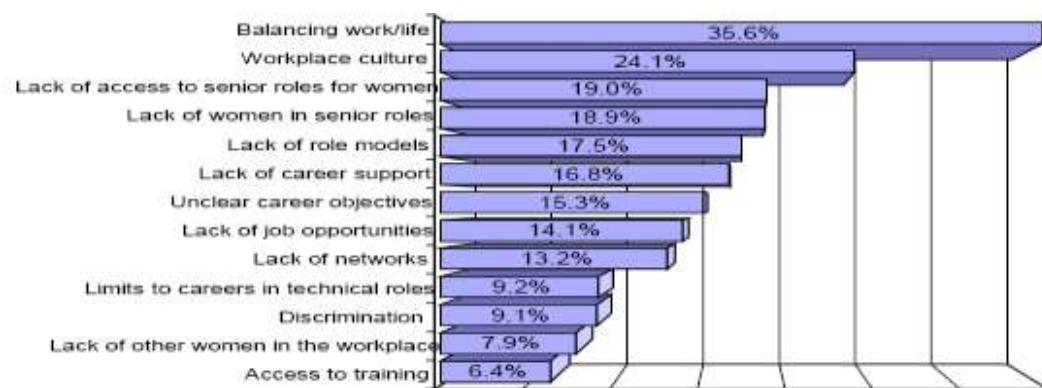


Fig. 1: Survey responses from women engineers: Have the following factors significantly affected your career advancement? (Source: APESMA, 2007)

Engineering is “culturally, normatively and numerically male-dominated” (Watts, 2009: 39). This factor, underpinned by the concept that the ideal worker must prioritise work before family and spend unlimited hours at work, results in the notion that professional engineers are committed to their organisation if they work long hours (Acker, 1990; Lewis & Humbert, 2010). Women engineers are commonly judged as being less committed than their male counterparts and not viewed as ideal workers because they place a greater priority on family rather than work, and their commitment is usually evaluated by male managers. This acts as a career barrier for women engineers (Ismail & Ibrahim, 2007). In Australia, 50 percent of women engineers reported that the paternalistic environment resulted in their work commitment being questioned (Roberts & Ayre, 2002). Generally, employers and recruiters are apprehensive about employing people who have taken time out of the work force (Cabrera, 2009). As a result, women experience career barriers such as difficulty attaining positions of management or power because they experience employment gaps through taking time off work to have children and care for family (Ismail & Ibrahim, 2007). The masculine culture within engineering organisations also influences HR policies and practices which can create barriers to retaining women engineers, as well as influencing career outcomes for women engineers (Acker, 1990; Bell, 2009; Cabrera, 2009).

Evidence suggests that Australian civil engineers experience significant time-related work demands and work-associated stress (Lewis & Humbert, 2010; Lingard, 2004). The number of hours worked each week is a significant predictor of emotional exhaustion, increased stress and conflict in dual and single income relationships (Wharton & Blair-Loy, 2006), but is especially felt by parents (Lingard, 2004). The presence of children in a family is found to generate a greater sense of conflict for these employees as they faced difficulty balancing their work and family lives (Lingard, 2004). Childless respondents did not experience this conflict, but reported exhaustion due to hours spent at work pursuing career advancement (Lingard, 2004). Lingard (2004), claims that greater attention should be paid to issues of work and family to prevent WFC and burnout. Mills et al. (2008, p. 2), found that family-friendly policies benefited women and men equally. Based on his study of Australian engineers, Lingard (2004) warns that multiple intervention strategies should be developed to cater for

employees who are parents or childless, and from dual or single income households (Lingard, 2004). Care must be taken in interpreting Lingard's findings due to the low response rate (36%) and the small percentage (7.7%) of women respondents.

Debate among a limited set of studies exists around the effect of family-friendly organisational policies. A number of researchers allege that every employee is an individual with a different approach to work and life, and requires individually tailored processes to ensure work-life balance is achieved (Kossek, Lautsch & Eaton, 2006; Smithson & Stokoe, 2005). Ballout (2008) found women employees and managers experience more conflict in balancing work and family than men, and organisational flexible work practices can greatly reduce WFC. Canadian research, (37 women engineering graduates interviewed from one oil company), maintains HR family-friendly policies are mere rhetoric, which only impedes careers of women in traditionally male-dominated occupations (Ranson, 2005). The gender neutrality of terms, such as 'family-friendly policy' and 'work/life balance', which are aimed equally at men and women, have actually been ineffective (Ranson, 2005). Ranson (2005) argues women benefit from, and take advantage of, these policies more than men. Women's organisational commitment is questioned and the view that they need special consideration is reinforced when they choose to take advantage of these policies (Ranson, 2005).

METHODOLOGY

This is a qualitative study based on the critical research (CR) framework developed by Alvesson and Deetz (2000). The CR framework is comprised of three tasks: insight, critique and transformative redefinition and has been used in the successful qualitative document analysis by Dumay and Lu (2010) to facilitate understanding of how rhetoric and management policies and practices on human capital are used by Westpac (Australia). The data will be analysed using Bickman and Rog's (2009) document analysis method: collecting, coding, categorising and connecting data to relevant theory. Bickman and Rog's (2009) document analysis method integrated with Alvesson and Deetz's (2000) CR framework results in the Critical Research Document Analysis (CRDA) framework. This CRDA framework will facilitate the document analysis method for analysing data for this study and is described in Tab. 1.

Tab. 1: The CRDA Framework applied to GOGH, WARHOL and HART

Stage of CRDA framework	Actions required
Insight: <i>Collecting data</i>	- GOGH, WARHOL and HART, professional engineering web documents, EOWA and ABS reports collected, and interviews conducted. - Text files created from the web documents and interview transcribed - Files added to NVivo 9 as Source files
Critique: <i>Coding and Categorising data</i>	- Coding nodes created noting organisational characteristics - Text files and interview transcripts coded and reports for each coding node compiled in NVivo 9 - Relationships to existing theory identified
Transformative redefinition: <i>Connecting data to relevant theory</i>	- Critical relevant knowledge developed - Practical understanding gained of each organisations' culture, HRM career development, and family-friendly policies and practices

Developed by Ball (2010) from Alvesson & Deetz (2000) and Bickman & Rog (2009)

Research design

The research design for this study has been developed in consideration of suitable qualitative research methods and data collection approaches, as well as available time

and limited financial resources (Bickman & Rog, 2009). In order to address the research question, three engineering organisations which operate globally, employing women engineers with offices in Brisbane, were selected. Data was collected from the text in the companies' websites and EOWA reports (Bickman & Rog, 2009). Semi-structured, in-depth interviews were conducted with the HR manager and three women engineers from GOGH, WARHOL and HART. The companies, HR managers and engineers have all been given aliases to provide anonymity. The data obtained from the websites, documents and interviews provide knowledge about each organisation's core business, size, structure, vision, culture, policies and emergent issues, and were analysed using document analysis. The data management was facilitated using NVivo 9. The codes for categorising the qualitative data developed, and themes emerged to explain what is actually happening in engineering consultancies (Stake, 2010). The themes developed around family-friendly policy formation, women's knowledge of entitlements, career barriers due to flexibly working, employment gaps and lack of childcare facilities.

DOCUMENT ANALYSIS FINDINGS

A comparison of three engineering consultancies' websites and EOWA reports is seen in Tab.2. This includes information on workplace profiles; diversity and EEO policy.

Tab. 2: Comparison of GOGH, WARHOL and HART (Source: The companies' Australian websites and latest available EOWA reports) (*Professional roles are comprised mostly of engineers)

Engineering Consultancies	GOGH	WARHOL	HART
Established	Mid 1900s	Late 1800s	Late 1920s
Ownership	Privately owned - held in trust for employees	Privately owned – not by the employees	Privately owned by the employees
Workforce	1122	1993	4133
*Professionals:			
Total	245 women 526 men	239 women 944 men	511 women 1706 men
Part-time	37 women 19 men	50 women 27 men	105 women 48 men
Women in Top, Mid, Low levels	21%; 37%; 20%	4%; 11%; 30%	6%; 16%; 36%
Women: Management levels (%)	16% (as at 2008)	21.9% at Management level 8.3% (1) at Executive Management level (2010)	20.2% - company reports this figure holds steady in spite of the GFC (2010)
Websites - Diversity and EEO No link to EOWA reports on any company website	EEO: Commitment to workforce diversity and EEO reflected in staff rewards Diversity: individuals, cultures, ages, and race - no mention of gender - 36.4% of images are of females	EEO: not specifically mentioned – 1 reference to flexible work arrangements No mention of diversity of people, age, gender, nationality	EEO: Committed to EEO in consideration of increasing numbers of women in engineering, increasing flexible work options and family-friendly practices - Diversity: a multicultural and diverse firm, cultural and individual differences contribute to firm' s success
Overall projected culture	People and iconic project focussed. Like-minded curious, independent people making a difference and a better world. Women are welcome	Values-based with focus on sharing and seeking knowledge, safety, ethical behaviour, respect, success, integrity, responsible – Masculine influence	Values-based with focus on respect, teamwork, integrity, rich and diverse culture, care for and about people, relationships, communities and environment – Masculine influence

EOWA report and Family-friendly policy	2008 - Flexible working and return to work programs listed as future actions to be taken No information on purchase of extra paid leave	2009-10 - Devotes most attention to Family-friendly policies of the 3 companies Offers 12 flexible work opportunities in 'Whole of Life Flexible Work Options' Purchase up to 4 weeks extra paid leave	2010 - Work/life balance addressed through flexible work arrangements. Employees encouraged to discuss flexible with their manager Purchase up to 2 weeks extra paid leave
Number of weeks paid Maternity Leave	Information not available EOWA report specifies GOGH's insurance covers women on Maternity Leave	16 weeks (after 12 months service)	6 weeks (after 12 months service) 12 weeks (after 24 months service) Ability to extend Unpaid leave from 12 to 24 months, (12 months longer than the legislated 12 month)
Retention payment	Retention Payment is made following return to work from paid Maternity Leave	No mention	No mention

INTERVIEW FINDINGS

Organisational culture and policy formation

The interviewees report that a masculinist influence exists in organisations, on worksites, at specific professional associations and in their dealings with clients. This quote represents the interviewees' perceptions: "engineering is always going to be a boys' club and it is now" (Engineer1). The companies' structures reflect this culture and organisational policy formation, for example, "Just look at our management structure...we don't have enough women in our [top management] and we have very few senior female technical people." (Engineer3). Formation of diversity and EEO policy appears to be different at the three consultancies and is evident in the HR managers' range of responses to the question of how their policy was formed. Their responses range from "I'm not the primary driver so I don't know" (HR1), and "we've got a very small corporate people team whose job it is to write policy, and they consult with us" (HR2), to "we try to...design and implement things that are collaboratively developed and then we would then put it on a procedural basis" (HR3). In general these policies cover discrimination, bullying and harassment, grievance procedures and EEO.

Knowledge of entitlements

The interviewees were all asked what they knew about their company's policies and practices for diversity and EEO. In general, the response is that they know the policy should exist, and that access to the policy details is through the company's intranet. There is agreement that a bit of effort is required to find any policy. One common comment from the interviewees is that until there is a need to find particular details of the provisions for special circumstances, such as Maternity Leave or Carer's Leave, the engineers are not motivated to check their entitlements. The engineers identify four career barriers they experience despite the existing family-friendly policies.

Career barriers

The literature identifies a number of career barriers that women engineers encounter in their profession (Bell, 2009). The interviewees identify that negative effects on their careers include perceived and actual effects of gaps in employment through taking maternity/carer's leave (Metz, 2005), the perceived lack of women engineers' commitment due to use of flexible work practices, the perceived suitability of engineers as part-time managers, and the lack of childcare facilities and options (Ismail & Ibrahim, 2007)

Employment gaps

Of the nine engineers interviewed, five (Engineer2,3,4,6,7) experienced gaps in their employment either through maternity leave or working overseas or interstate. The gaps range from two months to 14 months. Four of the engineers (Engineer2,3,5,9) discussed the experiences of other professionals in their organisations who had employment gaps. The engineers report that employment gaps can have negative effects on their careers which include the different perceptions of commitment depending on the gender of those taking time off to care for children, losing their role in a team, possibly sacrificing career progression by going backwards or standing still in their returning role and have to catch up with technical developments.

The HR managers confirm that all three companies aim to support women engineers' return to work on a part-time basis following maternity leave. Policy at GOGH and HART supports female staff returning on a part-time basis from Maternity Leave as recognition of the valuable contribution they make to their companies. WARHOL's policy seems to support the engineers' perceptions that facilitation of part-time work for women engineers returning from employment gaps may be role dependent.

Flexible work practices

Flexible work practices identified by the interviewees include working part-time, or flexible hours, working at home or remotely and purchasing additional annual leave. As with Maternity/Paternity Leave, the number of weeks available for purchase is company specific (see Tab.2). These practices are described as being available and used by both men and women in the engineering consultancies. Of the nine engineers interviewed, three work part-time. One works half days (Engineer7), while two work four days a week (Engineer4&5).

Despite all three companies' policy and practice supporting flexible work to attain work/life balance, two negative perceptions are expressed in the interviews. The first is a perception that those who work flexibly or part-time are not as committed to the job or organisation as those who work full-time:

...now that I'm part-time I can almost feel it. I'm not the full-time member of the group; therefore I'm not contributing as much as everyone else, so therefore maybe I'm not developing the business the way everyone else is... (Engineer5)

The second perception applies equally to men and women engineers. Working part-time as an engineer or a team manager in project-based work is described as "difficult" and "a juggle" because work still needs to be done, and clients' needs must be met. Whereas part-time managers who work internally (i.e. only in the office) are not perceived as disruptive to getting jobs completed. Six of engineers interviewed have not experienced project-based managers working part-time and cannot imagine how this would work. As well, there is the opinion that these part-time positions are not supported by their organisations and their processes.

The three HR managers convey different organisational views about project-based engineers as part-time managers. At GOGH there is no issue with part-time managers, as the organisation has a "strong belief in work/life balance", so that any staff member is supported in their choice of adopting a part-time phase in their career. At WARHOL and HART the continuing education of their managers is identified as their main priority in breaking down traditional views of work. At WARHOL this education

centres on increasing managers' knowledge, awareness, and acceptance of working flexibly, while at HART a further step is taken as the HR manager counsels engineers returning from maternity leave on a part-time basis to rethink the way that they consider work hours. HART's HR manager also advises returning engineers to actively re-educate the members of their team.

Maternity/Paternity leave

The facility exists in each company for men and women to access Maternity/Paternity Leave following the birth or adoption of a child. Each company has a slightly different policy regarding the number of weeks leave which are available (see Tab. 2). Two of the engineers (Engineer4&7) have used the Maternity Leave while at their company, while two others (Engineer1&8) indicate that they were motivated to investigate their company's policy as they intend to use this leave in the future. The interviewees describe programs where the engineer on leave can maintain a predetermined level of contact with their company. The engineering consultancies are flexible in their work offerings to engineers returning from Maternity leave.

Even though extended periods (12 months or longer) of Maternity/Paternity Leave are available, the engineers agree that returning to work, particularly in a part-time capacity, is not a simple matter of walking back into the same position they left. They explain that the length of time they have taken off determines how much technical "catch-up" they have to undertake. As well, the position and project they return to must be suitable for part-time work due to the nature of their work.

Lack of Childcare facilities

The lack of childcare options is acknowledged in the literature as creating a career barrier for women engineers (Probert 2005). Although flexible work practices go a long way to helping engineers balance family and work responsibilities, the interviewees identify that is no access to or provision of childcare in their companies. Two interviewees suggest that the lack of childcare options is acting as a career barrier for women engineers to attain their career goals or reach senior positions in engineering companies, for example:

...at the company level the main thing that needs to change is childcare options...that's the one thing that holds women back more than anything else is the cost and time and availability of childcare...(Engineer8)

A HR manager also found that employees expressed need for onsite-childcare facilities as an unexpected result of an employee survey. The company's response was to "manage expectations to say that we're probably not going to do in-house childcare...we can't find enough space to house people, let alone the children."

DISCUSSION

In general, all three companies do not take advantage of using their websites to encourage prospective women employees. Of the three companies, GOGH devotes the largest percentage of its website to EEO issues, but does not take advantage of informing its audience of specific initiatives that makes it a recipient of the EOCFW award. None of the companies provide links to their diversity and EEO policy. The interviewees also reported that finding these policies on the companies' intranets

required a bit of an effort. In fact they could only describe those family-friendly policies that they had taken advantage of using. All three companies are missing out on using this easily accessible, public forum to inform prospective and current employees of their initiatives which support women in their careers.

The masculinist influence described in the literature (e.g. Bell, 2009) remains a cultural and structural influence on these engineering consultancies. This is demonstrated by the lack of women in senior positions in the three companies and the clustering of women in the lower professional levels in WARHOL and HART (see Tab. 2). GOGH is the exception of the clustering effect for which there is no apparent reason (Tab. 2) and is worthy of further investigation.

Findings from the interviews suggest that women engineers working part-time are experiencing conflict (Lingard, 2004), but not in their struggle to balance work and family, but rather in their attempt to satisfy their career goals. A masculinist influence is on family-friendly policies for flexible work and childcare continues to effect women engineers' careers. This is evident from the interviews with the women engineers in this study who are using flexible work practices, such as part-time work, and those who had experienced career gaps, or knew of women in their companies who had experienced extended periods of Maternity Leave. These women face two career barriers.

First, as Ismail & Ibrahim (2007) found, women engineers' commitment is questioned. Second, some interviewees found that those women who choose to return on a part-time basis face career barriers. In some cases they may not have a position to return to because of a belief that an engineering position must be suitable for a part-time presence as engineering managers must be continually available to satisfy client and project needs. Some women engineers interviewed actually held this belief as they had no experience of part-time engineering managers on projects and believed there are no processes in place to support this form of flexible work. This prevents some women engineers from returning to their former positions. Some women report feeling like they are standing still, or going backwards in their careers while they work part-time. The HR managers are working in different ways in their organisations on re-educating employees to accept part-time engineering managers. This requires more work to gain acceptance to break down one career barrier faced by women engineers.

The interviewees identify a lack of organisational policy and initiatives for childcare as a continuing career barrier. Engineering consultancies have been told by employees that this issue requires a solution, and their reaction is that childcare provisions are "under consideration". Organisations continue to talk about looking into childcare provisions, but it appears that no real action is being taken to resolve this issue. As Ranson (2005) suggests, the continued consideration of this family-friendly initiative seems to be one of rhetoric with no concrete policy in sight. Engineering organisations must develop policy for childcare to eliminate at least one career barrier for women engineers.

This study is limited due to low numbers of interviews with women engineers. It is recommended that interviews with both men and women engineers from additional consultancies would provide greater understanding of the issues addressed in this study. While the generalisability of this study may be compromised, two particular issues requiring further consideration by engineering consultancies have been identified and would begin to address the low numbers of women in engineering and also their

retention. First, these companies must find a satisfactory solution to address employees' need for company supported childcare. Second, these companies must frame the notion of part-time engineers, and particularly part-time engineering managers, to ensure that this becomes accepted and facilitated in their organisations to guarantee that women engineers can achieve work-life balance and continue with their career plans. This requires re-education of managers and workers, and development of supporting policy.

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WOMEN LEADING DIVERSITY AT SKM

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ABSTRACT

Sinclair Knight Merz (SKM) has made a serious commitment to encourage diversity and equality in the business through the establishment of a funded employee led initiative that identifies, recommends and reviews opportunities for diversity and equality within the business. In 2006, senior women in SKM's Melbourne office recognised the need for greater representative of females within management and leadership roles in the organisation, strategic recruitment and retention of female staff, and better mentoring and networking opportunities for current employees. Consequently, Women in Consulting (WiC) was established as an internal group whose mission is to engage women at all levels within SKM and provide opportunities for staff development and career progression. Fundamentally, WiC represents SKM's acknowledgement that diversity and equality is not just about providing a better workplace for all staff but is a financial imperative for the future of the business.

Some four years later WiC has established committees throughout Australia, New Zealand and the UK. WiC's achievements to date include being instrumental in influencing and developing internal SKM policy such as increasing parental leave and supporting flexible working arrangements including training. WiC has become a powerful voice in SKM with a seat on the Global Diversity Committee, instrumental in achieving EOWA Employer of Choice for Women status and provides extensive client and internal networking opportunities for women in SKM. In addition, a number of SKM's clients within the industry have approached WiC to help establish similar initiatives in their own organisations.

BODY OF PAPER

Introduction

Under-representation of women in business and the subsequent under-utilisation of the talent of females in the workforce has been a much discussed and long debated topic around tables in lunch rooms and board rooms in many organisations across all industries. It would appear that while most organisations want to increase opportunities for, and consequently numbers of, women in their workplaces, the reality continues to be far from the dream. Females at Sinclair Knight Merz (SKM) have realised that to engage and encourage women at all levels within the organisation leadership must start with them in order to place diversity firmly on the agenda. By leading diversity within SKM, women have inspired SKM business leaders to think differently about the future possibilities of tapping into a broader and more dynamic workforce.

SKM is a multidisciplinary consulting and project delivery organisation established in 1964. It has global capability in strategic consulting, design and project delivery. SKM operates primarily in three geographic areas Asia Pacific, the Americas and Europe, Middle East & Africa (EMEA) with approximately 6,500 people in more than 40 offices working in the Buildings & Infrastructure, Mining & Metals, Power & Energy and Water & Environment sectors for clients ranging from federal, state and local government authorities to large multi-national private and public corporations. Our people are from a broad spectrum of disciplines including engineers, planners, architects, economists, scientists, project managers, technicians and administrative staff.

SKM is an employee-owned organisation that visibly embraces shared values and an open culture. We have a commitment to service and quality, with high standards of safety and business ethics, along with a leading-edge approach to delivering a sustainable future. These key elements of our business, as well as a strategic vision to further expand into new markets and geographies, has resulted in SKM making a serious commitment to encourage diversity and equality in the workplace.

SKM has recognised that diversity within all levels of the business is a financial imperative for the continued growth of the organisation, as labour markets become tighter, and the demand for high quality talent increases. We have acknowledged that all staff must see career opportunity and long term possibilities within the business, to ensure that we recruit, promote and retain the best skills. We are certainly not the first to acknowledge this; many organisations and substantial research has been undertaken that suggests businesses produce better results by encouraging a broad cross-section of the community, at all levels, within an organisation. In recent years, McKinsey is one such organisation which has undertaken extensive research into the relationship between organisational and financial performance and the number of women in senior roles. Their research has shown that there is causal link between those companies achieving better corporate outcomes and the number of women within their senior and leadership ranks. (Desvaux *et al* 2008).

SKM has encouraged diversity in its business in a variety of ways for many years, by senior management as well as employee-led initiatives. The greatest success in recent times has been through the establishment of a funded employee-led initiative that identifies, recommends and reviews opportunities for diversity and equality within the business, known as Women in Consulting (WiC). The SKM WiC initiative drives review and cultural change, staff education and awareness, as well as consistent execution of diversity policies. WiC seeks to identify, recommend and review opportunities for diversity and equality, specifically related to gender, in all areas of the business. This paper provides detail on these strategies and goals and describes the varying success of these to date. It also recommends key areas that still need to be addressed and developed going forward.

Diversity at SKM prior to WiC

Prior to the founding of WiC, SKM had already recognised the need for diversity to help support many of its business goals. Great People, Great Teams has been a cornerstone strategy of SKM's business plan for many years, as the importance of attracting and retaining staff is paramount to SKM's success, particularly in the increasing talent shortage within the engineering sector. Diversity was also considered critical to SKM's Strategic Global Positioning strategy, in order to grow clients and attract staff outside of Australia.

In 2004 and 2005, SKM implemented a number of policies relating to diversity, good working relations and grievance procedures. SKM also created a Diversity Committee

focussing primarily on age-related issues. In Australia, a paid maternity leave policy was already in place, with a maximum of six weeks' paid leave, and employment for part-time, casual and contract arrangements were easily accessible. What was clear, however, was that the policies were Australian-centric and had limited relevance in attracting and retaining staff with cultural and gender-diverse backgrounds. SKM's language continued to be Australian and "blokey" despite the shift towards expanding internationally. Specifically, retention and progression of mid-level female staff continued to be an increasing problem, which resulted in very few eligible female candidates for senior roles.

History of WiC

In 2006, two senior female staff members from SKM's Melbourne office met with regional management to discuss their concern regarding the small percentage of women in senior leadership roles and in the private shareholding arrangements within the organisation. This discussion led to the creation of a small working group focussed on addressing the need for greater representation of females within management and leadership roles, strategic recruitment and retention of female staff as well as the provision of better mentoring and networking opportunities for current employees.

Consequently, the WiC initiative was created as an internal working group by women in the business, whose mission was to engage females at all levels within the company and provide opportunities for staff development and career progression. Key to the success and visibility of this initiative was active CEO and Regional Manager sponsorship. Fundamentally, WiC represented SKM's acknowledgement that diversity and equality were not just about providing a better workplace for all staff, but was a useful vehicle for serious cultural change within the organisation.

Key to the Melbourne WiC Steering Committee's success was the formal establishment of a Business Plan aligned to SKM's four core business strategies, a formal reporting process to the regional management team and a designated budget for the Steering Committee to manage. The Steering Committee also agreed on a vision statement for WiC *"to advance and support women at SKM by promoting the value of women in consulting environments."* Both the vision and the business plan have continued to shape the focus of WiC and to prioritise initiatives.

By setting clear goals around developing policy, and publicising diversity-related endeavours, as well as engaging senior management through financial commitment, the WiC Steering Committee earned respect and credibility as a valuable business asset supporting an important aspect of business strategy.

Growth of WiC

As WiC became more visible within the business, and importantly, through the ongoing promotion by the CEO, senior female staff from other regions began to enquire about the purpose and value of the initiative in their regions. This led to the gradual establishment of other committees throughout Australia, New Zealand and most recently, the UK and Asia. Each regional committee has a business case and budget for activities and events. The committees consist of a broad mix of staff, both male and female in some regions, which represent a cross-section of age, seniority and discipline.

WiC has a global steering committee represented by all regional chairs, which aims to create consistency in vision, purpose, the planning of activities and the sharing and publicising of information. The aim is to work together across regions and cultures to provide greater opportunities for all. A great outcome from working as a collective has resulted in the accreditation this year of an Equal Opportunity for Women Agency

(EOWA) Employer of Choice for Women Accreditation in Australia. Achieving this citation has been a key priority for WiC since its commencement.

Whilst WiC aims to work with consistent themes, a noticeable outcome has been that each regional committee has needed to develop priorities and goals specific to its own regional requirements. The Western Australian WiC committee, for example, has a high number of staff in seconded positions to external clients and in project offices, as well as numerous staff in remote office locations. This has meant that a primary objective for this team has been to concentrate on connecting and linking female staff members back to the business as a means of increasing engagement and retention. WiC performs the role of linking project office female staff to the business through events, networking and mentoring opportunities, as well as keeping staff informed about any new diversity policies.

The WiC initiative has also resulted in the creation of broader committees that focus on wider diversity issues. WiC has become a powerful voice in SKM with a seat on the Global Diversity Committee. This committee has identified a number of diversity items for the organisation to address and reinforced that diversity is a priority by ensuring it is now a standing agenda item at every leadership meeting within the organisation. Regional Diversity Committees in Australia and New Zealand, Asia and the UK have also been established to support and prioritise implementation of the global diversity initiatives at local levels.

Initiatives, Achievements and Successes

WiC has had a number of successes in the past five years and continues to gain momentum in the organisation. Key initiatives have been driven by females in the business, most of which support staff from both genders. As an agent for change in the organisation, WiC has become an important driver of initiatives which align with and support SKM's strategic initiatives, particularly those related to the attraction and retention of staff, and global growth. Some specific examples include:

- Supporting increased parental leave policies in Australia, with twelve weeks' paid parental leave, has been available to both genders since 2008. The policy has not only increased the number of weeks' paid leave, but has also included the primary carer role, whereby male or female partners can take paid leave as the primary carer, allowing the mother to return to work. Significantly, this is a cultural change, highlighting that both partners are important for the family. A number of males in SKM, from all levels of the organisation, have taken paid parental leave since its inception. The UK WiC committee is currently involved in supporting changes to the maternity leave policy in the UK, following a number of mergers and a contract review. These policies not only deal with the length and conditions of the leave itself, but also help to make returning to work a smooth process.
- Reviewing and providing guidance for Flexible Working Policies and practices globally for all staff. WiC is a successful promoter of the policies and practices across the organisation through newsletters, lunchtime sessions and branding. An online Flexible Toolkit has been launched with strong support by WiC.
- Through the EOWA Employer of Choice for Women goal, WiC has supported SKM in instigating a number of reporting measurements globally, such as attrition rates by gender, percentage of females in management roles, percentage of female staff, etc. WiC has also been a strong supporter of implementing bullying and harassment training across the organisation for all levels of staff; this training is now mandatory in Australia.

- Implementing a mentoring program specifically for female staff, and not aligned to the usual talent management process, which in the past has excluded many females. This is currently being piloted in NSW with male and female mentors and 20 mentees. The intention is to expand this to other regions through WiC, in the next year.
- Encouraging women in the business to network both internally and externally. Funding is provided by WiC for female staff to attend external events held by organisations such as Engineers Australia, National Association of Women in Construction (NAWIC), Women in Mining and Resources, Institute of Professional Engineers New Zealand and Women in Science, Engineering and Technology in the UK.
- Lunchtime “Skills Sessions” are organised and funded by WiC and open for all staff members, both male and female, to attend. These skills sessions range from interactive sessions on various topics such as networking skills, commercial management, coaching and presentation skills, to interviewing senior female staff about their careers, panel events and external speakers. Attendance rates are usually very high and both genders are attracted to the events.
- Regular internal pulse surveys of female staff are undertaken to gauge what issues are important to them, which assists in driving the business plan.
- Sponsorship for attendance at external leadership courses and seminars for women in the business.
- Regular SKM client events specifically focussed on female clients, such as boardroom lunches, cocktail events and panel discussions.
- Global communication is established through a number of channels. A SharePoint site has been established to allow knowledge-sharing, as well as give all staff access to meeting minutes, etc. Regular quarterly newsletters are emailed globally, and highlight the successes and achievements of women in SKM. In addition, the WiC Chairs communicate through regular teleconferences to share learnings.
- SKM’s UK business acquired another organisation, Enviros, in 2010 with a large number of female staff in a number of regional offices of varying sizes. The UK WiC team has been instrumental in supporting the cultural integration of the two organisations through connecting women across offices and teams.
- Connecting with female engineering students and female school students to encourage more female representation in the engineering sector, through sponsorships, networking, internships and presentations.
- Leading SKM’s celebration of International Women’s Day each year, in recognition of the importance of equal involvement of women in all aspects of life and business.
- Sponsorship and attendance to this event! SKM is a silver sponsor of the ICEWS15 conference through WiC and will be funding staff to attend.
- In 2008, the South Eastern Australian WiC team was awarded the City of Melbourne Crystal Vision award through NAWIC for an innovative, proactive and effective organisation which is successfully advancing the interests of women in the construction industry.
- Submission and accreditation of a citation for EOWA Employer of Choice for Women status in Australia in March 2011.

Diversity Initiatives across SKM

The WiC initiative has also been instrumental in identifying the need for a more focussed management approach to diversity and as such provided a springboard for the Global Diversity strategy. Under the direction and leadership of the CEO, SKM reinvigorated the Global Diversity Committee with the CEO as Chair in 2008. The Global Diversity Committee seeks to encourage strategies for diversity of thought and behaviour at SKM to attract and retain talent in all segments, to create global mindsets to help grow business in new markets and to broaden our client base. The purpose of the committee is to provide advice and ideas, set priorities and undertake initiatives reporting to senior management or the SKM Board, depending on the activity. Four strategies were quickly identified by the committee to pursue: developing and implementing an Intercultural Awareness Training program, strengthening and promoting flexible working arrangements, supporting the promotion of women and culturally diverse staff members into more senior roles, and specifically, with WiC's guidance, striving for EOWA Employer of Choice for Women accreditation in Australia.

The CEO has also been a strong supporter of the appointment of a Global Diversity Manager on a part-time basis. This is a new role in the organisation and seeks to enhance and consolidate the development of the diversity agenda across SKM.

Other diversity initiatives driven by the CEO in the past five years include:

- An open and transparent recruitment policy where all leadership roles in the organisation are advertised internally, with a diverse interview panel including at least one female.
- Active sponsorship of female talent in the organisation, including the CEO personally reviewing attendance at each senior leadership development program, to ensure females are included.
- Striving for gender pay equity through analysing annual salary reviews by gender.
- Implementation of mandatory annual performance reviews for all staff globally, whilst not specifically a diversity initiative, has supported the diversity platform and engendered a feedback culture.
- Diversity as a standing agenda item at all senior management meetings.
- Diversity included as a key theme in many leadership development forums across all career streams, which helps to support working across cultures and recognising unconscious bias.
- Stronger reporting mechanisms, including a rigorous analysis of exit interview data by gender, discipline and location, including a survey to follow up with staff members three to six months after their departure.

External Connections

One of the greatest emerging benefits since the commencement of WiC has been the ability to connect in different ways with our clients and delivery partners. Primarily, through events such as client functions, professional meetings/events, one-on-one meetings, mentoring opportunities and discussion sessions, this has enabled SKM to assist others in broadening opportunities for women, as well as learning more about the culture and aspirations of our clients.

WiC has developed a reputation in the industry for leading diversity strategies and a number of our clients and competitors have approached us to assist them in developing similar networking initiatives in their own organisations. Specifically, Abigroup and Australian Rail Track Corporation in NSW, and Yarra Valley Water in Victoria have now worked with the WiC teams to understand our intent and strategies, and some have since established their own internal networks. This has supported diversity in general in the industry, and has helped strengthen relationships with our clients.

It is important to WiC to actively support and promote external industry organisations which offer networking and career development opportunities for women in industry. Organisations that we are currently members of or linked to include: Women In Engineering (part of Engineers Australia), National Association of Women in Construction (NAWIC), Women in Project Management, Women in IT, Australian Institute of Management, Women in Resources Queensland (WIMARQ), Queensland Resources Council (QRC), Institute of Professional Engineers New Zealand, and the UK Resource Centre for Women in Science, Engineering and Technology.

Impact and Results

The impact of all the diversity initiatives including WiC, have achieved some outstanding results for SKM in diversity. Whilst the number of females entering our industry remains low, particularly with only 13.9% of professional engineering graduates in Australia in 2008 being female (Engineers Australia, 2010), we are proud that within SKM the attraction and retention of female staff has improved, with 32% of all new hires being female.

Despite the global financial crisis and downturn within our industry in late 2008 and throughout 2009, our diversity initiatives have gone from strength to strength with the percentage of female staff increasing during this time. In May 2008, prior to the global financial crisis and arguably at the height of the industry's talent shortage, 25% of SKM's global staff was female; by February 2011, this percentage had increased to 27.4%, with overall staff numbers remaining stagnant. The percentage of part-time staff, a key indicator of flexible working practices, has increased globally from 4.6% to 5.3% including sixteen part-time managers. Attrition of female staff has also slowed, with a significant reduction in variance of attrition rates between female and male staff to 1.4% in February 2011 down from 5% at the end of the 2005/06 financial year when WiC was instigated.

As at February 2011, 15% of management roles globally are held by women, including one female leadership team appointment as a direct report to the CEO in 2010. More crucially, 23% of team leader roles, which are considered the feeder roles to management level, are held by women globally. SKM's board consists of three female directors (two executives and one non-executive), representing 37.5% of board membership.

Cultural diversity has also improved over the same period, despite Australia remaining the strength of SKM's financial success. In May 2008, 25.8% of SKM's staff was located outside of Australia; by February 2011, this had increased to 28.1%, with entities having been established during this time in countries including Kenya, Brazil, Colombia, Peru, Oman, Ireland and the Czech Republic. See Fig.1 below.

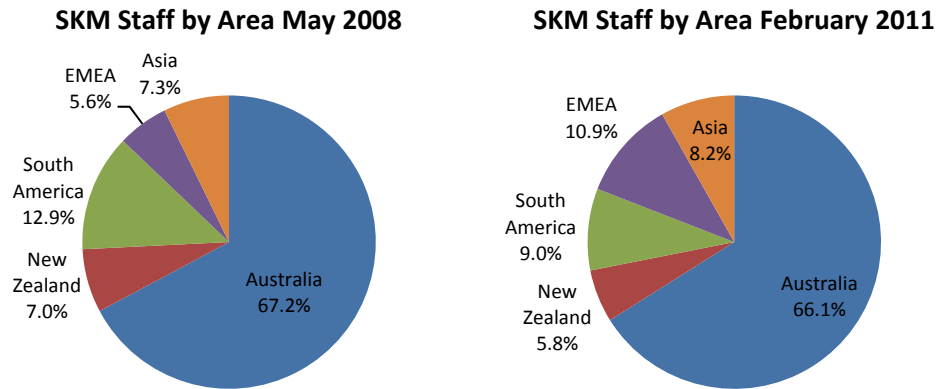


Fig. 1: SKM staff by geographic area May 2008 and February 2011

SKM runs a bi-annual global employee engagement survey which is administered by Towers Watson, with diversity as a key measure. In the October 2010 survey, with two thirds of all staff responding to the survey, the diversity category had statistically significantly increased by two percentage points versus the August 2008 survey, and five percentage points versus the August 2006 survey. Even more significantly, SKM's overall diversity score was seven percentage points higher than Towers Watsons' Global Professional Services Norm and nine percentage points higher than Towers Watsons' Global Engineering and Construction Norm, which are two key external benchmarks for SKM.

Future Priorities

Celebrating and acknowledging the progress that has been made in taking forward diversity in our business at SKM is very important, and delivering a paper at a conference like this helps us to recognise those achievements. However, there are still further steps to take and areas in which we can improve.

As we grow our business to be truly global, WiC needs to expand and be represented across all our regions to support the strategic growth of our business, and to that end we envision establishing committees in Asia and South America. In line with our growth, we need to get smarter at communication and develop better channels to share knowledge of progress of cross-regional initiatives. This could take the form of more regular global WiC conferences and establishing sub-committees.

Demonstrating WiC and the Diversity Committee's successes, results and effectiveness through internal and external marketing is an area we need to progress and take forward to the next level. Including WiC in our external branding for attracting employees through our internet site is in the plan for the 2011/12 financial year.

We need to continue to listen to the issues that affect our colleagues and respond with initiatives that reflect the issues and challenges that are important to them. Regular feedback is a feature of how we maintain our focus.

Continuing to develop connections and relationships with our clients and delivery partners is a great way to share ideas and network with other women in the industry. This is an area we can integrate into our day-to-day business at all levels, and demonstrate our worth to the wider business – a “no brainer”.

Initiatives that we have yet to develop further, but are included our business plan are: a 'bridging program/keeping in touch' framework for employees and managers to enhance belonging and retention of staff who are either seconded, site-based, on parental leave, other long service leave, etc; awareness of career development tools and techniques inside and outside the business; and career planning for areas such as administration and support staff who are not normally highlighted as well as the technical and managerial streams.

A question is always asked in SKM: What will success look like in five years? In five years' time, WiC would like to become part of the fabric of the business similar to a Community of Practice and an underlying aspect of diversity within SKM. In other words, WiC may not need to exist, because diversity will be so embedded in our business, that it no longer needs a specific program to encourage its adoption.

Key Learnings and Conclusion

We have learned that there are some key factors in the success of WiC and diversity in the organisation. SKM will continue to strive to promote and raise awareness of diversity issues inside and outside SKM's business.

Central to the implementation of diversity initiatives is the commitment of the CEO and leadership team to acknowledge the value, engage in the process and lead by example. Organisations can no longer afford to appoint managers that resemble themselves in terms of gender, age and career history and must learn to recognise that those candidates with different professional experience are able to contribute high-level, astute and innovative approaches to decision-making, as well as bringing to the management a wider understanding of evolving markets, technologies and client needs. Leading by example, use of language and attendance and support at internal and external WiC events is a visible way for management to show commitment to the diversity process.

WiC has been enhanced through an annual budget, and has achieved credibility through a well-constructed business plan aligned to SKM's corporate strategies. Notably, during the Global Financial Crisis, none of the WiC budgets were cut, when other areas of the business experienced a downsizing. The strategy alignment gives WiC licence to say "yes" or "no" to new ideas and initiatives in a robust manner.

WiC has ensured that almost all events, forums and initiatives are not exclusively for women. Rather, involving and engaging all staff, including senior men in the organisation, has increased the profile and success of WiC. In order to achieve support and engagement from the wider business, all staff need to feel able to contribute, benefit and own these. If WiC were to have female-only committees and events it would create a "mystique" and exclusivity which is not conducive to the aim of diversity, which is inclusivity.

Branding has been important. Clarity of purpose and intention needs to continue to be communicated well, internally and externally. WiC has experienced some misconceptions and we are still learning how to communicate what we stand for, what we do and what value we bring to the business. In many cases, our initiatives such as flexible working, career progression etc, are not gender-specific, as they affect all

people in the business, and WiC is merely a vehicle to take these forward for all. Delivering that message is sometimes a challenge.

Recognition that different regions, and parts of the business, have different priorities and diversity needs, is also important. A “one size fits all” approach does not respect the market, culture and diversity mix in each geographic location. The general growth in our South American and Asian regions is supported by WiC, to connect cross-cultures and engender a spirit and acceptance of diversity across the business.

WiC is aligned with the organisation’s mantra that selection of staff for leadership, senior and committee roles must be merit-based, as tokenism undermines credibility of a candidate and respect for their skills and experience. Quotas and positive discrimination is an emotive topic. It is not something that SKM supports, as experience suggests this can be counter-productive and can breed resentment. However, perceived inequitable employment and career advancement attitudes could prohibit SKM’s ability to attract and retain staff globally. Our Great People strategy is a critical determinant in the achievement of business goals and influential in delivery for our clients. It is essential for business growth and innovation to encompass a broad and diverse mix of people from differing backgrounds, gender and cultures who have varying thinking styles and behaviours. WiC is one initiative which enables SKM to actively support such initiatives in diversifying workplace culture. WiC can help staff network, gain experience and ultimately opportunity, development and the exposure needed to contend for vacant leadership and senior roles, as well as career development in other areas of the business.

SKM works in an industry where females are a smaller percentage of the workforce. For SKM and the industry to remain dynamic and continue to innovate, attracting and retaining a diverse workforce is important to business success. By continuing to think differently about our employee value proposition and how we work together across culture and gender will only continue to enhance our future business strategy. WiC is simply one vehicle to help leverage that value proposition and support diversity of thought and behaviour to assist SKM to become a world leader in strategic consulting, engineering and project delivery in our core industry sectors.

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Finding, recruiting, and retaining women engineers for national security R&D positions

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ABSTRACT

Sandia National Laboratories¹ is America's premier science and engineering lab for national security and technology innovation. We are a world-class team of scientists, engineers, technologists, post-doctoral fellows, and visiting researchers all focused on cutting-edge technology, ranging from homeland defense, global security, biotechnology, and environmental preservation to energy and combustion research, computer security, and nuclear defense.

As the "Silver Tsunami" hits the workplace, and the Baby Boomer generation looks to retire, the task of finding highly talented US citizens with advanced degrees in electrical, mechanical, and computer engineering for our national security missions becomes increasingly challenging. Statistics from American Society of Engineering Educators from 2009 (Gibbons, 2010, see reference 1) confirm that the annual pool of non-foreign graduates earning MS degrees in these fields number about 5800 annually. Of that total, only about 1 in 4 is female. Sandia's stringent hiring standards further narrow the talent pool and make finding female candidates for our national security positions a real challenge.

This paper describes a number of world-class benchmark programs developed and deployed at Sandia to attract and retain the best and brightest female and minority candidates into the talent pool. The most successful programs have been our Masters Fellowship Program (MFP) and Critical Skills Masters Programs (CSMP). High-performing BS candidates with high academic achievement are hired before they graduate and are sent to one of the country's top graduate schools, all expenses paid, plus stipends for living expenses. These programs have tackled the problem of a limited MS pool by removing financial considerations from BS graduates' decisions regarding pursuit of a graduate degree. It also allows Sandia to "grow its own" graduate engineers from the relatively more populous BS population of females and minorities. Upon graduation these candidates receive a substantial bump in pay to our MS start rate. A large proportion of participants in these programs remain a significant time period at Sandia, often for their entire careers, and many assume leadership positions as their careers progress.

Another successful technique used to attract outstanding candidates is Sandia Science & Engineering Expo (SEE) a program that identifies top recruits and invites them en masse to our location for a day of multiple interviews in a variety of mission areas across the company – a sort of "speed dating" format. This technique makes the matching function more efficient and speeds the timeline for hiring. Sandia seeks out top MS and PhD engineering and science students desiring full time employment after graduation. In an era of increasing competition for highly qualified scientists and

¹ Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

engineers, Sandia must take advantage of every opportunity to showcase its capabilities to tomorrow's technology leaders. SEE gives top masters degree and doctoral candidates from across the nation an opportunity to visit and see the most exciting in basic and applied research and development facilities that Sandia has to offer. The strategic recruiting event provides an opportunity for managers and staff to meet and interview very highly recruited new graduates and, we hope, bring them to Sandia. This is one important way we can keep this laboratory competitive into the next decade and beyond.

This paper will discuss the structure, parameters, and implementation of these programs, along with retention and benefits of these successful programs.

INTRODUCTION

Sandia National Laboratories is a federally funded research and development institution in the United States, with missions in defense, national security, energy, and applied research in a number of science and engineering fields. It has two principal locations in Albuquerque, New Mexico and Livermore, California. Its workforce of more than 8200 includes over 3800 managers and staff with advanced degrees in science, engineering, and related technical fields. Sandia is a government-owned, contractor-operated company that has a prime contract with the Department of Energy to operate the facilities on behalf of the federal government. Although Sandia employees are not federal employees, we are bound by the same federal employment laws and abide by the same Equal Employment and Opportunity (EEO) policies of federal agencies. Moreover, Sandia considers a diverse workforce to be an imperative in the workplace to drive innovation and produce the highest quality work.

Our President and Laboratories Director, Paul Hommert, states on Sandia's internal website regarding diversity and inclusion, "My vision for Sandia is to continue to build and sustain a diverse workforce composed of individuals who know that they are an important part of Sandia because they are valued, included, treated with respect and dignity, and are fully productive contributors to mission success. Toward that end, we must be mindful always that we conduct our business with a diverse set of customers and achieve mission success through diverse partnerships. Being committed to diversity and inclusion, we can ensure that Sandia attracts, retains, and develops a world-class workforce."

RECRUITING TOP TALENT – A GIANT CHALLENGE

As one of the premier national laboratories in the United States, we hire (by design and necessity) only "the best and the brightest" individuals capable of functioning both technically and professionally with the best minds and foremost subject matter experts in the country. Identifying, recruiting, hiring, training, and retaining this highly educated, high-powered workforce is a formidable task. In addition to intellectual capacity, we demand outstanding academic credentials from top universities, US citizenship, and the ability to obtain high level security clearances, due to the sensitive nature of the work we do. Though Sandia has a reasonable total hire package, the fact that private industry can generally offer more attractive starting pay to many of these outstanding candidates increases the challenge of capturing their attention and retaining them once they are with us.

Sandia National Laboratories is not the only institution in the United States with these challenges. Many of our sister national laboratories, most notably Lawrence Livermore National Laboratory (LLNL) in California and Los Alamos National Laboratory (LANL) in northern New Mexico, have similar issues. Even beyond defense-related work, national laboratories devoted to nuclear reactor design and safety have needs for highly talented staff in sensitive positions.

With these criteria, the available talent pool each year is quickly narrowed down from the total number of graduates, which is already a low percentage compared to other technologically developed countries such as Japan (National Science Foundation, 1994) Data from the American Society of Engineering Educators (Gibbons, 2010) provides some insight into just how many candidates are eliminated under these stringent criteria. For example, of the 41,632 master's degrees awarded in the US in 2009, 44% were foreign nationals ineligible for employment in Sandia's defense-related programs. In addition, data show that the availability of women and minorities are limited and has not grown appreciably in the last decade. In 2000, women received 21.7% of master's degrees in engineering. That figure has hovered in the 21-23% range over the last 10 years, with 23% going to women in 2008-2009. Similarly, figures have ranged between 4-5% for African Americans, 4-6% for Hispanics, 15-18% for Asians, and 11-15% for other ethnicities. Keep in mind these figures include foreign nationals who likely make up a large percentage of these minority graduates but are not eligible for hire in national security positions.

INNOVATIVE STRATEGIES FOR ACQUIRING TOP TALENT

HIRE UNDERGRADUATES AND SEND THEM TO GRADUATE SCHOOL

Realizing that the US master-degreed candidate pool was limited in terms of US citizenship, Sandia started a program in the late 1960s that identified top undergraduate students with high potential and sent them to graduate school at top universities. The program was designed to increase the available pool of talent with advanced degrees as quickly as possible. Diversity of the workforce evolved to become an important factor through the 70s and 80s and remains a requirement for one of our existing programs. Originally, candidates were required to complete their degree within one year. Sandia paid their tuition, fees, books, moving expenses, and also paid them a stipend equal to 60% of their normal salary² so that they would not have to work and could devote their full attention to their studies and complete their degree quickly. The only thing Sandia asks in return is that, upon completion of graduate studies, students remain at Sandia for at least the amount of time they spent in school.

Currently, Sandia offers two programs with essentially these same features. The Master's Fellowship Program (MFP) is for outstanding underrepresented minority candidates about to receive their bachelor's degree in a science or engineering field of interest to Sandia. MFP helps Sandia meet its Affirmative Action goals while fulfilling its requirements for technical employees with advanced degrees. Our recruiting process involves teams of alumni that visit campuses of top universities and attendance at major technical and diversity conferences through our operating parent company, Lockheed Martin. While the minimum GPA is officially 3.2 on a 4.0 scale, the students we recruit

² The FY11 annual starting salary for this program is \$72,200, which translates to a stipend of \$43,600 while in school.

for this prestigious program are often in the 3.5 and above range and frequently have been identified as top recruits by our teams and as outstanding students by their professors. They also often have multiple internships and research experiences on their resume.

The other program we offer is called the Critical Skills Master's Program (CSMP). This program is similar to MFP but is open to any US Citizen who is an outstanding student that meets the qualifications and is majoring in a field of study that meets our current critical skill gap areas. The terms for both programs are as described above, except that students are now allowed 18-24 months to complete the program, depending on whether they have elected to do a thesis program.

Historical data gathered indicate that 579 individuals will complete or will have completed this program by the end of 2012. The following diagrams show statistics by gender and ethnicity in these programs over the last 4 decades.

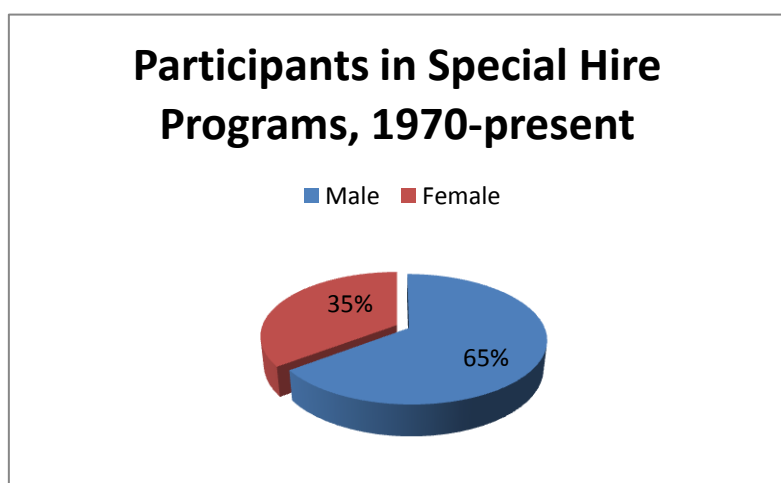


Fig. 1: Total participation in Special Programs, by Gender

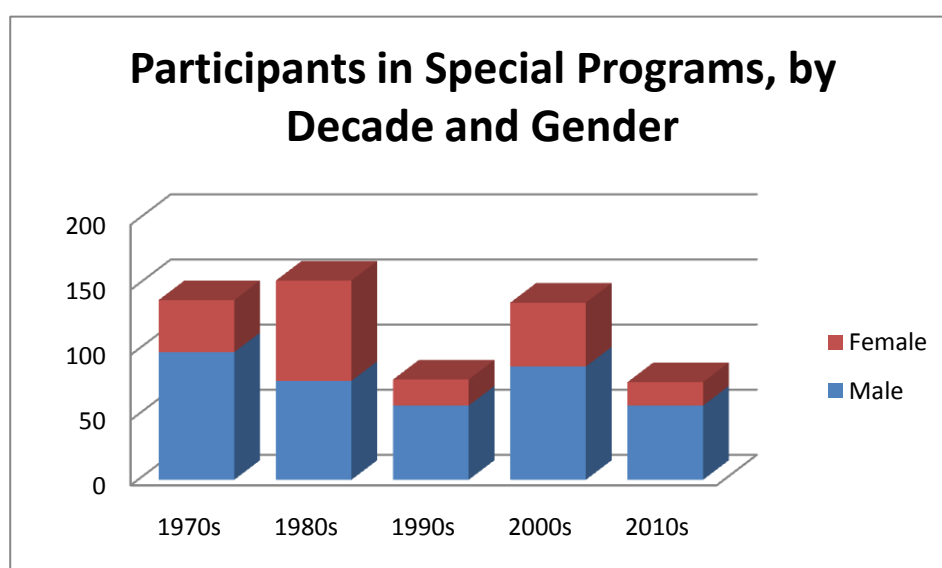


Fig. 2: Participants in Special Programs by Decade, by Gender³

³ The 2010 data contain only 3 years of data, through 2012.

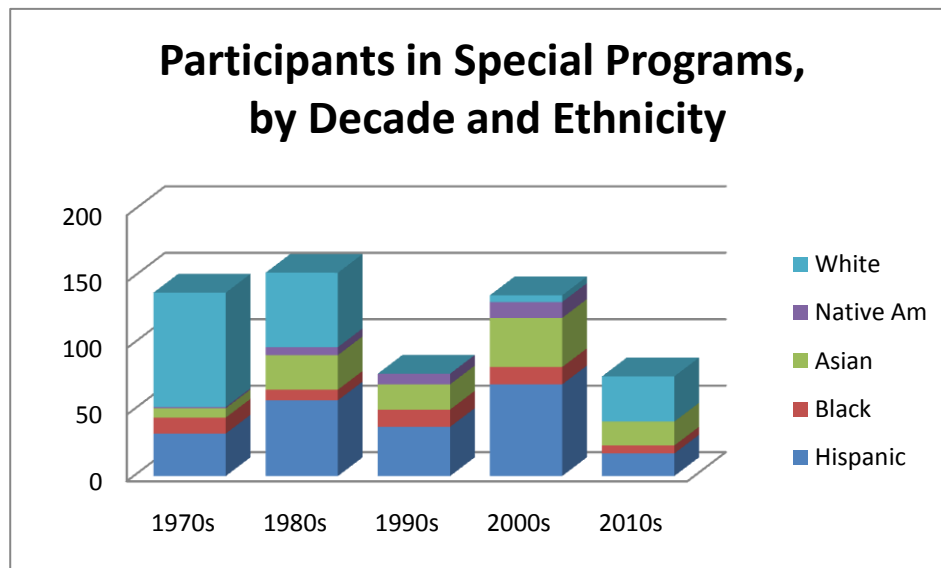


Fig.3: Participants in Special Programs by Decade, by Ethnicity⁴

BENEFITS

The benefits of these special programs are manifold. Returning to the statistics from ASEE, we find that the percentage of BS engineering graduates in 2009 with US citizenship is 96%. Though the percentage of females and minorities are low, especially in the disciplines of the greatest interest to Sandia, the numbers of BS degrees granted are much higher – a total of 74,387. Sandia immediately increases the sheer numbers of candidates in the pool by looking at the bachelor's level. These programs tackle the problem of a limited MS pool by removing financial considerations from BS graduates' decisions regarding pursuit of a graduate degree. These students are getting an incredible deal for the graduate education, as well as a guaranteed job upon completion of the MS degree. This tends to build loyalty to Sandia. Though the retention rates are not as good as Sandia's overall rates, candidates who go through this program are not as likely to leave after they fulfill their obligation to Sandia as one might expect. We also find in reviewing our historical data that many who completed this program go on to become leaders in the organization. Of the 579 participants to date, about 10 % of each gender has risen to some level of management or senior technical leadership. In fact, our recently retired executive vice-president, Joan Woodard, was a product of this program in its early years. These programs are clearly an important pipeline for developing the next generation of leadership at Sandia.

RETENTION

Sandia's retention strategy is to employ a system of tools and activities that enables both proactive and real-time addressing of talent issues in an effort to retain a highly qualified, diverse workforce. Retaining a diverse and qualified workforce at Sandia includes integration of a diverse ethnic and gender base as well as diversity of thought. Our goals are to attract, hire and retain the right people, integrate and develop these talented employees from day one, and keep them interested and engaged in order to contribute to SNL's vision and mission. To date, the results of SNL's retention efforts have been very effective as evidenced in our low attrition rates (YTD-FY'09 0-5 yr service 3.5%). This is extremely low by industry standards.

⁴ The 2010 data contain only 3 years of data, through 2012

The 5-year retention rates of the MFP and CSMP programs are about 4 in 5. This means that some employees take advantage of the program, serve their required time, and move on to careers elsewhere. (A small number of these are terminated by Sandia for being unable to complete the requirements of the program.) There is clearly some risk in offering such an attractive program to highly talented staff, in terms of retaining these people for the long term at Sandia. However, the proven benefits in building our future leadership and a diverse and highly talented technical workforce are so strong that Sandia is willing to take that risk.

HAVE AN ON-SITE MASS RECRUITING DAY

Another strategy that has worked very well in terms of hiring success is to identify top recruits (both undergraduate and graduate) and bring them to Sandia for a visit and multiple interviews. This program, called Science and Engineering Expo (SEE) was first deployed in 2006 to bring in top MS and PhD candidates in a variety of areas. Candidates are typically invited on site as a group for 2-3 days. They are introduced to Sandia at an opening function, often a social or dinner prior to interviews. At least ½ day is set aside for round-robin interviews by multiple managers in a central location, which has been jokingly referred to as “speed dating”. Tours are conducted for at least ½ day. PhD candidates are usually invited to give seminars on their thesis topics. This same concept was recently applied to a specific diversity group who happened to be having a conference in Albuquerque, and to a group of outstanding students from one of our top recruiting schools, with great success.

Sandia presented their sixth SEE event on 10-14 November 2010 as a Diversity SEE (D-SEE) hiring in collaboration with the American Indian Science and Engineering Society (AISES) national event. We invited nineteen top recruits an opportunity to visit the most exciting facilities and technologies in the areas of basic and applied research and development that Sandia has to offer. In turn, Sandia extended ten offers and received eight acceptances, with two pending.

Sandia subsequently held their seventh SEE event on 15-18 November 2010 with the University of Texas recruiting team, offering thirteen top technical MS and PhD candidates from across the nation (UT-Austin, Purdue, and the University of Florida) an opportunity to visit the most exciting facilities and technologies in the areas of basic and applied research and development that Sandia has to offer. In turn, Sandia extended twelve offers and received eleven acceptances.

WHO PAYS?

Part of the success of these programs is due to the fact that much of the expense for these candidates' graduate education is paid out of corporate overhead, rather than by individual line organizations. The corporate cost of keeping a student on either of these programs currently runs ~\$60K/year/participant, depending on the university and its location relative to Sandia's sites. Corporate-level support provides a powerful incentive for line organizations who may be worried about hiring full-time graduates to take on candidates in their pipeline but defer their financial obligation until the student graduates. It also levels the playing field so that all organizations have an equal chance to participate in the program.

SUMMARY/CONCLUSIONS

The Masters Fellowship and Critical Skills Masters Programs at Sandia National Laboratories address issues of finding, hiring, and retaining top technical talent with US citizenship for sensitive defense-related positions, while improving the pool of qualified women and minorities who are chronically underrepresented in engineering. These programs fill our hiring pipeline to ensure a steady stream of highly qualified and motivated hires that are likely to stay with Sandia for a reasonable period of time. In addition, SEE events that bring in groups of talented individuals from a particular discipline, ethnic group, or university also help meet hiring needs in a tailored fashion and further help address diversity goals in hiring. The choice to underwrite these programs with corporate overhead funds levels the playing field and provides a strong incentive for participation by the line organizations.

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- Numerous internal proprietary data and reference materials from Sandia National Laboratories have also been used in the preparation of this paper.

REFLECTIONS ON A YEAR OF ENGINEERING LEADERSHIP

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ABSTRACT

Doug Hargreaves has completed a year as President of Engineers Australia, a 90,000 strong membership based organisation representing the engineering profession. In preparing for the year Doug decided that the core of his own leadership is his values and that the legacy he wanted to be remembered for at the end of his year, was how his values underpinned everything he did.

The framework for this values approach was a book he co-authored entitled 'Values Driven Leadership'. The essence of Doug's philosophy is that a leader who bases their leadership on a strong sense of values will create an environment where people have a strong sense of Belonging, Identity, and Purpose.

This paper reflects on Doug's year of leadership of Engineers Australia and offers insights and examples of where his values driven leadership approach played out and contributed to various scenarios he encountered over the year. The paper will share Doug's approach to leadership and offer an understanding of how an effective leader actually does what he does. Too often leadership is seen as a nebulous capacity that people either have or do not have. In this paper, we will identify the specific skills and abilities within a values framework that will allow any leader to be more effective in their role.

INTRODUCTION

If five years ago someone had said to me that I would be President of Engineers Australia, the peak body for the profession with about 90000 members, I would have responded with a comment along the lines of "No Way". It was not something I aspired to or coveted. In fact, the notion had never entered my head. Having said that, however, I am conscious of the fact that I had a history of involvement in Engineers Australia and had willingly taken on various roles over the years.

When originally approached to consider the role of President, I was very humbled by the esteem with which I held those who approached me. I agreed to contemplate the suggestion but felt great trepidation as I had watched others in the role and the pressures they succumbed to and the enormity of the role they had undertaken. So the questions I asked were related to what is expected of a President, what is the actual role

versus what it appears to be, what have I to offer, am I capable of fulfilling the requirements of the role. To be honest, it was a very difficult process of contemplation as I started from the premise that I was not a worthy holder of such a significant position.

I undertook to speak with five Past Presidents and ask them what they set out to achieve when they started and what in fact happened to their dreams, wishes and goals. That was a fascinating series of conversations as all indicated they had high hopes of specific goals they wanted to achieve but all said that once in the role, the role itself became all consuming and that in fact none has been able to achieve all that they had set out to do. This was a significant point in my contemplation.

I accepted the invitation of others to nominate for the role of National President and through due process I was elected to the role. My message at the beginning and throughout the year was consistent and specific. And this relates back to the issue of what goals I set for the year of my Presidency. I did not set out a series of goals, but I did set out to influence all those with whom I had contact. My message was simple and hopefully as the year progressed and concluded it became the message with which people will identify my year.

LEADERSHIP AND VALUES

One of the fundamental tenets of leadership is that the leader know her/himself. If you as a leader try to lead in a way that is not aligned to your values, then people will very quickly see through it and the effectiveness of your leadership will be diminished significantly. This means that you need to *Walk the Talk*. If you don't, your leadership style (as seen by your people) will be as one of leadership by position rather than leadership by valuing people. To me, the latter is the preferred way because if you value your people, they will achieve far greater than any alternative.

In Dalglish and Evans (2007), a chapter is devoted to each of ten leaders. The leadership style and systems of values of one of the authors of this paper (DJH) is depicted in this book. Leadership tips include listen, be open, be enthusiastic, know where you are going and how you are going to get there, know your people, know what your organisation is about, live your values and be persistent.

Evans and Hargreaves (2010) sets out something of my (DJH) story and the impact my values have had on what I do and those around me. The essence of the book is that in an organisation where leadership is based on a strong sense of values, the people in that organisation develop a sense of Belonging, a sense of Identity and a sense of Purpose. The rules that have governed my behaviour and actions over the years have a very strongly held set of values that underpin all I say and do.

The principles proposed in Sanborn (2004), Lundin et al (2004) and Maxwell (1999a, 1999b) align well with my thinking and behaviour systems. My fundamental philosophy of leadership is that

People do the work and any organisational structure and sets of procedures should be enabling mechanisms for people to do their work.

Clearly, valuing people is crucial to any effective leadership.

The Fred Factor principles of

- Everyone makes a difference
- Success is built on relationships
- You must continually create value for others and it doesn't have to cost a penny, and
- You can reinvent yourself regularly.

and the Fish principles of

- Play (have fun and be lightedhearted)
- Make their Day (focus on engaging with others in ways that lift their spirits)
- Be There (living in the present moment and giving others our full attention)
- Choose your Attitude (understanding that whatever attitude you are carrying with you right now, it is the one you are choosing)

align perfectly with my style of leadership.

Given that *People Matter*, how does a leader actually put this into practice? A whole series are pertinent: openness, transparency, honesty, empathy, support, encouragement, listening (and hearing) are but some of these behaviours.

Given all of this, my message is: Clearly understanding our own values; clearly and demonstrably living by those values; with conviction communicating those values to all with whom we have contact; and at all times being consistent in our words, deeds and behaviour around those values, will and does lead to a better process and a better outcome for all concerned.

I would like to challenge you to contemplate your own values and how these influence your behaviour in your roles in your work place and in your life. Consider how you can be more effective as an individual in all aspects of your life. Open yourself to hearing a story that is probably different but yet is as old as time itself in terms of the question of what is leadership and how do we identify effective leadership

You might be wondering how you can influence anyone in your current position. Let me assure you that you can and probably already do influence others. Patterson et al (2008) provides powerful messages of how we can influence others. The Authors found that from Boston to Bangkok, there were quiet but tenacious influencers who had solved world-sized problems in world-class ways; simply by influencing peoples' behaviour. An example is that in Thailand, over 5 million people avoided contracting HIV because of a remarkably effective influence strategy developed by a quiet but enormously effective influence genius who has a lot to teach us all.

Throughout my year I talked about B.I.P. The sense of Belonging, Identity and Purpose that is created for people when leadership is values based. In many ways over the year, I saw evidence of this impacting on others both as individuals and as groups.

Openness and Transparency

Probably the most overt demonstration of my leadership style and the values that underpin it was the July 2010 Congress. Congress consists of about 50 members elected

and nominated from various constituencies around the country and overseas. The debate was related to the proposed changes to Engineers Australia Royal Charter and Bylaws. There was a degree of discontent between Congress members about the proposed changes. Before the two-day debate, I sent to all Congress members the rules for debate that I intended to use. For me, it was crucial that all members had opportunity to have input into this discussion. Before the actual debate, I set aside sufficient time for anyone to ask questions, primarily for background to some changes and for points of clarification but there would not be any debate in this period. The debate began and progressed according to my Rules. This in one sense was very controlled but it allowed everyone to have equal opportunity to put their case. Towards the end of the first day, I perceived that some members weren't satisfied with the debate but did not know what to do. Rather than take a final vote, I adjourned the debate to allow people time to think through what had happened. I did receive some criticism for adjourning the debate rather than taking a final vote. Next day, we reconvened and more motions were put forward. As before, I followed the Rules. Many members congratulated me on the manner in which the debate was conducted because it clearly demonstrated a willingness on my part for openness, transparency and valuing everyone's opinion. Others commented on the very professional manner in which the debate was conducted. Three typical comments were:

- We didn't get what we wanted but we were given plenty of opportunity to present our case, we cannot complain about the process
- I am so proud of our profession in that there was good rational debate without a 'slanging match', and
- You have led this debate with complete openness and transparency, well done.

Similar comments were made following the November Congress meeting. This was not a debate but rather a formal meeting. Some papers were put to me to be included in the agenda. I sought to have two of them modified before I would put them on the formal agenda but due to timing issues, they could not be included as part of the formal Congress papers. These papers were modified just prior to the meeting and so I allowed them to be put as part of the meeting. I was not obliged to accept these papers but I did and they were discussed in the normal way.

Listening, Hearing and Acting

I met with representatives of several regional groups and started the discussion by seeking their thoughts and ideas relating to the impacts of an increase in population. After some time, it became obvious that people preferred to discuss another topic that was current and concerned them greatly. I heard this and accepted this change, not overtly but we just moved into 'their' topic. I was somewhat surprised that one member raised my handling of the meeting afterwards. I was clearly listening and hearing and acted upon what I perceived; a mark of a good leader, according to him.

Engagement with the profession and the community (know where you want to go)

About the same time as I took over leadership of Engineers Australia, the Australian Government Treasury released its Intergenerational Report 2010 (Australian Treasury, 2010) that predicts that the country's population will increase to about 36 million by 2050. I saw that this could have a significant effect on the engineering profession in that

there would need to be significant investment in infrastructure. I saw an opportunity for our profession to be involved in this national debate. So the main goal of my visits to about 30 groups around the country was to engage our members in this important aspect of the future of Australian life. Most groups consisted of members of the engineering profession but some groups included members of the broader public. Subsequent to this series of discussions, an on-line survey was conducted and this was followed by an on-line discussion forum. Members actively and eagerly engaged in these discussions. During this time, the Australian government appointed the Honorable Tony Burke as the Minister for Sustainable Population. He set up three working groups and an issues paper was published in December 2010 calling for submissions from interested parties. In February 2011, we were invited to a workshop discussion with the Minister and we submitted a report in March 2011. This submission, I believe is quite different to many others because it is based on member views. I have engaged members in this discussion. Several members have commented to me that this initiative is characteristic of a good leader; firstly because a big picture long term goal was set and secondly because of the significant engagement of members in the discussion. This clearly helps members to feel that their views are valued and hence they have a sense of belonging and a sense of purpose to the organisation.

People Matter

As I visited the various Division offices around the country, I made sure that I thanked all staff for their work and encouraged them to continue with their good work. Here, I simply acknowledged their value for the organisation. The same is true for the National Office where about 80 staff are employed. It is also extremely important that I acknowledged the immense amount of work done by the volunteers. The volunteer effort is the backbone of the whole organisation and so it is crucial that they feel that their work is valued. This in turn leads to a sense of belonging, a sense of purpose and a sense of identity (BIP). One person said that they were so pleased that our paths had crossed because they had learned so much about valuing people.

During the year, the Chief Executive became very ill and so I called a meeting of the Directors in National Office. I needed to be reassured that all of the operations and functions of the organisation would continue. I was very pleased to hear the Directors offer to share the extra workload and help each other. This clearly demonstrates the team approach but it also indicates that staff leadership of the organisation have a sense of purpose and ownership.

The latter half of my Presidency was extremely busy because we initiated the national vote for the changes to the Royal Charter and Bylaws. I received a very large number of emails, some supportive of the changes and some not supportive. I personally replied to most of these emails. Several members replied to my email by saying that they did not expect to get a personal reply and thanked me saying that this is a mark of a good leader.

VALUES-DRIVEN LEADERSHIP

As to Values Driven Leadership, you may be asking, how does one approach it?

The most obvious starting place is to take the time to clearly identify your own values and to be able to enunciate those into your total life. This is not just something you do at

work, as your values underpin everything you stand for, your concept of right and wrong and your view of your world. You are then aligning your work environment with your values. That is, ensuring that there is not a conflict between what the employer stands for and what you stand for. You then display the behaviors that are consistent with your values and are on display for all to see as the essential you.

Some simple tips though that may assist in identifying what a Values Driven Leader will do are:

- ***Be Consistent:***
Real trust only develops when people know they can depend on you all the time. When you say you will do something – do it!
- ***Use Honest Communication:***
What you do should match what you say.
- ***Put Others First:***
If others succeed you cannot fail to succeed.
- ***Be Humble:***
Nobody will trust you if they think you are driven by ego.
- ***Be Transparent:***
Acknowledge your flaws and people will respect you and relate to you better.
- ***Have a Servant Spirit:***
Giving yourself to others shows that you really care about them.

To many people this is the process of becoming the leader whom you admire. Be clear in what is important to you and be able to stand up for those values and represent them in all you do. Within this, there is a basic principle that has two aspects to it. The first is to take the time to value your staff and the second is to take the time to value yourself. It is through our willingness to value what is important to us and those around us that we provide the sort of leadership that others look up to, and followers want to share in the journey.

CONCLUDING OBSERVATION

For me, the year I have been through has been an incredible honor and privilege. The people I have met, the stories I have heard, the actions I have seen, all have contributed to an experience I will never forget. What I have gained and learnt over the year far outweighs what I brought to the situation and for that I will be forever thankful. Some phrases that I think are useful to remember are:

‘If you get it right with your people, there is nothing you cannot achieve’.

Value your people: Value yourself

To get it right with your people embrace B.I.P.

Create a workplace where every person and every stakeholder has:

- A sense of Belonging
- A sense of Identity
- A sense of Purpose.

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THE STUDY OF TWO PHASE FLOW WALL EROSION USING A GENERALIZED COMPUTATIONAL FLUID DYNAMICS PREDICTION MODEL

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ABSTRACT

Solid particle erosion in a two phase flow is a complex mechanical process, by which material is removed from a solid surface due to the impact of solid particles on the metal surface. Experiments showed that the particle velocity has the greatest contribution toward wall erosion. The aim of the present research was to reduce the wall erosion through velocity control in the upward / downward bends. To this end, a vortex flow was created by subtracting a spiral volume, from the inner volume of a horizontal pipe, just before an upward/downward bend, generating a changed volume. Due to the new geometry, a vortex flow was created reducing the flow velocity to above saltation values. Also the computational fluid dynamic modelling confirmed and in some cases infirmed, accepted erosion patterns described in the existing literature. The comparison between the control volume and the changed volume showed significant erosion reduction. The wall erosion in mm–wall thickness loss per hour is 0,032 mm/hour for the control volume against 0,02 mm/hour for the changed volume. The life expectancy of the installation where the changed volume was used is about 1,6 times that of the control volume installation. Furthermore the maximum impact points in the changed volume are scattered in a spiral pattern in the bend avoiding the total wall perforation for a longer time. Most importantly beside the difference in erosion between the upward bend and the downward bend, the bend radius has a significant influence over the erosion magnitude and location.

INTRODUCTION

The first known occurrence of the term "erosion" was in the 1541 translation by Robert Copland of Guy De Chauliac's medical text "The Questyonary of Cyrurygens", and by 1774 "erosion" was used outside medical subjects. As early as 1921 Swedish engineer Johan August Brinell investigated the erosion behaviour in single phase flow.

Solid particle impact velocity has been recognized by researchers as the most significant factor for erosion. Experimental results showed that the erosion rate is proportional to the exponent of the solid particle velocity or the fluid velocity surrounding the particles. F.J. Blatt (1989) studied the particle velocity close to the wall of a pipe in two-phase liquid-particle flow, and concluded that the flow velocity significantly influence the erosion rate. Depending upon the experimental conditions, the values of the velocity exponent may vary from a minimum of 0.8 up to 8.0. The CFD modelling results

confirmed the experimental results, reinforcing the usefulness of virtual models in determining the final actual setup of an installation.

WALL EROSION THEORY

According to Mazumder *et al* (2004), solid particle erosion is the mechanical process by which material is removed from a solid surface due to the impact of small solid particles on the metal surface. For ductile materials, erosion is caused by localized plastic strain and fatigue in the metal surface, while in brittle materials the impact of solid particles can cause surface cracks and chipping of micro-size metal pieces. The particle size, shape, density, concentration, impact angle, flow velocity, impacting surface material property and geometry of equipment are some of the major parameters.

Among all the various factors, the particle impact velocity has the greatest influence on erosion. The particle impact velocity and impact angles depend upon the fluid velocity and fluid properties. To predict the severity of erosion behaviour in both single phase and multiple phase flows, there are several erosion prediction models available. Most of them are based on empirical data and the downfall of the empirical models is that they can only be applied to operating conditions that are similar to the experimental conditions, and cannot be generalized to other flow conditions, Mazumder *et al* (2003).

Generalized erosion prediction models

The generalized models such as CFD based erosion models, take into account details of the flow effect and pipe geometry. To simplify the CFD model some of the parameters may be excluded. For dilute phase loading of less than 10%, the average inter-particle distance is around twice the particle diameter, therefore particles interactions can be neglected and a single phase model can be used to represent the mixture, (ANSYS Fluent manual). The multiphase modelling in the present research was done through Discrete Phase Model (DPM), sub-modelling capability Erosion /Accretion where:

- Trajectories of particles/droplets/bubbles are computed in a Lagrangian frame;
- Particles can exchange heat, mass, and momentum with the continuous gas phase;
- Each trajectory represents a group of particles of the same initial properties;
- Particle-particle interactions are neglected.

RELATION BETWEEN EROSION, PRESSURE DROP AND BEND GEOMETRY

The effects of a bend in a pneumatic conveying pipeline are twofold: it causes a loss of energy which results in an additional pressure drop and can cause product attrition or pipeline wear, or both. A wide research work has been done in the field but the results are very conflicting. Marcus *et al* (1984) stated that the short radius bends cause the least pressure drop, whilst Mills & Mason (1985) find short radius bends better in some circumstances while long radius bends were better in other. Generally it is agreed that the contribution of bends toward the overall pressure drop is very significant therefore a whole lot of research was done specifically for the pressure drop due to bends. The work done by Bradley (1990) and Bradley & Reed (1990) examined the pressure drop

effects of bends for design purpose. In the research conducted at the University of Johannesburg it was observed that bends with a larger radius induce less pressure drop and wall erosion, than the bends with a shorter radius.

EROSION PREDICTION

Literature survey - Location of maximum pipe erosion in bends with a R/D ratio of $2,5 \div 4$

Extended experiments to locate the maximum wear in an elbow were conducted by Mazumder *et al* (2004 and 2003). The experimental results showed that the location of maximum wear due to erosion is different for horizontal flow compared to vertical flow. Deng *et al* (2005) investigated the location of maximum erosion in a bend with different bend orientations and geometry, using sand as solid particles at a mass ratio of solid particle to air of 10. Experimental results showed maximum damage in the horizontal to vertical downward bends with total penetration location at 25° and 8° respectively, from the entrance of the bend. Among all different bend orientations, the horizontally to vertically downward bend showed maximum erosive wear damage and therefore, had the shortest life.

University of Johannesburg research – Location of maximum pipe erosion in bends with a R/D ratio of $2,5 \div 4$

In the present study, the CFD results did not confirm Deng *et al* (2005) conclusion. According to the CFD modelling the erosion in the elbow is more significant for a vertical upward bend than for a vertical downward, with maximum mass loss erosion of 4.3 units and 2.69 units respectively, resulting in a ratio of 1, 598. Figure 1 shows a detail of the maximum erosion and the points where it occurs, in upward and downward bends with a R/D ratio ranging from $2,5 \div 4$ (volumes 1 and 3).

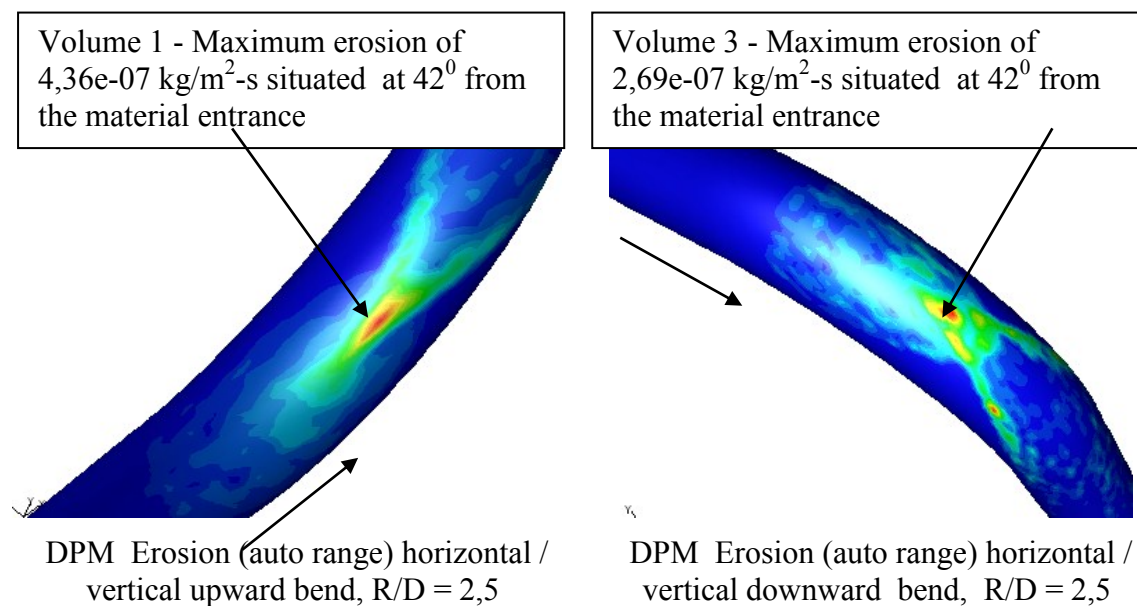


Fig. 1: Location of maximum erosion points in bends with a R/D ratio of $2,5 \div 4$

Location of maximum pipe erosion in bends with a R/D ratio of 4 ÷ 6

For bends with a ratio of $R/D = 4 \div 6$, the CFD results show the presence of two maximum erosion points in the bend as shown in figures 2 and 3. Although both bends are radiused bends, the radius size has a significant impact on the pressure drop and bends erosion for the anthracite powder lean phase transportation. This conclusion contrary to Bradley (1990) results, applied to white wheat flour and polyethylene pellets, that the bend radius is of no consequence for pressure drop and wall erosion.

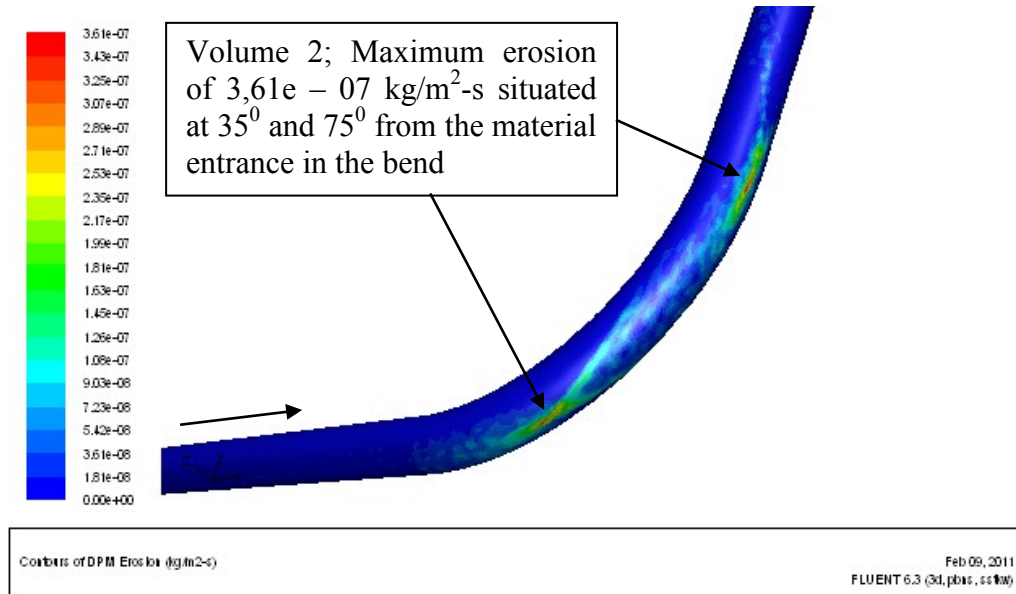


Fig. 2: DPM Erosion (auto range) horizontal / vertical upward bend, $R/D = 5$

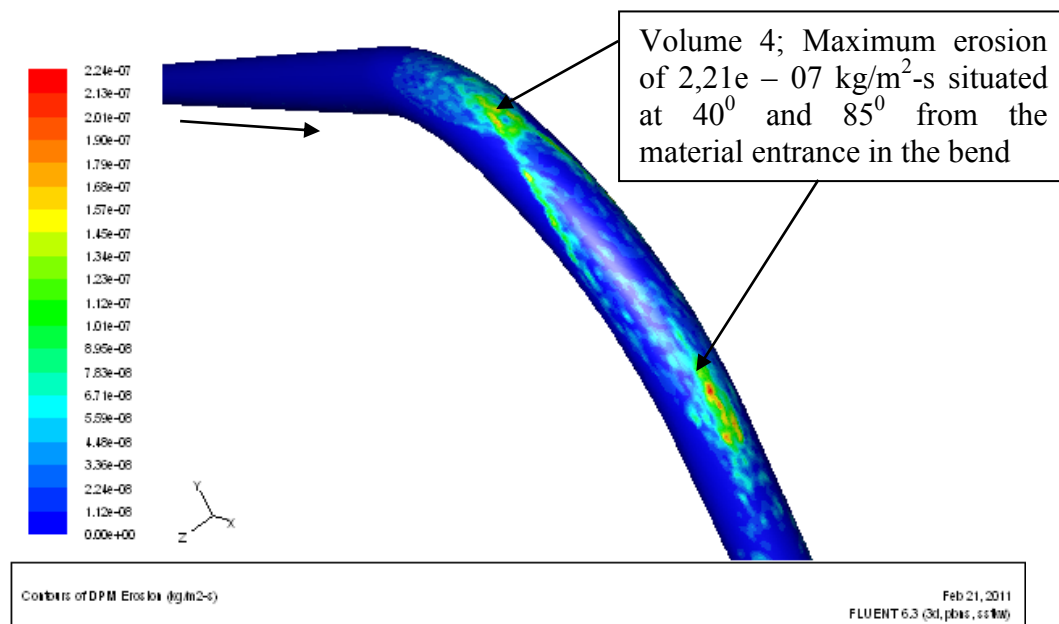


Fig. 3: DPM Erosion (auto range) horizontal / vertical downward bend, $R/D = 5$

As can be seen in figures 1, 2 and 3 the erosion area in the control volumes is concentrated over a small, very focused area, leading to total penetration.

EROSION REDUCTION - UNIVERSITY OF JOHANNESBURG RESEARCH

Reference volumes

The four CFD reference volume shown in figure 4, were generated from a horizontal 50 mm internal diameter pipe volume for a length of 800 mm, followed by the bend and a short vertical portion of 200 mm after the bend. Volumes 1 and 3 have a R/D ratio of 2,5 while for volumes 2 and 4 the R/D ratio is 5

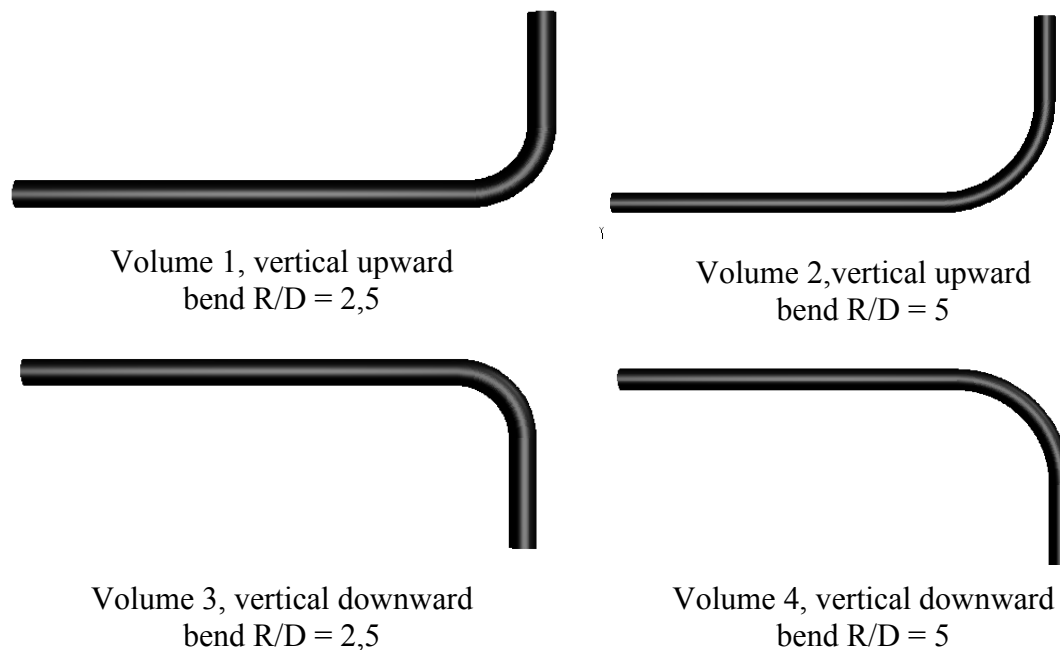


Fig. 4: Reference volumes geometry

Velocity flow control through modified volumes

To reduce the wall erosion in the bend via flow velocity control, the reference volumes were modified by subtracting a spiral shaped volume of 1,5 turns, rectangular cross-section of 12 mm depth x 10 mm width and a pitch of 100 mm, thus **Volume 1-S**, **Volume 2-S**, **Volume 3-S** and **Volume 4-S** were created. The starting point of the spiral shaped volume is at 600 mm from the beginning of the horizontal section, and ends at 750 mm along the horizontal, for all modified volumes. For the control volumes the maximum velocities recorded were as follows:

Volume ₁ = 32, 8 m/s; Volume ₂ = 30, 1 m/s; Volume ₃ = 32, 5 m/s;

Volume ₄ = 30,1 m/s;

Figure 5 shows the velocity path lines defined by velocity magnitude in the bend area for the modified volumes. The recorded values are as follows:

Volume _{1-S} = 28, 6 m/s; Volume _{2-S} = 28, 3 m/s; Volume _{3-S} = 28, 8 m/s;

Volume _{4-S} = 28, 5 m/s;

The modification of the volume induced a velocity decrease as follows:

- In Volume 1-S the velocity decreased by 12, 8 % as compared to Volume 1,
- In Volume 2-S the velocity decreased by 6, 0 % as compared to Volume 2,
- In Volume 3-S the velocity decreased by 11, 4 % as compared to Volume 3,
- In Volume 4-S the velocity decreased by 5, 3 % as compared to Volume 4

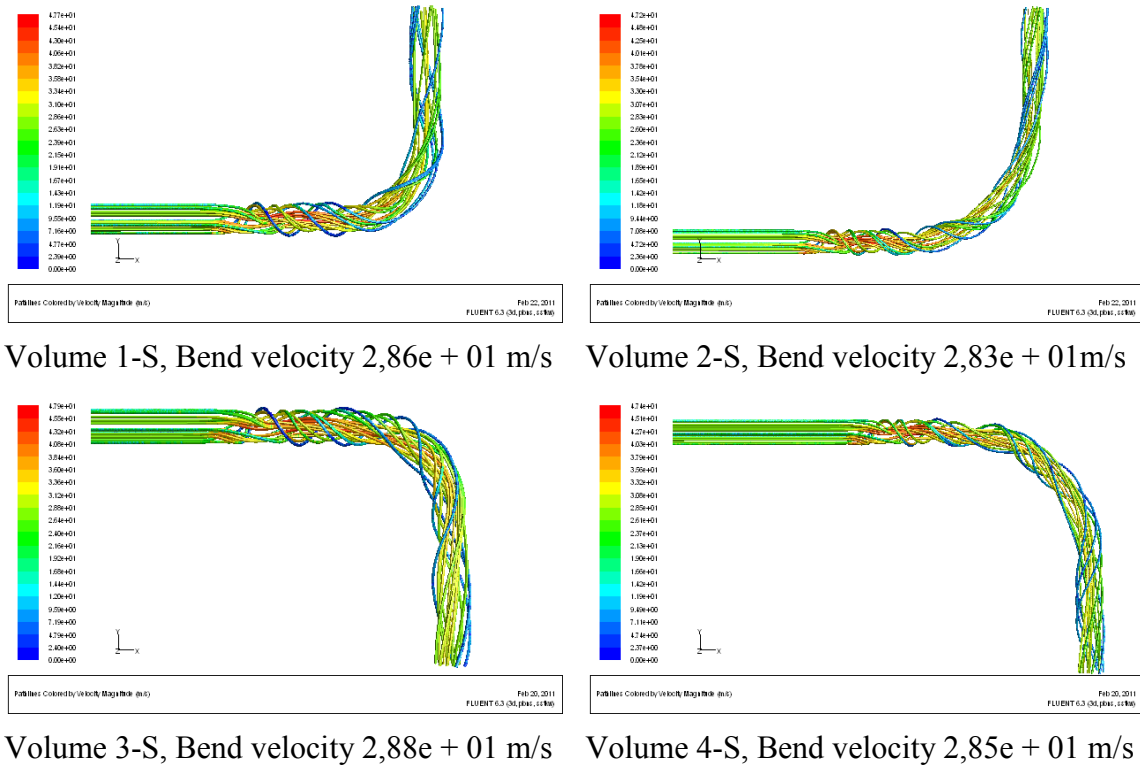


Fig. 5: Velocity path lines defined by velocity magnitude for the modified volumes

Wall erosion reduction in the Modified volumes due to velocity decrease

Figures 6 and 7 show the maximum and average erosion values, in the modified volumes 1-S and 3-S respectively.

For the modified Volume 1-S the maximum erosion points of $2,71e-07 \text{ kg/m}^2\text{-s}$ are very few concentrated in the spiral groove, meaning that the tip of the rectangular spiral introduced in the pipe will be eroded in some points, while the bend wall is subjected to the average erosion value $1,49e-07 \text{ kg/m}^2\text{-s}$.

For the modified Volume 3-S the maximum erosion points can be seen at the tip of the spiral, as for volume 1-S, having the same value of $2,71e-07 \text{ kg/m}^2\text{-s}$, while the bend wall is subjected to the average erosion value $1,22e-07 \text{ kg/m}^2\text{-s}$

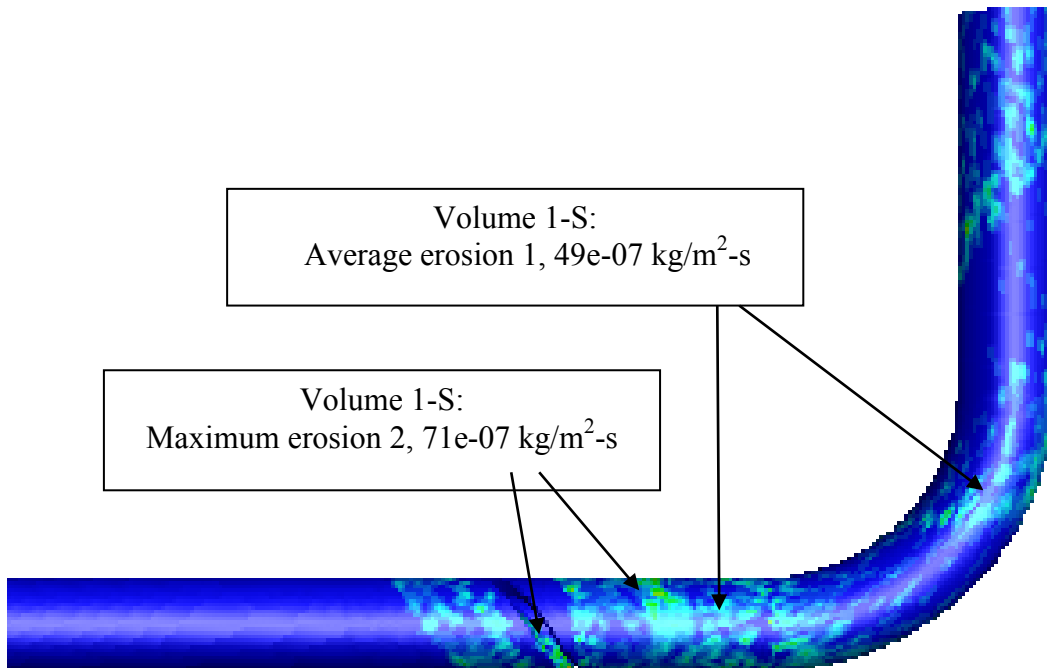


Fig. 6: Volume 1-S - DPM Erosion (auto range) horizontal / vertical upward bend, $R/D = 5$

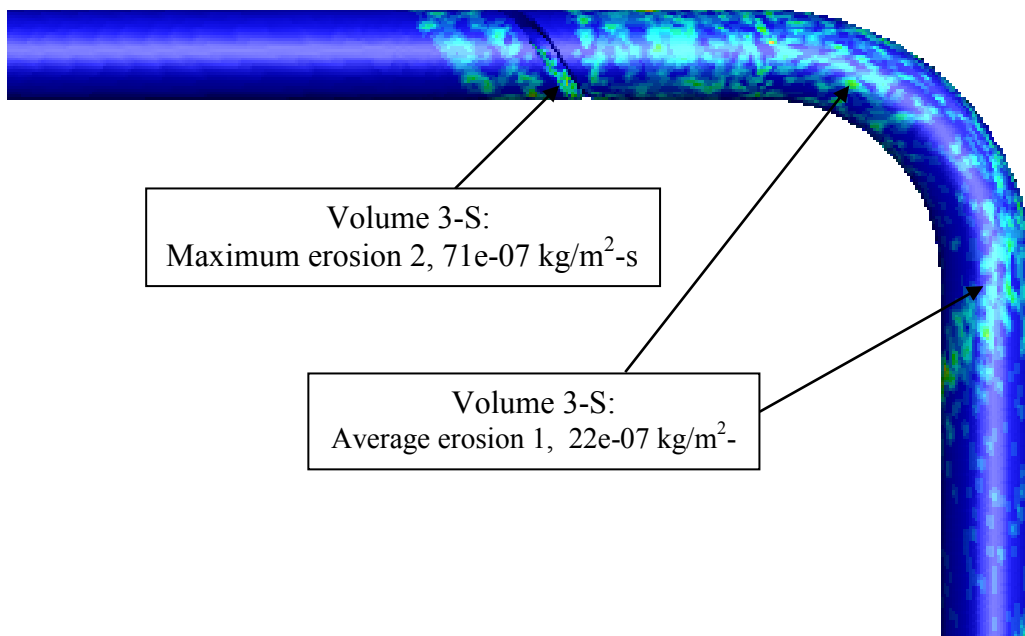


Fig. 7: Volume 3-S - DPM Erosion (auto range) horizontal / vertical downward bend, $R/D = 5$

Figures 8 and 9 show the maximum and average erosion values, in the modified volumes 2-S and 4-S respectively.

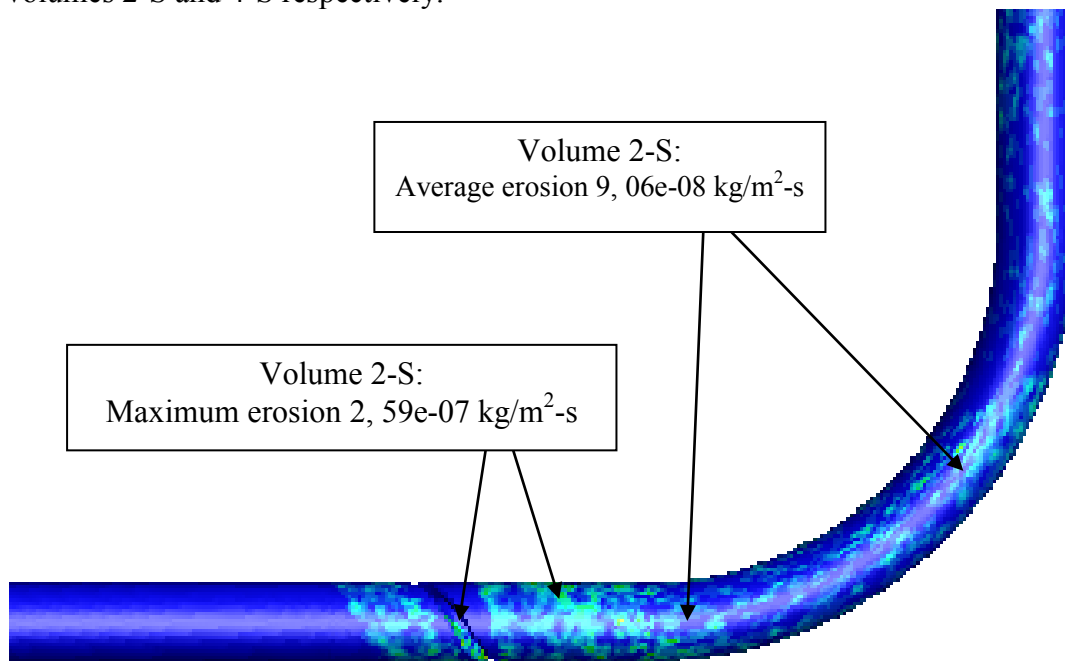


Fig. 8: Volume 2-S - DPM Erosion (auto range) horizontal / vertical upward bend, R/D = 5

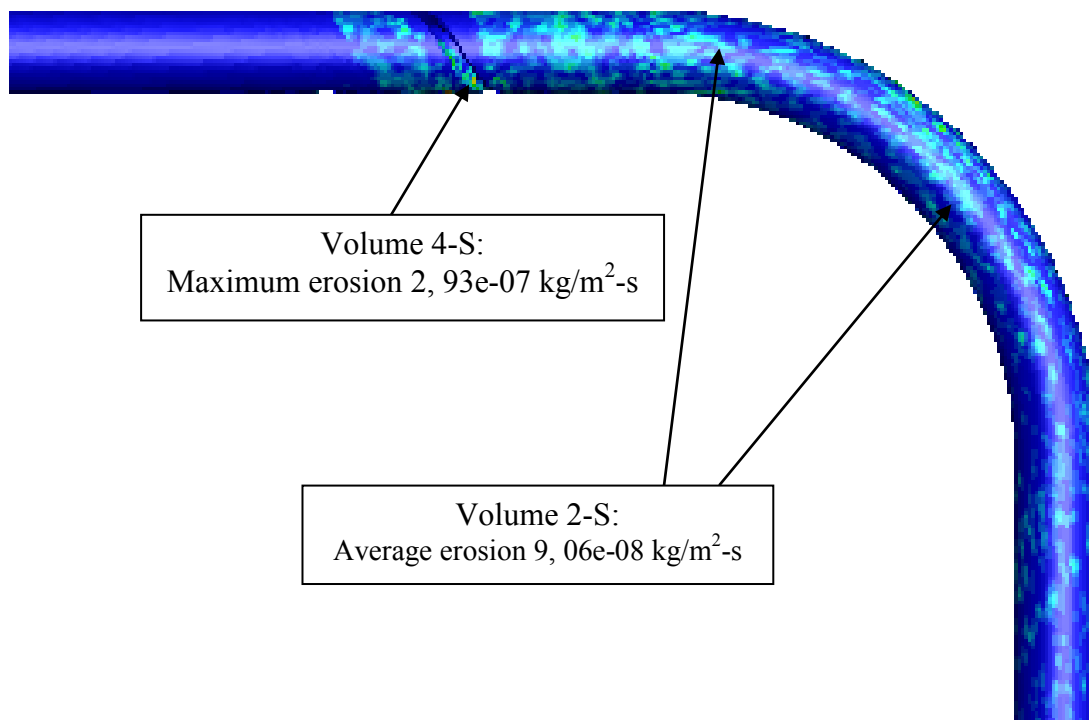


Fig. 9: Volume 4-S - DPM Erosion (auto range) horizontal / vertical downward bend, R/D = 5

Calculation of mass loss through erosion and the installation life expectancy

To calculate the mass loss in the bend, the area considered was half the pipe circumference (0,0785 m) multiplied by 1/3 of the bend length (0,0783 m), resulting in an erosion area of approximately $6,146 \times 10^{-3} \text{ m}^2$. The pipe wall thickness was 3,91 mm. The mass loss for reference volumes was calculated using the maximum erosion values recorded. As the maximum erosion points in the modified volumes (1-S, 2-S, 3-S and 4-S) are very few, the mass loss was calculated using the average erosion values. Table 1 lists the values for the reference volumes 1, 2, 3 and 4 while table 2 lists the corresponding values for the modified volumes 1-S, 2-S, 3-S and 4-S. The life expectancy was calculated considering that the installation is fully operational for 4 hours per day.

Table 1: Installation life expectancy for reference volumes

	Volume 1	Volume 2	Volume 3	Volume 4
Overall static pressure loss	17,08 kPa	17,34 kPa	17,56 kPa	17,765 kPa
Maximum velocity	32,8 m/s	30,1 m/s	32,5 m/s	30,1 m/s
Maximum mass loss through erosion [kg/m² – s]	$4,36 \times 10^{-7}$	$3,61 \times 10^{-7}$	$2,69 \times 10^{-7}$	$2,21 \times 10^{-7}$
Installation life expectancy	30 days	36,3 days	49 days	59,3 days

Table 2: Installation life expectancy for modified volumes

	Volume 1	Volume 2	Volume 3	Volume 4
Overall static pressure loss	22,5 kPa	28,4 kPa	29,1 kPa	28,6 kPa
Maximum velocity	28,6 m/s	28,3 m/s	28,8 m/s	28,5 m/s
Average mass loss through erosion [kg/m² – s]	$1,49 \times 10^{-7}$	$0,906 \times 10^{-7}$	$1,22 \times 10^{-7}$	$1,17 \times 10^{-7}$
Installation life expectancy	88 days	144,7 days	107,4 days	112 days
Installation life expectancy increase compared to control volumes	293 %	399 %	219 %	189 %

CONCLUSIONS

- The DPM modelling of the reference volumes show a heavy erosion concentrated on a well defined area in the bend. This will result in complete penetration after a minimum of 30 days (120 hours) for volume 1 and a maximum of 59,3 days (237 hours) for volume 4.
- The modified volumes show a dramatic increase of installation life expectancy

ranging from a minimum of 88 days (325 hours) for volume 1-S to a maximum of 112 days (578, 8 hours) for volume 2-S.

- c. All volumes showed a sever pressure drop ranging from 17,08 kPa for volume 1 to a maximum of 29, 1 kPa for volume 3-S.
- d. For all volumes the particle velocities are within comparable values all being above saltation velocity.
- e. Careful consideration should be given to the pressure drop as there is the risk of pipe clogging.

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QUAD TREE GRID GENERATION USING THE CONCEPT OF LINKED LISTS

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ABSTRACT

The grid system of CFD(Computational Fluid Dynamics) is divided into two parts: the body fitted grid system and the non-body fitted grid system. The main advantage of body fitted grid system is to impose boundary condition simply and directly while this grid system has some difficulties in generating grids around a complex body. Furthermore high dependence on users' skill of generating grids is required. The main advantages of non-body fitted grid system are to generate grids around a complex body efficiently and not to require users' dependency.

This paper applies the Cartesian grids which is one of non-body fitted grids system. The Cartesian grids apply quad tree data structure and store information of cells' heredity. This data structure is efficient to make adaptive Cartesian grids and to find each cells of mother and child cells' information. Furthermore it is expected to apply solution adaptation simply for analysing the flow. We use the concept of linked lists and FORTRAN language for constructing quad tree data structure.[2,6] The concept of linked lists can readily treat cells' data when process of creation and destruction of cells are repeated and also be efficient to access the cells' information. The grids generated by this process are used for solving the governing equation like a Navier-Stokes equation which applies Immersed Boundary Method or Cut-cell Method.[1,3,4,5]

INTRODUCTION

In the field of the CFD (Computational Fluid Dynamics), Cartesian grid system is one of methods to make computational mesh regardless of the body shape. The Cartesian grid system is more useful to make grids near complex body shape like an aircraft or a space shuttle compared to the body-fitted grid system like structured grids and to make grids automatically. In order to generate the Cartesian grids system, we make initial grid with rectangle cells (2D) and cube cells (3D). This initial grid is composed of cells of the same size. Each cell on the body shape is divided into several cells by stages so that cells near a body have appropriate cell size. Therefore we generate the Cartesian grids which have small cells near the body shape and large cells in far field region. The Cartesian grid system has information of child cell and mother cell. Here, Child cell is a formed grid after division and mother cell is an original grid before division. This connection with mother cells and children cells is called tree structure. This paper construct quad-tree Cartesian grid system that one mother cell have 4 children cells. Quad-tree structure is useful to generate or remove cells in arbitrary parts. The Cartesian grid system needs not only information of cells' heredity, but also information of neighbour cells. The information of neighbour cells is used for balancing cells size due to analyse flow with accurate results. Because the Cartesian grid system needs

information of cells' hereditary and neighbour cells, so it needs a lot of data compared to other grid system. Therefore, grid generation time and size of data depend on how to treat data structure of grid system. In other words, a technique to treat data influences on program efficiency. There are some of techniques to treat data. One is a way to store data in arrays. When generated and removed cells, we need repeatedly a process of arrays' allocation and deallocation. The iterative process is inefficient. Other one is a way to store data in arrays using pointer of FORTRAN. This way needs repeatedly a process of arrays' allocation and deallocation too. Another one is a way to use the linked list concept. This linked list concept uses pointer of FORTRAN language, connects each cell and stores cell information. It does not need a process of allocation and deallocation.

This paper applies the linked list concept when generate the Cartesian grid system and constructs grid generation program using FORTRAN language. The efficiency of linked list concept is verified by comparing to other techniques to treat data structure.

QUAD TREE CARTESIAN GRID GENERATION

In this section, this paper examines the way to generate Quad-tree Cartesian grid system and the way to apply how to treat data structure.

Quad tree Cartesian grid

Quad-tree Cartesian grid has uniform cells which are divided into 4 parts per a cell until cells near a body shape have appropriate size. Quad-tree structure connects mother cells to 4 children cells. In figure 1, a cell with level 1 is divided into 4 cells with level 2 like the cell A. A cell with level 2 is divided into 4 cells with level 3 like the cell B. Through this process, cells near a body shape have maximum level defined by user. Figure 2 is an example of Cartesian grids of circle shape and final grids used in CFD.[2,6]

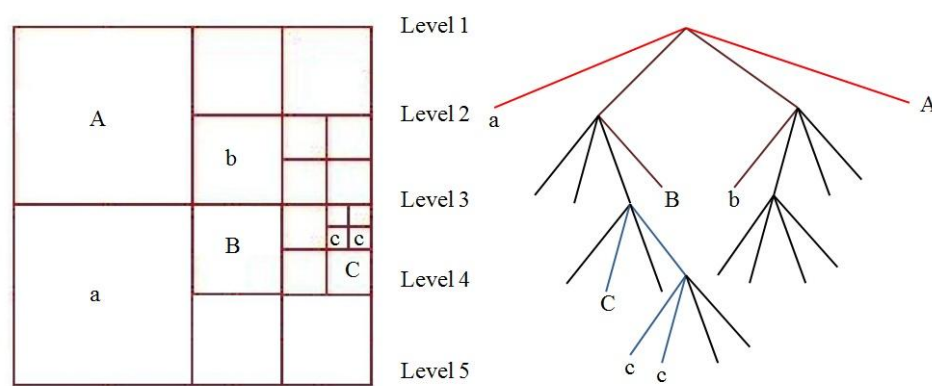


Fig. 1: Quad-tree structure

If level differences between own cell and neighbour cells are big, grid system influences results of flow analysis.[2] Furthermore, it need balance process which is cell refinement with a little size difference between the next cells. Therefore, it needs neighbour cell information. In the case of structure grid, it finds neighbour cells using just cells' index. In the case of unstructured grid, it finds neighbour cells using geometric information. Cartesian grid system needs a process finding neighbour cells. It is useful to find neighbour cells because quad-tree structure has cell information of

cells' hereditary. In the figure 1, cell A's bottom cell is found cell by tracing cell A's mother cell. Cell C's top cell is also found by tracing and cell C's top cell is two cell c. The Cartesian grid system is generated using cell refinement process and cell balancing process with cell information. In this process, we need appropriate technique to treat data structure which influence on the efficiency of grid generation because grid data structure is flexible.

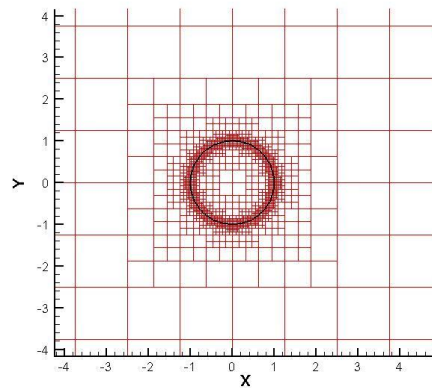


Fig. 2: Quad-tree Cartesian grids of a circle shape

Linked list concept

Cartesian grid system has information of cell's mother cell, children cells and neighbour cells. Therefore it needs a lot of data size. Grid system is generated by stages so it needs to treat data flexible. This data treatment influence on the program efficiency such as data size and grid generating time. This data structure has three ways.[2]

One is a way to store cells' information of mother cell, children cells and neighbour cells in arrays. If hundred cells are generated, it needs 100x13 allocate array. Whenever generate new cells, a process of array's allocation and deallocation is iterative. This repeated process is inefficient. Moreover, this technique also needs array to store neighbour cells' information.

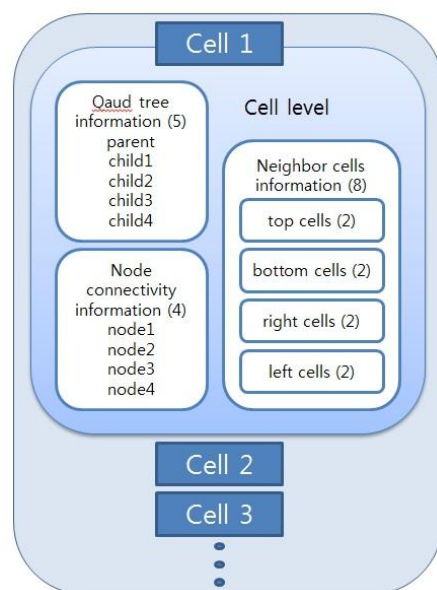


Fig. 3: data structure of cell array

Other one is a way to store information of cells' heredity using pointer of FORTRAN language and the other information of cells in array. This technique also needs iterative process of array's allocation and deallocation for storing node connectivity and location information. It is more efficiency than former technique which store whole information in array but it needs iterative process of allocation and deallocation.

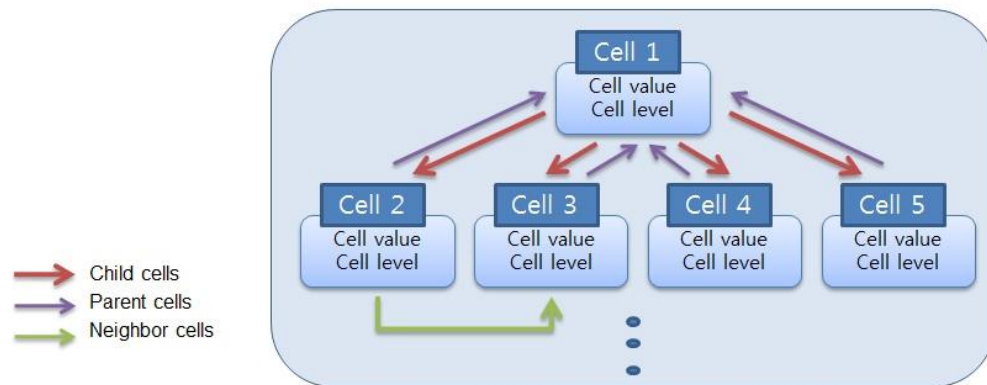


Fig. 4: data structure of pointer

Another one is a way to connect cells' information using pointer of FORTRAN language. Each cell connects other former cells and later cells like a linked list. Cells' heredity and information of neighbor cells is linked. Thus, when added new cells' information, this technique does not need a repeated process of array allocation and deallocation. It needs reconnection process which is more efficient and easier than array's allocation and deallocation.

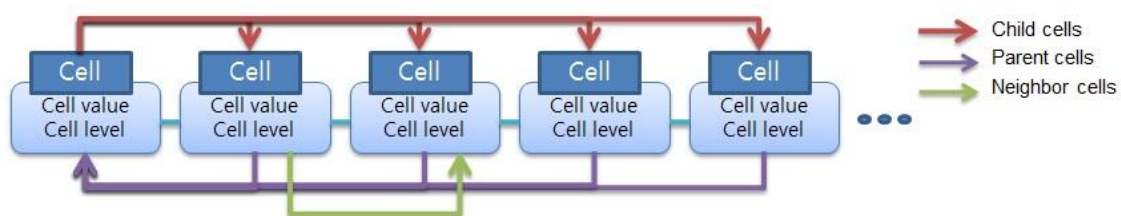


Fig. 5: data structure of linked list

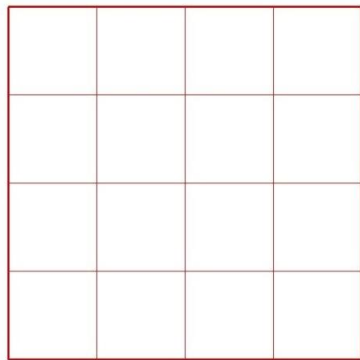
THE RESULTS

The efficiency of linked list concept is verified by comparing to other techniques to treat data structure.

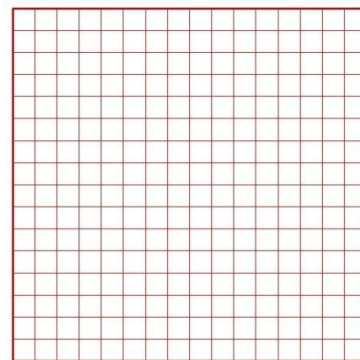
Figure 6 is grids along each level. Initial grid has 25 nodes and 16 cells. It is divided into several cells. Level 3 grid is generated by initial cell refinement. It has 289 nodes and 336 cells. Level 5 grid has 4425 nodes and 5456 cells. Level 8 has 263169 nodes and 349520 cells. Increasing the level data and its size are greater than lower level. Table 1 shows data size and generating time each level and each data structure. Data structure of linked list is efficient at time and data size, especially at high level.

Tab.1: data information

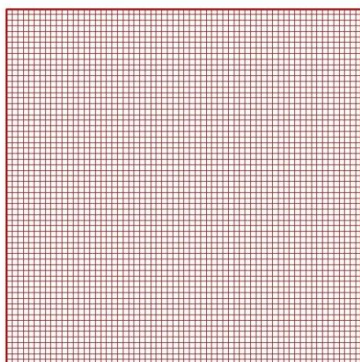
	Level	Time	Data size	Data Compared level 3
Cell array	3	0.015s	420Kb	-
Pointer	3	1.033s	400Kb	-
Linked list	3	0.016s	308Kb	-
Cell array	5	2.703s	772Kb	1.83 times
Pointer	5	-	-	-
Linked list	5	1.459s	532Kb	1.72 times
Cell array	8	28m30.54s	26Mb	61.90 times
Pointer	8	-	-	-
Linked list	8	3m10.28s	10Mb	32.47 times



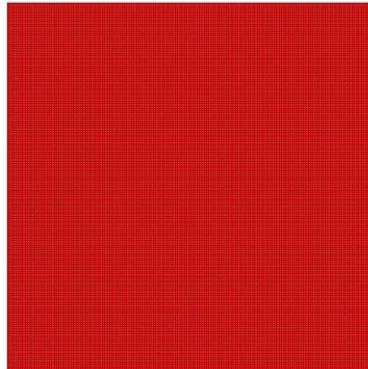
(a) Initial grid



(b) Level 3



(c) Level 5



(d) Level 8

Fig. 6: test grid

CONCLUSION

The aim of this paper is to enhance program efficiency which is depended on data structure. We apply the concept of linked lists to the quad-tree Cartesian grids system. The main advantage of linked lists are less data size and less grid generation time than the other techniques. This technique is validated by comparing to other technique. When use the Cartesian grids system, the linked lists is efficient. Furthermore, we expect that flow solver using the linked lists concept is efficient.

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RESPONDING TO CLIMATE CHANGE: USE OF PUBLIC PARTICIPATION GIS TO UNDERSTAND PREFERENCES OF ADELAIDE PARK VISITORS.

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ABSTRACT

Climate change provides a wonderful example of the need for transdisciplinary research. However, the difficulties of bringing various partners together to contribute to climate change research in a strategic manner has thwarted many well-intended researchers. Whilst the use of geographical information system (GIS) technology in mapping biodiversity, hydrology and even fire risk has been prolific, little attention has been provided to how this technology can also facilitate the collection of social data and provide a platform that allows for integrated and coherent results among disciplines. A study in a selection of parks in the Adelaide metropolitan area revealed strong support for strategies such as improving public transport, increasing use of water sensitive grass, addition of urban forests, and the establishment of community gardens. Low levels of support were associated with strategies such as allowing natural water features to dry up, increasing the amount of paved areas and seasonal closure of some parks. A prototype internet based PPGIS system with a Google™ map interface has been developed to enable participants to map the areas of the parks they use, how they use them and indicate whether or not they would still use them this way, if the temperature increased. They can also map those areas they feel would be most appropriate for a variety of climate mitigation strategies. The project is the first step in a larger project that will provide valuable insights into how we can optimise use of Adelaide's parks, from a variety of perspectives, including climate change, economic, biodiversity and health.

INTRODUCTION

Climate change is undoubtedly one of the most critical issues of our time. It is axiomatic in climate change research that multiple disciplines are required to provide practical strategies. Authors such as De Bono (2009) argue that changing the way we

think about these issues could reap the greatest advantage. However, frequently climate change researchers find themselves in a multidisciplinary environment where experts contribute their own “piece” to the problem, rather than using a desired transdisciplinary approach that involves convergence among disciplines and a mutual integration of the disciplinary epistemologies (Gayraud 2005). In reality there is a whole spectrum of interdisciplinary approaches between the simplistic categories of “multidisciplinary” and “transdisciplinary” and it is argued that the most appropriate approach in any given problem is dependent on the character of the problem and the state of development of interdisciplinarity in that line of research (Royal Society 1996). Climate change research is evolving to be more holistic in its approach and becoming more integrated as the problems become more defined. Interdisciplinary research involves the creation of a methodology and theory that allows more coherent and integrated results (EURAB 2004). This study developed a prototype public participation GIS (PPGIS) methodology to provide a platform that would allow integration of public recreation information into a wider climate change project that also collected economic, hydrological and biodiversity information via a spatial platform.

Park Management and Climate Change

The values associated with parks are extensive, ranging from protecting biodiversity, increasing economic value of adjacent properties, through to increasing health and well-being (Weber and Anderson 2010). Parks are also valuable assets in terms of climate change. For example they play a mitigation role: trees offset local heat effects of global warming; and many parks provide important stormwater protection as well as water storage. They can also play an adaptation role, for example urban parks provide tangible examples of the effects of climate change, thus facilitating excellent opportunities for public education and interpretation about climate change.

Likely changes that will need to be addressed by park managers in terms of predicted climate change include: increase in extreme and damaging events (eg. fire, drought, flood and heat waves); less rain, longer more frequent droughts, and heat waves with strong winds. This will result in increased stress to plants and wildlife, decreased biodiversity, more dieback, loss of shade trees, more risk trees and greater fire risk (Saunders 2009). The high number of coastal parks in Australia will be subject to increased beach erosion as a result of rising sea levels and increased storm surges.

It is important to note that climate change will also impact visitation and recreation patterns in parks. For example, as carbon taxes are introduced the cost of long haul travel will increase and this combined with denser cities and increased populations (eg. through climate change refugees), will likely result in more people visiting urban parks and consequent crowding/capacity issues. The warmer temperatures will likely increase use of parks throughout the year (extending the shoulder season) and place additional pressure on parks offering water based recreation opportunities during the hottest times of the year (Saunders 2009b). Hotter temperatures will also increase demand for drinking water and shade. The importance of transport and energy efficiency will increase, as will demand for more extensive and integrated cycling and pedestrian networks, and better access to public transport. Higher transport costs and increased

demand for water will also increase the importance of local food, which could be sourced via community gardens in parks (Saunders 2009b).

There are a variety of ways managers can respond to these predicted changes. For example, they can use more resilient species (e.g. native grasses); water ovals less; establish urban forests and community gardens; add artificial shade structures; move campgrounds to areas likely to be able to sustain water based recreation; add water tanks and increase focus on fire management. However, to really understand the most appropriate responses, managers need input from visitors. They need to understand how visitors currently use parks and how this might change under a climate change scenario. Specifically, information that would be useful to park managers includes where visitors recreate, what activities they participate in, what benefits they derive from recreation and how those activities and benefits are likely to change under predicted climate change scenarios. Public participation GIS provides an excellent platform to gather such information. Importantly, using a geospatial platform allows for the planned integration of other data layers, for example biodiversity, hydrological and economic data.

The Value of PPGIS

In this paper, we discuss the development of a public participation geographic information system (PPGIS) as a method for assisting park managers plan for climate change. The term “public participation geographic information systems” (PPGIS) was conceived in 1996 at the meeting of the National Center for Geographic Information and Analysis (NCGIA). PPGIS combines the academic practice of GIS and mapping at local levels to produce knowledge of place. Since the 1990s, the range of PPGIS applications has been extensive, ranging from community and neighborhood planning to mapping traditional ecological knowledge of indigenous people (see Sieber, 2006; and Sawicki & Peterman, 2002 for a review of PPGIS applications).

Brown and Reed (2000) used PPGIS to ask individuals to identify the location of landscape values for the Chugach National Forest (U.S.) planning process. Reed and Brown (2003) subsequently developed a quantitative modeling approach using the PPGIS mapped attributes to determine whether management alternatives were place-consistent with publicly held forest values. Research using PPGIS has also been conducted to identify the location of highway corridor values (Brown, 2003); to identify “coupled social-ecological” hotspots (SES) where human and biophysical systems are closely linked (Alessa et al., 2008); to identify preferences for tourism and residential development (Brown, 2006); to identify priority areas for conservation (Raymond and Brown, 2007; Pfueller et al., 2009); to identify place attachment (Brown and Raymond, 2007); and to measure urban park and open space values for park planning (Brown, 2008). Researchers with the Canadian Forest Service designed and developed the first internet-based participatory mapping application to collect data on the locations of forest landscape values across a 2.4 million hectare study area in the province of Alberta, Canada (Beverly et al., 2008) and Brown and Weber (in press) used internet-based PPGIS to collect data on environmental values and impacts for a Parks Victoria planning process incorporating nine park units in eastern Victoria (Australia).

Research Objectives

The aim of this paper is to provide an explanation of how a PPGIS has been developed to improve our understanding of likely changes to park based recreation given predicted climate changes. It is part of wider study that aims to understand the combined values of public green space and how values change, vary, and evolve. This understanding needs to be quantitative in order to allow an all-inclusive cost-benefit analysis under different future change scenarios and uncertainties. This will then lead to a better utilisation of green space under pressure from different interest groups under realistic engineering and financial constraints. The specific objectives of this study were:

- Identify the benefits park visitors perceive to be important
- Determine the support for a number of proposed adaptation and mitigation strategies designed to reduce the impact of climate change
- Determine key threshold points where people would decrease the amount or type of recreation activity they were involved in
- Use this information to develop a PPGIS platform capable of gathering social data related to climate change in an efficient manner.

METHODS

Study Location

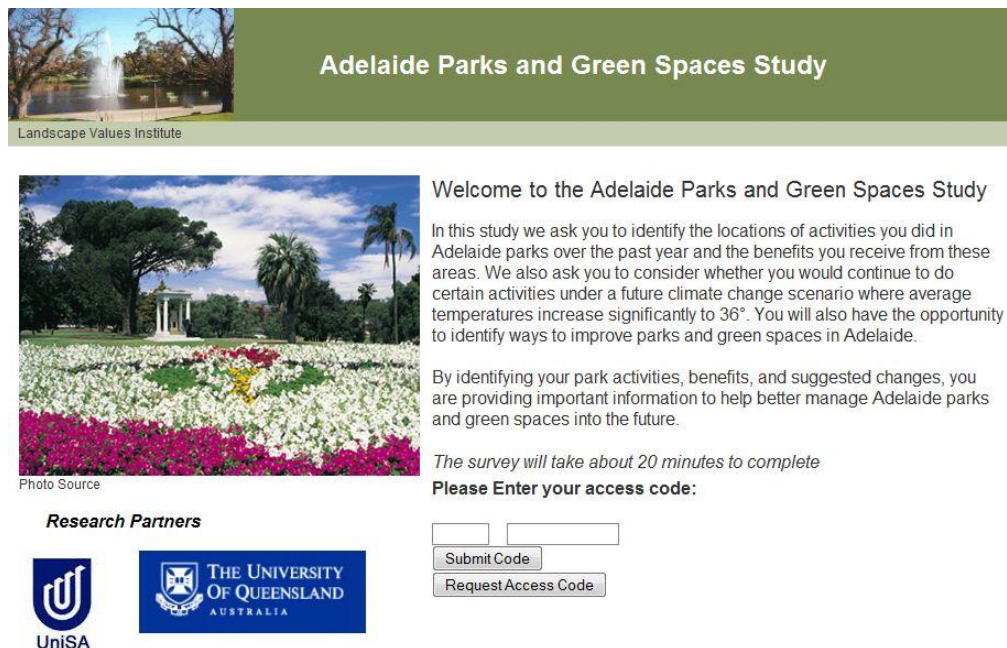
The sites chosen for the first phase of this study included seven parks in the Adelaide metropolitan area. These parks were located in the northern and eastern suburbs and comprised mainly of larger council managed parks. All parks included a playground, some native vegetation, walking trails, toilets and picnic facilities.

To gather the data to set up an appropriate PPGIS, on-site interviews and participant observation was used. The survey was conducted in the summer school holiday period and included both weekend and weekday periods. Blocks of surveying were conducted early morning, mid-morning, early afternoon and late afternoon/early evening. Due to safety concerns at some parks no surveying was conducted after 6pm. A convenience sample was employed with interviewers speaking to as many participants as possible during the survey period. Respondents were asked a series of questions pertaining to their use of the park, including frequency of use, average duration and typical times they visit. They were questioned as to how hot it could get before they wouldn't come to the park, or would not participate in certain activities. They were also asked to indicate their level of agreement with ten management strategies that could reduce the impact of climate change on parks. Finally, participants were asked to take a mail back survey with a stamped return envelope home with them to complete at a later date. This survey contained questions about the benefits they derived from their park experience as well

as other questions designed to gather information about the overall role of parks and outdoor recreation in their lives. Benefits were measured using the REP scales developed by Driver and associates (Driver et al. 1991). Additionally, participant observation was used to gather data on preference for park equipment use, type of activity and intensity of activity. Children were only observed if the parents had first been interviewed and then given consent for the interviewer to observe the child for a period of fifteen minutes.

This data was then used to develop a web-based PPGIS system. The system was based on success with development of similar systems for use by Parks Victoria and the New Zealand Department of Conservation. It was developed to gather spatial data on activity, benefits and preference for climate change management strategies, as well as general data on a range of issues associated use and motivations. This data needed to be collected in such a way that it could be integrated with other geospatial data being collected in associated with climate change implications to economics, hydrology and biodiversity.

The prototype developed begins with a welcome page explaining the study and the time needed to complete the survey (approximately twenty minutes). Participants then enter an access code to begin the survey (see Figure 1). An option to request an access code is provided for those who do not received an access code via council invitation (which will be mailed to participants). The survey consists of two components; (a) a spatial component where participants map activities, benefits and where they think various climate change management strategies would work, and (b) a series of questions measuring respondent characteristics such as their self-assessed physical and mental health, frequency of use of parks, intensity of use and basic demographic questions including age, gender, income, and level of formal education.



Adelaide Parks and Green Spaces Study

Landscape Values Institute

Welcome to the Adelaide Parks and Green Spaces Study

In this study we ask you to identify the locations of activities you did in Adelaide parks over the past year and the benefits you receive from these areas. We also ask you to consider whether you would continue to do certain activities under a future climate change scenario where average temperatures increase significantly to 36°. You will also have the opportunity to identify ways to improve parks and green spaces in Adelaide.

By identifying your park activities, benefits, and suggested changes, you are providing important information to help better manage Adelaide parks and green spaces into the future.

The survey will take about 20 minutes to complete

Please Enter your access code:

Research Partners

Figure 1: User interface introducing the study.

After reading background information and consenting to participate, respondents are offered an optional demonstration of how the PPGIS system worked. They are then presented with a map of the Adelaide metropolitan area (see Figure 2) and three tabs that list activities, benefits and management preferences. These have been based on the key activities, most common benefits and preference information from the on-site surveys. Participants drag icons from each tab onto the appropriate location on the map. The system uses a GoogleTM interface which allows participants to easily locate themselves in the Adelaide metropolitan area and then zoom into a precise location within the specific park. To encourage respondents mapping at an appropriate scale that allows meaningful interpretation, the system only allows respondents to browse and navigate at a large map scale (in Google Maps, zoom levels 1-12) and then map at a small scale (zoom levels 13 – 19).

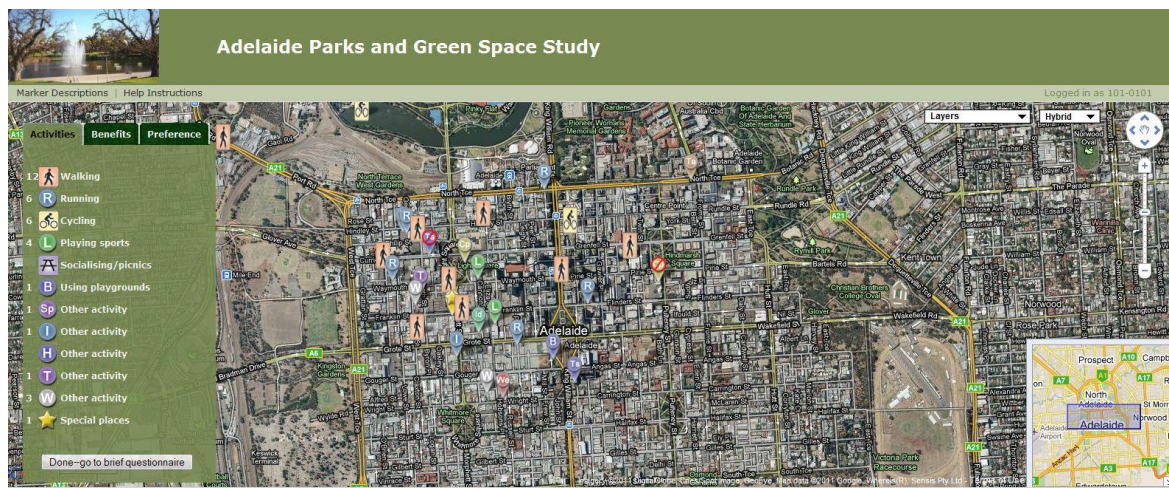


Figure 2: Example of map showing “Browse scale” image of Adelaide with various activities a hypothetical respondent has participated in.

When entering data, respondents find the appropriate area and zoom in until they get a message on their screen advising them they are now at a scale where they can map. They then drag and drop the items. After dropping the item, a prompt screen comes up asking them whether they would still participate in this activity, or derive this benefit if the temperature was 36 degrees and they can also provide comments (see Figure 3). This threshold and the items listed on each tab were derived from the first on-site phase of the study.



Fig 3: Screenshot showing how after mapping a benefit, participants are prompted to explain if they would still accrue this benefit in a warmer climate.

After respondents complete the mapping exercise they click on the button “done mapping” and are provided with the survey. Results from this study will be combined with data layers examining hydrological, biodiversity and economic changes likely to occur as a result of climate change and will feed into a custom designed interactive decision making tool that will assist park managers respond to climate change.

RESULTS

A sample of 146 on-site interviews were completed. A total of 121 people agreed to complete the mailback survey and 68 mailbacks were returned giving a response rate of 56%. The study revealed that overall park usage was low, with most use occurring in key developed zones, such as playgrounds and picnic areas. The most common activities were using the playgrounds, walking, cycling and picnicking. The most frequently cited important attributes of a park were variety of play equipment (55%) and shade (23%). The main barriers to greater use of the parks were time (57%) and weather (13%). Encouragingly one fifth of participants used parks regularly (21%) but more than half (57%) rarely visited parks. On average, respondents reported they would not use the park if the temperature rose above 33.4°C (range 28 - 40°C; mode 36°C). The key benefits of visiting parks are shown in Table 1.

Table 1: Benefits important to park visitors

Benefits	Mean* (n=68)
Spending time outdoors	4.64
Bringing my family closer together	4.34
Get away from the usual demands of life	4.16
Spend time with friends	4.14
Feel healthier	4.05

*Measured on a 5 point scale where 1= very unimportant; 2=unimportant; 3 = neither important or unimportant; 4=important and 5=very important

Table 1 is consistent with findings from other research in Australian parks examining the benefits perceived to be important by park visitors (eg. Weber and Anderson 2010) and suggests using a reduced list of benefits, rather than items from all 20 Recreation Experience Preference domains, is justified. Respondents support for proposed changes that could be adopted to minimise impact by climate change are presented in Table 2.

Table 2: Visitor support for proposed climate change associated strategies

Strategy	Mean* (n= 146)
Improve public transport	6.18
Increase water sensitive grass use	6.16
Add urban forests (heat effect)	6.14
Increase connecting trails	6.02
Establish community gardens	5.45
Increase use of non-native plants (improved temperature amelioration effect)	5.41
Add sustainable water features	5.06
Allow natural water features to dry up	4.09
Increase paved areas	3.67
Seasonal closure of some parks	3.14

*means measured on 7 point scale where 1= very strongly disagree; 2= strongly disagree; 3= disagree; 4 = neutral; 5 = agree; 6 = strongly agree; 7 = very strongly disagree

DISCUSSION AND CONCLUSION

The most common activities visitors participated in were using the playground, picnics, walking and cycling. The most important benefits to visitors were spending time outside; spending time with family; escaping the usual demands of life; spending time with friends; and feeling healthier. The most popular management strategies as perceived by this sample of visitors were: improve public transport; increase use of water sensitive grass; add urban forests; and increase connecting trails. Overall, support for proactive management associated with climate change was high. Content analysis suggested few people associated the addition of urban forests, which would assist in temperature amelioration, with increased fire risk. The least popular strategies were increasing paved areas and seasonal closure of some parks. Thirty six degrees was the most common temperature cited by respondents as to when they would cease coming to the park.

This information allowed us to create a public participation GIS platform which in pre-testing has proven to be both user friendly and capable of integrating with other data sets – a necessary trait if researchers are to provide managers with data that is readily useable and reflective of the complex tradeoffs that will occur in any strategy designed to target climate change. As we become more adept at collecting social data via PPGIS systems, we will be better positioned to develop a truly integrative system that allows a transdisciplinary approach to climate change.

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JOIN THE QUEUE: THE DIFFICULTY OF ENGAGING RURAL COMMUNITIES IN PARK-BASED VOLUNTEERISM

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ABSTRACT

Rural communities in high-consumption nations are often touted anecdotally as being the “backbone of the country,” pragmatic people who put sustainability concepts into practice. It seems logical that rural residents could serve as excellent volunteers for parks, especially if a rural town was the gateway to a large protected area. However, this study of South Australia’s Lamerloo/Pinaroo region and adjacent Ngarkat Conservation Park highlights a number of barriers to park-based volunteerism. Key among those barriers is the existing extensive commitments of many residents. It was found the majority of residents volunteered for at least two organisations or committees, and described the community as “burned out” in terms of voluntary affiliations. The perception that the parks agency was improving management of the area, along with the fact that people had their “own area to manage” also hindered willingness to volunteer. There was a moderately strong belief among rural residents that they as individuals could make a difference to our environment, but many respondents cited the 2010 federal election as an example of rural areas having limited political power compared to “urban greens” who they believed could influence environmental policy. The surprising result, however, was that the use by residents of the nearby protected area was found to be low and their concerns centred more around fire and weed management rather than biodiversity protection or recreation. We suggest that if a park agency wants to improve community engagement, rather than a traditional model of inviting volunteers to come and help, it may need a more dynamic model of partnering with existing organisations, building social capital amongst youth, and offering innovative programs that encourage greater participation in the park.

INTRODUCTION

Rural residents are often very attached to nearby natural settings. They may associate them with fond family memories or as a place for engaging in favourite activities. When a government agency manages that land, in particular if it is managed in a way perceived to be unsatisfactory by the community, relationships between park agencies and local communities can be problematic. Local residents near parks may engage in problematic recreational activities that impact the resource base, and decry loss of control to a centralized authority. This uneasy relationship between local citizenry near protected areas and government may take the form of ignoring rules and prohibitions.

Note: The authors acknowledge and thank Denni Russell, a graduate of the Sustainable Environments degree, for her leadership on project implementation and data collection.

(e.g. illegal collection of bushland products, depreciative trail/track behaviours), messy public meetings and protracted consultation, and hostile interpersonal relations. Alternatively, local citizens may prove to be the greatest asset a park agency has – providing a source of volunteers, peer regulation, lobbying and a means to justify the value of parks. In resource strapped natural resource agencies in Australia, building community capacity has become a key focus to extend limited staff and financial assets. The dynamic of globalization in fact demands collaborative local relationships. Nationally, managers with land protection responsibilities wrestle on a daily basis with interwoven issues of place attachment, trust, community dynamics, sustainability and economic well-being. The balancing act works better in some places than others. In 2011 South Australia's Department for Environment and Natural Resource (DENR) explicitly stated their desire to build social capital as a strategy that can help preserve parks for future generations. To do this, agencies need to engage with local communities – understand their attachment to parks, their priorities and barriers to greater involvement.

This study proposes to document the nature of community engagement – especially volunteerism, and analyse how community perspectives have evolved to date in a location where, despite periodic conflict, a productive relationship between park officials and residents exists. Resident surveys, community profiling, and a focus group offer the opportunity for systematic analysis of factors that defuse or spur local conflict over use of parks. By modelling relational dynamics, study outcomes are generation of preliminary strategies for cultivating an effective community-agency relationship, with potential expansion of the research at a later date to communities facing development projects (e.g. mining, desalinisation plant).

The Importance of Social Capital

Community engagement is “the process of involving the community in the planning and development of policies and services” (Gregory et al. 2008). Through building capacity, engaged and capable people are better able to participate in planning, managing and implementing conservation outcomes. Cuthill and Fien (2005) argue that such citizen participation is a basic building block for the development of social capital. Woolcock and Sweetser (2002) define social capital as the resources that individuals can access through memberships in particular types of networks. The resources that people can access are dependent on several key factors, including the number and type of their associations/connections, level of trust, reciprocity and exchanges, support, money, and other norms and sanctions that facilitate cooperation and cohesion in communities, and that result in benefits for community members (Coleman, 1988, Kawachi et al., 1997, Pretty & Ward, 2001, Woolcock & Sweetser, 2002). Social capital is thought to be linked to overall well-being, as well as to individual social, economic and health benefits (Australian Bureau of Statistics, 2006). The multidimensional entity can be conceived as consisting of four main components: (1) network types (e.g. bonding, bridging and linking); (2) network qualities (e.g. trust, reciprocity, common rules, cooperation and civic participation), (3) network structure (e.g. size, density, power relations) and (4) network transactions, for example, sharing support and sharing knowledge (Magis, 2010). Well-functioning networks are associated with many positive outcomes, including increased happiness, health and longevity (Stone, 2003).

Expanded engagement, in particular ongoing communication, is difficult in a society characterized by increasing atomization (Edmonds 2011). Typically civic participation is dominated by ‘the incensed and articulate,’ the ‘usual vocal suspects’ with vested

interests, the ‘squeaky wheels’ whose concerns generate attention, and ‘ghettos of the like-minded’ who reinforce shared views (Carson 2001 cited in Hartz-Kamp 2009). Some authors (Gregory et al 2008, Hartz-Karp 2007) have suggested broadening public representation by asking a random selection of residents to participate, or formulaic composition according to a desired profile of those drawn into dialogue.

Volunteerism is a critical component of social capital. A general study in Tasmania (Crowley et al. 2008) notes the prevalence of older volunteers, citing motivations of altruism and helping to save something in danger of being lost through modernization or development. Weaver and Lawton (2008) find that positive attitudes toward a park do not translate into overt action, but do link greater use of the park to a ‘tepid’ propensity to volunteer. The applied literature shows multiple policy variants to counter the increasing societal reluctance to volunteer and difficulty in creating free time blocks to volunteer. Amenity-rich regions in the United States have targeted new in-migrants to bolster flagging pools of volunteers, a strategy which has been especially successful for environmental work as part of a desired outdoor lifestyle (Weaver and Lawton 2008). Churches have provided a source for volunteers in protected areas in Germany (Schierenberg 2008). Parks Victoria monitoring of marine reserves by volunteers has generated action by a cadre of well-educated local residents, as proximity to the protected area is shown to increase volunteer hours (Koss et al. 2005). As is commonly acknowledged, non-volunteers in the Koss et al. study (2006) cite lack of time as the primary barrier, followed by lack of confidence in scientific skills, and recommend more investment in detailing task responsibilities and more convenient scheduling in drawing additional citizen participation.

Learning about the dynamics of rural communities necessitates creative integration of work in local engagement, conflict resolution and benefits-based park management. Benefits-based management is a framework that focuses on inputs such as setting conditions and activities necessary to facilitate the attainment of desired individual and community benefits (Driver & Bruns 1999). It incorporates cutting edge conceptual advances such as place attachment and agency trust in considering the bond between people as places as they may influence response to altered resource conditions and park management scenarios. As managers move toward a more holistic paradigm of ecosystem management, failure to consider the emotional, symbolic and spiritual value of land and the attachments people have with specific places is almost certain to generate conflict (Williams & Vaske 2003). Bruckmeier & Tovey (2009) term this desirable dynamic as local, livelihood-oriented discourse, embedded in a fundamental respect for community values (Beierle & Konisky, 2000). Understanding the package of benefits residents desire from adjacent parks offers a tool for learning to build community rapport and support for park management.

Methodology

South Australia’s DENR approached the researchers with interest in a case study of improving relationships between the parks agency and the nearby gateway communities. A panel of DENR employees suggested several parks where there were simmering issues with local residents, but not overtly hostile conflict. Other criteria for selection included a location within a 4-hour drive from Adelaide, a ‘moderate’ population size such as a regional trade centre, with ability to clearly demarcate the community of interest (thus eliminating sites within the Adelaide Hills), and willingness among park managers and local government to partner in the study. Ngarkat Conservation Park (CP)

in the eastern part of the state, and the community of Lameroo, were chosen from 8 options and agreed to participate.

The researchers met with Council mayor, and then visited the park and management office, gaining access to internal reports and the repository of news stories about Ngarkat Conservation Park, and the adjoining protected area, Big Desert Wilderness Park, across the Victoria border. Fire management after large uncontrolled wildfires in 2006 and 1998, local and tourism use of four wheel drive tracks, and continuing access for permitted beekeepers were the foremost public issues. On referral from agency and Council staff, using a snowball methodology with selected individuals, 18 persons representing adjacent landowners, CFS, feral animal control, 4x4 club, (inactive) 'friends' of the park group, commercial apiculture, ecotourism, nature enthusiasts, and teachers were invited to an evening focus group session in Lameroo. DENR and Council representatives were not invited to and did not attend the session in order to encourage openness and protect confidentiality in a small rural town. Twelve persons attended the session facilitated by the lead author, with scripted questions related to relationship with the park (place attachment) and agency (trust levels), community resources (social capital), and community governance and resiliency.

Based on issue delineation in the focus group, a short survey addressing connection to Ngarkat NP and assessment of community volunteerism, was distributed at the annual Pinnaroo Show and Field Day, an agricultural display described by study partners as "THE most important event on the local calendar." One hundred and thirty eight questionnaires were completed by those residing within 80km of the park; the refusal rate was 22 percent. The study is currently in progress; the current phase is an initiative to obtain online resident feedback and encourage community dialogue through newspaper coverage of results to date.

Community Profile

The Lameroo region is defined for study purposes as the Southern Mallee District Council local government area, including Pinnaroo. Largest population centre Lameroo is located 200 kilometres east of Adelaide in South Australia (Figure 1). Australian Bureau of Statistics showed the 2009 population as 2,189. Additional census figures (Australian Bureau of Statistics 2006) indicate an aging, culturally homogeneous population and suggest stagnation of growth in an agriculture-dependent region. The largest proportion of the population is aged between 25 and 54 years of age (36%); only 21% of the population is under 15, and almost one-third are over 55. Of the population aged over 15, 60% are married and only 8% are divorced or separated. The population is not culturally diverse as English is the predominant language spoken (99%), and the majority of residents (91%) were born in Australia. Other countries of origin include England, New Zealand, Germany, Netherlands and Croatia. Religious affiliation – with the Uniting Church, followed by Lutheran, Catholic and Anglican faiths - is common, with only 19.6% of residents identifying themselves as having no religious affiliation.

Lameroo is an agricultural centre. The largest proportion of residents (36%) is employed in the sheep, beef, cattle and grain farming industry. Other dominant industries include hospitals, civic and professional services, local government administration and other livestock farming. Full time employment is most common (64%), and working residents gain a median individual income of \$430.00 a week (median family income is \$1,054.00). This is comparable to the median Australian income of \$466.00 and \$1,171.00 respectively. Post-secondary education profiles (Certificate 1 to a post-

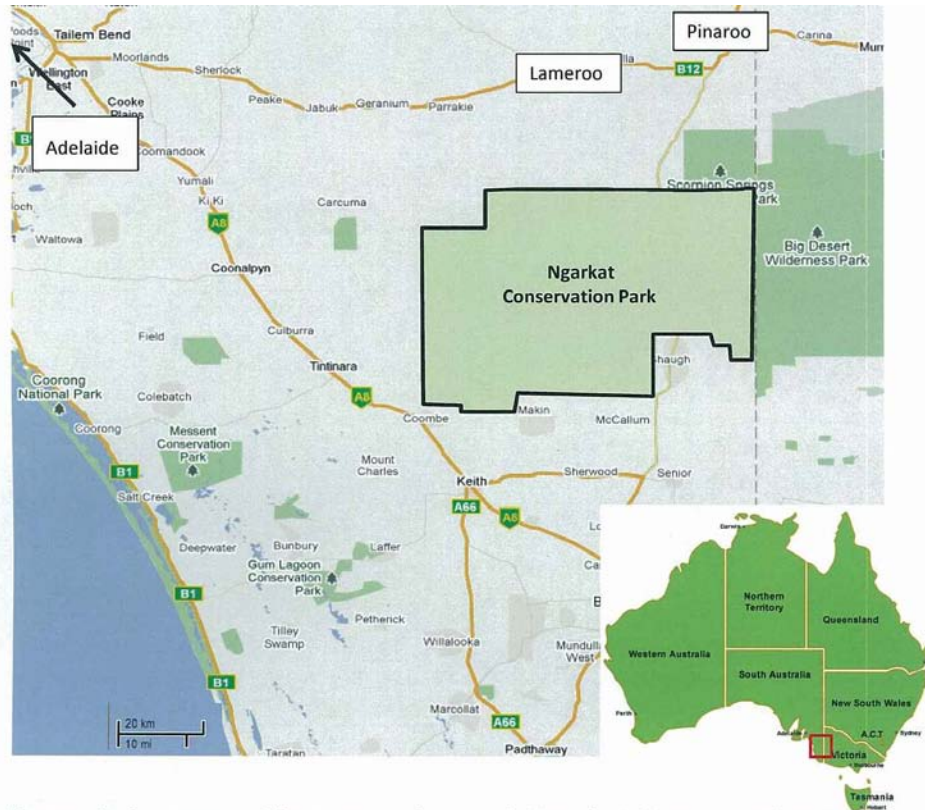


Figure 1: Lameroo-Pinaroo region and Ngarkat Conservation Park

Source: Google Maps 2011

graduate degree) show strong gender-specific patterns. The top field of study was in agriculture and environment, with only male representation (as did second-ranked engineering). Females are concentrated in the next most popular fields of study: health care (74%), management and commerce (89%), and education (86%) field. Only hospitality and food service training, which rounds out the top fields of study, shows gender parity. Finally, the census data (ABS 2006) reports Lameroo residents are very active, comparatively, with 49% volunteering for an organization or group, in stark contrast to the Australia average where only 22% participate in voluntary activities.

Focus Group Results

Participants had resided in the community for an average of 28 years (8 years was the shortest tenure), which generated a humoured discussion about ease of social access for ‘newcomers.’ Positive words used to describe the Lameroo region were: comradery, friendly, relaxed, safe, affordable, quiet, oasis, healthy rivalry, hospital, and sports. Negative adjectives were parochial, aging, decreasing population, and ‘too close’ (ly embedded). There was general agreement the prime of town was past (the population peak was in 1966), but that self-reliant character and innovative spirit were helping the region adapt and survive. Resolution of historical conflicts – a shearer’s strike, selling grain over the border, Bordertown Road planning, a proposed road in the park, and school amalgamation – had in fact strengthened the town and created resiliency. Current leadership was being demonstrated in the sheep industry, as a cadre of landowners perpetuated a custodial land ethic, shown in best practice farming with minimal tillage, improved growing capacity and stock health, and replanting/shelterbelt

campaigns. The decrease in population was termed the most troubling trend, with sports, community and youth groups spread thin, and unable to fill leadership and management posts. Yet, the oft-repeated statistic, “there were 53 fundraisers in town last year!,” suggests a core of volunteers operating competitively within an environment of severe funding lack.

Participants were personally appreciative of Ngarkat CP, and cited an array of biodiversity, tourism, recreation, spiritual (as a function of remoteness and the vast size of the park) and environmental services (pollination for lucerne, almond, canola and bean crops) benefits. They opined that the majority of local residents perceive Ngarkat as a weekend picnic spot, ‘don’t know what’s out there,’ and think ‘it’s just more hectares of mallee scrub.’ The ‘Friends of Ngarkat’ group was perceived to have faded “because everyone is too busy with other responsibilities in town.” The so-called ‘mayhem’ and misuse on the 4WD tracks was attributed to outsiders and ‘local idiots.’ Young staff at DENR was perceived to be short of resources allocated from the distant district and central office. The manner in which the school and sports activities hold the community together generated storytelling and emotionality, and missing educational links to the park were articulated. The facilitator found it difficult to control a divisive discussion of strongly held opinions about fire management stemming from two significant wildfires in previous decades. Conversely, a plethora of group-generated actions to improve non-fire park management, including community engagement strategies, were enthusiastically received by peers, although priority differed.

Survey Results

The short survey distributed at the agricultural event was designed to assess the relevance and range of opinion issues raised at the focus group, and to gain volunteers for a more comprehensive, follow-up questionnaire about place attachment, trust and social capital in relation to park management. Responses (N = 138) are representative of both town and rural dwellers, with 43% in the townships, 35% from rural properties, and the remainder from other locations within the 60km limit (including Victoria). First, residents are quite satisfied with the region as a place to live, rating it on average, 8.3 on a 10-point scale (1 = very poor, 10 = exceptional). The mode is 8, but 29% rate the region a ‘10.’ Self-described knowledge of natural environment features is slightly below average ($x = 2.6$) on a 5-point scale, but most (46%) believe people like themselves can have ‘a lot’ of influence in taking action to protect the environment (versus ‘none,’ ‘not very much,’ or ‘some’). This contrasts with focus group commentary (and conversations during data collection) about the 2010 federal election as illustrative of rural areas having limited political power compared to ‘urban greens’ who are believed to be more powerful in pressuring for environmental policy shifts.

Familiarity with Ngarkat NP shows a normal distribution, averaging 2.1 on a 5-point scale; fourteen percent place themselves in endpoint categories, with ‘none’ (coded as 1) or ‘excellent’ (coded as 5) awareness of the park. The majority (52%) think park management over the last five years has improved, but one-third are uncertain and 11% think the situation is worse. When asked to describe their *current* level of involvement with the management and planning of Ngarkat CP – ‘none,’ ‘not very much,’ ‘some,’ or ‘a lot’ – 79% report no involvement ($x = 1.3$ on 4-point scale). Using the same categories to select a *desired* level of involvement, again, most (43%) prefer no involvement. However, 35% wanted some volunteer opportunities, and 7% wanted ‘a lot’ of participation, although social acceptability response bias is a possibility.

When current and desired levels of involvement are cross-tabulated, the same 58 individuals (43%) still have no history of and prefer not to volunteer with the park. Further, 60 persons (44%) want increased involvement, most commonly shifting from ‘not at all’ to ‘some’ volunteerism. Only three persons wanted to reduce their commitments to the park. Our data confirms census data on significant volunteerism in Lameroo/Pinaroo, with 54% of the sample reporting membership in a community group, averaging involvement with 2.2 groups per head. Asked to evaluate (5-point scale where 1 = strongly disagree; 5 = strongly agree) the statement ‘volunteer burnout is a major problem in the region,’ the item averaged 4.3. Eight-four percent of respondents agreed or strongly agreed with the description.

Given the significant number of local residents who are unengaged with the park and plan to maintain that status, further data analysis concentrated on distinguishing ‘the uninvolved’ from the those desiring to be ‘engaged.’ Using the two subsets detailed above, some distinctions do emerge (Table 1). Differences in mean scores and distribution regarding general knowledge of environment, perception of ability to influence policy, management evaluation, and community ratings are not statistically significant. Familiarity with Ngarkat CP, however, shows subgroup mean differences in the predicted direction, and there are proportionally many more respondents who report ‘poor’ awareness in the subset of those currently uninvolved with the park with no future intention to volunteer. The ‘uninvolved’ group also shows half the rate of community volunteerism as those who desired to increase their participation in the park. The ‘uninvolved’ subset perceives volunteer burnout in a weakly populated rural region to be more problematic, despite their lower rates of volunteerism.

Table 1: Statistically Significant Differences in Volunteerism Subgroups

Variable	Measure	Uninvolved with park (n=58)	Desired park engagement (n=60)
Familiarity with Ngarkat	Mean (5pt scale)	1.7	2.3
	% ‘poor’	22.4	6.6
Volunteer in community	% ‘yes’	37.9	65.5
Volunteer burnout	Mean (5pt scale)	4.4	4.2
	% strongly agree	54.2	43.9

In analysing all respondent comments about critical management issues, residents overwhelmingly wrote about fire management regimes, accounting for 49% of 153 open-ended remarks. Other priority topics were control of feral animals and non-native plants (n=28), local control of better 4WD tracks (n = 7), and under-resourced and limited on-site presence of the few park staff (n = 7). When clustered, comments about user benefits (e.g. 4WD tracks, camping, access, tourism) outnumbered observations of existing management problems (e.g. bureaucracy, encroachment, rubbish, lack of tourism promotion) and species protection. There was greater dispersion in replies when respondents were asked to detail one preferred management change in the park, with 38 individuals proposing altered fire regimes, especially the top-ranked call for more regular controlled burning (although some individuals wanted fewer prescribed burns). In priority order, proposals that received at least five (of 100) mentions were: a

more focused campaign for eradication of feral animals and weeds, management in stronger cooperation with residents and landholders, greater ranger presence, improved track/road access, education of locals about the park, and increased tourism promotion.

Discussion and Conclusion

Community engagement is presumed to be a desirable practice with positive outcomes, and the Lameroo region exhibits connectedness through high levels of local volunteerism. Many people in the region – with greater frequency than the national average – are involved in volunteering, and paradoxically those that do volunteer, are prepared to do more, though citing volunteer burnout. It is a truism to say that busy lives and change characterize the 21st century in modern economies. Lameroo's rural residents strive to provide the same activities and opportunities for their children as residents in urban areas receive, thus necessitating participation in multiple community groups. The research confirms Crowley et al.'s (2008) articulation about the challenge of overlapping social networks in rural areas. The same parent who coaches a sports team may staff the tourist information centre and serve on the planning committee for a musical event fundraiser.

The research looked at how Ngarkat CP involvement is embedded in this social context. There is substantiation of strong place attachment, with scores in rating the Lameroo region as an attractive place to live serving as a proxy measure for connection to place. Likewise, trust levels in the park agency at the local level do not appear to be a major source of conflict, evidenced by perception of improving park management (or openness to learn more about management). Although we do not know whether trust differs with district or state level environmental management, respondent comments suggest agency trust decreases with increasing distance from the regional centres. However, we conclude some elements of social capital are problematic, with initial results showing many individuals have no connection with Ngarkat CP. Researchers repeatedly heard, "Ngarkat is a good place for a picnic," suggesting a rather utilitarian interface with the park, rather than a conservation icon, local education resource, important recreation setting, or an attraction anchoring the region's identity. Whereas volunteering for fire control is firmly institutionalized, the volunteer corps for weeding, trail/track maintenance and construction, and marketing is weak, especially since the collapse of the Friends of Ngarkat group.

Given the action-oriented nature of the research, these preliminary results have altered the study design. The intended comprehensive community survey about place attachment, trust in governance, and community decision-making about the park has been eliminated. Consistent with the ethic of active, participatory research, the researchers are now presenting results to date directly to the community, through local print media. We have summarized key findings in language accessible to the public, such as: "Many of you are unfamiliar with, disconnected from or disinterested in Ngarkat CP... why is this situation occurring?" Residents are then encouraged to and instructed how to provide feedback and reaction in an online reporting site; researchers will perform content analysis on this text data to analyse patterns of perceptions and help define strategies for improvement. Another example of a prompt is: "Results suggest volunteer burnout is a severe problem in the region. Is this true, and how can the community support and 'create' volunteers?"

In the interim as this supplemental data collection phase takes place, researchers have, in this paper, linked issues and management proposals generated in the survey, to focus

group commentary, to generate suggestions on volunteerism (putting complex fire management issues aside). Currently, park staff can reach out to a small enthusiastic group, many of whom participated in the focus group, with the expertise to provide input on technical and management issues. The issues of labour-intensive, lower skilled feral and weed control potentially present an opening to involve the public on the ground in working bees, and even offer youth employment. But findings suggest broader public engagement in biodiversity management may be difficult as these tasks potentially require a higher level of scientific/technical expertise. The educational profile of a sizeable number of males in the region in environment is particularly well matched to leadership on these tasks, but the gender gap would need to be addressed through expanded capacity building. Greater connection with schools is potentially served by integration of lessons with field trip excursions, and in this case many women are educated in the profession. Finally, a park-related community event may reverse the lower levels of park familiarity characteristic of those who do not volunteer. Consequently a final query to residents through the newspaper relates to action strategies to increase involvement: “Will these suggestions – working bees, youth employment, biodiversity task-oriented training, stronger connections between the park and the schools, community events - encourage you to have more involvement with Ngarkat CP?” Lastly, the park agency may trial random, but voluntary assignments by simply asking a wider range of residents to participate in planning and oversight responsibilities (Gregory et al 2008). Statistics on interest in volunteerism suggest there would be moderately positive response.

The Lameroo region and Ngarkat Conservation Park are representative of many similar Australian locales with a resilient and optimistic, but declining rural population, in proximity to large acreages of undifferentiated mallee scrub that is critical to biodiversity conservation efforts. The landscape offers the potential to enhance local lifestyle, with untapped tourism assets. The evolution of the park-community relationship in achieving a greater degree of local input and volunteer effort is not in crisis, but is not optimized either. This ongoing work continues to profile this dynamic relationship and propose adjustments in social capital to improve community engagement.

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Reviewer #2:

1. The English is acceptable with only a few minor corrections. There is some repetition that could be removed with conscientious editing and a tendency to be overly verbose. Some editorial corrections have been made on the manuscript for consideration.

2. The authors state that "*The toxicity of copper has been well documented*". This needs to be supported by at least one or two references.

Response: The '**well documentation**' of copper toxicity is in the same report by J.L. Gerberding, 2004 on Toxicology Profile for Copper compiled for Agency for Toxic Substances and Disease Registry CAS 7440-50-8, U.S. Department of Health and Human Serv, Atlanta, GA, pp. 12–15.

3. Page 2 "Papini & Majone"- please include the year for this reference.

Response: The year of publication for the reference has been included.

4. Materials – what was the solution:solid ratio used when making Na-MMT?

Response: Sodium-exchanged MMT (Na-MMT) was prepared by treating 20 g MMT with 10% (w/v) of 1 M of NaCl solution under mechanical stirring for 24 h at ambient temperature.

5. In the experimental section the authors do not actually say what the optimised reaction time or other conditions were. This needs to be added.

Response: These conditions were stated under experimental section and specifically under '**batch adsorption sub-section**'. The optimised reaction time and some other conditions were: reaction time, 250 min; pH, 5.8 ± 0.1 ; temperature 25 ± 0.1 °C; agitation, 200 rpm.

6. On Page 3, experimental section you state that no precipitation was observed for blanks but subsequently on Page 4 you state that precipitation occurred at pH. 6. Please resolved this disagreement.

Response: The text reports that precipitation commenced at pH > 6 and not pH 6.

7. Why was the amount of MMT used in "real" wastewater treatment (1g to 50 mL) more than what was used for the optimized batch studies (0.3 g). Was the same solution: solid ratio used??

Response: Correction has been effected in the text, 0.3 g MMT was also used in the real wastewater treatment.

8. If precipitation is occurring at pH >6, then this is not adsorption and this voids the study if adsorption parameters are derived. I observed that you have overcome this issue by restricting pH to 5.8. However, this is an important issue to resolve if adsorption or precipitation is occurring.

Response: Adsorption may still occur even at precipitation (metal speciation). This was made clear in the text However from blank experiments, it was observed that precipitation commenced at pH > 6 and therefore the large increase in the extent of adsorption beyond this pH was ascribed to the onset of precipitation.

9. The effect of pH section is too wordy and can be summarized more succinctly without any loss of information. I think this section can be halved in size.

Response: Reviewer 1 feels this section (size) is okay.

10. The adsorption Isotherm section is very well written and this is what the pH section above should be like.

Response: Noted.Thank you.

11. There is some room for more in depth discussion of mechanistically what the adsorption parameters mean, but the current discussion is adequate.

Response: Noted

12. Page 6, the authors state original pH of 6.1 of wastewater, so at this pH should not most of the Cu be precipitated as described earlier in the text? Or was the pH of the solution adjusted to 5.8 for treatment with MMT?

Response: Correction has been effected. The pH of wastewater ought to have been reported 6 ± 1 .

13. The authors mention Cr^{6+} , but Cr6 such as in $\text{Cr}_2\text{O}_7^{2-}$ would be negatively charged and not adsorbed by MMT. Do the authors mean Cr^{3+} ? Some modelling of the wastewater using GeochemPC or some other software may be appropriate to determine what the dominant species in solution where. The concentration of Cr given as 0.049 mg/L in the text does not match that given in Table 2 which was 0.317 mg/4L

Response: Correction already effected.

14. Table 2. Why are the units for metal given as mg per 4 L in the heading? These quantities should properly be expressed as mg/L.

Response: These quantities have been properly expressed in Table 1.

15. Table 1. The CEC, d spacing and surface area were not discussed in the experimental section. How where these determined? This is also true of the parameters in Table 2. No information has been supplied on how each of these parameters was actually determined in the experimental section. This needs to be added to the experimental section.

Response: How CEC, d spacing and surface area were determined has been discussed under experimental – ‘material sub-section’.....Using Braunauer–Emmett–Teller (BET) nitrogen adsorption technique, specific surface area, pore volume and pore size distribution were obtained using surface area and porosimetry analyzer (Micromeritics - TriStar 3020 Gas Adsorption Analyzer).....

Effective Planning and Management of Water Resources through Borehole

Profiling using GIS. A Case of Nairobi, Kenya

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ABSTRACT

The provision of clean and sufficient water is a basic human rights issue. With the ever increasing world population coupled by the many fragile wetlands and other water catchments which are not being protected, the governments of today should seek ways of ensuring that there is adequate and sustainable water. Indeed according to a World Bank Report of 2004 Kenya receives a renewable supply of freshwater of less than 650m³ per person per year as opposed to the recommended 1000m³. The Kenyan Government undertook reforms in the Water Sector to ensure effective, efficient, sustainable and autonomous developments with one of the specific mandates being the drilling of boreholes. The overall objective of this study was to develop a GIS database to be used for profiling boreholes for management purposes using Nairobi as a case study. This entailed capturing the spatial and attribute data specifically the location of the boreholes in x,y,z using GPS and their descriptive information on the name, yield, status, soil type, quality of water and the catchment it serves. The results obtained showed that there are 703 boreholes with varying depths of between 18m and 473m of which 40% have a yield of over 10,000m³. The ground elevations were found to range from 1439m to 2244m above sea level. The distribution of the boreholes was found to be within 1500m and 1750m elevations. Spatial profiling of boreholes generates visualizations as demonstrated in this study that are useful for effective planning and management of water resources in the country.

Study Background

The continuous increasing world population coupled by the many fragile wetlands and other water catchments that are not being protected or conserved is forcing the governments of today to seek ways of ensuring that there is adequate and sustainable water to all its citizens. The United Nations World Water Development Report, 2003 (UN, WWDR, 2003), states that of the world water only 2.53% of it is fresh. 0.67% of the 2.53% world fresh water resources are available for extraction in the form of rivers, ground water or fresh water lakes. The remainder is in form of ice and is located at places from which it is economically not feasible to extract. Kenya is classified as a “water scarce” country receiving a renewable supply of freshwater of less than 650m³ per person per year as opposed to the recommended 1000m³ per person per year (World Bank, 2004). This problem is compounded by lack of demand management strategies and adequate data for water resources allocation with regard to surface and groundwater abstractions (WWDR2, 2006).

Kenya has recognized that water is very central in poverty reduction and while emphasizing provision of services to the poor the need for ensuring adequate water for competing demands is captured in the Economic Recovery Strategy that would facilitate in the achievement of MDGs (ERS, 2003).

In urban areas, the actors competing for water include industries, residential, commercial, public purposes, education institutions and recreational facilities. The

challenges faced in cities in trying to fulfil these conflicting demands include water supply (sources, capacity, network coverage and unplanned developments) and quality management which refer to pollution levels of water sources. In addition accessibility to water in terms of individual standpipe, hand dug wells, boreholes, communal points and people being served. Other considerations involve affordability (where less 5% of the income is used to purchase water), sufficiency (20 litres per capita per day) and distance and time taken to access the water points (200m and less than 1 hour).

Water Services Reforms in Kenya

In between 1990 and 1992 the Government of Kenya (GoK) in conjunction with the Japan International Cooperation Agency (JICA) undertook the 2nd National Water Master plan whose objective was to promote orderly planning and development of water resources in the country. This study recommended among others the formulation of a new water policy that culminated in the publication of the Sessional Paper No 1 of 1999, the “National Policy on Water Resources Management and Development” (Ministry of Water and Irrigation, 2005).

In order to effectively manage and protect the water resources in a sustainable manner the Management and Development aspects have been separated through enactment of the Water Act 2002. An autonomous institutional framework comprising the Water Resources Management Authority (WRMA) and its Regional Catchment Offices has been created with the appointment of Catchment Area Advisory Committees (CAACs) and the establishment of Water Users Associations (WUAs) which include NGOs, Community Based Organizations (CBOs) and the private sector. The establishment of these institutions will allow for decentralization, participation and sustainability in the management of water resources. One of the main mandates is to ensure that the increasing population has enough access to water through exploration of new and alternative sources key among them being boreholes.

Groundwater

Groundwater is normally exploited in form of shallow (dug) wells or deep (drilled) boreholes. However, the latter is considered a very expensive source of water due to the high drilling and operation costs attributed to pumping from high depths beneath the ground surface. For instance, drilling a 200m borehole would cost about US\$ 25,000 (Earthtrends, 2003). In Kenya, exploitation of groundwater is controlled by WRMA in accordance with the Water Act 2002. Water resources assessment that involves continuous measurement and recording of data, including their quantity and quality and the various human and other factors which affect the resource provides a crucial basis for planning and management of water resources. This information also contributes to macroeconomic and sectoral planning in agriculture, industry and rural development.

In general, Kenya receives an average annual rainfall of 570mm/year with a range of less than 300mm/year in drier Arid and Semi-Arid Areas to more than 2000mm/year in the wetter highland areas. Of this water, only a small portion infiltrates the ground to recharge the groundwater which is critical to sustainable groundwater management. However, no efforts are made to quantify recharge rates. Quality of water from boreholes in Nairobi, Western, Central and Nyanza is generally suitable for domestic use. As of the year 2000, there were an estimated 19,000 boreholes countrywide (Ministry of Water and Irrigation, 2005). One of the challenges the water sector has been facing is lack of co-ordination in boreholes drilled because of the many players involved. This is exacerbated by the fact that existing records are incomplete both in time and coverage, while the capacity for data collection, storage, analysis and dissemination is poor. According to the Ministry of Water and Irrigation there is need

for information on the spatial distribution of the boreholes, their yield, their depth and date of completion. In addition the effect of completion date, depth and elevation on yield is also useful in the effective planning and management of boreholes. This information will enable the ministry to continuously monitor, assess and evaluate water resources thus ensuring water security. In this regard, GIS lends itself as useful tool for generating the Borehole Profiles and presenting them spatially.

METHODOLOGY

This section gives a detailed account of the study area, data used and how it was collected, the development of the GIS database as well as how the Borehole Profiles were generated.

Study Area

Nairobi is located at 1°16'S, 36°48'E and occupies an area of approximately 684km². It has a population of about 3million. The altitude varies between 1600m-1900m above mean sea level with the western part being on high ground (1700m-1900m) and eastern side being generally low with a general altitude of 1600m. It experiences a tropical climate with two rainy seasons the highest received between March and April and the shortest between the months of November and December. The mean annual rainfall ranges between 850mm-1050mm whereas the daily temperature is in the range of 12-26°C.

Data Sources and Collection

The data sources used in this study included both spatial and non-spatial. The spatial involved the location of the boreholes (source: field survey, 2009), administrative boundaries for Nairobi (Survey of Kenya), Shuttle Radar Topography Mission (SRTM) data which provided the elevation information (ILRI, 2007), soil (ILRI, 2007), as well as population (Kenya National Bureau of Statistics, 2009). The spatial location of the boreholes was obtained using a Global Positioning System (GPS). Specifically, handheld (navigation) receivers with a positioning accuracy of about 1m were employed. The reference frame used was arc 1960 datum. The 3-D (x,y,z) coordinates for the boreholes were acquired in the UTM coordinate system. For each of the boreholes the attribute data including the yield, depth, quality and use of the boreholes were sourced from the Ministry of Water and Irrigation.

GIS Borehole Database Development

Creating a GIS database for enabling generation of profiles for the boreholes in Nairobi involved first identifying profiling variables and their specifications. Then the captured spatial and non-spatial data specifically the location of the boreholes in x,y,z and their descriptive information on the name, yield, status, quality of water, number of people it serves, etc., were integrated into the GIS database using ARCVIEW and MS-ACCESS software respectively (Longley et.al., 2004, Hansen & Hansen, 2008). The spatial database was then edited to ensure quality and integrity of the data.

Borehole Profiling

Within the context of effective planning and management of water resources through borehole profiling the factors considered in this study as expressed by the Ministry of Water and Irrigation included the number and their spatial distribution, the yield, the depth, date of completion and soil types. Consequently, the profiles generated showed the number and their spatial distribution. The distribution of the boreholes on the basis of the completion date and the relationship with yield was demonstrated. The depth of

the boreholes is also an important consideration and their distribution on this basis was also created using a total of 9 classes with an interval 30m. In addition the boreholes were also categorized into 9 classes based on yield and used to understand their spatial distribution. Other profile indicators generated on the basis of yield are depth and elevation.

RESULTS AND DISCUSSIONS

This section gives a detailed account of the results obtained on borehole profiling and the discussions emanating from the study.

Results

From the field survey a total of 877 boreholes were found and using their spatial co-ordinates it was established that 708 are within Nairobi. Of these 708, 5 boreholes did not have data on depth and hence were not used in subsequent outputs. The number of boreholes per division, the population served and number of people per borehole is shown in table 1.

Tab.1: Boreholes and the Population per Division

DIVISION	NO OF BOREHOLES	POPULATION (2009)	PEOPLE PER BOREHOLE
MAKADARA	50	297 434	5 949
PUMWANI	11	302 211	24 474
CENTRAL	21	334 942	15 950
KASARANI	69	438 925	6 361
EMBAKASI	123	534 884	4 349
PARKLANDS/WESTLANDS	143	307 610	2 151
KIBERA	215	486 739	2 264
DAGORETTI	71	440 509	6 204
	703	3 143 254	4 471

Among the 8 divisions in Nairobi, Kibera has the highest number of boreholes (215) which translates to 2,264 people per borehole, followed by Parklands/Westlands (143) with 2,151 people per borehole and Embakasi (123) also with a ratio of 4,349 people per borehole. This is evidence of unreliable water piped supply to cater for the demand. Pumwani and Central have the least number of boreholes 11 and 21 giving rise to 24,474 and 15,950 people per borehole respectively. These two divisions being within the CBD have reliable water supply compared to those further away.

The spatial distribution of the boreholes within Nairobi is shown in figure 1.

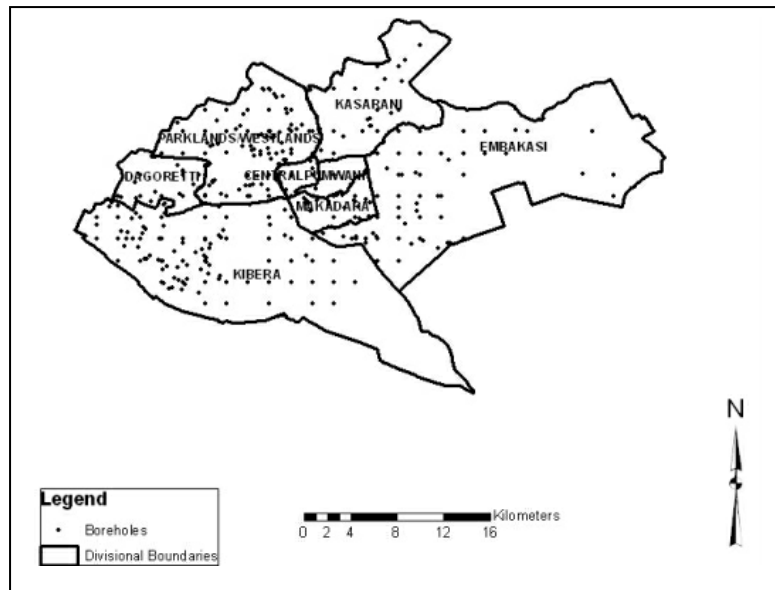


Fig. 1: Spatial Distribution of Boreholes within Nairobi per Division

From the figure it is evident that each division has a fair share of a number of boreholes. However, a visual comparison indicates that Kibera has a high number of boreholes, whereas Pumwani and Central have very few. The area covered by these two divisions is also much smaller in size. In general boreholes tend to be more concentrated to the west of Nairobi.

From the field survey (2009) it was established that some boreholes were drilled in the 1930s whereas others in the 2000s as shown in figure 2.

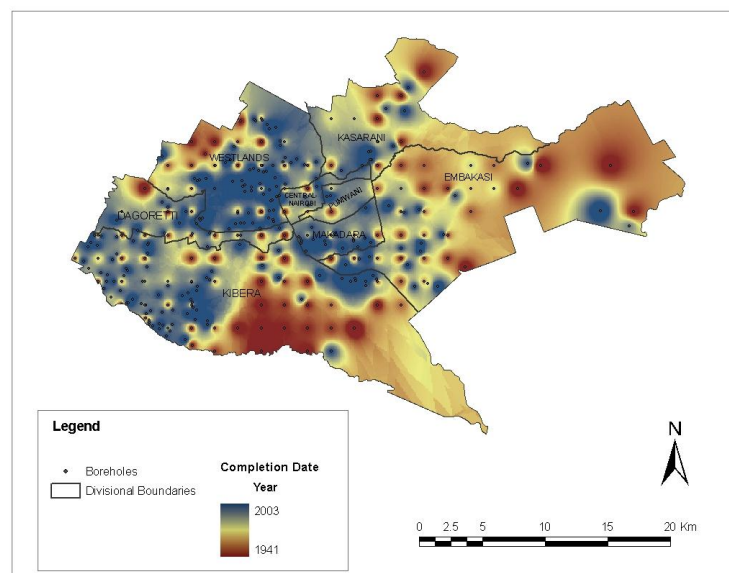


Fig. 2: Spatial Distribution of the Boreholes on the basis of the completion date

In general, this illustrates essentially well-established areas of groundwater use and relatively recent ones. This visual information enables spatial comparison of old and new boreholes, for instance central tends to have more new ones compared to the western, southern, eastern and to some extent the northern part of Nairobi.

Further analysis on the basis of yield and completion date was conducted where the yield was categorized into 4 main classes. The results are shown in table 2.

Tab. 2: Completion Date and Yield

Completion Date (yr)	Yield (000, m ³)				
	<=5	6-10	11-15	16-20	21-25
<1960	178	116	49	16	2
1960-1970	10	9	4	0	1
1971-1980	15	19	10	2	2
1981-1990	15	11	5	1	3
1991-2000	38	52	13	8	1
>2000	10	20	26	20	5

It is clear that the boreholes completed before the 1960s have very low yield with majority having a yield of less than 10,000m³. By comparison, those that were drilled after the year 2000 tend to have a better yield with most producing more than 10,000 m³. This information is useful in establishing the economic sustainability of boreholes.

Depth is another important profile indicator on the boreholes. In this study, the depths were categorized into 9 classes and their spatial distribution is shown in figure 3.

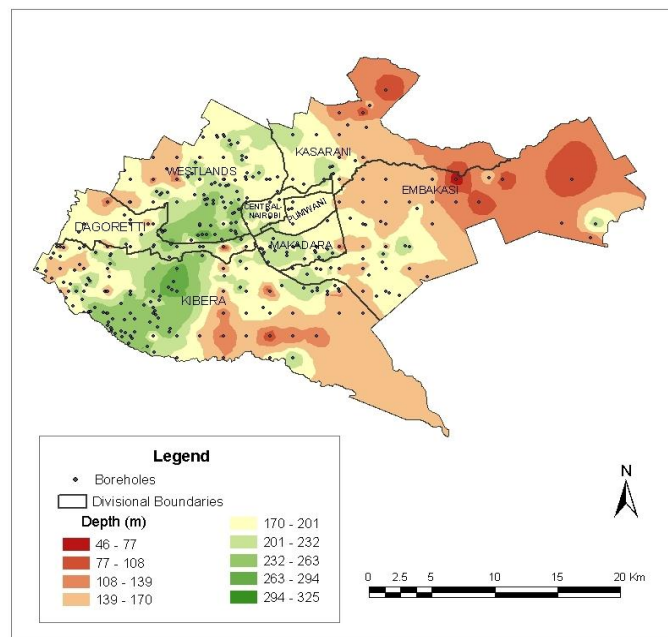


Fig. 3: Spatial Distribution on the basis of depth

The spatial interpretation indicates that most of the deep boreholes (>200m) are concentrated in the central and partially to the southern part whereas the shallow ones (<= 200m) are mainly to the eastern, western and northern part, with isolated cases of deep boreholes. This is an indication of the abstraction levels and the water table in general in Nairobi. This fact is emphasised more in table 3.

Tab. 3: Boreholes depth

DEPTH(m)	NO OF BOREHOLES	PERCENTAGE%
<=100	110	15.6
101-200	368	52.3
201-300	197	28.0
301-400	27	3.8
>400	1	0.1
TOTAL	703	100.0

From the statistics shown in table 3, more than half of the boreholes specifically 368 (52.3%) have a depth of between 100-200m, whereas less than 1% have a depth of above 400m. The implication is that when drilling boreholes the abstraction levels do not have to go beyond 300m. This is useful for planning purposes.

The spatial distribution of the boreholes on basis of yield is depicted in figure 4.

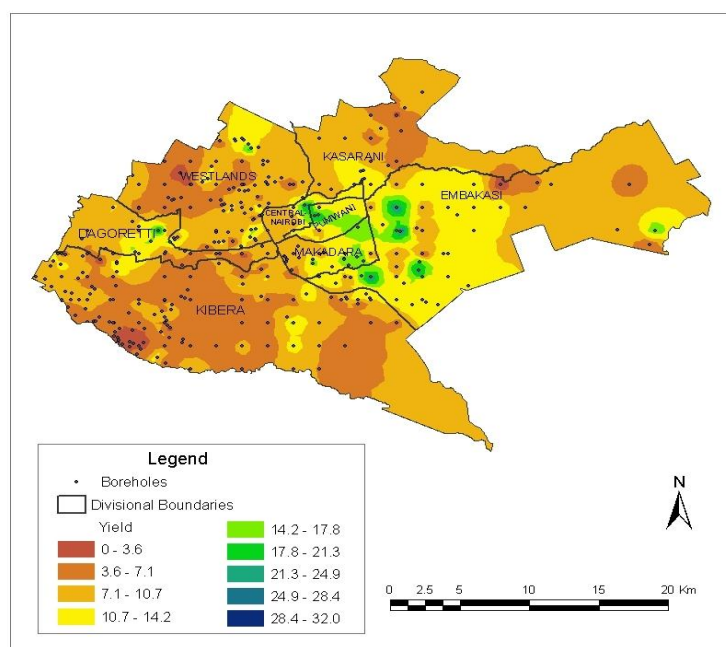


Fig. 4: Spatial Distribution of the boreholes on the basis of yield

There were 9 categories ranging from those whose yield is between 0-3 to those between 28-32. Spatial analysis revealed that low yield boreholes are found in the south-western part specifically Kibera division and partly to the north of Nairobi. High yielding boreholes are clustered in the central and partly eastern side. This is useful information that can be exploited in identifying potential areas for groundwater exploration.

Table 4 shows the statistical distribution of the boreholes on the basis of yield.

Tab. 4: Boreholes Yield

YIELD ('000 M ³)	NO OF BOREHOLES	PERCENTAGE%
<=5	266	39.3
6 -10	227	33.6
11-15	107	15.8
16-20	50	7.4
21-25	14	2.1
26-30	7	1.0
>30	5	0.7
TOTAL	676	100

Only 27 of the boreholes did not have information on yield. Of the 676, 266(39.3%) have a yield of less than 5,000m³. In general, about 73% (493) of the boreholes have a yield of less than or equal to 10,000m³ with less than 1% having a yield of more than 30,000m³.

Another useful indicator in effective planning and management of boreholes is on the spatial relationship between the boreholes depth and yield. The result of this analysis is depicted in figure 5. To enable visualization, yield information was mapped as contours whereas depth is in form of raster.

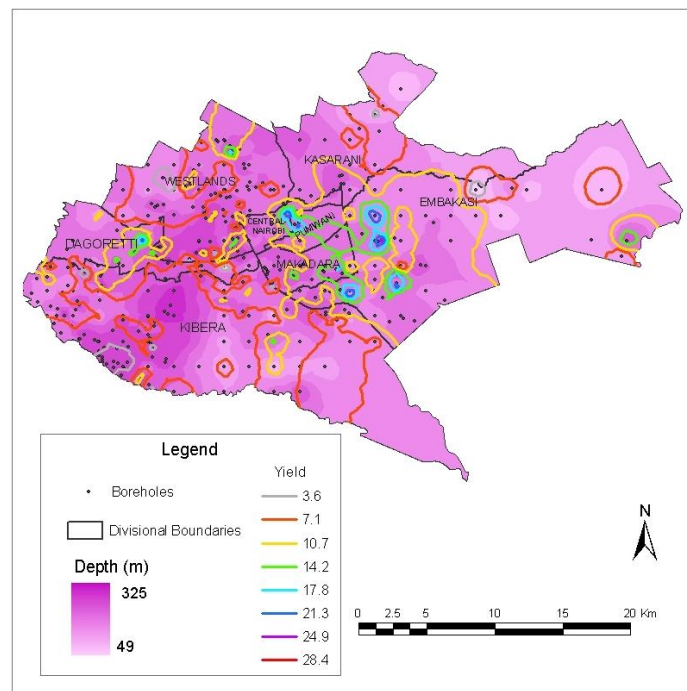


Fig. 5. Spatial distribution of boreholes on the basis of depth and yield.

A visual interpretation of figure 5 reveals that deep boreholes do not necessary yield much water, where evidently most of them are clustered in the central and southern part of Nairobi. On the other hand high yield is evident in the eastern side where depth is not as deep compared to the areas in central and southern parts. This is useful information in planning future drilling of boreholes in that depth alone is not sufficient in determining yield.

The relationship between the spatial location of the boreholes, depth and yield is shown in figure 6.

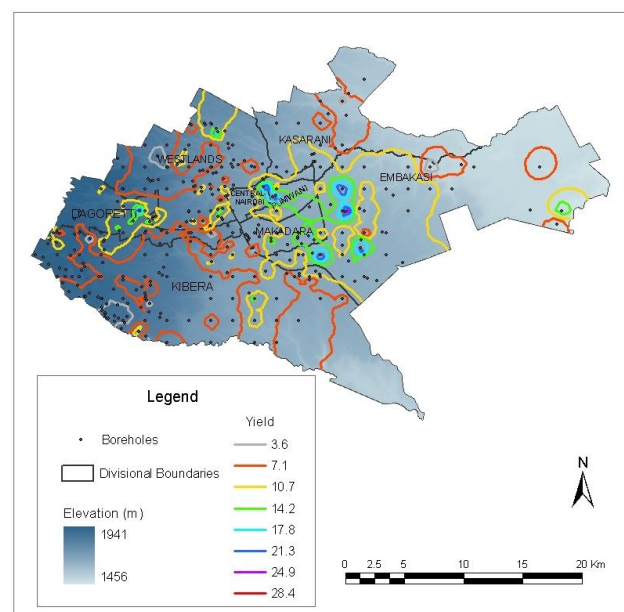


Fig. 6. Spatial Distribution of the Boreholes on the basis of yield and elevation

In general the western part of Nairobi has a higher elevation compared to the eastern part. Visually, the yield tends to be much lower to the Western part compared to the Eastern side.

Table 5 shows the statistical variations of the number of boreholes on the basis of elevation.

Tab.5: Boreholes and Elevation

ELEVATION (m)	NO OF BOREHOLES	PERCENTAGE%
<=1500	13	1.8
1501-1600	86	12.2
1601-1700	212	30.2
1701-1800	191	27.2
1801-1900	173	24.6
1901-2000	14	2.0
>2000	14	2.0
TOTAL	703	100.0

A total of 576 (82%) of the boreholes are found between 1600m and 1900m height. This information is useful as it does give some indication on the suitability of boreholes drilling on the basis of elevation. Only approximately 2% are found in areas of elevation less than 1500m and above 1900m there are 4%.

Discussion of the Results

The borehole profiles generated in this study include the number and the spatial distribution, their yield, date of completion and depth. In addition, the relationship between depth and yield have also been spatially analysed as well as the date of completion and yield. The influence of the soil type on the depth and spatial location of the borehole has also been examined. The results reveal that, Nairobi has more than 700 boreholes which are used for domestic, agriculture, industrial and livestock purposes where most namely 576 (82%) of the boreholes are found between 1600m and 1900m height mainly the Western part. The boreholes vary in terms of depth, yield as well as the date of completion. Deep boreholes (>200m) were found to be clustered in the central and partially to the south of Nairobi whereas the rest are found in the eastern, northern and western part. In terms of yield about 73% (493) of the boreholes have a yield of less than or equal to 10,000m³ and these are found mainly in south and western part with the high yield being concentrated in the central and eastern side. This is useful in deciding on their continued viability. A spatial relationship between yield and completion date revealed that old boreholes (before the 1960s) have low yield (less than 10,000 m³) and are largely found in the south-western part. By comparison, recently drilled boreholes (after the year 2000) have a better yield (more than 10,000 m³) are clustered in the central and partly eastern side.

Conclusions

Kenya being a water scarce country, it is all the more important to ensure that the water resources are continuously monitored, assessed and evaluated in order to plan for water security. Existing records are often incomplete both in time and coverage of the country while the capacity for data collection, storage, analysis and dissemination is poor. This necessitates the use for GIS as a tool for data storage, management, manipulation and visualization. The study has shown that it is possible to generate various profiles and present them spatially that would be useful for effective planning and management of

boreholes using GIS. The advantages include enabling storage, ease in manipulation and information extraction and disseminating borehole profiles. The power of visualization in form of maps has been demonstrated which adds value in decision making particularly licensing of new boreholes and where. In addition updating of the database is much easier, thus ensuring that current information on the existing situation of the available boreholes is captured and any new ones can be planned appropriately.

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MAKING THE MOVE OR KEEPING THE CONNECTION? ENGINEERING WOMEN AS MANAGERS – AN AUSTRALIAN STUDY

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ABSTRACT

This paper describes the initial stages of current research exploring the advancement of women engineers to managers and leaders in technical organizations in Australia. The aim of the research is to provide an understanding of women engineers' transition to manager and leader from the perspective of those that have lived through this experience. In doing so, it extends existing research on women in non-traditional work, management and leadership and engineering practice. The voice provided by the study broadens and enhances the view of management and leadership in engineering. By focusing on successful transitions, the research findings can inform policy and practice to retain and advance women in engineering – a profession in which women are overwhelmingly underrepresented.

The study uses a qualitative research design guided by phenomenological and feminist perspectives. In depth semi-structured interviews have been used to capture the experiences of women working in non-traditional, male dominated workplaces. This paper presents preliminary analysis of an initial set of eight interviews and focuses specifically on the transition to manager. It explores emerging themes relating to the participant's newfound roles as managers - Technical Competence, Retaining the Technical Link and Me as Manager. These themes highlight aspects of the participants' experience of becoming a manager. They also reveal how management is conceptualised in engineering, specifically by women engineers who have advanced to senior positions in the engineering profession, and begin to inform a broader and more inclusive view of management in the engineering profession.

INTRODUCTION

This paper describes preliminary analysis from a current research project regarding the advancement of women engineers to managers and leaders in technical organizations in Australia. The aim of the wider research project is to provide a more detailed understanding of the transition to manager and leader. It is linked to existing research on women in non-traditional work, management and leadership and engineering practice and aims to uncover the views of women in engineering management and leadership roles. Through its focus on successful transitions, the research findings can inform policy and practice aimed at improving retention and increasing women's representation in senior roles in engineering, a profession in which women remain overwhelmingly underrepresented.

The paper draws on the phenomenological interpretation of the accounts of an initial

group of eight women engineers from Western Australia who are currently working in senior roles in technical organisations. The focus of this paper is their transition to manager, and three emerging themes relating to the participant's newfound roles as managers are explored - 'Technical Competence', 'Retaining the Technical Link' and 'Me as a Manager'. These themes highlight aspects of the participants' experience of becoming a manager and reveal how management is conceptualised in engineering, specifically by women engineers who have advanced to senior positions.

CONTEXT

Women in Engineering in Australia

Despite initiatives at government, industry body and organizational levels the level of participation by women in the engineering profession in Australia remains disappointingly low. Only ten percent of degree qualified engineers working in engineering and engineering related occupations are women (Kaspura, 2010). The low participation rates have been attributed to small numbers of women enrolling into engineering courses and a high attrition rate post graduation (Mills et al., 2008).

The attrition rate of women engineers in Australia is found to be close to 40% greater than men engineers of equivalent experience (APESMA, 2007) spiking at between 7 to 10 years of work experience (Mills et al., 2008). Similar patterns have been observed in the USA where women are twice as likely as men to leave engineering and science careers and also have higher exit rates than women in other professions (CAWMSET, 2000, Hewlett et al., 2008). Further Australian studies observe that the retention issue is persistent with insignificant improvement in the last decade (Mills et al., 2008, Roberts and Ayre, 2002).

Research on engineering women in Australia combines quantitative data with women's educational and workplace experiences to establish some features of life as a woman engineer. A sense of satisfaction from engineering work is found, along with an awareness of their minority position and a feeling of being unprepared for the workplace generally and the engineering work environment, requiring the development of coping skills to 'get by' (Gill et al., 2005). From their analysis of the experience of engineering men and women, (Mills et al., 2006) describe engineering as an uncomfortable profession for women strongly influenced by workplace culture. (Bastalich et al., 2007) explore the cultures of engineering and the 'engineer' and the implications of these for women engineers and gender balance in engineering.

Advancement to Management

The limited advancement of women in management has been associated with a concrete wall and a glass ceiling implying that impenetrable barriers exist (Eagly and Carli, 2007). The gloomy picture painted by the management statistics contrasts with the desires and priorities of women. Women want to advance, are equally as ambitious as men and opportunities for learning, development, promotion and progression are high priority (EOWA, 2008). For those that have chosen to remain in engineering, advancement to senior and management roles can be described as a labyrinthine process – achievable but challenging and convoluted (Eagly and Carli, 2007).

Research on the transition of engineers to managers focuses on required skill sets, the motivations for movement from technical to managerial roles and the problems faced

during transition (Badawy, 1982, Roberts and Biddle, 1994, Wearne, 2004). Engineers have a relatively narrow view of what constitutes ‘real engineering work’ (Trevelyan, 2007) and may be inherently oriented toward technical jobs (Shapira and Griffith, 1990). However, the technical career path may be truncated and management considered the path to authority, influence and status (Roberts and Biddle, 1994) so a dissonance can exist between the desire for advancement and salary growth and a preference to remain in the technical ‘real engineering’ world.

THE STUDY AND ITS METHODS

The broader research that informs this paper explores the transition of women engineers to managers and leaders. The research focuses on the experience of women in non-traditional, male dominated workplaces who have advanced to management and leadership roles, placing the participants’ stories at centre and acknowledging the importance and diversity of their experiences (Stewart and Lane, 1994). By exploring the experiences of those that have persisted and progressed, the study provides an alternative and complementary approach to previous studies that have investigated barriers to progress (Gill et al., 2005, Marongiu-Ivarsson and Ekehammar, 2000, McIlwee and Robinson, 1992, Mills et al., 2008).

Twenty-four in depth semi-structured interviews have been undertaken with women engineers from four Australian states who have moved from technical to managerial and leadership roles. For the purposes of the study managerial and leadership roles are those that have responsibility for human and financial resources as the major role responsibility. The participants have come forward from a range of industries including the resources industry, infrastructure, transport, and defence and government. The women occupy a variety of senior roles and their experience level ranges from new manager to senior executive.

This paper draws on the preliminary phenomenological interpretation, based on Moustakas’ phenomenological method (Moustakas, 1994), of the accounts of an initial group of eight women engineers from Western Australia who are currently working in senior roles in technical organisations. Three themes relating to the participant’s experience of becoming a manager ‘Technical Competence’, ‘Retaining the Technical Link’ and ‘Me as a Manager’ are discussed below.

FINDINGS

Technical Competence

Participants spoke frequently of technical grounding and competence. Technical grounding was seen as an essential foundation for becoming a manager in engineering related industries, with a need for a solid grounding and broad technical experience. A manager with 20 years of work experience in mining industry explained:

You have to understand what it is that you are managing if you want to be a manager, so you need a good technical grounding and a breadth of experience in the field I think. (P3)

One’s technical background was important in establishing “street-cred”. A solid technical background was a measure of competence and it established their credibility as a manager with others.

I think that you need to have been able to have some experience to give you... in some area on the ground... to give you a bit of street-cred when you are talking to the people who you are looking after. (M2)

In addition to contributing to credibility, a number of women in this group described their technical ability as a protective measure - as a shield to ward off tough team members or as a safety net to fall back onto during a phases of uncertainty when taking on management roles:

For me, I'd done work experience where I'd literally just driven trucks and shovelled dirt and that sort of thing. And whilst that didn't teach me a huge amount about the individual sections of the work that I managed, it gave you the ability to talk to the people that were doing that sort of work. And just a bit of street credibility. And I think that's really important because they can be tough on you otherwise. (M2)

Another participant with 20 years of experience stated:

The challenge has actually been on the [Project name] role where I was out of core discipline and I didn't have my technical skills to really fall back on and in terms of gaining credibility. (M5)

Technical competence and credibility were also raised when discussing the promotion of others to more senior roles. A participant from the oil and gas industry, who has input into the promotions of a group of engineers as part of her role, married technical grounding with the external perception of competence:

When we are promoting people it (technical grounding) definitely helps them because this is an issue of competence. So it depends on the person, but engineers do tend to be technical people and they do size people up on their technical competence. (M5)

Technical ability is important in the participants' move away from purely technical engineering roles. It is an indication of what engineers value, consider important and credible in themselves and in others who are advancing in their profession. Technical competence emerges as a value measure of engineers by other engineers - a currency of the profession.

Retaining the Technical Link

Despite having moved into roles that were labelled as manager, several of the women have a continued connection to technical work beyond their move to manager. Many of the women continued to perform technical tasks as part of their organisational role:

I do have some technical roles as well - I have to run projects, interface with clients, set other peoples tasks, review and check the work. (P1)

When I swapped companies, they called me the Lead Structural Engineer, which was nice and I went into more of a role of liaising with clients, scoping work, managing work, still doing some structural engineer work but mainly managing other people doing it. (P3)

The importance of technical grounding and competence highlighted previously is reinforced by this continued connection to and active performance of technical work in addition to management responsibilities. Being a manager means both coordination and doing of technical tasks to the participants in this group.

I like it!

For some women a preference for technical work, accompanied by a reluctance to let go of technical tasks was apparent. In some cases it resulted in a struggle to meet the demands of the dual role and lead to a sense of being overwhelmed. One manager continued to perform technical work on a major project for a client upon being made manager. She admitted that:

I do actually enjoy some of the technical stuff and I do like having a bit of balance between the two roles. (P1)

However, she acknowledged that she struggled to meet the demands of the dual role. She conveyed a sense of being completely overwhelmed.

Some of it's my fault, in not being able to really let go of some of the technical stuff. Possibly I hold onto it a little bit too much. / Maybe I do create some of my own nightmares. (P1)

For some women in this group, the continued strong link to technical work was a feature of their role. In one case being a manager was an after thought, something that was tacked on the side of her senior role.

I still do technical work even though I manage people. To me it (managing people) is more of a peril than a joy. (M1)

A Necessary Career Strategy

The retention of technical ability has been a necessary career strategy for some. A number of participants described a convoluted management pathway, with moves from technical roles to manager and back again. This was particularly the case for managers forced to revert back to technical engineering roles upon returning from maternity leave.

After that I had a child... and took a year's maternity leave, came back part-time and I guess [Company Name] have been pretty clear that they will not offer a management role on under four days a week. I only wanted to work three days a week so at that point I went back into a technical role. (M5)

There was a sense of frustration from these women who had made the move to manager and then were forced to return to work in a role with lesser responsibility. They felt that they were being utilised at a level below their ability and were frustrated by their loss of influence. Maintaining their technical expertise and 'retaining the technical link' was a strategy adopted to be able to continue workforce participation in senior technical roles, deemed suitable for part-time workers.

Me as a Manager

In addition to speaking of the change in their day-to-day tasks and responsibilities, the participants spoke of how they felt about the move to manager. Becoming a manager was included a range of feelings from uncertainty to isolation to glee:

Obviously when you first start doing it and every decision you make is like "oh my god am I doing the right thing / Half the time I feel like I'm pulling stuff out of... you know... (P1)

Management can be very much an "us and them" scenario. You become one of the managers, rather than one of the workers, which can be quite isolating sometimes. (P3)

I was thrilled. You felt good about yourself. I certainly became more interested in work. (M2)

The transition to manager not only included an 'experience shift' but also a 'mind-shift' or a change in thinking and self-perception. The change in thinking of oneself as a manager was a process that did not occur automatically with the change in role. When asked whether there was a point in time that she felt that she was now a manager, one participant replied emphatically:

Not by appointment. That sounds weird doesn't it? (M4)

Engineering Identity

When speaking of how they saw themselves, the 'Engineer Identity' came across strongly. Despite occupying management roles, several participants referred to themselves as engineers rather than managers.

I'd reached the top. I didn't want to move into more of the business side. I'm still an engineer, I still do technical work even though I manage people. (M1)

Another participant who had moved away from her original core discipline expressed her engineer identity as being part of a school of thought.

I still think that a lot of the way that your thinking is driven, especially in this industry, relates back to the engineering way of thinking. And I like that. And I profess to trying to hang onto that to some extent as I think that's something unique and valuable to me. And I encourage it in other engineers as well. **It's a school of thought, rather than just a job title.** (M4)

In the transition from technical engineer, two groups emerged - those that embraced the idea of 'Me as Manager' and those that were more reluctant to assume the label. Degrees of adoption of a new manager identity are observed.

I always knew that I wasn't going to be a design engineer or anything like that. (P2)

I think I was just curious and I didn't ever see myself as purely technical. I always thought that my skills were broader and I could bring more to the profession than just the technical skill. And I was interested in more than just that. (M4)

Some participants held tightly to their existing engineer identity. Despite coming forward to participate in the project as managers and leaders in their profession, and therefore identifying in some way as such, a struggle to fully adopt or accept this manager identity is expressed:

I've struggled with wanting to hold on to the specialist technical type skills which I've developed up over the last ten years in sort of... because (specialty) is a kind of a black art. / It's a specialist area that you get a feel for after working at it over time and those skills are really valuable as well and... it's very good to keep that alive as well. (M3)

I'm trying to keep my feet in both camps at the moment and it's hard. (M3)

One participant with 15 years in managerial positions summarized:

I still try not to think of myself as a manager. (M1)

The retention of the engineer identity by some of the women can be linked to the concept of technical competence as the currency of the engineering profession. The degree of adoption of a manager identity is strongly influenced by the perceived importance of retention of technical expertise.

DISCUSSION

The themes explored in this paper highlight aspects of women engineers' experience of becoming a manager. The belief amongst this group was that technical competence was required to become a manager and was a basis for managerial credibility. In becoming a manager, their technical grounding and ability allowed them to i) position themselves for the move to manager, ii) establish credibility and gain support of followers by being seen as technically competent by others and iii) have the security of technical ability while settling into and acting out the role of manager.

These observations indicate that technical skill and competence identifies the participant as successful. This follows Gill et al (2005) work on the high achievement in mathematics and science at school level by engineering women. The authors surmise that the identification and acknowledgement of being good at maths and science "constitutes the claimant as successful, as an achiever in a field that is recognised as high status, difficult and male-coded". A parallel can be drawn to the importance placed on technical competence by the participants in this study. Their ability in technical engineering work identifies them as achievers in a high-status and difficult profession and maybe a tool used to "get on" in a male dominated workplace and to negotiate their workplace identity.

Evetts' work on engineering women's careers in the UK identified three techniques for managing gender within the organisation (Evetts, 1998). The third and preferred strategy of "building a reputation" is one that resonates strongly with the word of the women in this study. Evetts suggests that by building a reputation and earning respect, the contradictory expectations of women as engineers can be avoided. In the case of this group of engineering women, perhaps it is the threefold contradiction of woman, engineer and manager that is in play.

Technical competence emerged as a currency of the engineering profession. This was expressed by participants at varied levels of management, including those in senior management and executive roles. Recent work by Ferguson (2010) examined the importance of attributes of professional mechanical engineers at various stages of career. Management, Communication and Personal Attributes were rated as the most significant attributes for engineers later in their career, while attributes such as engineering knowledge base, mathematics and design received a lower rating. The findings of Ferguson's work are interesting in light of the account of the women in this group, who place a high significance on technically based skills for their own transition to management and also for the progression of others.

Given the emphasis placed on and value attributed to technical skill, it is perhaps not surprising that many of them continued to perform technical work when becoming managers in addition to management responsibilities. The reasons for keeping this connection ranged from enjoyment and preference for technical work to a view that becoming a manager was undesirable but inevitable to structural constraints within the organisation that forced the return to technical roles.

A preference for technical work, and a reluctance to let go of technical tasks are associated with Badawy's career-types of the "Professionally Loyal Technologist" and the "Undecided Technologist" (Badawy, 1982). Badawy estimates that the majority of engineers fall into these two categories, and that the decision to make the transition to manager and the success of that move is determined by factors such as the motivation to

manage, management skill and capability and the strength of the tie to the individual's engineering speciality.

What is not considered in the discussion on transition to management of engineers is the oscillation between technical roles and management roles described by a number of the women in this study. In their work on women's careers, Hewlett and Luce (2005) describe "off-roads and on-roads" as the exits from and re-entries to the career track. The movement between technical and managerial roles that some of the women in this group have experienced is reflective of this concept. The event of having a child and subsequent caring responsibilities combined with company policy on managerial roles created an off-road for these women.

Of concern is the influence of organisational structural constraints on the career progress of the study participants. The rigidity of job design for managers in engineering related industries and company policy prescribing managerial roles as full-time roles curtail women's advancement to manager. Part-time managerial roles are difficult to obtain and to sustain. Recent work by Tomlinson and Durbin (2010) in the United Kingdom explores the transition to part-time work of a group of female managers. Their research found that part-time work is commonly requested - with 49% of working women seeking a permanent or temporary reduction in hours at some point in their career. However, women working in part-time managerial roles are very uncommon. In the UK, ~4% of women managers work part-time.

It is disappointing that organizations retain the inflexible mind-set of equating manager with full-time employment and long hours. The lack of women in part-time management roles and the feelings experienced by women seeking and occupying these positions indicate that organisations are severely limiting their choice of managerial candidates by not offering sustainable, well designed part-time management roles.

Women managers that participated in this study hold firmly to their engineering identity. Preliminary analysis suggests that an engineering identity has great value for women engineers and that management roles they hold do not appear to have the same value. Returning to Gill et al. (2005), engineering is a field that is high status and difficult. Success in the engineering profession may be hard won and relinquishing the associated professional identity is not straightforward.

Discussing his new book "Managing", Mintzberg (2009) stated:

One of my favourite conundrums is how do you stay connected when the very fact of being a manager disconnects you from what you are managing? In other words, yesterday you were an engineer, today you are managing engineers, so you are no longer doing engineering, so how do you face that?

The transition to manager is influenced strongly by the past technical roles and it would seem that several in the group face the transition by i) still doing engineering; ii) perceiving themselves as still being involved in engineering and engineering thought; and ii) thinking of themselves as engineers first, and managers second.

Professional identities are dynamic and have a constantly evolving nature impacted by changes in roles, changes within the organisation and the introduction of new technology (Korica and Molloy, 2010). Ibarra's work on identity and career discusses the transitional state experienced when making a major career change (eg: moving from one industry to another). The transition from one job to another incurs a period "when

our identities are in flux” and “we oscillate between holding on to the past and embracing the future” (Ibarra, 2004). Ebaugh’s study of role exits described the temporal process of ‘becoming an ex’, which was accompanied by feelings of anxiety, fear and of not belonging (Ebaugh, 1988). A parallel can be drawn to the experience of advancing from engineer to manager. As the women in this study have transitioned to management, the flux of identities is evident, with “a multitude of selves – old and new, desired and dreaded – coming to the surface, noisily coexisting”. The idea of ‘Me as Manager’ or the perception of oneself as a manager becomes part of a conglomerate and flexible professional identity that is strongly influenced by the past.

CONCLUSION

This paper describes preliminary analysis of a current research project regarding the advancement of women engineers to managers and leaders in technical organizations in Australia. It draws on the phenomenological analysis of an initial group of eight interviews of women engineers from Western Australia. Preliminary analysis has evoked three themes of Technical Competence, Retaining the Technical Link and Me as Manager. The findings and discussion have highlighted the significance of technical expertise and the continued connection with technical aspects of engineering on the advancement to management. In turn, the engineering identity of the participants speaks loudly and is held firmly even after significant management experience.

The findings begin to provide an insight into how management is conceptualised in engineering, specifically by women engineers who have advanced to senior positions in the engineering profession. Flexible job design and structuring managerial roles that enable the fusion of engineering and managerial identities may be steps towards improving retention rates and making management roles more attractive career destinations for engineering women.

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“I LIKE THE CHALLENGE”: A STUDY OF WOMEN ENGINEERS WHO HAVE STAYED IN THE PROFESSION

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ABSTRACT

Evidence that women leave the engineering profession at a higher rate than men continues to emerge. This paper reports on a two-phase study (an online survey, followed by interviews with some of the participants) of a group of women who have stayed in the engineering profession. The group studied comprised all women who graduated in civil engineering from a single institution (a technical university in Australia) between 1974, when the first woman graduated, and 2008. Ninety-five percent of this cohort is still working in the profession – a statistic which far exceeds that of most comparable studies. The survey used was virtually identical to a national survey undertaken by the authors in 2007 of all female members of Engineers Australia (EA) – the professional organisation for engineers in Australia. On nearly all the indicators of workplace satisfaction, the single institution respondents responded more favourably than the women in the national survey. Yet 40 per cent of this cohort had children compared with 22 per cent of the national survey respondents. These results raise questions about what is different about the characteristics of the women in the university study and their workplaces: why/how they have stayed in engineering, and successfully combined work and family when many women engineers leave the profession. The paper analyses the survey data and preliminary interview findings to offer some potential answers to these questions.

INTRODUCTION

Across the western world it is well recognised that proportionally more women than men leave the engineering profession (APESMA, 2007; Hewlett *et al*, 2008, for example). Since women comprise a small proportion of engineering graduates the process of their recognition and integration into the profession is impeded by this persistent attrition, and the benefits to the economy predicted to follow higher representation of women in the profession are consequently continually delayed (Hewlett *et al*, 2008). Research has previously focused on women's reasons for leaving engineering, but investigating what makes women stay is also clearly important. Consequently we undertook a survey of a

group of Australian women civil engineers whose retention rate exceeds that of most reports into this critical issue. Comparison of the survey results with those of an Australian national survey of professional women engineers showed that although the group of civil engineers were nearly twice as likely to be responsible for children (a circumstance often cited as the reason women engineers leave the profession), they were statistically significantly more satisfied with their job conditions than the women in the national survey (Ayre *et al*, 2011). Sixteen of the civil engineers who participated in the survey volunteered to be interviewed, and this paper reports preliminary findings from the interviews as we try to identify why these civil engineers are more satisfied and content in their work than the national group.

Women's attrition from the profession

Early studies of women's attrition from the engineering profession reported that in the US women's exit rates were twice those of men (Preston, 1994, CAWMSET 2000). A more recent US study (Hunt, 2010) confirms that women still leave in higher proportions than men, albeit with less startling differences: 9.8% for men, and 12.9% for women. In Australia it was recently estimated that "women are leaving the engineering profession at a rate of 38.8% faster than their male counterparts" (APESMA, 2007: 2).

In 2000 the Institution of Engineers, Australia (now known as Engineers Australia, the Australian professional engineering body) commissioned a study to investigate why women leave the Australian profession. The study showed that women constantly had to resist negative stereotypes about their abilities and commitment to engineering, were excluded from mentoring and social networks, and experienced sexual harassment and discrimination. An additional level of discrimination was encountered by women with children trying to meet their caring responsibilities in an industry with little flexibility in its systems and procedures in matters such as work hours (Roberts & Ayre, 2002). The report's recommendations were widely publicised within the industry in Australia, and in 2007 Engineers Australia (EA) commissioned a second study to investigate whether there had been any changes. The follow up study found that there had been considerable increases in the availability of 'family friendly' workplace provisions such as flexible working hours, part-time working, leave without pay, careers' leave, and paid maternity leave. There had also been a marked reduction in the incidence of sexual harassment (from 27% to 21%), although this was still disturbingly high. However, with one exception (flexible work hours), the take-up of the increased family friendly provisions was very low, and moreover there had been little improvement in retention of women engineers (Mills *et al*, 2008).

Previously, in a series of qualitative and quantitative studies into the workplace culture of the engineering profession we have found features of its male dominated context lead to the discomfort, disadvantage and in many cases disillusionment and eventual departure of numbers of women engineers. Around the country women engineers reported encountering discrimination, disrespect and being disconnected from the power structures of their organisations (Mills *et al* 2006). In this context their decisions to leave appeared hardly surprising. More curious perhaps is why some women stay – hence the current focus.

WOMEN WHO STAYED

In 2009 we surveyed all female students who had graduated with civil engineering bachelor degrees from a single institution which we have described as Australian Technology University (ATU). ATU was designated a university in 1991 on the amalgamation of an Institute of Technology and a College of Advanced Education, both of which were previously degree-awarding institutions in their own right. ATU's commitment to equity and making higher education accessible to those traditionally under-represented there is embedded in its Act of Establishment, and it has a record of successfully recruiting and graduating students who lack the usual entry requirements to undertake higher education.

A total of 76 women had graduated with bachelor degrees in civil engineering between the time of the first graduate in 1974 at the Institute of Technology (one of ATU's antecedent institutions) to the end of 2008. Current contact details were sought by utilising alumni databases, social networking sites such as Facebook and by asking members of the cohort to provide contact details for others that they knew. After this process, no contact details were able to be obtained for 11 of the graduates. Of the 65 who were sent the survey, 56 responded (86%). It cannot however be assumed that the majority of the 20 who were either non-contactable or who did not respond have left the profession. Four of the un-contactable graduates were international students, who may well be working as engineers in their own countries. Others who were un-contactable were reported by other members of the cohort to be 'on the move', either temporarily working as engineers overseas, or taking a career break to travel, or intending to return to the profession in a few years' time.

The on-line survey that was used for the ATU study was based on the previous national survey used by Engineers Australia, with only minor changes in order to make it appropriate for respondents from only one institution and one engineering discipline. Remarkably, only three of the 56 respondents to the ATU survey had left the profession: a 5.4% exit rate which is considerably less than typically recorded. Measures of workplace satisfaction and family responsibilities of the ATU group were compared with the national EA survey. On all indicators of workplace satisfaction, the ATU group were more satisfied than the national group. Furthermore the ATU group were nearly twice as likely to have responsibility for children. They also had higher availability of family-friendly workplace provisions, and were more likely to use them than the national group, although the use made of these provisions by the ATU group was, as with the national group, lower than might be expected. The survey comparisons have been reported in more detail elsewhere (Ayre *et al*, 2011). Respondents to the online survey were invited to volunteer to be interviewed in order to explore some of these issues in more depth and preliminary findings from these interviews are explored below.

The interview study

The purpose of the interviews was to gain further understanding of factors which contribute to women's success and retention in the male dominated field of engineering. Sixteen of those who had already taken part in the ATU survey volunteered to be interviewed. Semi-structured interviews were undertaken in 2010, at each volunteer's choice of venue. In most cases this was their place of work, but three chose to be interviewed at home, and one at her

former university campus. The 16 interviewees' ages ranged from 27 – 43, similar to that of the 56 surveyed, but a higher proportion of interviewees were in their 30s and 40s when compared with the overall age profile of the 56 surveyed, where there were nearly as many respondents in their 20s as in the 30s and 40s together. Nine interviewees (56.3%) had children: a higher proportion than in the full ATU survey group (40%), and both of these were higher than the national statistic of 22% for women engineers. The proportional split between working in the public or private sector (44% public: 56% private) was exactly the same for the interviewee group and the ATU survey group, but very different from the national ratio of 17% public: 83% private indicated by census data for all Australian Engineers (Institution of Engineers, n.d.). Thus the interview group was representative of the larger survey group in some, but not all respects. However, since the purpose of the interviews was to explore in more depth how women engineers succeed in the Australian profession, it was an advantage to have a heavier weighting of older participants, as these women are manifestly 'stayers'. The higher proportion of engineers with caring responsibilities is also an advantage in view of the many findings that the difficulties of raising a family comprise a major cause of women's attrition from the profession (Mills *et al*, 2006; APESMA 2007; Bagilhole *et al*, 2007; Hewlett *et al*, 2008). Issues of family formation and maintenance arising from this study will be explored in a later publication.

The interview questions ranged over how and when participants had decided to become an engineer, how they managed their caring responsibilities, their views on what makes a good engineer, how to 'belong' or fit in to the profession, and whether their education adequately prepared them for the realities of the engineering workplace. Further, interviewees were asked why there are so few women engineers, and to what extent they themselves had been active in promoting engineering as a career for women. The full results of the interviews are still being analysed, and here we report only the findings about what our group of female civil engineers think it means to be a good engineer, how to fit in to engineering and whether they felt that they belong in engineering.

A good engineer and good at your job

Participants nominated a number of characteristics and skills of a good engineer, with three skills sets predominating and mentioned almost equally frequently. One is to be good at problem solving (including related skills such as analytical and critical thinking, creativity, applying commonsense, assessing risk, making reasoned judgements). Another is to have people skills, including oral and written communication skills, teamwork, providing and receiving support, management, negotiative and persuasive skills and being able to apply these with colleagues, superiors, managers, clients, suppliers, site workers, and the public. The third skill set (remembering that this is not a ranked order) is technical, sometimes referred to as "academic", knowledge and skills. Although technical skills were mentioned as frequently as the other two, this was often in the context of being less important than people skills. For example:

Obviously an understanding, an ability to read plans, a technical mind is important, but generally I suspect that if I had applications from two engineers who had graduated from the same class at the same university, we would probably choose the more grounded, the better communicator, rather than

analysing them down to their grades. (Respondent A, private sector, 14 years experience).

When asked what it means to be good at your current job, the same three sets of skills again predominated, but now people skills was a clear winner, with problem solving and technical skills mentioned only half as often. Taking responses to both of these questions together, all participants mentioned people or associated skills as needed either to be a good engineer or to be good at their current job or both, with problem solving and technical skills in equal second place. The profile of the 'good engineer' presented in the interviews is very similar to that found by Mills *et al* (2006) in the study of 41 female and 10 male engineers across Australia and across all engineering disciplines.

The vast majority of respondents asserted that technical competence and knowledge was essential to be a good engineer, several stating that it was "a given". However, they frequently went on to say that managerial and people skills were often equally or more important. (Mills *et al*, 2006: 142).

All but two of the ATU women interviewed felt that they fitted their own definitions of a good engineer, and that their managers agreed. (The two who did not give a wholehearted 'yes' at this point were both in the very early stages of making a change of direction. They were both certain they wanted to stay in engineering, at least for the time being, but felt they had not yet found the right field from the wide range of options open to a qualified civil engineer.) All others demonstrated great enthusiasm for engineering and their present job, with responses like "I like the challenge", "I really enjoy being an engineer", alongside their claims to having (or more often, having developed) the necessary people skills, problem solving skills and technical expertise. In the latter case however, there were again the occasional relegations of technical expertise to secondary importance like this one from a project manager:

Why I've done so well is because of my communication skills. It's not because I'm technically brilliant in my field by any means, but I have enough technical skills, and I think I am able to communicate technical issues to laymen as well... I'm very approachable and just sort of get things happening... (Respondent B, public sector, 20 years experience).

Echoing an argument previously expressed in Gill *et al* (2008) the women engineers took their technical skills almost for granted – the *sine qua non* of being an engineer – but issues to do with good communication appeared to be highly relevant for the demands of the job. Perhaps as a result of not being part of their typical professional training, these skills took on a new significance.

Belonging in engineering

When asked whether they belong in engineering, all but one of the participants agreed, most of them strongly and enthusiastically in terms like "Yes, definitely". (The one who was unsure at this stage was one of those who was in the process of making a new start.) When asked how they know they belong, many replied by referring back to their fit with their own definitions of a good engineer or being good at their current job, for example:

I have a combination of technical and non-technical skills. (Respondent C, public sector, 19 years experience)

It's what interests me – I think that's truly important at the outset. You have an interest in solving people's problems. Engineering's obviously a lot more technical than that, but the philosophy behind it is that we create solutions that meet people's needs, meet their expectations. And I enjoy doing that, I enjoy being involved in that creative exploration of solution finding if you like. (Respondent D, private sector, 8 years experience).

I guess it's the challenge – I like challenges ... it becomes like an addiction. Like you want the next challenge. Yea, that's what's sort of kept me here. (Respondent E, private sector, 8 years experience).

In addition to feeling comfortable, and enjoying the work, social theorists identify other dimensions of 'belonging', such as acknowledgement, respect and recognition from colleagues, and involvement in decision making (Faulkner, 2007 for example). There were some allusions to these qualities in answer to questions about whether the respondents belonged and what people had to do to belong in engineering. Responses to the question about whether the women felt that they belonged in engineering included:

Right now, the group I'm working with, I do feel part of that group using my engineering skills accordingly. (Respondent C, public sector, 19 years experience).

It feels comfortable. I go to meetings and we talk about things...the discussions that I have I feel that I'm participating - more than participating really, in decisions that are being made. (Respondent B, public sector, 20 years experience).

All but three of the participants however, had not always felt they belonged. Interviewees claimed they have had to work at this to effect the necessary change. The changes needed were either a change in behaviour, for example being more assertive, or changing expectations, or changing role or job.

I've had to force myself into more public situations to get myself out there ...if you're not respected in those communities or they don't know who you are, they sort of ignore you or go above you. So you'll not get involved in decisions because ... you're not seen as being able to make a decision or you're junior. (Respondent F, private sector, 9 years experience).

With any job you've got to prove yourself within the first one or two months. ...Once you prove yourself as a female, let them know what you're talking about and you're quite capable then I normally find that people will ...liaise with you ... in a respectful way. (Respondent G, public sector, 12 years experience).

I've just had to be more serious, and more tough when dealing with clients – just to gain that respect. (Respondent E, private sector, 8 years experience).

To conclude this section of the interview, participants were asked to summarise what people had to do or to be to belong in engineering. Although we deliberately did not specify whether the 'people' in this question were male or female, we were mindful that one aspect of not belonging is being outnumbered (Murphy *et al*, 2007). One of the few who mentioned gender at this point remarked that it was "the sort of thing you've never really thought about until someone asks you the questions". She continued:

I guess as a female ... it's significant... Obviously if you're a male it's not an issue. You don't consider the fact that it's male dominated because you're male

and it's not an issue. In some circumstances being such a male dominated industry, it does prevent you from getting that feeling of belonging. (Respondent H, public sector, 12 years experience).

As with the similar question posed earlier about whether the interviewee herself belonged in engineering, many of the replies reprised the definitions of being a good engineer or good at your current job and specified good technical capability, a love of solving problems and thinking outside the square, and being able to communicate effectively. This latter skill involved communication with specialists and non-specialists at all levels which entailed, for example, not talking 'down' to tradespeople and site workers.

DISCUSSION

The interviewees were all stayers who defined a 'good engineer' in much the same way as had been found in an earlier similar Australian study involving both men and women (Mills *et al*, 2006). It was notable that for most of the interviewees their day-to-day work principally involved people-related tasks rather than high level technical skills. These respondents spoke enthusiastically about their current job, in which they identified a close congruence with that of their understanding of a 'good engineer'. Furthermore, they were sure that they performed well in their current role because of their own enjoyment and satisfaction with it, as well as the feedback and recognition they received from their managers, colleagues, clients and others with whom they associated in their professional roles.

The original Engineers Australia study (Roberts & Ayre, 2002) was devised, at least in part, to identify reasons why women may leave the profession, and its interviewees (reported in Mills *et al*, 2006) accordingly comprised those who were disaffected as well as those who were happy in their jobs. In contrast, the purpose of the present study was to explore the factors which assist women to succeed and stay in the profession. Our interviewees therefore volunteered on the basis of being strongly or very strongly committed to engineering as a career, and most had been in the profession long enough to have achieved some demonstrable success. From their responses, it appears that an important factor leading to this satisfaction and success may be a strong match between an individual's expectations of an engineering role and the reality.

The match between expectations and reality further contributed to a sense of belonging in engineering. The interviewees almost unanimously felt they belonged, because of their acceptance by teamworkers, their ability to devise and deliver efficient and feasible solutions for projects, and the respect shown to their views and opinions. For some, it was also important for belonging to have other women as colleagues.

I feel I belong now because there's more ...engineering graduates who are females ...late 20s, early 30s, here working as consultants amongst the older engineers who've got to get used to it. (Respondent J, public sector, 22 years experience).

It is important to note however, that the majority of our interviewees did not feel they belonged in engineering from the outset of their careers. All of them mentioned either having to change something about themselves before they felt they belonged, or that a

change in their work environment was needed. In relation to changing themselves, it is interesting that this mainly related to communication styles. Interviewees mentioned needing to become more vocal (and hence more ‘visible’ in meetings and on site), more assertive and ‘tough’ in order to belong. One used the words “I had to learn to be one of the boys ...”, one of the main coping strategies identified by Mills *et al*, 2006; Bastalich *et al*, 2007; and Powell *et al*, 2009. Another strategy mentioned by several: having to “prove yourself” is also mainly related to communication style since it involves showing determination and confidence, and also that, as one interviewee said: “you know what you are doing”, meaning that you have the technical competence. This confidence in a new engineer’s competence, it appears is not automatic despite professional accreditation and previous experience, but has to be confirmed by an appropriately confident delivery style. One respondent described her own effective style as “dominant” and “forceful”, but she added that she knew other “equally effective women who are not like that”, that is less authoritarian.

Many interviewees however, only felt they belonged in engineering after a change in their work environment. In some cases this happened by chance: a new manager or new colleague changed the social dynamics of the team, or an increase of women in the team had the same effect. More often the interviewee had to effect this change herself having identified that she was not achieving her career objectives in her current situation (such as not getting enough technical experience), or was unable to achieve her employer’s objectives because of lack of cooperation from her team or even open hostility. In many cases the employer’s policies were sufficiently supportive to encourage reasonable requests to change to another role within the same organisation, and several interviewees who had done this now felt they belonged. But in one or two cases the interviewee had to change employer to feel that she belonged in engineering.

CONCLUSION

Our study of a group of 56 women engineers was undertaken to identify factors which contributed to their career success and their retention in the profession. All of the online survey participants were female graduates in civil engineering from a single Australian institution over a period of 19 years (1988-2007). Following the online survey, 16 participants volunteered to be interviewed. Since the survey had identified an unusually high rate in this group of retention in the profession for female engineers, our particular focus in the interviews was on exploring the reasons behind their staying on.

In summarising the interviewees’ assessment of their own ‘fit’ in engineering and in their present job, we found that nearly all the participants were confident that they were good engineers and good at their current job and that their managers and other workplace associates agreed with them. The few who were not so confident of their success in their current job were in the process of changing to another engineering role in order to improve their opportunities of meeting their own career objectives. When asked whether they belong in engineering, *all* the interviewees replied in a strong affirmative. But nearly all said they had not felt this immediately on entering the profession. They had either had to work to gain the respect of their colleagues and clients, chiefly through adjusting their

communication styles to appear or become more assertive and confident, or they had changed their work environment to one which provided them with better opportunities to match their own expectations of being a good engineer.

The fact that many of the women interviewed had been pro-active in effecting a change to their employment situation in order to ensure that they could remain in engineering by working in an environment more conducive to their career and sense of belonging to the profession, is an interesting development not often noted in earlier studies. Our interviewees had found this relatively easy to do, possibly because Australia's booming economy over the last decade has led to a strong demand for civil engineers. But it may also be reflective of the growing shortage of professional engineers in countries such as Australia as the baby boomers retire. This may afford all young engineers, including women, more opportunities in the future to pick and choose the workplace situation that best suits their career and personal requirements.

Many of the interviewees worked for big private or public organisations where it is possible to change role within the same organisation, and some of the women made a conscious choice to work for such an employer because of this flexibility, while others had changed employers to achieve this. Some of the interviewees had managers who were supportive in facilitating such a move, understanding that it was in both the organisation's interest and the interviewee's that she should find the best niche for herself. This may reflect a willingness on the part of some employers to respond to such requests in order to keep their women employees in particular, something that employers frequently cite that they want to do but either don't know how to or maybe don't practice what they preach (Sharp *et al*, 2011).

Our findings from this investigation suggest that a mismatch between expectations of being a good engineer and the reality of the present job providing the opportunity to become a good engineer, is a key cause of women engineers' disaffection or discomfort in the workplace. Accredited professional engineers have the necessary knowledge and skills to work in many different engineering roles, and women who find their current work frustrating, boring or sexist or their career prospects static can and do exercise their labour market power to move within the industry whilst staying in the profession, as demonstrated by our study cohort. This may be a strong driver towards cultural change in the engineering workplace, as employers compete for qualified personnel in the predicted era of future skills shortages. It does offer an encouraging view of what may enable women to be 'stayers' in the future.

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PART-TIME ACADEMIA: WORK-FAMILY BALANCE UTOPIA OR FEMALE GHETTO?

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ABSTRACT

Part-time work seems to provide an ideal alternative to the “either/or” model of family and career; women can maintain their careers while still spending significant time with their families. This model can be very effective for women working in a clearly defined role in which they have existing recognised expertise. In that case, the mother can set clear boundaries between work and home while performing to high standard at work, and can maintain and develop her expertise over time.

Unfortunately this model is much more difficult to achieve in academia, for a number of reasons. The longer training time means that women are on average 30 years old by the time they finish their PhD and post-doc, or industry experience in the case of engineers. The early thirties, prime child-bearing years for women, are also the time when academics need to build their research expertise and reputation. This period of intense research activity is very important in building deep knowledge in one's field, a respected research profile and the track record essential for future research success.

Women who have children during this period and choose to work part-time simply do not have the opportunity to build the same depth of knowledge or profile as those working full-time. From this position, it is very difficult to develop the required research track record while juggling both research and teaching responsibilities part-time. Meanwhile, these women are frequently assessed against full-time colleagues using metrics which do not effectively account for either their part-time status, or their position on the “research start-up” curve. In engineering and science, there may be only one part-time academic in any department, which means an absence of role-models working in the same paradigm. These factors combine to create a discouraging situation where capable and effective women can work hard and still be judged poorly against their colleagues.

This paper presents suggestions for how universities leaders can enable part-time academics to flourish rather than flounder, and suggestions to assist part-time academics navigate to success.

CONTEXT

The opportunities available for women to study and work in the engineering, maths and science fields have increased enormously in recent decades. In 1983, approximately 5% of engineering enrolments were women, and in 2007 this had increased but plateaued at approximately 15% (Bell 2009). Enrolments in science also increased by 5% over this period and have now reached 40% women (Bell 2009). However balancing a career in academia or industry with primary care responsibilities for children is a very recent phenomenon, and continues to pose

challenges. The accepted paradigm is full-time work, for which there exists plenty of encouragement.

For women who choose to return to work *full-time* after a year or less of maternity leave, there are many role models for successful careers in industry, research and academia, along with a wealth of published experiences and advice (Armstrong and Bellis 1995; Marincola 2002; Stepp 2002; Kim 2003; Anon. 2006; Schiebinger *et al.* 2008; Royal Society 2009; Lahav 2010; Mejia 2010). However for many motivated professionals, having children involves many years out of the work-force, and/or part-time work for long periods, up to a decade or more. There are far fewer sources of career advice available for part-time professional women (Stepp 2002; Hosey 2007; Monosson 2008).

Working part-time can be a very effective model for women working in a clearly defined role in which they have existing recognised expertise (e.g. Hosey 2007). However part-time roles remain uncommon in both industry and academia; only 12% of engineers and 16.5% of scientists have part-time positions (APESMA 2007). Female engineers are eight times more likely to work part-time than men (APESMA 2007) and 7.5% of women engineers hold permanent part-time positions (Mills *et al.* 2008). The numbers are even lower in academic positions, both in Australia and overseas (Armstrong and Bellis 1995; Trifunac 2006; Bell 2009). Thus women who do work part-time do so in a system designed for full-time employees, in the absence of comparable role models, which may explain why career progression problems for part-time engineers are still common (Mills *et al.* 2008).

While the university sector is frequently perceived as a flexible working environment, the competitive nature of research funding based on a typical career path (Stevens-Kalceff *et al.* 2007; Bell 2009) and the increasing use of metrics developed for and by people with full-time continuous careers, actually produce substantial barriers to successful part-time careers, and the re-entry of people to academia after a break to raise children (Kane 2002; Sax *et al.* 2002; Bell 2009)

Numerous initiatives exist to increase the number of women in senior roles in both industry and the tertiary sector. Although only 12% of women in engineering and 16% of women in science have part-time roles, 31% of women reported taking extended leave, outside of maternity or parental leave, to care for family (Mills *et al.* 2008). Given the clear desire by many mothers to work part-time for a substantial period to cater for their families, increasing female representation in senior academic roles will require an increase in the availability and feasibility of long-term part-time roles, and the facilitation of re-entry to workforce after career interruptions.

This paper analyses the challenges currently faced by academics working part-time or re-entering the workforce after career interruptions to care for their families. It provides suggestions for how managers can support their part-time staff, and how administrators can increase the feasibility of working part-time within their organisation. While these issues are framed throughout this paper in terms of women, who represent the majority of family primary care-givers and part-time workers, most of the same issues will apply to men who wish to work part-time or re-enter academia after career interruptions to care for families.

RESEARCH DYNAMICS

Teaching and research (T&R) are the two key responsibilities of most academic positions. Research output, as measured by impact, publications and funding,

operates in a strong reinforcing feedback loop in which success is rewarded with further success: funding is required to perform research, and funding is awarded on the basis of track record, i.e. research success to date.

The higher your research output, the faster you generate more output, until some maximum output is reached, which will be a function of individual ability, research collaborations, time available etc. These dynamics follow a similar pattern to population growth, where rate of population growth increases with population until some “carrying capacity”, or maximum population is reached. A typical population dynamics model (e.g. Scheffer 2004) may thus provide a suitable model for the growth of research output over time for an individual, as plotted in Fig. 1:

$$\frac{dR}{dt} = rR \left(1 - \frac{R}{R_{\max}} \right) \quad (1)$$

where R is research output as measured by a research quality metric, $R_{\max}$ is research potential, i.e. the maximum research output achievable by a particular individual in given circumstances and r is the research output rate (/year), i.e. the rate at which existing research output generates further research outputs.

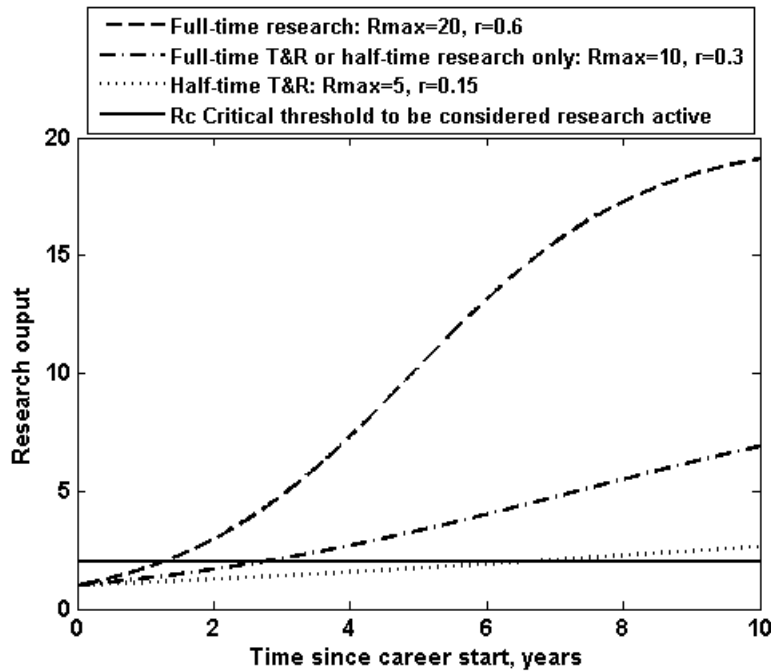


Fig. 1: Plot of research output over time (Eqn 1) for parameters describing different time available for research.

Both of the parameters in Eqn 1, Fig. 1 will undeniably be a function of individual abilities, both in terms of their pure research abilities, and their ability to harness an effective research team. $R_{\max}$ is also proportional to the time available: an individual may have a maximum output potential of 20 if working full-time on research only, but this would be halved to 10 if half of their time is devoted to teaching, and halved again to 5 if they work half time, and half of that time is devoted to teaching. The actual research output R is also affected by the research output rate r , which is also strongly affected by the time available to conduct research and maintain knowledge of current literature in the field.

This is demonstrated in Fig 1, which plots Eqn 1 over time for a range of parameters (r and R_{max}) which reflect the different time available to academics for research, depending on their teaching load and part-time status. Fig. 1 illustrates clearly the well-known “research start-up” phase (Fig. 1); the time at the start of their career where research output is low e.g., Trifunac (2005 & 2006), Kelly and Jennions (2006). What is also illustrated in Fig. 1 is that the research potential R_{max} , and output rate affects the duration of this start-up phase.

While the model is simplistic, and does not account for career breaks, lags or inter-annual variability, Fig. 1 does capture the essential feature of research output; that success generates success.

Minimum critical mass

The concept of a minimum “critical mass” is often used to describe the minimum size for a successful research centre (Kenna and Berche 2011) or the point at which research output becomes self-sustaining. The same concept exists in population dynamics; if a species population falls below a critical level, the birthrate will decline (e.g. Scheffer 2004). Hence we can use population dynamics to make Eqn 1 more realistic by including the term R_c , the critical output below which research declines:

$$\frac{dR}{dt} = rR \left(1 - \frac{R}{R_{max}} \right) \left(\frac{R - R_c}{R_{max}} \right) \quad (2)$$

If research output is less than R_c , dR/dt becomes negative, i.e. research output declines. In academia, this corresponds to track record. If your research output is below the critical threshold (R_c in Eqn 2) you will be considered “Not research active”, and thus not competitive in most funding schemes. The minimum threshold also reflects a minimum amount of expertise and knowledge of current literature within your field which is necessary to generate more findings. Fig. 1 illustrates that it will take 6 years for part-time T&R academics to reach a nominal “threshold”, compared to 2.5 years for new T&R staff or half-time research staff, and just over 1 year for full-time research staff.

While these numbers could be modified by different assumptions of the magnitude of impact, the implications are clear: it will be very difficult for part-time T&R staff to compete for funds with full-time staff, or even part-time research-only staff. Part-time academics will need very effective collaborative arrangements to survive in this environment. A particularly effective model would be to have part-time researchers filling a very specific role within an existing research group, for example modelling, whereby they can contribute and develop their expertise to the team, and maintain their connections with current knowledge, without needing to lead funding applications or have a complete knowledge of current literature at this stage of their career. However it may be difficult to develop this arrangement after having children, because once research output falls below a minimum critical value, it becomes difficult to find high quality collaborators.

Competing timescales

The values of the base case parameters in Fig. 1 were chosen to reflect a typical academic career path, starting from completion of PhD (generally at the age of about

30). Research output increases rapidly greatly over the first decade, until it reaches a sustainable maximum limit, where it is maintained for another couple of decades before declining during retirement (see for example, Trifunac 2005; Trifunac 2006).

Unfortunately this graph is exactly the inverse of female fertility, which drops off markedly as women approach 40 (Khatamee 1988).

Here lies the challenge for women who wish to work in academia but take substantial time out to have their family. If they delay having children until their late 30s, they can get their research output above the critical threshold where they can maintain it. Thus their track record would enable them to attract effective collaborators, and continue to remain research active, even with much less time on the job. However medical experts do not recommend this path. Having children when younger has many advantages, but the reality is that women who do so will find it very hard to obtain or maintain a teaching and research position unless they either work full-time, or choose between teaching and research.

Competitive exclusion: death by metrics

Metrics and activities such as the recent Excellence in Research Australia assessment involve measurement of individuals and departments based on research performance. They are commonly used even though their flaws are well known (Amin and Mabe 2000; Trifunac 2005; Kelly and Jennions 2006; Trifunac 2006; Lane 2010). These measures reinforce the “success to the successful” system archetype (cf. Meadows 2009) which characterises research in academia, and can lead to competitive exclusion, which ultimately reduces diversity within the system (Lane 2010).

This is because metrics provide very clear definition of which activities are valued by an organisation or system, and so drive behaviour in that direction (Lane 2010).. For example, rating individual authorship above group authorship rewards competitive rather than collaborative research. This will ultimately reduce diversity of individuals and behaviours within an organisation. Similarly, lecturers with industrial experience rather than a research background are very valuable for educating engineering students, but would rate poorly under most, if not all, research quality metrics. This system also provides dis-incentives for employing part-time academics, or academics returning from an extended career break (e.g. after having children), because their research output will be lower and delayed, and so reduce the department's performance on metrics.

The nature of this “success to the successful” paradigm, reinforced by metrics, can be very demoralising to capable women working hard in a system in which they are unlikely to ever succeed because they cannot obtain the critical mass. To compare their performance against full-time research-only staff using a metric which does not account for either part-time status or teaching load is unfair and destructive, but not uncommon. If metrics are to be more widely applicable, they should account for each researchers position in their career, especially part-time status and teaching load.

LECTURING: THE IDEAL PART-TIME ROLE, OR A FEMALE GHETTO?

The analysis above demonstrates that there are many aspects of research work which pose challenges to part-time academics, or those returning from a career interruption. From this it is possible to define characteristics of a role in which it

would be possible to succeed after a career interruption to raise children, or while working part-time:

- skills and qualifications required for the job can readily be obtained by the age of about 30;.
- success depends on performance in the role, rather than accumulated historical performance;
- success depends on the performance of the individual in the role, rather than competition with others (analogous to assessing student performance based on outcomes rather than a bell curve);
- the role has clearly defined, specific, achievable objectives;
- tasks of clear size can undertaken in discrete pieces, with some flexibility in timing
- performance does not require a minimum critical participation rate; i.e. 20 % of the job could be completed in 20 % of the time.

All of these criteria are satisfied to a large degree by university lecturing; while expertise is certainly developed over time, the qualifications and basic skills can readily be acquired by the age of 30. A person can teach one component of a course extremely well, with a relatively small time commitment. The timing is predictable, and while the lecture times are fixed, preparation can be done with very flexible timing.

The contrast with research is stark, and explains why most female part-time staff succeed in their teaching roles, but feel that trying to maintaining an active research program is a struggle. This creates “gender intensification” (Bell 2009) or a “female ghetto”, where women are over-represented in teaching roles, and then find it difficult to be promoted because they do not meet the research performance metrics (Bell 2009).

There are also pressures on managers which may lead them to encourage their part-time or career-break staff into teaching-focussed roles. These people are likely to perform poorly under most research metrics, and so “bring down” the department. In maths and engineering the number of female lectures is proportionally much lower than the proportion of female students. Approximately 15% of all Australian engineering students are female, but less than 5% the senior academics are women (Bell, 2009). The numbers of women entering chemical engineering has been much higher than 15% for many decades but this has not filtered through to the academic staff. Because it is considered important in many departments for female staff to have an obvious presence in teaching, most female staff have substantial teaching loads, and associated pastoral roles (Bell 2009).

CONCLUSIONS

Getting female students in the doors of university is the easy part. A real measure of success of female participation in engineering and science is their position in the workforce one, two and three decades later, which ultimately must account for women's role as primary care givers in most families. This is not just a problem for academia - several studies of engineering as a profession report that women leave engineering at a much faster rate than men, and the phenomena is world-wide (APESMA 2007; Mills *et al.* 2008; Bell 2009).

Because of the inherent “success to the successful” structure of research, there are many barriers to initiating a research program while working part-time in a teaching and research role, or returning from an extended break out of the workforce. This is due in part to the inherent nature of research, and the non-linear relationship between time and output, and the need for uninterrupted time which are extremely difficult to create when working part-time, teaching, and being the primary care-giver for children. However it is also reinforced by metrics and assessment of track record which do not adequately account for part-time status, career interruptions and teaching commitments. Since the rapid research output development phase coincides with the final decade of childbearing for women, many women simply don't get past the critical threshold, and are unable to participate.

In contrast, university teaching provides many of the features of a successful part-time role, in that success depends on the individual's current performance rather than historical accumulated performance. Telling the students you gave good lectures last year won't count for much this year! Finally, and perhaps most importantly, the skills and qualifications required for teaching can readily obtained by the age of thirty, the job can comfortably be re-entered after a prolonged absence, and there is no minimum threshold for participation; a person may give one or one hundred excellent lectures in a year.

As a result, women working part-time while caring for their families or returning from extended maternity leave tend to cluster in teaching. This “female ghetto” provides women with the opportunity to participate in the workforce while still having enough time and energy for their family. However the accumulation of women in teaching does reduce their opportunities for promotion and job security and removes a substantial pool of very intelligent, capable people from active research.

Without direct action, this trend is set to continue; increasing assessment of university performance using research quality metrics developed for full-time uninterrupted employment is likely to reduce gender diversity within the research workforce, and so reduce the pool of talent from which researchers are drawn.

RECOMMENDATIONS

For women working in part-time roles in academia: *how to survive*

Focusing on either research or teaching is currently the best model for part-time academics. Working in a research-only role as part of an established research team will enable you to maintain your expertise and track-record, and move into teaching at a later date. A teaching-only role will enable you to maintain some networks, expertise and confidence while caring for young children; however moving back into research after a prolonged absence will be very difficult. .

The current paradigm means that working part-time in a Teaching & Research (T&R) role will be very challenging. Since current expectations and systems cater primarily for full-time continuous employment, you will need to:

- *Be efficient and collaborate effectively:* Ideally find a position as part of a strong, effective, collaborative research team where your expertise is valued, your part-time status is accepted, and you can work with established researchers. This may require compromise and strategically concentrating on one key research area. Identify opportunities to build expertise and

connections with minimal time input, find useful mentors and compartmentalise your time very effectively (see Lahav 2010 for useful tips).

- *Choose your boss wisely!* You will be in the minority and you need to ensure that your manager can appreciate your contribution, nurture your development, and recognise that your worth is unlikely to be reflected in metrics which have been developed for, and by, people who have followed a more typical career path.
- *Be brave:* You may rate poorly on the ubiquitous metrics and may fail to meet various measures of success. You will need courage to choose a different path from the vast majority of your colleagues, a path that may not be recognised or rewarded in the obvious ways, and may be judged by many as a failure. Maintaining confidence in your abilities will be difficult under these conditions. Meeting with other part-time academics may help you navigate a system which was designed for and by full-time academics.
- *Be patient:* your children will grow up all too soon.

For women after a career break: *how to re-enter academia*

Landing a teaching and academic position after a substantial career break is both unlikely and unappealing, because the research start-up (or re-start) phase is quite punishing. Some universities and schools have re-entry schemes, however these will be competitive and so are likely to favour applications whose careers were well-established before they had children, and those with shorter career interruptions.

Re-entry through casual research or teaching contracts provides an alternative path, through which you may enable you to build up expertise, track record and contacts and so be in a position to find a permanent role at a later time. Good tutors and capable part-time post-docs/research assistants are valuable and hard to find: use this to your advantage.

For research group managers: *how to seize an opportunity*

Many very smart, capable women wish to re-enter research on a part-time basis as their families grow. If you can find innovative solutions to harness these researchers, you will have access to an untapped pool containing some very talented individuals. These people are often secondary income earners in their families, in which case they may be less likely than other post-docs to move on after a few years, and may have the flexibility to adapt to workloads which vary with the cycle of grant success.

For university managers: *how to help part-time staff thrive*

Part-time staff will need good guidance to enable them to survive in the “success to the successful” regime dominated by continuous full-time workers. You can help by:

- *Targetting time for research:* Allowing part-time staff to load their teaching into a single semester so that they can have one semester with the continuous time required for effective research;
- *Fair teaching loads:* Ensuring that part-time teaching and administration loads are fairly allocated compared to full-time loads;

- *Teaching relief during start-up phase*: allowing time to develop a strategic plan and get the research started is critical for any starting academic (Hapgood and Hardin 2008).
- *Effective mentoring*: Ensuring that part-time staff have good guidance, and assist them develop effective collaborations with other senior researchers.

For university administrators: *how to encourage a productive, diverse workforce*

The need to increase female participation in senior roles at university is a long-standing issue (Armstrong, 1995; Bell, 2009 ;Dever, 2008) and will require reducing barriers to part-time work and to re-entering the work-force after a career break. We recommend considering:

- *Judicious use of metrics*: aggressive application of metrics which do not account for part-time status, teaching duties or position on the research start-up curve will discourage female participation in academic roles.
- *"Return to Research" seed funding*: The competitive nature of research funding means that women having babies around the time they finish their PhD will struggle to win even operating funds against those without career interruptions. Hence there is a need for specific funding schemes targeting those returning to research.
- *Under-writing post-doc positions for Return to Research*: A scheme to underwrite a post-doctoral salary would enable Return to Research staff to attract post-docs, and work with the post-doc to apply for competitive funding and so shift beyond the minimum critical research output required to be self-sustaining.
- *Short-list female applications*: A policy requiring at least one male and one female applicant be short-listed for all jobs would increase the opportunities available for academics who have had career breaks to raise their children to present their case at an interview when normally their CV would be overlooked.
- *Remove bureaucratic barriers*: Unintentional bias to full-time staff is often part of university rules; e.g. ensure part-time staff are able to supervise PhD students, and apply for funding, and that performance metrics at least attempt to account for career stage, employment status, research only status etc.

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BASELINE STUDY ON THE STATUS OF WOMEN IN ENGINEERING AND TECHNOLOGY AT TERTIARY INSTITUTIONS IN KENYA

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ABSTRACT

Shunning of Science subjects by girls in Secondary schools jeopardize the capability of women to effectively compete in a shrinking job market, which favours practical technology based expertise. If unchecked, the trend is poised to adversely affect Kenya's ability to tackle the developmental challenges.

This study aimed at establishing the past and current gender based tertiary enrolment of women in science, engineering and technology in five public universities and their constituent colleges. Questionnaires were used for the study. The questionnaires were administered to chairpersons of departments, lecturers, and to the female students. The study captured information on women enrolled in the institutions as well as those who had graduated from the institutions over a five year period.

The study established clear gender imbalance with respect to the number of girls enrolled in engineering and technology courses. However, the study found that over the past five years, there were an increasing number of female students enrolling for engineering and technology.

This baseline study is the starting point towards the development of a Monitoring and Evaluation framework, whose long term objective is to establish the effect of enhanced performance of secondary school girls in science and mathematics on female enrolment in Science, Engineering and Technology at tertiary institutions in Kenya.

LITERATURE REVIEW

Women constitute approximately 50 percent of the world's population, therefore, science and technological advancement towards sustainable development cannot be fully achieved without their full and unique contribution. Traditional roles and cultural prejudices militate against the interest of girls in science subjects (right at primary and secondary level) and their continued interest to higher education levels. Several studies have examined the reasons for this lack of interest and under-representation of women and girls in science.

In studies undertaken across several African countries (Imbuga, 1999), it has been shown that there exists historical imbalances and limited engagement of women in National development. The studies illustrate that the hindrances emanate from lack of access to science education, right from primary schooling through tertiary level. In

Nigeria, there have been discussions on the strategies that could be employed to motivate and sustain science education among girls/women from the Nigerian perspective (Nkechi & Imafidon, 1999). In the discussions, the contributions of women in policy making, science and international women organizations to solving gender imbalance have been highlighted.

In Uganda, low participation of women in science and technology has been documented (Dumba, 1999). It is reported that one of the crucial determinants of sex segregation in the labour force is lack of technical and scientific qualifications by girls and women. The problems affecting access to science education in Uganda and remedies to mitigate the situation has been addressed (Ichwekeleza, 1999). Similarly, Sarpong (1999) addresses the factors influencing the choice of engineering career among Ghanaian women.

In Malawi, participation of women in sciences and engineering at tertiary level has been found to be extremely low (Chimphango, 1999). At the University of Malawi it has been reported that from 1990 to 1997, female students at the university constituted less than 15% of the total students graduating from sciences and engineering. On the other hand, 40% of the students that graduated in 1997/1998 academic year were female and only 13% of these graduated in sciences and engineering.

Low enrolment of women in engineering education is not only a problem in Africa, but is also encountered in the western world, especially in UK, US and Australia .In the work by Mills *et.al* (2010), it is shown that over the years, traditional engineering education has failed to retain female students. In addition, issues that need to be addressed in order to make engineering education more gender inclusive have been identified. Specifically, the incorporation of gender inclusive curriculum within the mainstream engineering courses and programs has been shown to be particularly important.

In a paper presented to the Institution of Engineers of Kenya (IEK) (Adora, 2003), it was reported that the total number of women engineers that graduated from all departments of the University of Nairobi was a mere 3.05 %. However, most of these women are registered as graduates as well as corporate members of IEK and as consultants with the Engineers Registration Board of Kenya (ERB, 2010).

Year 2002 was a new era in Kenya's political dispensation because it was the beginning of multi-party democracy. Hence, Kenya women engineers woke up and felt the need for greater representation in order for them to participate in a process that would permanently impact on their lives. However, despite an increased democratic space in the country, the participation of women engineers in National Policy matters remained low.

To address the concern of low participation of women in engineering and technology, Kenya women engineers sought networks, which would strengthen them. These networks were based both locally and regionally. Towards the end of 2008, a few women engineers in Kenya were contacted by UNESCO to partner with their Botswana

counterparts to participate in forming a network. As a result of this contact, the Forum for Women Engineers and Girl Scientists in Africa (Forum WEGSA) was founded and established as a society in Botswana in January 2009 (Massaquoi, 2010).

Forum WEGSA is intended to be an Africa wide network of engineers, technologist, applied scientist and supporting professionals. It is partitioned into regional hubs: Southern Africa, Eastern Africa, Western Africa and Northern Africa, with the member countries referred to as Chapters. Forum WEGSA-Kenya Chapter was launched on 15th January 2010, and was registered as a society in Kenya in October 2010. Forum WEGSA is a resource base for the women professionals who were concerned that their impact in the major aspects of development remained elusive despite their potentially powerful contribution in Nation building.

METHODOLOGY

This was the first phase of an ongoing baseline study that Forum WEGSA is carrying out in four countries, namely: Botswana; Kenya; Ghana; and Zimbabwe. Information on the institutions offering degrees in engineering and technology was obtained from the Commission of Higher Education (CHE), the corporate body that deals with accreditation of public and private universities in Kenya.

Data for this study was obtained from academic records of the relevant institutions. The data for the University of Nairobi covered statistics from 1972, when the university produced the first locally trained engineers, to date. The motivation for this study was specifically because there has not been any baseline upon which improvement could be measured.

According to the Commission for Higher Education (CHI), the public universities in Kenya that offer engineering and technology courses are as shown in Table 1.

The seven Public Universities shown in Table 1 have constituent colleges which are distributed across the country. The institutions have different calendars ranging from seven months (KU) to nine months (UoN and JKUAT). All the institutions offer five year Bachelor's degrees.

This study targeted five public universities which have been running for more than 10 years, namely: University of Nairobi, Moi University, Kenyatta University, Egerton University, and Jomo Kenyatta University of Agriculture and Technology.

Table 1: Public Universities offering engineering and technology courses

	University	Year launched
1	University of Nairobi (UoN)	1970
2	Moi University (MU)	1984
3	Kenyatta University (KU)	1985
4	Egerton University (EU)	1987
5	Jomo Kenyatta University of Agriculture and Technology (JKUAT)	1994
6	Maseno University (MSU)	2001
7	Masinde Muliro University of Science and Technology (MMUST)	2007

RESULTS

The graduation statistics for the five targeted public universities are tabulated in Table 2, and presented graphically in Figure 1.

Table 2: Graduation statistics in engineering in five universities

Institution	Years	% Female	% Male
UoN	2005 to 2009	9.23	90.77
MU	2008	14.29	85.71
KU	2009 to 2010	15.93	84.07
EU	2010	9.59	90.41
JKUAT	2006 to 2010	13.58	86.42

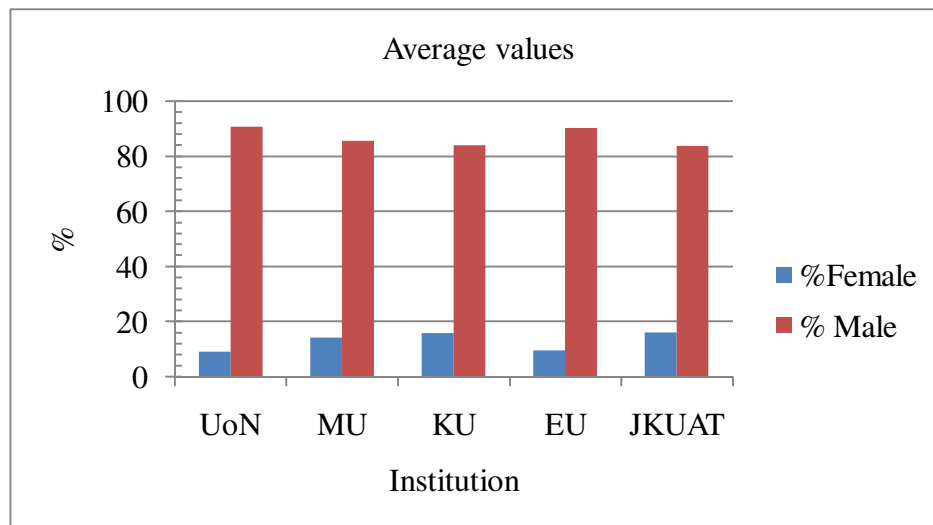


Figure 1: Graduation statistics in engineering in five public institutions

Statistics for University of Nairobi and Jomo Kenyatta University of Agriculture and Technology were chosen as the sample data. These two institutions were chosen to represent the oldest and the youngest public institutions respectively.

Current Enrolment at University of Nairobi

University of Nairobi offers Bachelor of Science (B.Sc.) Degrees in five disciplines as follows: Civil and Construction Engineering (CCE); Electrical and Electronics Engineering (EEE); Environmental and Biosystems Engineering (EBE); Geospatial and Space Technology (GST); and Mechanical and Manufacturing Engineering (MME).

Figures 2 and 3 are samples of the current students' enrolment in two departments for the academic year 2009/2010. Figure 4 shows graduation statistics at the university for the period 2003 to 2009.

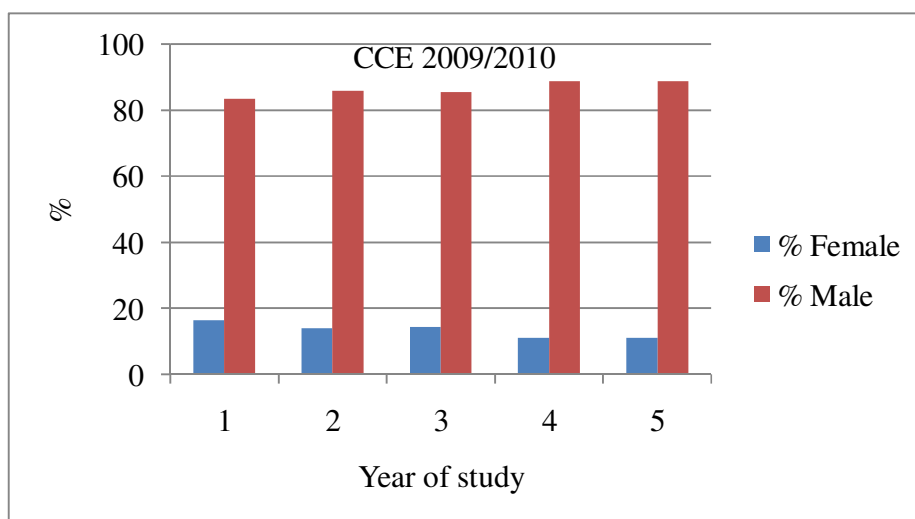


Figure 2: Enrolment in CCE at University of Nairobi for calendar year 2009/2010

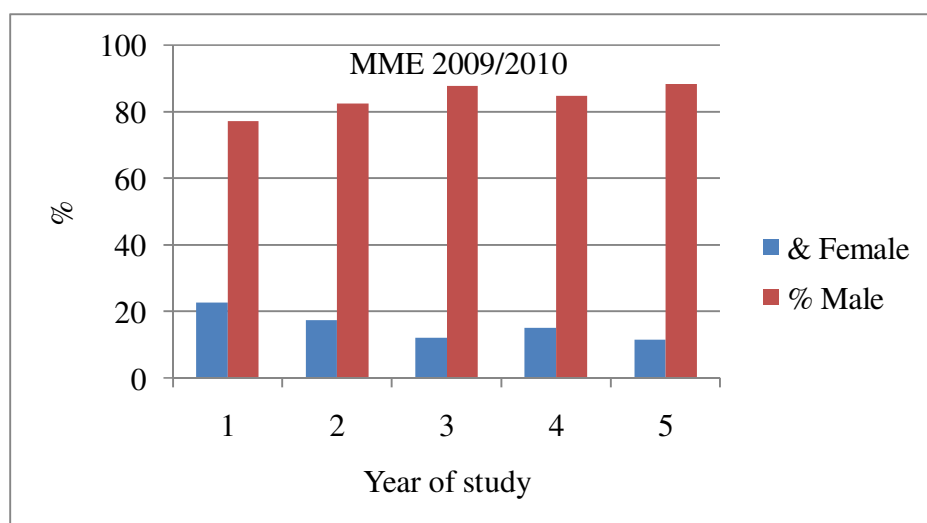


Figure 3: Enrolment in MME at University of Nairobi for calendar year 2009/2010

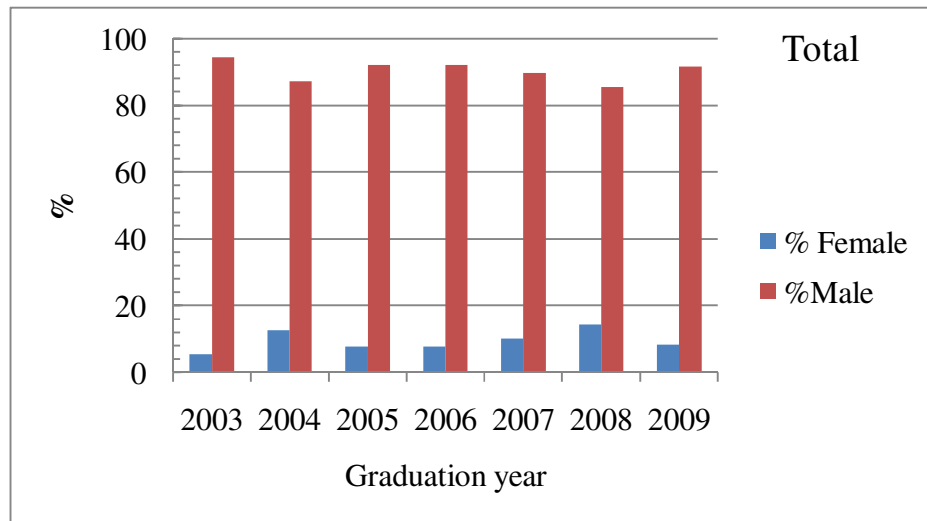


Figure 4: Engineering students at University of Nairobi for period 2003 to 2009

Graduation Statistics at Jomo Kenyatta University of Agriculture and Technology

The College of Engineering and Technology at JKUAT consists eight departments which offer B.Sc. Degrees in the following: Civil Engineering (CE); Electrical and Electronic Engineering (EEE); Electronic and Computer Engineering (ECE); Mechanical Engineering (ME); Geomatic Engineering and Geospatial Information Systems (GEGIS); Mechatronic Engineering (McE); Biomechanical and Processing Engineering (BPE); Telecommunication and Information Engineering (TIE); Mining and Mineral Processing Engineering (MMPE); and Soil, Water and Environmental Engineering (SWEE). The enrolment and completion in each undergraduate programme at the College of Engineering at JKUAT are shown in Figures 5-7.

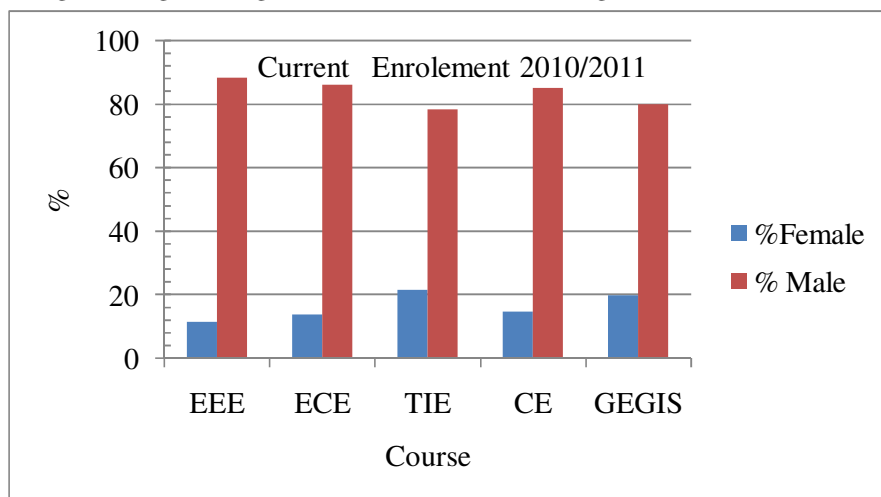


Figure 5: Total enrolment in engineering at JKUAT during 2010/2011 academic year

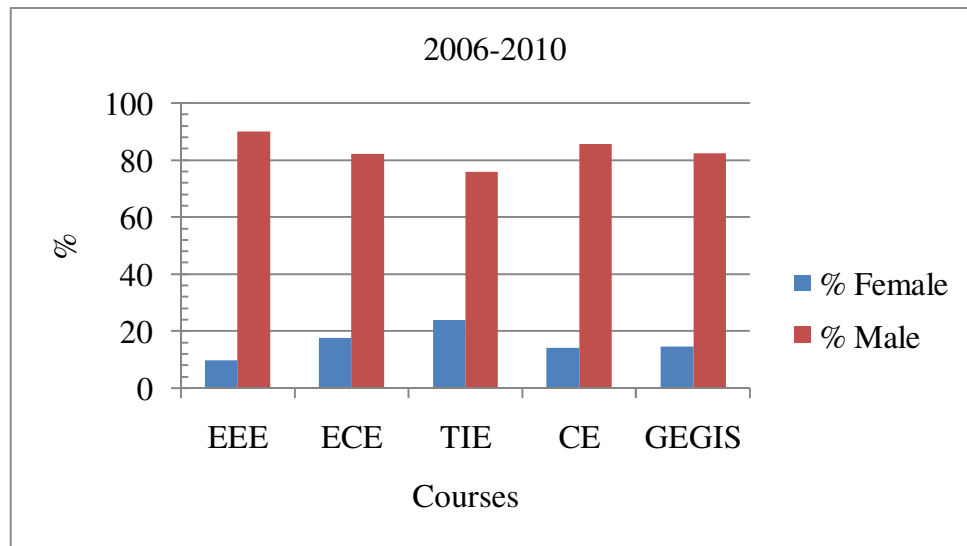


Figure 6: Completion rates in engineering at JKUAT for years 2006-2010

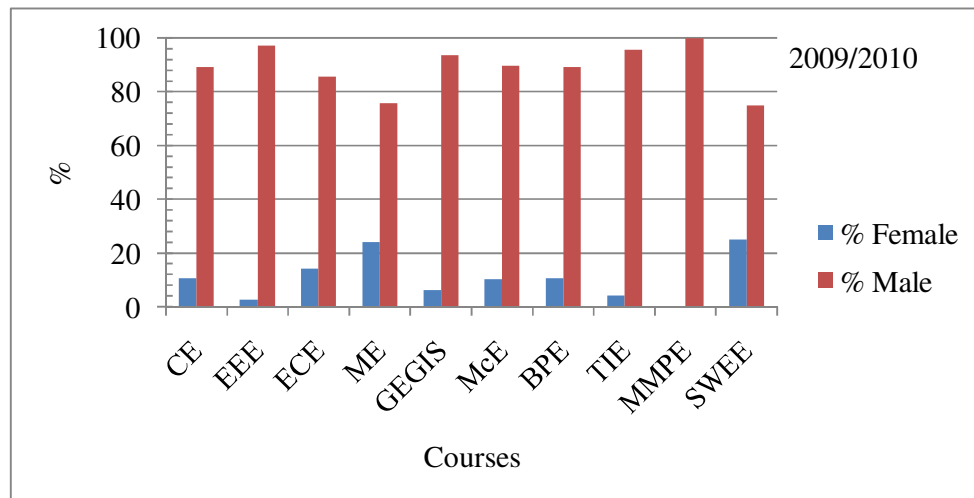


Figure 7: Completion rate in engineering at JKUAT for 2010

DISCUSSION

In an effort to review any existing information on the status of women engineers in Kenya, the authors found that a similar survey on the status of women engineers has not been widely undertaken in most African countries, hence the literature was predominantly from one main source.

The University of Nairobi (UoN) is the pioneer institution of University education in Kenya and the region. Therefore, this study found it necessary to trace the graduation statistics to 1972, when graduates were awarded the B.Sc Engineering degree of the University of Nairobi.

The statistics of UoN show that whereas the graduation of girls was 3.05% over a 31 year period, it increased to 9.23% over the next eight years. This increase was over 200% over a relatively shorter period, an increase that was considered significant. This increase in the number of female students graduating in engineering could be attributed to greater awareness and a wider democratic space that was ushered in by a multi-party government that came into power in the year 2002. However, a completion rate of 9.23% for female engineering students is still lower than the target of 30% representation that is recommended in Kenya's new long-term national planning strategy that is officially known as Kenya-Vision-2030 (2007).

The statistics of Jomo Kenyatta University of Agriculture and Technology (JKUAT) compares closely with that of Kenyatta University as shown in Table 2. The average completion rate for female students from all the departments over a five year period (2006 to 2010) was 16.12%. This research found that there was a higher enrolment of female students in the younger universities compared to the older ones. For example, there was an increase of 4.35% in the graduation rate of female students in JKUAT compared to UoN over a five year period. This was a significant difference, which could be attributed to differences in the engineering programs between the older and newer universities. In Kenya, new universities have introduced more innovative approaches to engineering teaching which are more responsive to the market needs. The innovation includes opening up of constituent colleges and introduction of flexible learning hours, a practice that attracts more female students. This aspect of innovations in engineering education in Kenya needs further exploration.

The increase in female engineering students in the newer universities could also be attributed to traditional stereotypes which seem to have persisted in the older institutions. However, Nationwide, the completion rates for female engineering students are much lower than the National target, which is a major concern.

The political strategy and vision of Kenya under "Vision 2030" envisions a country with a democratic system reflecting the aspirations and expectations of its people. The Vision also stipulates a state in which equality is entrenched, irrespective of one's gender for the benefit of all. This would be expected to be reflected in the statistics of female students' completion rates from all engineering schools in public universities in Kenya. However, as shown in this study, the completion rates range from 9.23% at (UoN) to 15.93% (KU). It is interesting to observe from the results of this study that the school of engineering at KU (that was founded most recently) has a higher percentage of female students in engineering than the older institutions. There is need to investigate further whether there could be traditional and political influence on the rate of enrolment of female students in engineering in Kenya.

In Africa, women and girls are a major determinant of national development. They are responsible for nutritional issues, providing water, feeding their families, education, health care, family planning, production of food crops and trade. The significance of improving scientific and technological literacy among them can therefore not be overemphasized. Ironically, in the field of engineering, women have lowest representation as shown in this study.

CONCLUSIONS AND RECOMMENDATIONS

The study established the following:

1. Statistics of currently enrolled female engineering students in the oldest and youngest public universities in Kenya.
2. A data base of the percentages of female engineering students graduating from five public tertiary institutions.
3. The percentage of female students graduating in engineering is lower in the older institutions.

It is recommended that:

1. The data base of currently enrolled female engineering students is extended to capture a 5 year period for all public universities.
2. There is need to investigate further whether there could be traditional and political influence on the rate of enrolment of female students in engineering in Kenya.
3. Need to have strategies to enhance female enrolment in engineering and technology.
4. Need to have strategies to heighten awareness among female engineering and technology educators to strive for higher goals and to be role models for young girls.
5. Attention needs to be paid to organizations that are capable of firstly, compilation of data on the number of women engineers graduating from both local and foreign universities and secondly, tracking the professional participation of women engineers.
6. Strengthen the Forum for Women Engineers and Girl Scientists in Africa (Forum WEGSA) whose objectives are in line with this research.

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RATIO OF FEMALE SCIENTISTS IN HIGHER EDUCATION INSTITUTES IN JAPAN

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ABSTRACT

Japan's 3rd Science and Technology Basic Plan (FY2006–2010) set its gender policy by establishing an overall hiring target and field-wide targets for female scientists working at higher education institutes. The overall target was achieved in 2007; however, our analysis reveals considerable disparities among fields. For example, in the fields of engineering and science, where the populations of female are relatively small, the proportions of female scientists in employment amounted to only about half the targets. At the same time, the hiring ratio of foreign-born female graduates from doctoral courses at Japanese universities was also low. Nevertheless, a larger problem is that the use of such hiring targets alone is not sufficient to facilitate a clear future vision for female scientists at universities.

On the other hand, in 2003, the Japanese government announced its goal to boost the ratio of female in leadership positions across all areas of society to 30 % by 2020. Defining professorship as a leadership position at universities, we used data in 2007 to project the number of years necessary to achieve the goal. The results indicated that the possibility of achieving the goal by 2020 would be extremely low. Some measures in the direction have to be considered, including the aggressive hiring of female doctorates and female international doctorates.

1. INTRODUCTION

Japan's national goal has been to become a "Science and Technology Oriented Creative Country." Having the advantage in science and technology and a good strategy is the critical factor of innovations to achieve the national goal and to lead global competition. Hence, fostering human resources who form the basis of science and technology is a fundamental issue for Japan. However, as it to be described in Section 4, female scientists in Japan are not fully utilized.

The series of Science and Technology Basic Plans, which is endorsed by the Cabinet, aims to direct Japan's national five-year Research and Development policy, such as prioritizing certain fields in which to invest, the strategy for science diplomacy, and human resource management. In consideration of the lagging female participation, the 3rd Science and Technology Basic Plan (FY2006–2010) particularly emphasised the promotion of female scientists in the context of human resource management, and set the overall and field-wide hiring targets of female scientists for higher education institutes (hereinafter referred to as "HEIs"). The targets, which were designated based on the ratio of female doctoral students, are 25 % for the natural sciences as a whole, 20 % for Science, 15 % for Engineering, and 30 % each for Agriculture and Health. The Gender Equality Bureau of the Cabinet Office also set its own numerical target in the

3rd Basic Plan for Gender Equality, focusing on the ratio of females in leading positions. The target aspired to increase the ratio of females in a leading position to at least 30 % by 2020," which is frequently called the "202030" goal.

This paper will focus on HEIs to investigate the current states and achievements of female-scientist participation in terms of employment, using the data described in Section 3. We will also examine the feasibility and prerequisites to attain the numerical targets for the ratios of hiring female scientists and female faculty members in leading position at HEIs.

2. LITERATURE REVIEW AND MAJOR MEASURES IN OECD COUNTRIES

Several studies have been done by various entities, including governments and academic societies, to understand why the growth in the female population in science and technology against the male population is limited.

For instance, the collective work done by the National Academy of Science (2007) clearly illustrated the situation experienced in USA. That is, although the female population has been increasing in HEIs, the higher the academic degree, the lower the population of female students (NAS, 2007). Also the higher the job position, the lower the ratio of female scientists in HEIs. In OECD's report on female's careers in science published in 2006 a similar pattern was observed in the EU (Regnier, 2006), as well as in Japan (Ito, 2003; Miura, 2009). In spite of this general climate, the ratios of female scientists vary by field; for example, in the hard-science fields, such as physics and some engineering fields, the ratio of female scientists is lower than in others (NAS, 2007).

According to OECD (2006), a great number of measures and supporting programs have been implemented to encourage females to work in the science and technology field. In USA, under the provisions of the Science and Technology Equal Opportunity Act of 1980, the National Science Foundation (NSF) has strived to promote female scientists through its education, employment, and funds (Ward, 2006). At the beginning of the 1990s, German academia launched special funding schemes for female scientists (Löther, 2006). In the UK, various kinds of support were provided for female scientists (Butcher, 2006). Those challenges exemplify how pressing the issues are.

Several studies have been done in Japan to discuss female students' avoidance of the sciences, in order to encourage them to participate in the natural sciences, especially in Science and Engineering (Kawano, 2009; Muramatsu, *et al.*, 2004). The government and funding agencies in Japan have strived to enlarge the female population in natural sciences through establishing incentive systems and providing funds too. For example, based on the 3rd Science and Technology Basic Plan, Japan Science and Technology Agency (JST), a governmental funding agency, launched a scheme to provide grants to organizations such as universities, institutes and NPOs that organize campaigns to recruit female high school students for enrolment in natural science courses. This scheme was started in 2006, and each year five to more than ten organizations receive a year-long grant. The grant per organization is limited to 3 million yen. JST also has programs started in 2006 to encourage female scientists to combine their research and personal lives harmoniously, by providing supplemental grants to contract work out or hire an extra assistant (JST, 2006).

Is it assured that the number of female scientists, and eventually the number of females in leading positions, will increase if there is growth in the number of female students majoring in natural sciences? However, the survey on the transition of female doctoral students in several fields suggests that this is not a problem that can be solved easily. For example, with regard to life sciences, the ratios of female doctoral students in social

and behavioural sciences are more than 30 % and 15 % respectively, but the ratios of female professors are only 15 % in both of those fields (NAS, 2007). It means that a certain ratio of female students may be a necessary condition for a certain ratio of female professors, but this condition alone is not sufficient. We believe that some major measures should be implemented instead of simply waiting for the number of female scientists and leaders to grow continuously and automatically over time in line with a possible increase in the number of female students. Some measures are being taken in Japan, but a macro-scale analysis of dynamism need to be conducted in terms of how female students embark into academia as full-fledged scientists.

3. DATA USED IN THE RESEARCH

Statistics Survey on School Teachers

This survey has been conducted by the Ministry of Culture, Sports, Science and Technology (MEXT) every three years. Data on university faculty members from the latest report, published in 2007 was used in this paper. The survey includes the profiles and the transferring records. The number of faculty members serving a university predominantly is 167,071, and 27,199 faculty members have been transferred.

Statistics Survey on Careers of Doctoral Graduates in Japan

The National Institute of Science and Technology Policy (NISTEP) carried out this survey between July and October, 2008, by requesting the HEIs in Japan (414 HEIs in total) that have doctoral courses, to collect answers on the attributes and the post-graduation careers of people who completed a doctoral course in Japan between FY2002 and 2006, and 75,197 graduates were surveyed. See NISTEP (2009) for results of the survey.

4. FEATURES OF FEMALE SCIENTISTS IN JAPAN

The ratio of female scientists in Japan is low compared to the rest of the world. According to the “White Paper on Gender Equality 2010,” Japan’s ratio of female scientists is the lowest in the world (13.0 %), whereas Lithuania has the highest ratio (49.3 %), followed by USA (43.3 %), the UK (26 %) and South Korea (13.1 %) (Gender Equality Bureau, 2010). Although it may be necessary to consider which countries should be compared to Japan, the ratio of female scientists in Japan is obviously lower than those of other countries. The population of female scientists has been increasing slightly along with increases in female students’ enrolment in HEIs (Ogawa, 2001). Even a comparison of the ratios of female scientists by sector shows that Japan has the lowest ratios in HEIs, the government, and the private sector (21 % in HEIs, 13 % in the government, and 7 % in the private sector, as counted by the number of persons). About 60 % of female scientists work for HEIs, whereas about 60% of male scientists work for private corporations in Japan (EC, 2009).

Focusing on HEIs, Figure 1-A shows that the ratio of female scientists predominantly serving at an HEI generally decreases as the job position gets higher. Figure 1-B shows the gender distribution by field. The ratio can vary by field; for instance, the ratio of female scientists is relatively smaller in Science, Engineering and Agriculture than in Health and Humanities.

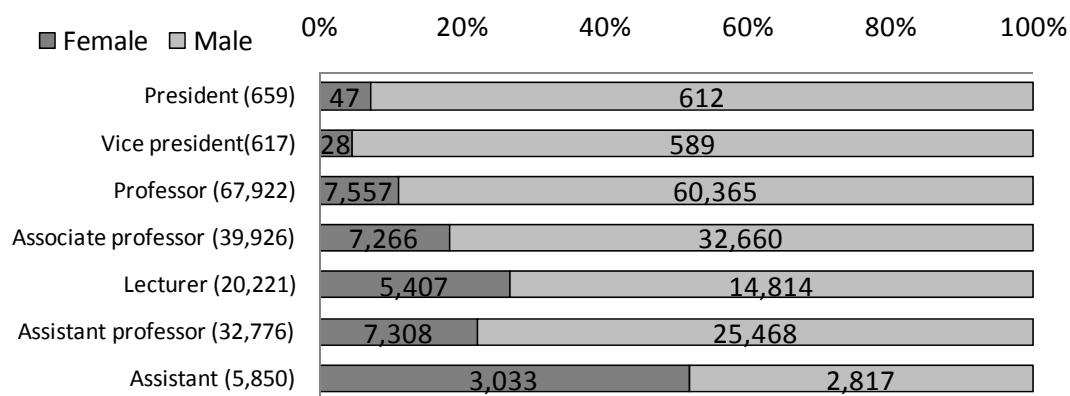


Figure 1_A: Gender distribution of faculty members by position in 2007

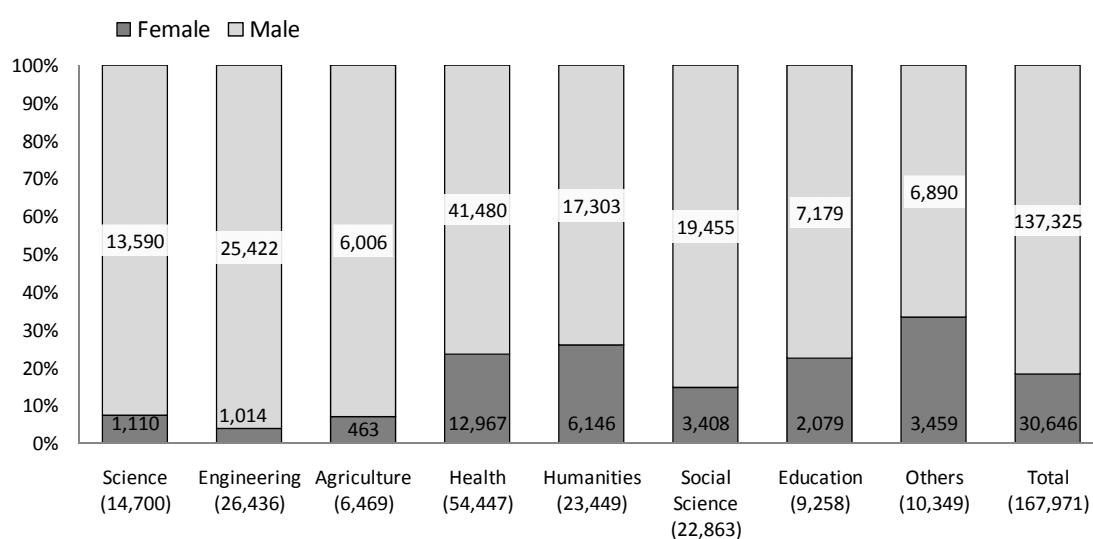


Figure 1_B: Gender distribution of faculty members by field in 2007

Source for Figures: Statistics Survey on School Teachers

5. NUMERICAL TARGETS IN THE 3RD S&T BASIC PLAN

Numerical targets for hiring female scientists were stated in the 3rd Science and Technology Basic Plan (FY2006–2010) and the 3rd Basic Plan for Gender Equality. In this part, the numerical targets of the 3rd Science & Technology Basic Plan and the current status of progress are examined, and in the following part, the numerical targets in the 3rd Basic Plan for Gender Equality and the status of progress are examined.

Newly-hired scientists at HEIs

In FY2007, there was a total of 8,251 newly-hired scientists in natural sciences at HEIs in Japan, 2,068 (25.1 %) of which were female. The numerical target of the ratio of the total number of female scientists hired in natural sciences was accomplished at the time of the survey. However, looking into each field (Figure 2), only in Health was the target attained. Therefore, the accomplishment of the numerical target in natural sciences as a whole is owing to the high ratio in Health (30 %). Also the figure shows the low ratios of female scientists in both Science (12.3 %) and Engineering (6.9 %). In Engineering, the achieved ratio is especially low, not even meeting half of the numerical target.

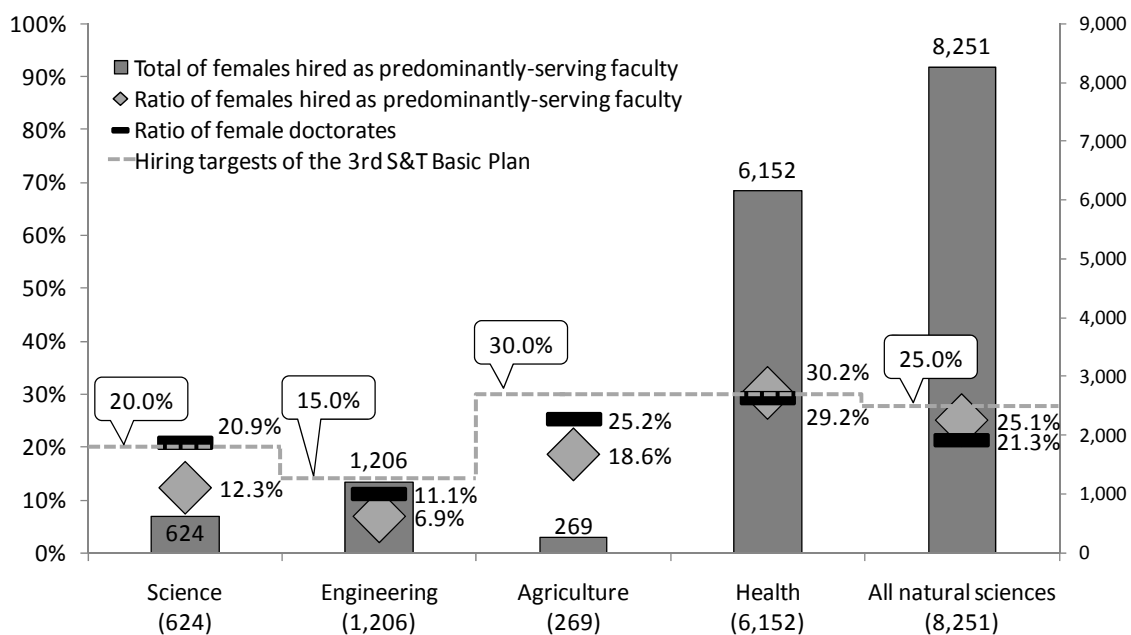


Figure 2: The number and ratio of hired scientists by field in 2007

Source: Statistics Survey on School Teachers and
Statistics Survey on Careers of Doctoral Graduates in Japan

Newly-graduated employees at HEIs

In 2007 HEIs employed a total of 8,251 people in natural sciences, 1,238 (15.0 %) of which were new graduates. It is assumed that the non-new graduates employed at HEIs are transferred from post-doc positions, or are scientists who used to work outside of HEIs, at industries or public research institutes, for example. This group may include new master course graduates too. 347 (26.9 %) of the 1,238 employees were female. The ratio of females among the new graduates hired in the natural sciences as a whole exceeds the numerical target of 25 %, while in Science and Engineering, the numerical targets are not accomplished and the achieved ratio is less than half of the targets (the target and the achieved ratio of newly-hired employees is 20 % and 8.9 % in Science, and 15 % and 6.1 % in Engineering).

The numerical target in the 3rd Science and Technology Basic Plan applies to newly-hired scientists. Hence, if the same ratio of female graduates were hired in Science, the target would be attained. As for Engineering, because the ratio of female graduates is 11.2 %, female scientists should be hired at a higher ratio in order to fulfil the numerical target of 15 %. Therefore more aggressive means are required. For instance, HEIs in Japan could hire females at more than the ratio of female graduates, or recruit doctorates from an overseas university.

Figure 3 shows that the ratio of female international students, who make up 25.6 % of female doctoral students in natural sciences, 20 % in Science, 50 % in Engineering, 37 % in Agriculture, and 17 % in Health, did not remain at the same proportion as those who completed doctoral course in the faculty pool. Since male international students also show the same pattern, it may be necessary to reconsider how we include international students in the science and technology workforce at HEIs.

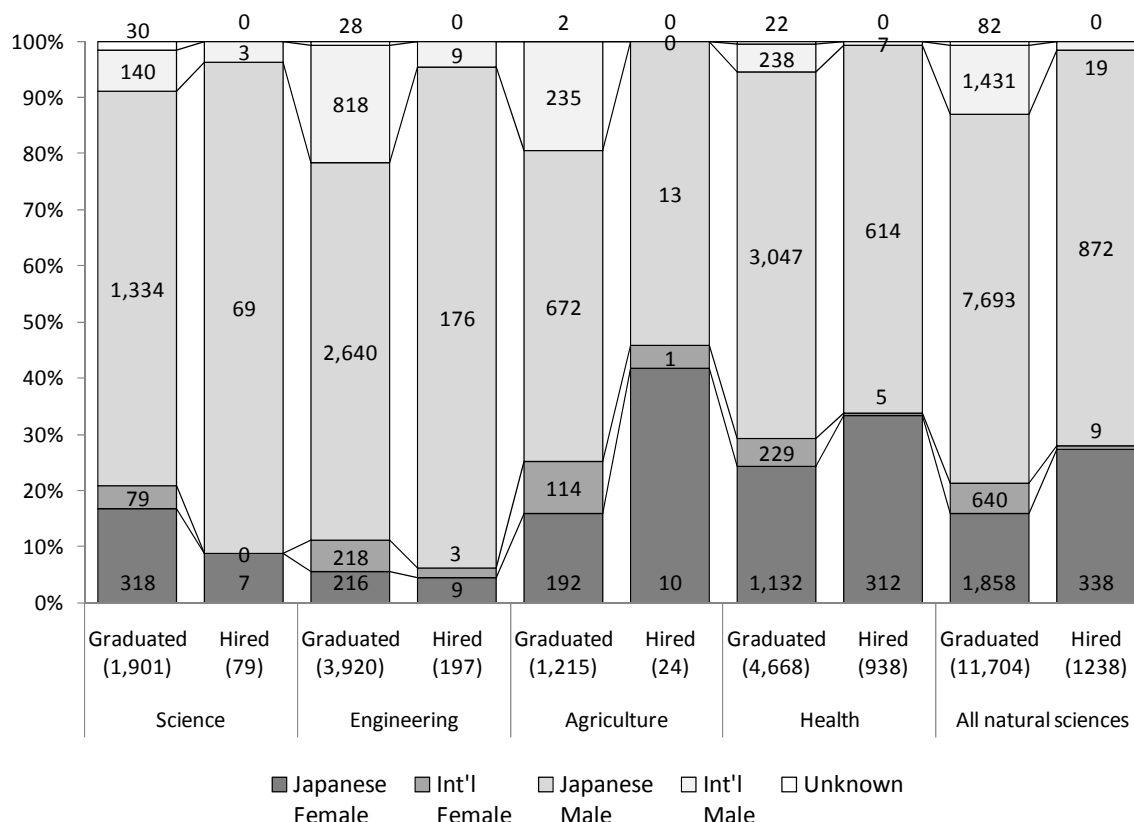


Figure 3: New graduates from doctoral course and employees in HEIs in 2007

Source: Statistics Survey on School Teachers and
Statistics Survey on Careers of Doctoral Graduates in Japan

6. BASIC PLAN FOR GENDER EQUALITY: AIMING FOR A 30 % FEMALE RATIO IN LEADING POSITIONS

Leading Positions at HEIs

In this study, the “leading positions” at HEIs are represented by associate professors and professors. The Gender Equality Bureau of the Cabinet Office surveyed the ratio of females in leading positions by sector and concluded that “the progress of gender equality in the female participation in the policy or decision making process is generally moderate.” It found that 15.5 % of faculty members (lecturers, associate professors and professors) at HEIs and 11.9 % of scientists are female (Gender Equality Bureau, 2009). However, Saito, *et al.* (2011) clarified that over 70 % of scientists at the HEIs experienced their first principle investigator (PI) when their titles were professor or associate professor. Considering that a principal investigator is to be in a leader's position and managing a project in the research environment, according to the leading research institute's report (RIKEN, 2010), we exclude lecturers from the leading positions.

Assessment of the Attainability of 30 % Target

Attainability of the target by 2020

The ratio of female scientists by job position in 2007 is far from the numerical target of 30 % as shown in Figure 4. In natural sciences, only 7.1 % of professors and 10.4 % of assistant professors were female. The highest ratio of female scientists is found at the associate professor position in Health (25.9 %). Every job position in Engineering has the lowest ratio among the natural sciences. The ratio of female professors in

Engineering is as small as 1.5 %. The numerical target of 30 % has not been accomplished in any of the field or job positions.

In order to see whether the numerical target of 30 % will be attained by 2020, we predict the ratio of females by age.

The average ages by job position are 56.5 for professor, 42.0 for associate professor, and 36.2 for assistant professor, according to the Statistics Survey on School Teachers. To simplify the prediction, we substitute the average ages by job position with 55 for professor, 45 for associate professor, and 35 for assistant professor. The retirement age of professors is assumed to be 65 according to Japanese convention. Although HEIs have different rules on retirement, the compulsory retirement age is usually set between 63 and 65. From the statistics, the age distribution of the scientists is assumed to be similar across genders and fields.

Assuming that the ratio of female scientists at HEIs in 2010 will be the same as that in 2007, the associate professors and assistant professors of science in 2010 will become professors and associate professors respectively in 2020. Consequently, in 2020, the ratio of female professors in the natural science fields as a whole will be 10.4 %, or more specifically, 6.4 % in Science, 3.9 % in Engineering, 6.3 % in Agriculture, and 19.2 % in Health (Figure 4). Even under the strong assumption that no female scientists will drop out of the employment pipeline, the prospective ratios of female scientists in all fields and positions will be lower than the numerical target of 30 %.

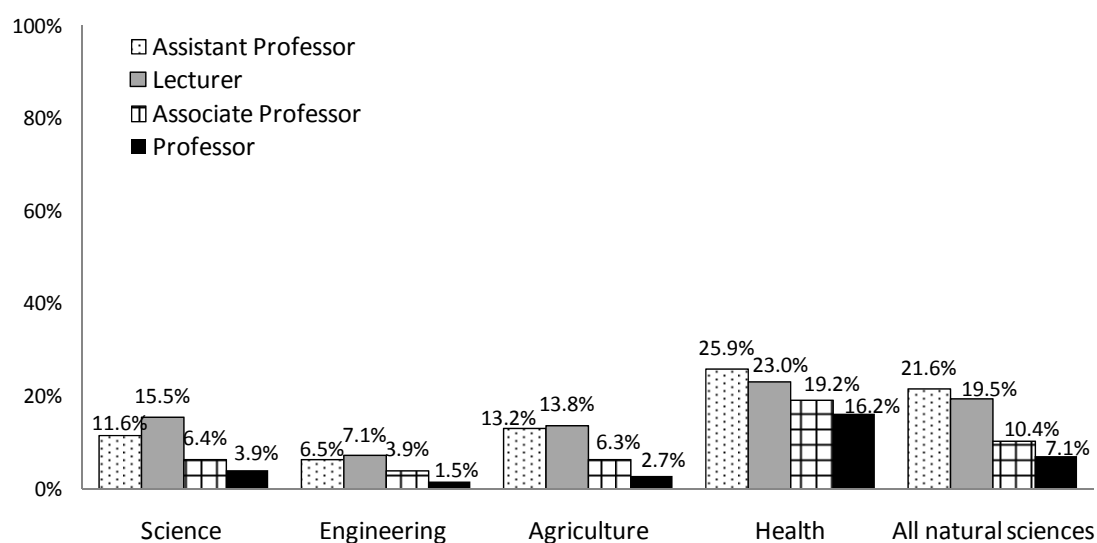


Figure 4: The ratio of females in job positions in natural sciences

Source: Statistics Survey on School Teachers

Promotion Rate and Turnover Rate

In Science, Engineering, and Agriculture, the ratios of professors and associate professors are high compared to the ratios of other positions (Figure 5). This results in a chimney-shaped distribution, in other words, an inverse-pyramid shaped distribution. Looking closer by gender, a gender difference is found in the job-position distribution. Female scientists form a pyramid shape in which the junior-class population such as assistant professors and lecturers is reasonably larger than that of professors and associate professors. In contrast to the female scientists, male scientists form a chimney or inverse-pyramid shape dominated by professors and associate professors. This gender-age distribution may secure a gender difference in the promotion rate if the aptitude remains in the future. However, it should be clarified whether such gender

difference is actually a result of the so-called pipeline problem resulting from the lower ratio of female students, or the result of some sort of promotion-system problem, such as a glass ceiling.

The turnover rate of female scientists at HEIs is 7.8 %, which is just 1.0 percentage point higher than the rate of male scientists, according to the Statistics Survey on School Teachers. However, the turnover rates become 6.6 % for females and 4.4 % for males if the group of employees retiring upon reaching the compulsory retirement age is excluded. This means that in comparison to males, 2.2 % more female scientists leave their jobs. Background information on female scientists quitting their jobs is lacking. It is known that leaving the job due to the compulsory retirement age is the most common reason for male scientists in Japan, while the members of the male junior-class population tend to leave the job for a new job or post.

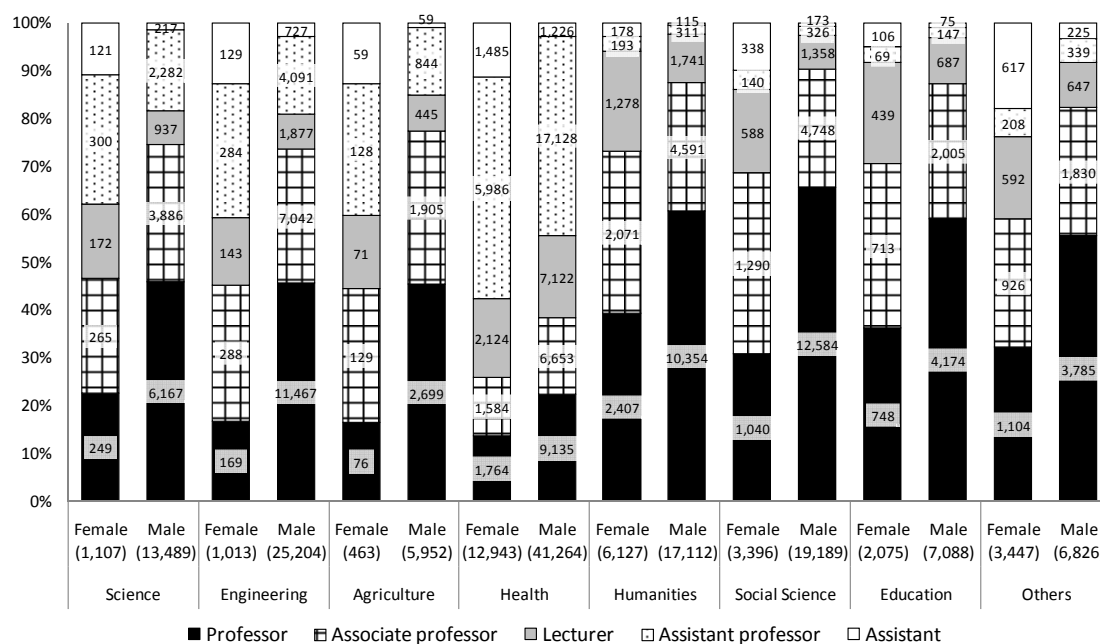


Figure 5: Job-position distribution of scientists in Japan

Source: Statistics Survey on School Teachers

7. CONCLUSIONS

Regarding the problems of the low ratio of females among the scientists in Japan, we analysed the situation at HEIs, where about 60 % of the female scientists are working. First, we analysed to what extent the numerical targets of hiring female scientists prescribed in the 3rd Science and Technology Basic Plan have been accomplished. The numerical target for natural sciences as a whole has been attained; however, the achieved ratio differs from field to field, for example, the target is accomplished in Health, whereas it is not fulfilled in either Science or Engineering.

Next, we examined the attainability of assigning females to 30 % of the leading positions represented by associate professor and professor at HEIs. Even under the strong assumption that the promotion or turnover rate is not affected by gender, the prospective ratios of female scientists in all fields and positions will be lower than the numerical target of 30 %. At any rate, the expansion of female-scientist hiring should be based on increasing the number of females in doctoral or earlier-stage courses. The tendency of females to stay away from the natural sciences has already been discussed and various studies have been put forward for the phenomenon. However, we do not have any clear answer or any simple solution. Beside the problems that female scientists in the natural science fields face in their careers, such as those regarding promotion or

taking leave, we point out the necessity of solving the problem already existing at the earlier stage, that is, of increasing the number of female high school students who want to go into the natural science fields.

We carried out our analysis under the assumption that the job turnover rate is not affected by gender. However the actual female turnover rate is more than 2 % higher than the male turnover rate. Although no clear reasons have been shown by the various research projects that have been conducted so far, problems concerning job-home management or job-relocation for spouses are suspected. We must wait for macro-level research and measures based on the findings presented by such research projects.

Measures in such direction have to be considered in addition to the aggressive hiring of female doctorates and female international doctorates. MEXT has been making various plans and higher education institutes have been taking efforts to attract female students to enter the natural science fields. As the conclusion of this report, we point out again that it is essential to make such activities go further.

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GENDER DIFFERENCES IN PUBLICATION OUTPUT: TOWARDS AN UNBIASED METRIC OF RESEARCH PERFORMANCE

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ABSTRACT

Quantifying the gender gap in research productivity has become a matter of serious concern among the policy makers. The objective of this study is (i) to measure the contribution of women to the scientific endeavour of the nation; (ii) to analyze the scientific areas where women have contributed more and (iii) to assess the gender equity in scientific productivity. This study reviews the publication productivity of men and women in S&T by drawing samples from contrasting social, political and economic systems in Europe, North America, Asia, Australia and Africa in order to identify the social structure in which women outperform men since the scientific discoveries are the outcome of a particular social context. The correlation between gender and research productivity will be computed by gathering the publication data from the 'SCOPUS' database and they will be aggregated into different socio-economic situations such as industrialized and semi-industrialized nations etc. This study will address important gender issues such as (i) what is the level of women's productivity in the sample regions and how does it compare with the numbers of women scientists in those countries? (ii) in which disciplines are women represented and what type of research do they favour? (iii) What is the level of international and domestic co-operation among women scientists? Based on the findings of this kind of studies, national, local and institutional policies can be revived to make women as the best contributors to scientific knowledge, scientific education and scientific occupation.

INTRODUCTION

The prime debate in gender science forums is (i) contribution of women to the scientific endeavour of the nation; and (ii) scientific areas where women have contributed more. Such kinds of debates run parallel to the discussion on gender equality in the scientific productivity. The contribution of the scientists is defined according to one of the following three criteria; (i) contribution to scientific knowledge (contribution based definition); (ii) contribution to scientific education (supply-based definition); and (iii) contribution to scientific occupation (demand-based definition). For the purpose of the present study, the contribution of the male and female scientists to the growth of scientific knowledge is taken into consideration. Here knowledge refer to the amount of "research output" in a period of "exposure", measured by the number of publications, either reported by respondents in surveys or found in bibliographic searches. The factors affecting the publication output includes age and gender of the scientists, their academic

rank and level of specialization, prestige of the institution , or department of affiliation and teaching load, marriage and children.

OBJECTIVES OF THE STUDY

The objective of this study is (i) to review the status of male and female scientists in their contribution to the scientific output of their nations; (ii) to examine the scientific areas where men and women have contributed more and (iii) to assess the gender equity in scientific productivity. This study maps the publication productivity of men and women scientists by drawing samples from diverse political, economic social situation in order to identify the social structure in which women outperform men since the scientific discoveries are the outcome of a particular social context. The data for the present study is based on the secondary resources and they are aggregated into different socio-economic situations such as industrialized and semi-industrialized nations etc..

REVIEW OF LITERATURE

Women's position in the social organization of science influence the number of scientific papers that women publish (Prpic, 2002). Men and women's engagement in science (proportion) determine their relative contribution (productivity pattern) to scientific output. Women continue to publish less than men and the causes of gender difference are mysterious and hence the term " productivity puzzle".(Cole & Zuckerman, 1984), Scientific publications are the most important component of the research system (Moed et al, 2004) (Van Raan, 1988); and if women publish less, they will be left out of the main stream of research (Davenport & Zinder, 1995); (Long & Fox, 1995); and continued to occupy lower levels of scientific position and recognition (Long & Fox, 1995); and will have limited representation as a human resource in science. According to (Prpic, 2002) there is a widening gap between the number of women graduated with scientific degrees and the number of women actually active in research. (Webster, 2001) has pointed out that women's lower rate of publication productivity is due to their lack of orientation of publication through national international networks. Women's position in the social organization of science influence the number of scientific papers that women publish (Prpic, 2002). Men and women's engagement in science (proportion) determine their relative contribution (productivity pattern) to scientific output. Women continue to publish less than men and the causes of gender difference are mysterious and hence the term " productivity puzzle".(Cole & Zuckerman, 1984), Scientific publications are the most important component of the research system (Moed et al, 2004);(Van Raan, 1988); and if women publish less, they will be left out of the main stream of research (Davenport & Zinder, 1995);(Long & Fox, 1995); and continued to occupy lower levels of scientific position and recognition (Long & Fox, 1995); and will have limited representation as a human resource in science.

The adverse influence of "discipline effect" on the scientific output of male and female researchers is emphasized by (Lemoine, 2002). Female faculties are more likely to work in non-tenure-track, part-time or temporary positions, and have lack of access to institutional support, resources or time needed for prolific publishing (Schneider, 1998). Even when all else is equal, female faculty tend to be more involved than their male counterparts in activities that detract from research, such as advertisement, administrative work and serving on departmental committees (Sarkees & Mc-Glan, 1992). Women are also more likely than men to interrupt their careers for child bearing, child rearing, caring for an elderly relative or supporting a spouse (Long, 1990);

Difference regarding the research activity of men and women can largely be explained in terms of differences in personal characteristics, structural positions and marital status (Xie & Shauman, 1998). Moreover, women choose institutional setting where publishing is not expected or encouraged. Besides, marriage and motherhood keep women away from publishing (Zuckerman & Cole, 1975) and (Cole & Zuckerman, 1994).

PUBLICATION ACTIVITY OF WOMEN IN DIFFERENT SOCIO-ECONOMIC ENVIRONMENT (COUNTRIES)

A country-specific analysis of the publications activities of the male and female scientists are investigated to examine the following issues: (i) Whether the scholars around the globe (both men and women) are motivated to conduct and publish research by the same incentives; (ii) Whether the correlates of productivity operate so differently across nations so as to suggest the need for country-specific predictive models; (iii) Whether the factors influencing faculty publication productivity vary in different nations, and especially of those from the developing world.

Gender Gap in the Publication Productivity of Ten Selected Countries

A study by Teodorescu is a cross-national empirical analysis of the correlates of faculty publication productivity in a ten-country sample. The countries included in the study are as follows: Australia, Brazil, Chile, Hong Kong, Israel, Japan, Korea, Mexico, the United Kingdom and the United States. Publication productivity have been measured as the number of articles published over a three-year period. By reviewing the findings of related literature on the professoriate in the developed world, the study seeks to determine the extent to which these hold for less developed academic systems as well, and more broadly, to identify the similarities and differences in the patterns of publication productivity across the examined nations.

Gender Gap in the Publication Productivity of High Income Group of Countries

Tab 1: Share of Women's Contribution to Technological fields, 2003-2005

	1991	1996	2001	2005	2003-2005
ESP - Spain	7.50%	9.30%	11.10%	14.20%	12.30%
FRA - France	6.00%	7.50%	9.90%	9.90%	10.20%
DEN - Denmark	5.00%	8.70%	8.10%	8.20%	8.90%
AUS - Australia	4.40%	6.10%	12.20%	8.10%	8.30%
USA - United States	6.30%	7.70%	8.80%	8.20%	8.30%
BEL - Belgium	5.00%	6.60%	7.90%	8.40%	8.10%
SWE - Sweden	5.20%	4.80%	6.70%	8.60%	7.60%
ITA - Italy	4.90%	5.10%	6.70%	7.60%	7.40%
NZL - New Zealand	2.10%	6.60%	10.10%	7.20%	6.70%
GBR - Great Britain	4.00%	5.70%	6.20%	6.70%	6.40%
IRL - Ireland	3.50%	6.90%	7.40%	7.90%	6.40%
SUI - Switzerland	1.60%	3.30%	5.70%	5.90%	5.90%
GER - Germany	2.40%	3.20%	4.50%	4.90%	4.70%
AUT - Austria	2.20%	3.10%	3.30%	2.90%	3.20%

Source: EPO: PATSTAT; Own Computations.

It can be seen from the above table that the relative contribution of women over the years 2003-2005 -averaged across all technological fields-is highest in Spain (12.3%) followed by France (10.2%) and a group of countries with similar levels (of more than 8%) consisting of Denmark, Australia, the USA, Belgium and Sweden. At the lower end

of the scale Germany (4.7%) and Australia (3.2%) rank last, a considerable distance from those to the top. There has been a strong increase in women's contribution to technology output in most countries, but it is still at a relatively low level. Moreover, the growth rates have flattened out since 1996 in most countries and a dynamic increase is hardly visible any more. After 2001, the share accounted for by women decreased in the USA, while it is stagnated in France, Denmark and Switzerland.

It is further inferred that women are- for one reason or another – less active publishing and patenting than men. There is only relatively little evidence based on cross-country comparisons. A maiden attempt was made by Naldi et al (2002, 2004) who has taken a large scale databases (FNDB) in Gender research in order to draw international companions over long time periods.

Gender Gap in the Publication Productivity of Medium and Low Income Group of Countries

In Brazil a study (Leta, 2003) was conducted to measured the Brazilian female contribution in scientific publication. The aim of the study was to monitor the Brazilian female effect in scientific production because of several policies that had been developed to improve women status in science. This study also aimed to discover whether there was a difference between Brazilian male and female academics publication in the three fields of immunology oceanology, and astronomy in terms of quality and quantity. The data for this research was obtained from the ISI web of science. Information on the sex, age and position of the author was obtained from the Brazilian national council for scientific and technological development. A break down of the article (Total No of Papers = 1868) by their subject catalogues have shown that women have achieved a highest rate of contribution in such field as environmental studies, nutrition, medicine, biology and chemistry. However, their rate of contribution is low in computer science. In contest to gender situation in Brazil, both in India and Mexico women have achieved equal level of contribution compared to their male counter parts.

Tab 2: Scientific Activity of Male and Female researchers in Mexico

Area of knowledge	Proportion of female (%)	Gender difference in scientific productivity (paper per year)
Exact Science	15	-0.16
Biology & Chemistry	36	-0.08
Health Science	39	-0.24
Social & Humanities	38	0
Agricultural Science & Biotech.	22	0
Engineering	12	0.06

Source: Computed

Gender Gap in the Publication Productivity of Islamic Countries (Iran)

(Lemoine, 2003) has attempted to examine whether the scientific productivity of Iranian female scholars differ quantitatively from that of male authors, and if so how. For the purpose of this study, the publications of journals articles in ISI ranked journals is considered as a valid measure of scientific productivity. More specifically this study tries to answer the following questions: (i) what is the gender distribution of Iranian

authors in ISI indexed journals in 2003? (ii) What is the gender distribution if Iranian authors in different areas? (iii) What is the gender distribution of Iranian author's international collaboration? (iv) What is the relative productivity of men and women?. It is noted that Iranian women are more active in certain areas of life sciences such as medicine & biology and less active in exalt science such as physics and mathematics,. Regarding their contribution, women's share is amounted to 13.4 percent (352 from the total of 2,626) of the articles published by Iranian authors in 2003. At the individual level, the productivity of male author was higher (0.60 articles per male author) than that of female authors (0.34 articles per female author). Women accounted for 0.34 of the contributing authors. In short, men accounted for 94 percent and women accounted for only 6 percent of the articles published in 2003.

A chi-square test ($\chi^2=7.9$, $df=1$, $p<0.01$) showed that the differences between male and female productivity is significant at the 1 percent level. Women's contribution is much lesser than expected. Women in Iranian science accounted for slightly less than a sixth of the academics in 2003, which means they were in a low minority and this could have had an impact on their productivity. Besides Iranian women are less likely than men to collaborate with International authors. Moreover, the general productivity of academic women seems to be lower than their male peers worldwide. The data for this study is computed by downloading the articles from web of science for the period 2003.

Tab 3: Productivity of Male and Female authors at the individual level (Iranian data)

Subject	Articles with female contribution		Articles solely written by male authors		Total
	No	Per cent	No	Per cent	
Chemistry and Chemical Engineering	130	15	758	85	888
Medicine	128	25	385	75	513
Engineering (various)	19	6	326	94	345
Physics	7	4	203	96	210
Mathematics	11	10	97	90	108
Metallurgy	5	5	90	95	95
Biology	20	22	70	78	90
Agriculture	2	3	62	97	64
Geology	3	6	41	93	44
Educational Sciences	3	7	41	93	44
Computer Sciences	0	0	31	100	31
Veterinary Medicine	2	7	25	93	27
Humanities	1	8	11	92	12
Nutrition	3	30	7	70	10
Environmental Studies	1	34	2	66	3
Other	17	12	125	88	142
Total	352	13.4	2274	86.6	2626

Source: Iranian authors in ISI Journals downloaded from WOS-2003

The contribution of authors by subject categories was also calculated to identify the strength of men and women is certain disciplines. Women's contribution is more in subjects such as environmental studies, nutrition, medicine, ecology and chemistry, while male domination is found in subjects like computer science, agriculture, physics, metallurgy, engineering and geology. These findings are in line with the findings of (Webster, 2001) and (Lewison, 2001).

Gender Gap in the Publication Productivity of a Socialistic Country (Poland)

Webster has adopted bibliometric techniques to investigate the presence of women in polish science through their scientific outputs. He has examined the scientific output of polish women as represented in SCI, for the period 1980-1999. The position of polish women relative to their male colleagues were investigated by looking at the following

issues: (i) What is the level of women's productivity and how does it compare with the numbers of women scientists in Poland?; (ii) In which discipline are women represented and what type of research do they favour?; (iii) What is the level of international and domestic co-operation among Polish women scientists?; (iv) Do Polish women tend to publish more in Polish than in foreign journals listed in the SCI.?

Tab 4: Scientific Output of Polish Women

Publications	Sub sample of young scientists 1990				Sub sample of young scientists 1998			
	F	M	T	Sig.	F	M	T	Sig.
All publications in career	6.2	8.8	2.017	0.045	7.6	11.2	4.119	0.000
Scientific publications in previous five-year period	3.8	4.1	0.468	0.640	4.8	6.8	4.443	0.000
Single-authored publications	1.5	1.4	0.080	0.936	1.6	1.9	1.607	0.108
Co-authored publications	2.3	2.7	0.585	0.559	3.2	4.9	4.375	0.000
International Scientific publications in five years	0.6	0.8	0.817	0.415	2.0	2.8	2.711	0.007

It is seen that gender gap gets widened during 1990-1999. This is in accordance with the proportion of women in higher level of education and profession. The following table also illustrates the fact that the drop in the rate of publication of Polish women is due to the fall in their representation in the educational system.

Tab 5: Share of Polish Women in Scientific Degree Granted: 1992-2000

DISCIPLINE	Ph.D			D.Sc			Professors		
	Total	Women	%	Total	Women	%	Total	Women	%
Agricultural Science	453	202	44.6	86	25	29.1	56	17	30.4
Engineering and Technology	774	140	18.1	152	14	9.2	62	7	11.3
Humanities	1133	551	48.6	240	94	39.2	160	42	26.3
Medical Science	1394	661	47.4	228	84	36.8	67	20	29.9
Natural science	862	386	44.8	217	63	29	86	19	22.1
Social Science	432	197	45.6	64	23	25.9	47	9	19.2
Total	5048	2137	42.3	987	303	30.7	478	114	23.9

The female to male ratio drops from 35% in the early 1980 to 32% in the early to mid – 1990's.

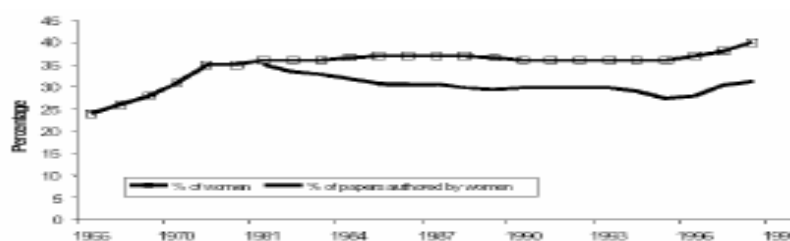


Fig 1: Women employed in higher education in Poland & papers published by Polish women in SCI Journals

The Comparison of women's scientific output and numbers of women employed in science shows that their publication levels are lower than expected. The disparity between employment and publications levels corroborates certain studies in other countries (Davenport & Snyder, 1995). The showing disparity between the size of the workforce and publication outputs can be explained in several ways. First, the effects of material law might have had a bigger impact on women's productivity than on that of men. Second, changes taking place in science policy, such as restructuring of research funding, made it more difficult for women to compete for increasingly scarce resources and therefore they conduct less research. Third, the state's policy to increase numbers of students might also have affected women more than men. As women occupy more junior positions within academics, they are more involved in teaching and administrative obligations and are left with less time for research. And finally, Polish women tend to publish more in Polish journals and with the decrease of these indexed in SCI.

There are observable differences in Polish women's participation in science depending on subject field. Women are highly represented in biology, biomedicine and clinical medicine but poorly represented in physics, mathematics, engineering and technology. Polish data closely correlates with Icelandic data (Lewison, 2001). The following graph illustrates the parallelism that exists between the publication activity of the Polish women to that of women in Iceland.

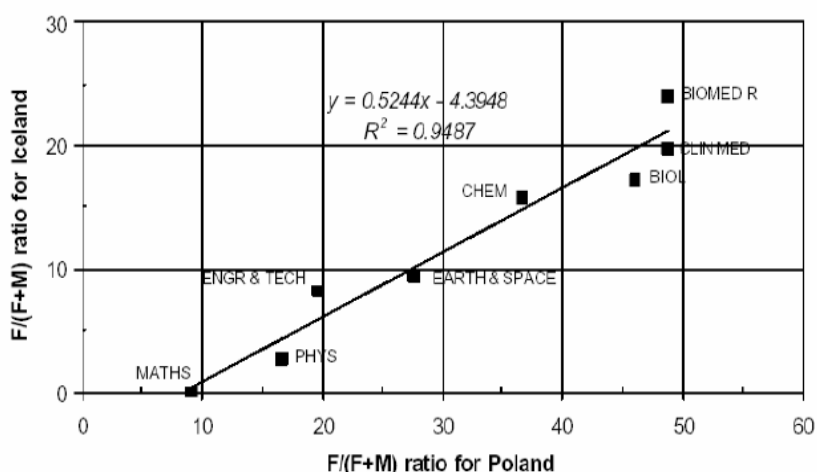


Fig 2: Women's Levels of Participation in Science for Poland & Iceland by subject field in SCI, 1980-1999

Correlation between Professional Category (academic rank) and Scientific Productivity

Many studies have illustrated that there is a positive correlation that exists between academic rank and a scientist's productivity. For instance, professors publish at a higher average rate than associate professors and research staff (Blackburn, 1978); (Dickson, 1983); (Kyvik, 1990). A study of Spanish scientists reported that out of 333 scientists employed in the material science centre (MAT) of the CSIC laboratory in Spain, 32 percent are women, but most of them are in the lowest category of the professional hierarchy. The following figure illustrates the gender structure of the scientists in MAT Lab.

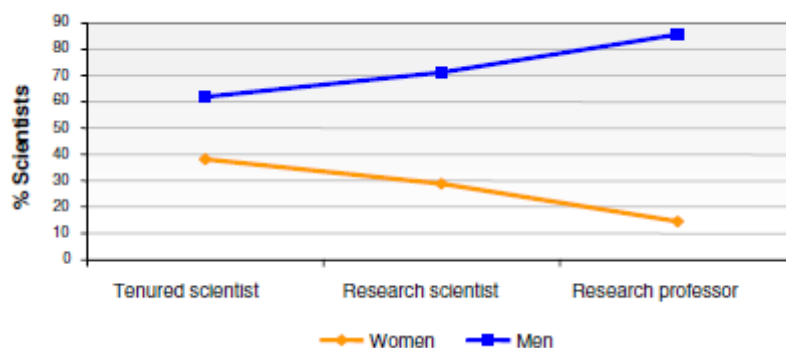


Fig 3: Scissor diagram of representing the academic position of male and female scientists.

It is reported that less number of researchers at the top professional hierarchy has led to lower productivity. The above figures established the hypothesis that position of the male and female scientists in an organization has a direct effect upon their research productivity. For instance, an analysis of the distributions of Italian University research staff (2001 to 2003) also reveals that women are primarily concentrated in “lesser” or “less active” roles and therefore women are less productive in research output than their male colleagues. The lower productivity of women could be explained by the fact that they tend to work in lower professional ranks than men.

Tab 6: Distribution of Scientists Who Publish by gender and role

Gender	Professor	Associate Professor	Assistant professor	Total
Male	8686	7596	5401	21683
No.of Publications	5895	4326	2921	13342
Female	1102	2758	3493	7353
No.of publications	760	1684	2071	4515
Total Staff	9788	10354	8894	29036
Total Publications	6655	6210	4992	17857

(Stack, 2004) analyzed the research productivity of more than 11000 Ph.D. holders employed in academia. After controlling structural and personal characteristics women still published less than men. The leading predictors of productivity included location/rank in a research university and efforts in terms of hours worked.

Impact of Specialization of Women Scientists on their Level of Productivity

(Leahey, 2006) analyzed how gender affected the extent of research specialization and how the extent of research specialization affected research productivity. According to her results, focused on sociology and linguistics, women specialized less than men and thereby lose out an important means of increasing their productivity. There are gender variations in the productivity of publications across discipline. In some fields, women achieved majority but in others barely made any inroads. Studies reported that there is close correlation between gender and the domain of their scientific output. Some authors attributed ‘discipline effect’ to the relative difference in output between male and female researchers. This kind of horizontal segregation is owing to factors such as educational stereo types. Horizontal segregation implies the fact that women are concentrated in less visible areas of sciences. According to Young, women’s research

style and topic choices might not fit traditional notions of what many reviewers and editors consider to be the best or most rigorous research (Sarkees & Mc-Glen, 1992). In consequence women's publishing opportunities are restricted, or ghettoized, to specific and gendered domain.

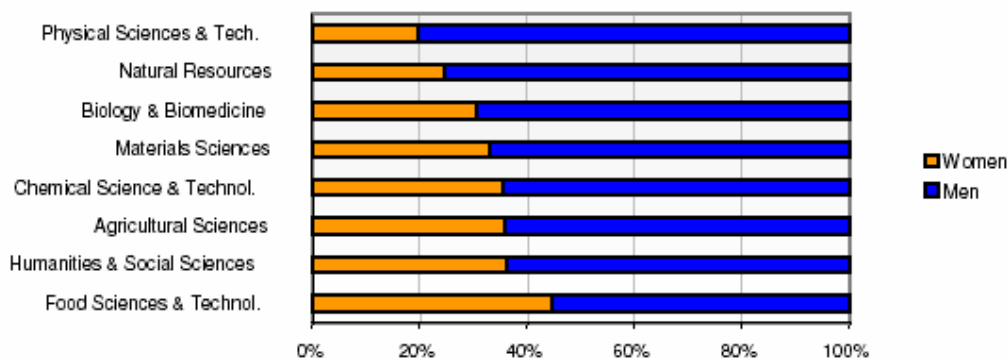


Fig 4: Effect of discipline on gender.

CONCLUSION

More and more social studies are required to identify the diverse rates of productivity between men and women. According to Sambunjak et al (2006), mentoring to the young women scientists will have positive effects on productivity. There needs to be a shifting in measuring the productivity from quantity to quality. A number of metrics is to be developed to assess the productivity which is not simply the publications.

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CURRENT TRENDS IN THE APPLICATION OF ATMOSPHERIC PLASMA FOR THE IMPROVEMENT OF WIND TURBINE EFFICIENCY THROUGH SEPARATION CONTROL

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ABSTRACT

Wind turbine aerodynamics remains a crucial area of research in the field of sustainable energy. Major challenges faced are problems associated with adverse aerodynamic loads encountered by wind turbines during operation. These problems, found to have a significant impact on the efficiency and life span of the wind turbines, advanced the studies and works for aerodynamic control methods for mitigating adverse aerodynamic loading on wind turbines. This work explores the feasibility of an innovative method of active airflow control to improve the performance of wind turbines using Dielectric Barrier Discharge (DBD) plasma actuators. These devices are capable of manipulating and modifying the flow field around a profile wall resulting to flow changes similar to those observed when the geometry of the profile itself is altered. The advantages of these devices being fully electronic without heavy and complex moving parts presents a great potential as being a viable active airflow control alternative to the wind industry. Discussions presented in this work have concurrently demonstrated that flow separation is delayed through the use of DBD actuators on the profile walls and may be practically applied to wind turbines. This indicated that with the use of DBD actuators, wind turbines may be capable of operating at higher angles of attack, with better operating efficiency and a longer lifespan.

NOMENCLATURE

b_e	=	electrode length of plasma actuator
b_t	=	turbine blade span
$C_{L\alpha}$	=	slope of $C_L - \alpha$ curve
C_w	=	non-dimensional power coefficient
c	=	airfoil chord length
E	=	electric field strength
F_B	=	body force vector

L	=	sectional lift
L_{ele}	=	inter-electrode distance of plasma actuator
n	=	rotational speed of blade
r	=	radius of turbine blade coverage area
U_o	=	free stream velocity
V_{wind}	=	wind velocity
W	=	power of the plasma discharge
α	=	angle of attack
δ	=	thickness of the plasma discharge
ϵ_o	=	permittivity of free space
θ_{pitch}	=	blade incidence angle
ρ	=	local fluid density

INTRODUCTION

Wind energy has been recognised as a clean alternative source for electricity, with an average annual growth rate of approximately 30% for the past decade (American Wind Energy Association (AWEA), 2004; BTM Consult ApS, 2005). Technological advances in wind turbines are becoming more essential to remain competitive with other fossil powered technologies. The improvements in wind turbine efficiency over a wider range of environmental conditions and the methods of lowering capital and maintenance costs therefore remains a crucial area of research for the wind industry. Each new generation of wind turbine designs have progressively improved the turbine blade aerodynamics, energy capture capacity, structural integrity, material, control systems and operational costs of the system (Berg *et al.*, 2008). Similarly, load control methods for wind turbines have also progressively improved in terms of their capabilities and effectiveness in reducing adverse aerodynamic loads on the turbine blades. Significant growth in wind turbine size and weight have also been observed over the years thus rendering it impossible to passively control turbines as was traditionally done in the past. The interaction of turbines with adverse aerodynamic loadings introduces stresses on the blades and the surrounding components that significantly shorten the life of system. These undesirable loads are further exacerbated with the increase in size of wind turbines thus making structural and fatigue loadings in wind turbines a major concern in turbine design. The mitigation of these adverse aerodynamic loading would be able to significantly decrease the system cost through the reduction in scheduled and unscheduled maintenance, general cost of the system and even improving overall system efficiency and reliability (Berg *et al.*, 2008; Veers *et al.*, 2003).

Various load reduction methods exist; many of which have changed markedly over the past two decades (Fig. 1). Load control in wind turbines is essential in minimizing the fatigue life of the blades and supporting structures due to changes in wind direction, speed and fluctuations (gusts), turbulence and the start-stop cycles of the turbines (Berg *et al.*, 2008). Until the 1990s, wind turbines were designed to utilize passive control whereby blade loading and power output was controlled through the adaptation of aero-elastic responses of the blades and stall regulation (Barlas & van Kuik, 2010; Nelson *et*

al., 2008). Subsequent wind turbine designs were developed with active control incorporated to allow the use of larger turbine blades. With active control, blade loads and power output are controlled through the adjustment of the aerodynamic properties and the pitch angle of the blades. This method of control allows for more efficient system operation, blade control and lighter blade weight allowances. Passive control methods are generally chosen for their simplicity, however, such systems are not necessarily reliable or economical to maintain for large wind turbines. In contrast, active control may provide more flexibility in terms of a wider range of operation thus allowing for more effective power extraction. However, since active control methods are more complex and require auxiliary power supplies, the application of such load control techniques requires careful analysis to ensure practical and economic viability.



Fig. 1: Wind turbines utilizing (a) pitch control (World News, 2010) (b) vortex generators (Wapedia, 2010)

The performance of wind turbines is constrained by the need to minimize adverse aerodynamic loads on the blades (Berg *et al.*, 2008). Active flow control methods have the most potential in reducing these adverse loads on wind turbines as these methods are focused on faster, more detailed and specific load control techniques, operating only when required. Reduction in adverse aerodynamic loads sustained by the turbine blades is generally achieved through flow separation control. Delaying flow separation and stall over the turbine blades would significantly reduce the drag on the blades and hence regulate the adverse loadings sustained by the wind turbines. Among the active flow control devices commonly investigated for the application in wind turbines are micro tabs, synthetic jets, suction, blowing, advanced blade pitch and twist control (Barlas & van Kuik, 2010). These devices, however, are generally complex, contributing additional weight to the blades and are unable to respond fast enough to relieve the load perturbations sustained by airfoils and turbine blades. Plasma flow control technology utilizing Dielectric Barrier Discharge (DBD) plasma actuators are devices that are fully electronic with no moving mechanical parts, high in frequency response, low in weight, easily attached a surface, able to withstand high force loads, are capable of operating in both steady and unsteady modes and are low in power consumption (Nelson *et al.*, 2008). As such, these devices present as an alternate active flow control method capable of providing various advantages over the other conventional active flow control techniques. Investigations into the potential of these plasma actuators to improve the performances of the wind turbines are a crucial area of research in order to contribute to

the continual development of the wind industry. This paper examines the viability and feasibility of utilizing DBD plasma actuators to improve wind turbine efficiency through separation control of turbine blades.

PLASMA ACTUATOR PHYSICS

DBD actuators are commonly used to generate non-thermal plasma discharge under standard atmospheric conditions. Plasma enhanced aerodynamics using DBD actuators have been investigated for a range of applications involving boundary layer control (Font, 2004; Jacob, 2004) flow separation control (Sosa & Artana, 2009; Labergue *et al.*, 2007) and stall control on an airfoil (Sosa *et al.*, 2007; Dyken *et al.*, 2004). DBD actuators consist of two electrodes separated by a dielectric layer. One electrode is left exposed while the other electrode is normally insulated in order to limit the generation of the plasma discharge to one side of the dielectric material (Fig. 2).

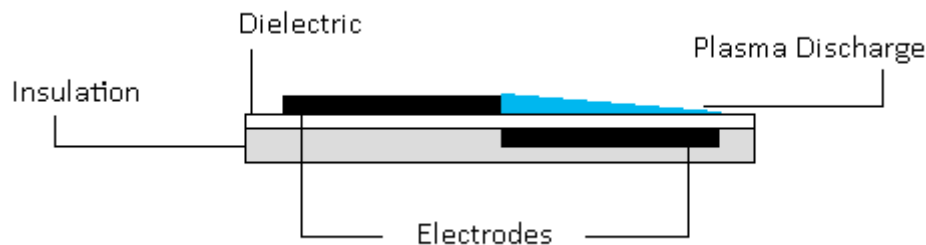


Fig. 2: Schematic configuration of a single DBD actuator

An electric field with sufficient strength to sustain electron-ion pairs is required to be applied between the electrodes of the actuators in order to generate a plasma discharge. This electric field is established when a high AC voltage is applied to the exposed electrode. Plasma discharge is then formed over the surface of the dielectric material between the exposed electrode and the insulated electrode. The production of the plasma discharge in the electric field between the electrodes causes the charged particles to accelerate towards the electrodes according to their polarity. The movement of these charged particles then collides with neutral air particles thereby resulting in momentum being transferred to the ambient air.

Plasma discharge characteristics are distinctly different in the two half cycles of the AC voltage applied to the exposed electrode (Corke *et al.*, 2010; Moreau, 2007). This difference in plasma discharge characteristics is attributed to the source of electrons in each stage of ionization. In the negative half cycle, electrons are released from the exposed electrode as a result of occurrence of photo-ionization due to the electric field (Fig. 3a). These electrons, accelerated towards the insulated electrode, are then impinged on the dielectric surface until a saturation of electron occurs on the dielectric surface. When this occurs, the electric field diminishes in strength and the plasma discharge self-extinguishes. When the positive half cycle begins, electrons previously impinged on the dielectric surface are then accelerated towards the exposed electrode thereby becoming the source of electrons in the half-cycle (Fig. 3b). Electrons previously impinged on the dielectric material however do not come off easily and as such contribute to an asymmetrical momentum coupling observed during both half

cycles with the ambient air. Details concerning the mechanism behind DBD actuators have been widely investigated (Cheong *et al.*, 2010; Gibson *et al.*, 2009; Thomas *et al.*, 2009; Enloe *et al.*, 2004) but will not be discussed in this work.

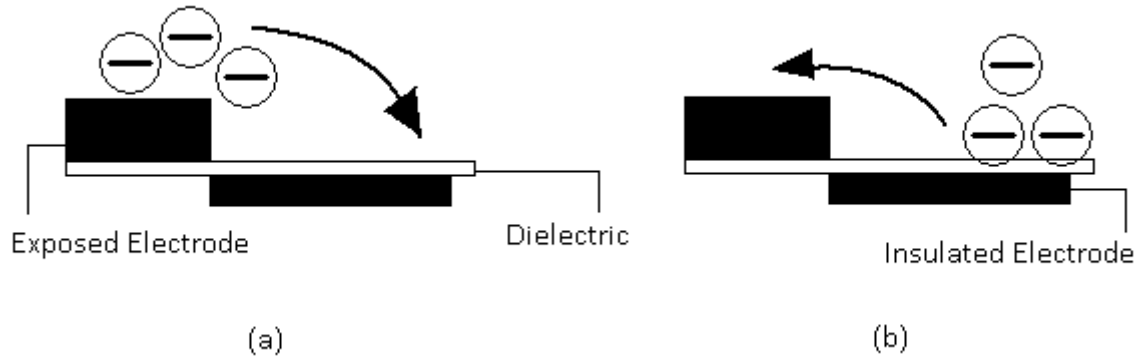


Fig. 3: Electron movement: (a) negative half-cycle (b) positive half-cycle

The main interest in the workings of the DBD actuators is that when the plasma discharge is generated, ambient air is drawn in towards the surface of the dielectric material and subsequently accelerated downstream of the actuator, in parallel with the dielectric material (Fig. 4). This induced airflow due to the plasma discharge is termed *ionic wind* in the literature. This induced ionic wind has the effect of modifying the characteristics of a fluid flow by injecting momentum into the boundary layer of the flow therefore enabling separation and stall control to be acquired.

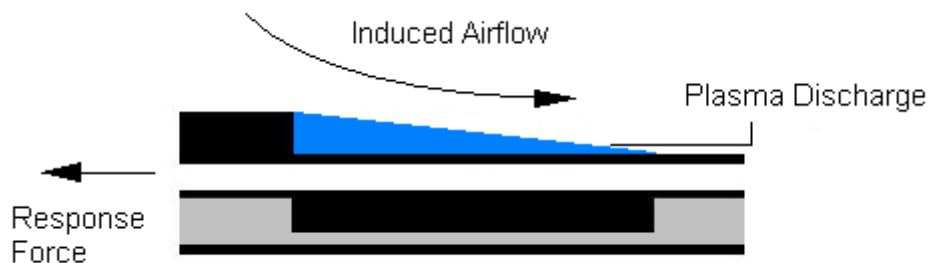


Fig. 4: Response force and induced airflow of plasma actuator (Cheong *et al.*, 2010)

SEPERATION CONTROL

Wind turbines are typically designed to operate in a specific range of wind speeds and as such, aerodynamic forces on the turbines are affected by the relative velocities on the blade sections. Below the lower bounds of this range, the wind speeds are too low for the turbine to generate power. However, when wind speeds exceed this range, the angle of attack of the blade increases and the flow about the blade separates and eventually begins to stall. When this occurs, drag on the blades increases resulting in the turbine sustaining adverse aerodynamic loading and even a decrease in the amount of power

harnessed from the wind. Analyzing the lift equation (Eq. 1) for a wind turbine blade, control over the power output and the blade loads of the turbines may be achieved through the manipulation of a number of factors namely: the flow velocity through a variable speed rotor, the blade length, the blade incidence angle through the variation of blade pitch or the blade section aerodynamics (Berg *et al.*, 2008). Implementing DBD actuators onto the wind turbines would enable load control to be obtained through the manipulation of the blade section aerodynamics.

$$L = \int_{r=0}^{b_t} \frac{1}{2} \rho [C_{L\alpha}(\alpha + \theta_{pitch} + \alpha_o) \{V_{wind}^2 + (2\pi nr)^2\} c] dr \quad \text{Eq. 1}$$

The aerodynamic performance of each blade section is unique and instantaneous due to the fluctuating nature of the relative velocities on the blades. Therefore, improvements in the local velocity field that varies both in the spatial and temporal manner across the blade would be required to achieve optimum wind power extraction of the system and to moderate the loadings sustained by the blades (Nelson *et al.*, 2008). Plasma actuators, being easily implemented across the turbine blades, would ensure that flow fields around the blades are modified effectively and efficiently when required. DBD actuators are able to modify the characteristics of a fluid flow by generating a mass-less wall jet in the boundary layer of the flow. The introduction of this mass-less wall jet injects momentum into retarded boundary layers thereby delaying separation or even reattaching flow that has separated completely (Cerretelli *et al.*, 2010). Delaying separation and stall therefore allows for an effective load reduction control on the blades which in turn leads to a vital role in improving power extraction efficiencies of the turbines and even improving the life cycle of the system (Fig. 4).

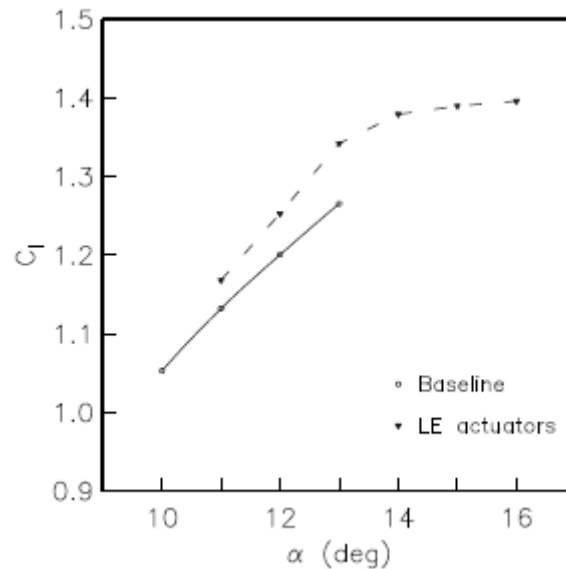


Fig. 4: Comparison of lift versus angle of attack with plasma actuator activated (LE actuators) and without plasma actuators (Baseline) (Nelson *et al.*, 2008)

Various works conducted with DBD actuators have successfully demonstrated the ability of these devices to control flow separation in numerous applications involving

turbine blades and airfoils. Huang *et al.* (2006) demonstrated that the actuators were able to produce a steady two-dimensional wall jet to energize flow near locations of separation by drawing in ambient fluid towards the wall and accelerating the fluid in the downstream direction. Plasma actuators were therefore found to be advantageous on low-pressure turbine blades as they were able to substantially reduce the separation region and that the actuators can operate only when needed and do not produce parasitic effects when they are not in use (Huang *et al.*, 2006).

Works conducted by Post & Corke (2004) and Orlov *et al.* (2007) investigated the use of DBD actuators placed near the leading-edge locations on airfoil for separation control. Plasma enhanced aerodynamics for the purposes of leading-edge separation control was found to significantly delay the separation and increase the stall angle of attack of the airfoil regardless of whether steady or unsteady actuation was used (Orlov *et al.*, 2007). Results obtained by Post & Corke (2004) demonstrated that actuators placed at the leading-edge were highly effective in reattaching leading-edge flow separation resulting in a significant suction-pressure recovery and drag reduction on the airfoil. This work also demonstrates that the body force vector contributing to the momentum addition into the flow boundary layer was successfully estimated mathematically for the purposes of the design of actuator-electrode arrangements on a profile wall (Eq. 2).

$$\mathbf{F}_B = \left(\frac{\epsilon_0}{2}\right)(\nabla \mathbf{E}^2) \quad \text{Eq. 2}$$

Similarly, research on separation control over airfoils demonstrates that DBD actuators are effective in controlling dynamic stall vortices and thus improve the lift cycle (Post & Corke, 2006) and are capable of reattaching naturally separated airflow (Jolibois *et al.*, 2008). Jolibois *et al.* (2008) also demonstrated that the electrical power consumption of the actuators may be significantly reduced by placing the DBD actuators close to the separation point and using non-stationary actuation with minimum duty cycle on the plasma actuators. Results from experimentation by Sosa & Artana (2006) also demonstrate that DBD actuators were able to completely eliminate laminar flow separation over an airfoil. This work also successfully evaluates the intensity of the actuation required by the DBD actuators in terms of a non-dimensional power coefficient and the effects of the actuator on the flow conditions (Eq. 3). This relation allows the actuator power input to be determined with respect to airfoil properties and flow conditions.

$$C_W = \frac{W}{0.5\rho U_o^3 b_e \delta} \left(\frac{L_{ele}}{c}\right)^2 \quad \text{Eq. 3}$$

These works demonstrate that DBD actuators are capable of delaying separation and even reattaching certain separated flows for the purposes of stall and load control on airfoils (Fig. 5). Important relations between actuator parameters, flow conditions and airfoil parameters have also been successfully established. Results of these works viewed collectively present the potential of DBD actuators to be a practical and plausible means of controlling the adverse aerodynamics loads sustained by wind

turbines. Once these relations are established, further investigative works implementing DBD actuators on turbine blades are required to establish these devices as a feasible alternative of separation and stall control for wind turbines. With the various advantages DBD actuators possess over other active airflow control techniques; these devices would significantly advance the wind turbine industry by providing an efficient and effective load control method for turbine blades.

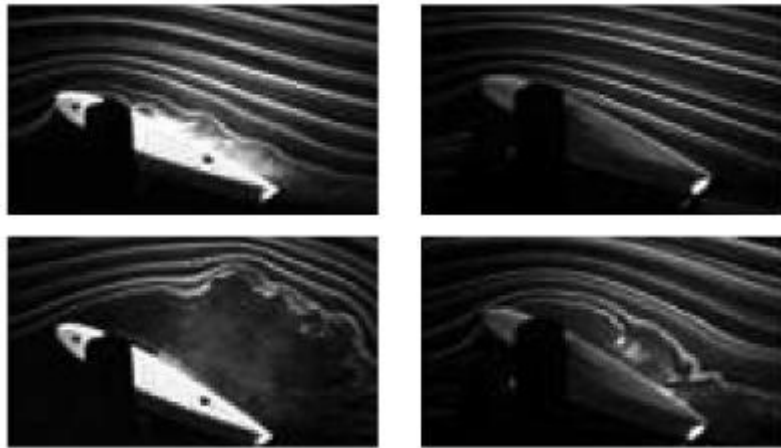


Fig. 5: Flow visualization records for no actuation (left column) and steady plasma actuation (right column) (Post & Corke, 2006)

CONCLUSION AND RECOMMENDATIONS

Current researches conducted have successfully demonstrated that DBD actuators are an effective means of separation and stall control. The work presented here demonstrates that DBD actuators may be a feasible method of load control for wind turbine blades. DBD actuators, being advantageous over other conventional methods of active airflow control have the capacity to significantly improve the efficiency and performance of wind turbines. These devices may be activated with a high frequency response and therefore would be able to provide load control on an ‘as required’ basis. When not in use, these devices do not introduce parasitic drag on the turbines. Coupling this with the low power consumption of the devices, a significant improvement in the life cycle, performance and efficiency of the wind turbines with DBD actuators as load controls would be expected. This paper demonstrates that further investigations into the implementation of DBD actuators on wind turbines for the purposes of load control is a crucial area of research in the wind industry and thus a highly valuable undertaking to ensure the continual development of the field.

ACKNOWLEDGEMENT

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DISCLAIMER

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Reviewer # 2

1. The English is acceptable but could be significantly improved by the editing of a Native English speaker. The flow is difficult to follow in places. Some of this has been corrected in the attached PDF. These corrections while minor individually constitute major revisions to the paper when considered in total.

Response: Good use of English has been expressed in the revised manuscript. Corrections highlighted by reviewers have been equally adhered to and effected. More references have been added to further enhance the quality of the manuscript.

2. Title: Replace Thermo-physical with Thermo-physical.

Response: Correction effected.

3. Page 2, Materials and Methods: Discussion of replicates, but no mention as to whether these are duplicate, triplicate or other, please specify.

Response: The Materials and Methods section have been revised based on Reviewer 1's comment.

4. Tab. 1. Replace with Table 1.

Response: Correction effected.

5. I am not convinced that all of the methods need to be restated in the manuscript given that they simply follow the standard methods described by the American foundry society (AFS), citation of this is perhaps all that is required with consequential considerable savings in space.

Response: Since all the methods follow AFS's, this section have been revised based on Reviewer 1's comment to considerably save space.

6. I think the number figures is excessive. Suggest composite some of the figures which have the same scale into one figure containing all the other figures. The individual figures can be designated a, b, c, d etc. This would also allow more easy intercomparison of the parameters determined that depend on sawdust percent.. This would also require renumbering of figures throughout the text.

Response: The range (values of y-axis) of the parameters measured had wide differences, putting all the figures together on a graph seems impossible though x-axis values are same for all.

7. The figure legend are inconsistent in labelling of the blends 70/30, BD 70/30, P70/30 etc. These need to be representative of the blends and not of the parameter being studied.

Response: Figures legend have been corrected and made consistent to represent the blends and not parameters studied.

8. The table format of the two tables is different and needs to be consistent.

Response: Table. 1 and Table. 2 are now consistent (same format).

9. Is Figure 1 necessary? I think it can be removed without loss of information, provided a suitable reference is given.

Response: Figure 1 has been removed in the revised manuscript.

OPTIMISING HYDROPOWER GENERATION THROUGH FLUID DYNAMICS RESEARCH

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ABSTRACT

A team of researchers from the University of Tasmania are leading the way in realising efficiency improvements and optimising hydropower generation. The headworks of hydropower stations are often several kilometres long with tunnels, open channels and pressurised pipelines transporting water from storage dams to the turbines. Significant efficiency improvements can be made by removing the thin biological slimes that grow on the walls of these conduits.

The team is studying the physics of the flow over these biological growths in both open channel and pipeline environments to understand the mechanisms for drag production through full scale testing on hydropower schemes and an extensive experimental program using dedicated laboratory rigs. This paper discusses the results to date, including: improvements of up to 25% in headloss in penstocks, modifications to the structure of the boundary layer and significant increases in friction coefficient, and details the new experimental pipe rig under development to further these studies.

INTRODUCTION

The majority of the electricity supplied in Tasmania, Australia, is produced by 29 hydropower stations operated by Hydro Tasmania. The potential for hydropower development in Australia has been well exploited, and operators are now investigating means to increase output from existing schemes, including efficiency improvements in water conduits. The University of Tasmania, in partnership with Hydro Tasmania, have been investigating headloss in hydropower conduits since 2003 over a series of three Australian Research Council Linkage Grants.

Some hydropower schemes require the transport of water over long distances from storage dams to power stations by way of tunnels, canals, flume, pipelines and penstocks (pressurised pipelines). These conduits are susceptible to the growth of freshwater biofilms which adhere at the liquid-solid interface as a thin biological slime and impede the flow of water. Biofilms consist of biological matter, including bacteria and algae, as well as trapped debris (e.g. dead organic matter, leaves, dirt, silt).

Biofilms can be grouped into three distinct categories: low-form gelatinous, filamentous or hard deposits. Natural biofilms may consist of one or more of these components – e.g. freshwater fouling in open canals can consist of a low-form gelatinous slime as well as alga filaments, and the fouling on ship hulls may comprise hard deposits (e.g. barnacles) as well as soft slimes or filamentous alga. Filamentous alga cause higher drag penalties than low-form biofilms (Lewkowicz & Das 1985; Schultz 2000), however, there have been few studies that examine in detail the physics of flows over alga filaments, or isolate the filaments from other biofilm components.

The detrimental effect of biofilms on skin friction drag has been well established over the last century and spans many industries including the shipping industry, hydropower generation, bulk water supply and cooling systems. However, the mechanisms behind the increase in skin friction due to biofouling are not as well understood.

Much research has been done on the effect of biofilms in the marine environment including full-scale ship trials (Lewthwaite *et al.* 1985; Townsin 2003), laboratory experiments (Schultz & Swain 1999; Schultz & Swain 2000) and economic analyses (Schultz *et al.* 2011). Lewthwaite *et al.* (1985) measured an 80% increase in skin friction and 15% loss in ship speed on a 23 m vessel over a 2 year period, which was attributed to the presence of a slime film. Townsin (2003) provided a good summary of fouling on ships and also conducted a full scale ship trial and found an increase in frictional resistance of 5% due to a slime film accumulated over a 40 day period. Schultz & Swain (1999; 2000) conducted detailed boundary layer measurements on marine biofilms in a recirculating water tunnel. A 68% increase in local skin friction coefficient was measured for a slime film when compared to a smooth surface.

The effect of biofilms on freshwater systems has also been studied. Minkus (1954) measured a reduction in pipeline capacity of 23% over 5 years due to a thin microbial slime deposit. Brett (1980) provided historical headloss data for Hydro Tasmania conduits. In open channels, biofilm growth causes an increase in depth to maintain flow rate, or a reduction in capacity to maintain adequate freeboard. In hydropower pipelines, biofilm growth increases the frictional headloss (energy loss) which corresponds to a reduction in efficiency and hence a lower generating capacity and less revenue.

This paper describes a large body of multidisciplinary work that investigates energy loss in water conveyances due to biological growths. The scope ranges from a scientific understanding of the physics of the flows over freshwater biofilms, measuring the headlosses in hydropower penstocks, to developing mitigation and control strategies.

EFFICIENCY IMPROVEMENTS IN HYDROPOWER PENSTOCKS

Headloss tests were conducted in hydropower pipelines pre and post removal of biofouling from the internal surfaces by high pressure water blasting to determine if efficiency improvements could be made by cleaning. Details of each pipeline tested are given in Tab. 1. Each pipeline was instrumented with two industrial pressure transducers at an upstream and downstream location (e.g. Fig. 1a) to cover the greatest possible length of conduit. Volumetric flow rate was measured using ultrasonic flowmeters (see Fig. 1b). Pipeline water temperature and ambient air temperature were recorded periodically for both pre- and post-clean testing (Barton *et al.* 2008). The water

Tab.1 Power Scheme Details

	Wilmot Penstock	Tungatinah Penstock 4	Poatina Penstock	Tarraleah Hilltop Pipeline
Output (MW)	35	125	300	90
Operating head (m)	252	300	835	299
Tunnel length (m)	4076	-	1008	-
Pipeline length (m)	526	877	1684	2141
Test section length (m)	332	-	2692	1074
Penstock diameter (m)	1.98	1.7 - 2.3	2.6 – 3.1	2.6

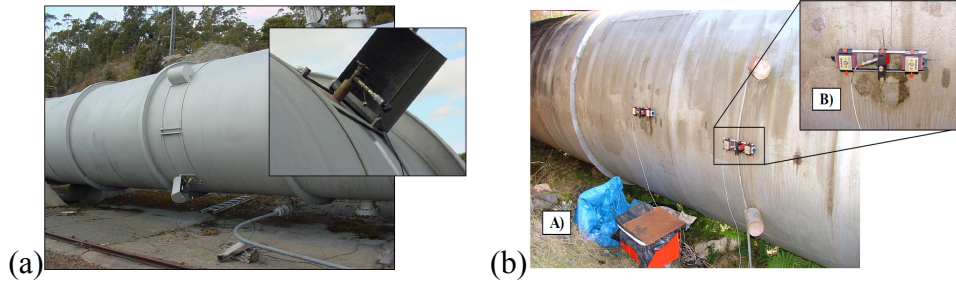


Fig. 1: (a) Pressure transducer on Poatina Penstock; (b) Ultrasonic flowmeter on Tarraleah Hilltop Pipeline

level in the upstream and downstream lakes was determined from Hydro Tasmania's centralised time series database.

The energy equation [1] was used to determine the total headloss between the two pressure tapping points, upstream and downstream, on each conduit. The static pressure, P , was measured using the pressure transducers, the velocity, V , was determined from the flow rate measurements and the elevation of the measurement points, z , was known, thus the only unknown variable was the total headloss, H_L . The total headloss consists of friction losses and minor losses, such as a bends, pipe transitions and valves, which were accounted for using standard loss coefficients. The friction loss can then be used to determine the friction factor using the Darcy-Weishbach equation [2].

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + H_L \quad [1]$$

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad [2]$$

Full-Scale Results

Wilmot Penstock

The Wilmot Penstock was tested in 2003. Only the penstock was cleaned and there was an estimated 12 months growth at the time of the pre-clean tests. The physical roughness of the biofilm was 1-4 mm. The test section length in this case was 332 m. Barton *et al* (2008) report a reduction in headloss as a result of cleaning of 1 m at a flow rate of 15 m³/s and a reduction in equivalent pipe hydraulic roughness from 0.21 mm to 0.04 mm.

Tungatinah Penstock 4

Tungatinah Penstock 4 was tested in 2004-2005, and had previously been tested in 1977. There was only a small reduction in roughness value, and the initial value was quite low, which suggests that there was not much biofouling in the penstock. The maximum reduction in headloss was 0.8 m.

Poatina Penstock

The Poatina Penstock includes sections of steel lined tunnel and steel surface penstock and had never been cleaned prior to 2004. Before cleaning, the biofilms were observed to be 2-5 mm and 1-3 mm thick in the tunnel and surface penstock sections, respectively (Barton *et al*. 2008). In June 2010 the biofilm was found to be < 0.5 mm in thickness.

There was no difference in the headloss for the entire test section between clean and fouled conditions. However, historical results show that the total headloss had increased with time. Considering the tunnel penstock and surface penstock separately revealed that conditions in the tunnel penstock improved significantly. The condition of the

surface penstock lining was poor and the fouled pipe hydraulic roughness was actually less than for the clean pipe measurements (Barton *et al.* 2008). As a result, the surface penstock is being completely refurbished in 2011, and headloss tests will be undertaken pre and post refurbishment.

Tarraleah Hilltop Pipeline

The Tarraleah Hilltop Pipeline was previously cleaned in the 1960s. The biofilm in the No.1 Pipe was 2-4 mm thick, with smaller areas of much thicker biofilm also observed. Barton *et al.* (2008) report a 2 m reduction in headloss as a result of cleaning, which represents a 25% improvement.

Discussion of Full-Scale Results

The full-scale headloss tests have shown that biofilms increase headloss and gains in power production can be made by removing them provided the underlying surface is in good condition. However, information is still required on biofilm regrowth rate. An opportunity exists with the relining of Poatina Penstock to monitor headlosses over the next few years as the pipe begins to foul. Pressure probes and flow meters could be semi-permanently installed and monitored regularly.

Barton *et al.* (2008) plotted the fouled pipe data in terms of a Moody diagram, which is used in pipe design. An example plot for the Wilmot Penstock is given in Fig. 2. Similar results were obtained for the other pipelines tested. The biofouled data deviates from the Colebrook-White friction law, which is typically used in engineering calculations to determine the hydraulic roughness from the friction factor (Barton *et al.* 2008). The clean pipe data trend is as expected for a typical engineering roughness. More data over a wider range of Reynolds numbers is needed to fully understand what happens when the pipes are fouled.

Purpose Built Pipe Rig

The potential for biofouling to deviate from the Colebrook-White relationship requires further investigation. The Moody diagram is widely used in industry to predict the impact of surface roughness on flow. The strength of the method lies in the universality of behaviour when based on dimensionless parameters and significant amounts of quality data will be required for this methodology to be challenged. However, given that industry continue to use the method for design and asset management decision making, it is imperative that the problem be further investigated.

Obtaining outages to perform headloss testing is increasingly difficult, given Tasmania's entry in the National Electricity Market and lower than average rainfalls in recent years.

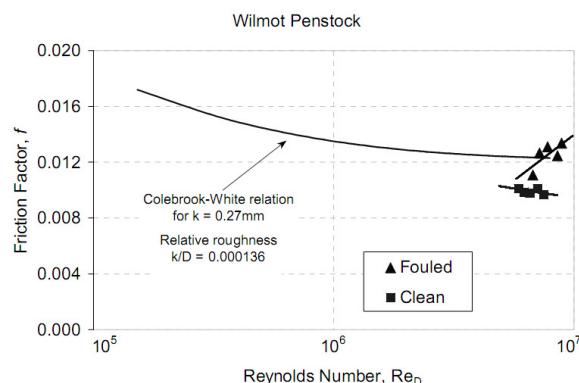


Fig. 2 Moody diagram for Wilmot Penstock



Fig. 3 Field pipe rig

To allow more flexibility in tests and to obtain the significant amount of data required, a new pipe rig has been designed and constructed to study in detail the flow through biofouled pipes. The installation consists of two separate rigs: one located in headworks of the Tarraleah Power Scheme (Fig. 3) and one located in the laboratory at the University of Tasmania in Hobart (under construction). Each rig contains a removable test section which is first placed in the field to allow the growth of biofilms, and then installed in the laboratory for detailed measurements. The mild steel test section is 1.5 m long and 100 mm diameter and was internally coated with a protective coating.

The field pipe rig consists of a pump situated in a hydropower canal which pumps water through a flexible hose to the test section. The water is then discharged through another section of flexible hose back into the canal. The laboratory rig consists of a long upstream section of similar pipe to the test section to allow the flow to stabilise before it enters the test section. The rig will be instrumented with pressure transducers and flow meters to allow the headloss due to the biofilms to be established. The velocity profile will also be examined, most likely by traversing a small Pitot probe through radial axis of the pipe. Preliminary results are expected by mid 2011.

PHYSICS OF THE FLOW OVER BIOFILMS

A purpose-built recirculating water tunnel (Fig. 4) was used to investigate the physics of the flow over freshwater biofilms (see Andrewartha 2010; Sargison *et al.* 2009). The consensus in the literature is that biofilms increase skin friction drag; however, there is little information about how they affect the structure of the flow. There is a large body of work that has looked at similarities in the structure of the boundary layer between flow over smooth and solid uniformly rough surfaces. The wall similarity hypothesis postulates that the structure of the boundary layer outside the near wall region is not affected by surface condition at sufficiently high Reynolds numbers, with the underlying assumption that the roughness height is small compared to the thickness of the boundary layer (Andrewartha *et al.* 2010b). Detailed measurements were undertaken for flows over both real and artificial biofilms to determine whether or not they conform to the same boundary layer structure as for typical engineering surfaces.

Methodology

Real Biofilms

Biofilms were grown on 1 m x 0.6 m plates installed in Tarraleah No.1 Canal (Fig. 5). The canal is subject to extensive biofouling by the diatom species *Gomphonema tarraleahae* and *Tabellaria flocculosa* (Fig. 6), which cause up to 10% loss of canal capacity. The test plates had two different substrates to mimic ideal and real conditions in hydropower canals: a smooth painted substratum or a sandgrain roughened substratum. The plates were deployed for 2 weeks, 4 months, or 12 months and each plate had a different biofilm thickness, composition and distribution. An example of fouling on a test plate is given in Fig. 6.

The fouled plates were photographed using a high-precision, repeatable method to produce three-dimensional models of each surface using digital close-range photogrammetric methods (see Andrewartha *et al.* 2010a; Barton *et al.* 2010). The models were used to extract cross-sections and statistical roughness information about each surface. The maximum peak-to-valley height of the sample length, R_t , was found to correlate the best with measurements from the water tunnel. Once photographed, the plates were installed in the water tunnel for drag and velocity profile measurements.

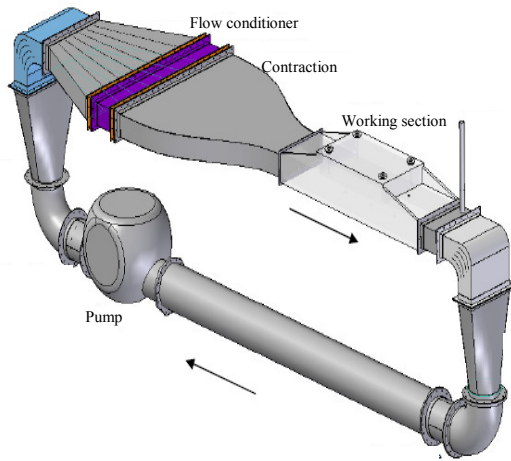


Fig.4 Recirculating water tunnel schematic



Fig.5 Test plate installation in canal

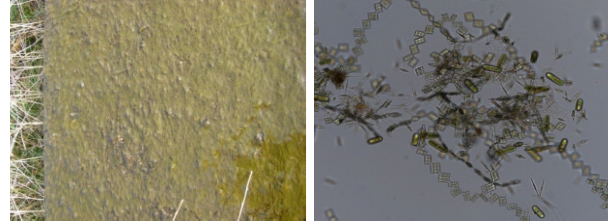


Fig 6 Fouling on a plate

Artificial Biofilms

Filamentous biofilms cause higher drag penalties than low-form biofilms; however, they have seldom been studied in isolation. Artificial streamers were used to study the effect of filamentous biofilms on drag and boundary layer structure in a controlled environment. Artificial streamers consisting of 80 mm long single strand wool were glued to a 1 m x 0.6 m painted plate. The filaments were laid out in a staggered grid pattern with 50 mm spacing in the streamwise and transverse directions. The filaments were glued so that the free ends were leaning downstream, even without flow, as observed with real biofilm filaments.

Measurements

The working section of the water tunnel is 2.2 m long x 0.6 m wide x 0.2 m deep with the test plates suspended from the lid. The flow control devices are described in detail by Sargison *et al* (2009). The water temperature is controlled and was set to 15 °C. Total drag measurements were undertaken to determine total drag force and drag coefficient for each test plate (clean and fouled). Full details are given in Andrewartha *et al* (2010a). Mean and instantaneous velocity profiles were obtained using a two-dimensional laser Doppler velocimetry system to investigate the structure of the turbulent flow over each surface (clean and fouled). Velocity measurements were obtained at $U = 1.00, 1.25, 1.75$, and 2.00 m/s at 70 positions in the boundary layer, with 10,000 random samples obtained per measurement position. The results were analysed according to widely used smooth and rough wall turbulent boundary layer techniques. Full details are given in Andrewartha (2010) and Andrewartha *et al* (2010b).

Results for Real Biofilms

Six fouled plates were studied and the results were compared to clean smooth and rough plates. The nomenclature for the test plates is rough plate (RP) or smooth plate (SP) and C (clean) or F1 (fouled plate number). The maximum peak-to-valley height of each test surface is given in Tab. 2. There was typically more fouling present on the bottom of each test plate due to variations in water level during deployment.

Tab. 2 Max. peak-to-valley heights, R_t [mm], at the top and bottom of each test plate

Location	RPC	RPF1	SPF2	SPF3	RPF4	RPF5	SPF6
Top	1.82	2.10	0.44	0.24	1.79	2.04	0.19
Bottom	1.73	3.31	2.04	0.17	1.87	2.67	2.25

Tab. 3 Summary of variables for drag measurements

Plate	Incubation Time	Average C_D	% Increase over SPC	% Increase over RPC	k_s [mm]
SPC	-	0.0035	-	-	-
RPC	-	0.0089	155	-	2.76
RPF1	11 months	0.0108	210	22	5.58
SPF2	12 months	0.0059	68	-	0.51
SPF3	2 weeks	0.0038	8	-	-
RPF4	2.5 weeks	0.0101	189	13	4.34
RPF5	15 weeks	0.0098	181	10	3.98
SPF6	16 weeks	0.0069	99	-	1.03

Andrewartha *et al* (2010a) report the increases in total drag coefficient (C_D) for each test plate given in Tab. 3. SPF6 had the largest increase in C_D over clean plate values with a 99% increase. The largest increase in C_D for plates with a rough substratum was 22%. Significantly higher drag coefficients and equivalent roughnesses (k_s) were observed on the test plates with a rough substratum. The biofilms were also observed to be much thicker on these plates (Andrewartha *et al.* 2010a). Similar results were found for the local skin friction coefficient (see Andrewartha *et al.* 2010b). These results show that the presence of biofilms increases the skin friction drag.

Fig.8 shows the mean velocity profile for each test plate in velocity defect form (see Andrewartha 2010). The data for each test plate collapse onto the same curve, which indicates that the presence of biofouling does not change the structure of the mean velocity profile. An example turbulence profile is shown in Fig. 9 for the streamwise direction. The data indicates that the roughness affects only the inner region of the boundary layer. Similar results were obtained for wall-normal turbulence profiles (i.e. turbulence in the vertical direction) and Reynolds shear stress profiles. These results show support for the concept of wall similarity over low-form biofilms and indicate that the presence of biofilms does not have a large impact on the turbulence structure in the outer region of the boundary layer.

The objective of any roughness study is to relate the physical characteristics of a surface to the drag it produces. The total drag coefficient is plotted against the average maximum peak-to-valley height of the biofilm on each test plate in Fig. 10. The scatter in the data was expected, given that biofilms are living and of highly variable roughness. The results indicate that the drag coefficient is a roughly linear function of the maximum peak-to-valley height of the biofilm, given by [3].

$$C_D = 0.0030R_t + 0.0032 \text{ (where } R_t \text{ is in mm)} \quad [3]$$

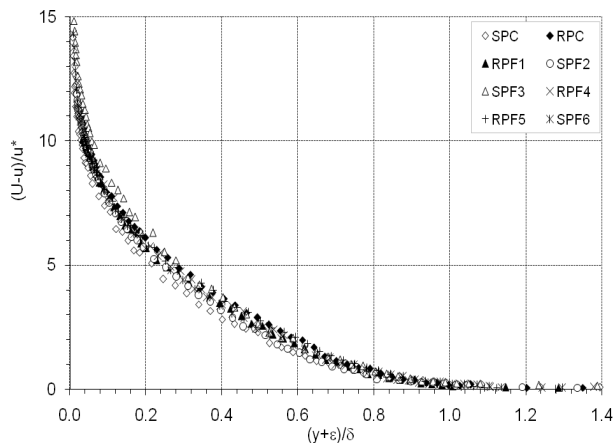


Fig. 8 Mean velocity structure

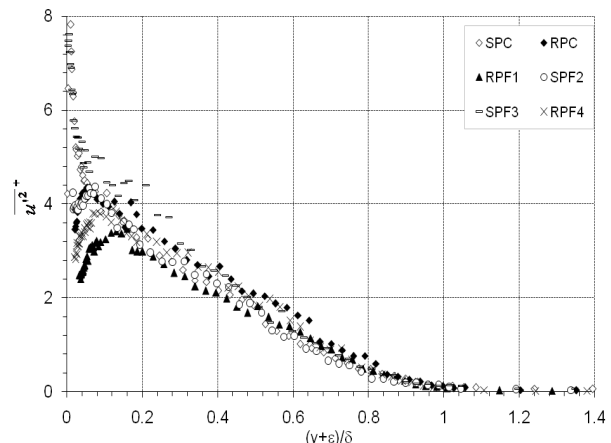


Fig. 9 Streamwise turbulence structure

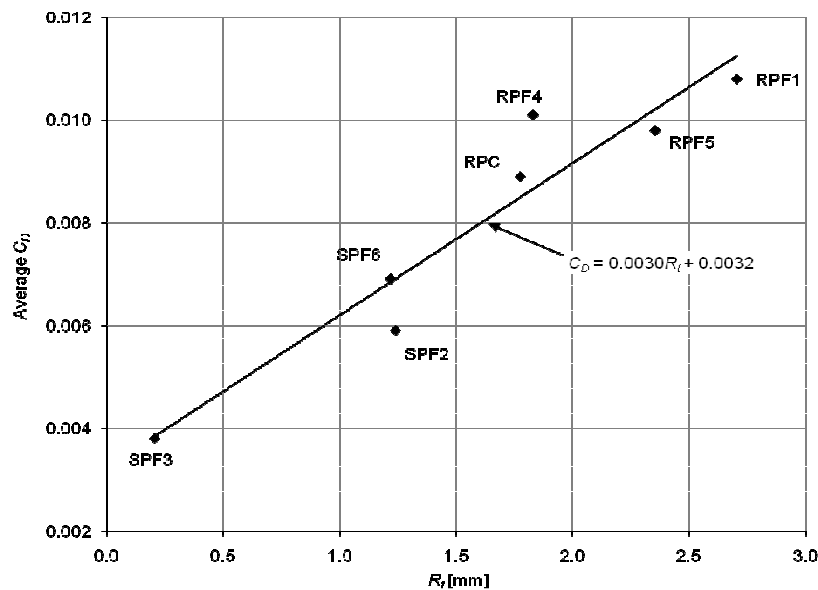


Fig. 10 Correlation of physical roughness with drag coefficient

Results for Artificial Biofilms & Future Work

The local skin friction coefficient for flows over the artificial biofilm was on average 23% higher than that for a smooth plate. Fig. 11(a) shows the mean velocity structure for the artificially fouled plate compared to a smooth plate. Similarly to the real biofilm, the data collapses onto the same curve which indicates that the presence of the streamers does not change the mean velocity structure of the boundary layer.

Andrewartha *et al* (2011) report that the streamwise (Fig. 11(b)) and wall normal turbulence intensity data for the filamentous test plate are both higher than for the smooth plate in a region that corresponds to approximately $y = 1$ mm to the freestream. The turbulence intensity in the very near wall region was not affected by the presence of the streamers. Previous results (Andrewartha 2010) noted an increase in turbulence intensity (max deviation $\sim 20\%$) which corresponded to the maximum extent of outward movement of the streamers. The array used in that study was not staggered and was less dense (100 mm centres compared to 50 mm). In the present study the increase in streamwise turbulence intensity is greater (maximum deviation $\sim 50\%$) and extends over a much greater proportion of the boundary layer.

Work is currently underway to capture the motion of biofilm filaments using high speed photography. Analysis methods to determine the extent of motion and frequency of oscillation of the streamers are under development. The results will be compared with instantaneous turbulence measurements.

MITIGATION AND CONTROL

It is current practice in the open canal at Tarraleah to dewater and physically remove the biofilm using rotary brooms attached to a tractor. However, this method is costly and inefficient, as not all of the biofilm mat is removed. Removal of fouling by high pressure water blasting in pipelines has proved to be effective, but is also costly. Chemical treatment methods have proved ineffective, as the majority of the biofilm mat consists of dead cells and inorganic material (Perkins *et al.* 2009) which is not affected by chemical dosing. Heat treatment methods were also found to be ineffective for the same reasons. The most effective long term mitigation method is to provide as smooth a surface as possible by applying protective surface coatings over newly applied concrete

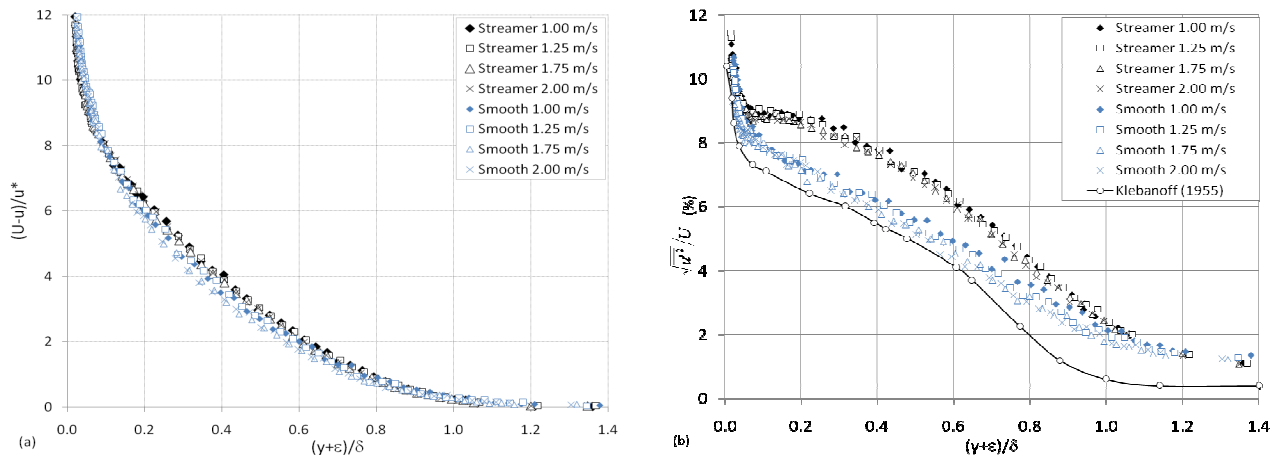


Fig. 11 Artificial biofilm (a) Mean velocity structure; (b) Streamwise turbulence structure

(for open canals). The increased wall shear stress makes it difficult for biofilms to establish. Trials of different surface coatings and substrates found that some coatings perform better than others, and that it is necessary to apply them to a smooth substratum to optimise biofouling mitigation.

CONCLUSIONS

This paper has described eight years of research into increasing the efficiency of hydropower generation through fluid dynamics research. The research has shown that significant improvements in efficiency and hence generating capacity can be made by removing biofouling from the internal surfaces of conduits, as biofouling significantly increases the skin friction drag. The aim of the current research is to move our understanding of wall flows and friction forward from typical engineering roughness to more complex organic interacting surfaces.

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TRANSFORMATION PLANNING FOR INTEGRATING UNMANNED AIRCRAFT INTO UNITED STATES OF AMERICA'S NATIONAL AIRSPACE SYSTEM

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ABSTRACT

The research presented combines Enterprise Architecture and Technology Strategy for analyzing, evaluating, and recommending appropriate solutions for integrating Unmanned Aircraft Systems (UAS) into the United States (US) National Airspace System (NAS). The discussion includes: Issues/interest surrounding UAS operations; Architecting the current state enterprise, Discussion of the future of UAS integration in the US NAS; leadership for success and future work. Technology Strategy coupled with Enterprise Architecting in an incremental systems approach emphasizes the development and application of ways of thinking that bring clarity to the complex co-evolution of technological innovation, the demand opportunity, systems architecture, business ecosystems, and decision-making and execution within the business.

Introduction: Strategic Background

Enterprise Description: The United States National Airspace System

Since the Wright brothers ushered in the age of powered flight and essentially launched an entire industry over 100 years ago in the United States, safety of flight has been a top priority to all involved. Pilots take seriously the responsibilities associated with operating an aircraft. As aviation evolved from a handful of experimental aircraft in the early 20th century, to more than 600,000 certified aircraft sharing the skies today, the air traffic system also advanced to maintain a high degree of safety and efficiency. From no regulations in 1903 to strict regulatory oversight under the US Federal Aviation Administration (FAA) today, pilots fly in accordance with regulations that have served well, as evidenced by the fact that the United States has the safest aviation system in the world [1].

The emergence of the Unmanned Aircraft System (UAS) into the Aviation industry resembles the early days of aviation. During that time, creative minds, engineering talent, and entrepreneurial spirit converged to produce new technologies and designs that spawned a new market, brought aviation to the general public, and altered forever the transportation landscape. Today that same spirit permeates within the UAS industry as innovators are vying to enter and dominate in a new and potentially lucrative market [2]. However, unlike the early years of Aviation, UASs have the challenge of entering a mature civil aviation system consisting of many aircraft, controlled by complex monitoring equipment, dominated primarily by commercial sectors, interest groups, and a large regulatory structure. Integration of UASs into the US National Airspace System (NAS) and their potential market success depends on a complex set of technical, economic, political, and legal factors.

Interest in Unmanned Aircraft Systems

UAS technology has reached a level of maturity that has placed these systems at the forefront of aerospace manufacturing and procurement globally. Interest in UASs continues to grow worldwide. Recent advances in computer technology, software development, light weight materials, global navigation, advanced data links, sophisticated sensors, and component miniaturization are strengthening capabilities and fueling the demand for UASs.

The international and military UAS market is forecasted to be worth \$80 billion by 2020. Currently, there are at least 610 UASs operated or developed in 57 different countries and the projected spending and Research and Development (R&D) continues to increase over the next decade (see Figure 1). Of these, the US is leading in terms of the size, variety, and sophistication of UAS systems, with Israel, France, Germany and the United Kingdom among the main countries involved with UAS procurement and development. In Europe many organizations have efforts under way to solve *sense and avoid* for UAS. In addition, Australian researchers, Canadian Military, the Israeli military and other nations' military are also addressing these challenges surrounding UAS integration through incremental steps examining policy, regulations, standards, technology, R&D, training, operations, procedures and an implementation plan.

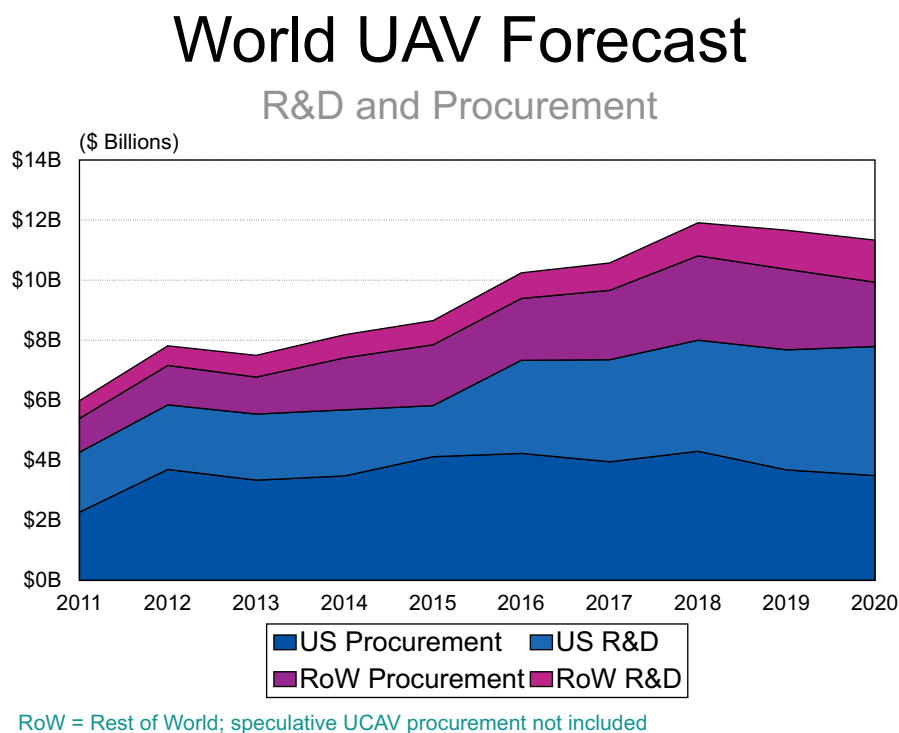


Fig. 1: World UAS Forecast [3]

Military operations in Afghanistan, Iraq, and in support of the Global War on Terrorism (GWOT) have particularly demonstrated the usefulness of UASs for intelligence, surveillance, reconnaissance (ISR), and communication related military applications. The US Army has demonstrated significant strides towards integrating UASs into full spectrum operations, to include airspace integration with piloted aircraft. This essentially paves the way for civil and commercial applications of UASs to emerge in the US National Airspace System. Furthermore, the US Army's integration of UASs

into the Military Aviation community greatly enhanced the safety of UAS flight and also required that the UAS community comply with flight standards, processes, and procedures required for piloted aircraft. As a result, even with the rapid increase in UAS flight hours, the accident rate has decreased greatly since its integration into the US Military Aviation Community and abiding by the respective safety protocols (See Figure 2 & 3). This demonstrates a significant step towards fully integrating UASs into the civil aviation community and with routine access to the US NAS, rather than leaving UASs to operate as an exception. The question is whether the current state of UAS operations within the military community can successfully translate into the civilian and commercial sectors and operate safely and routinely within the National Airspace.

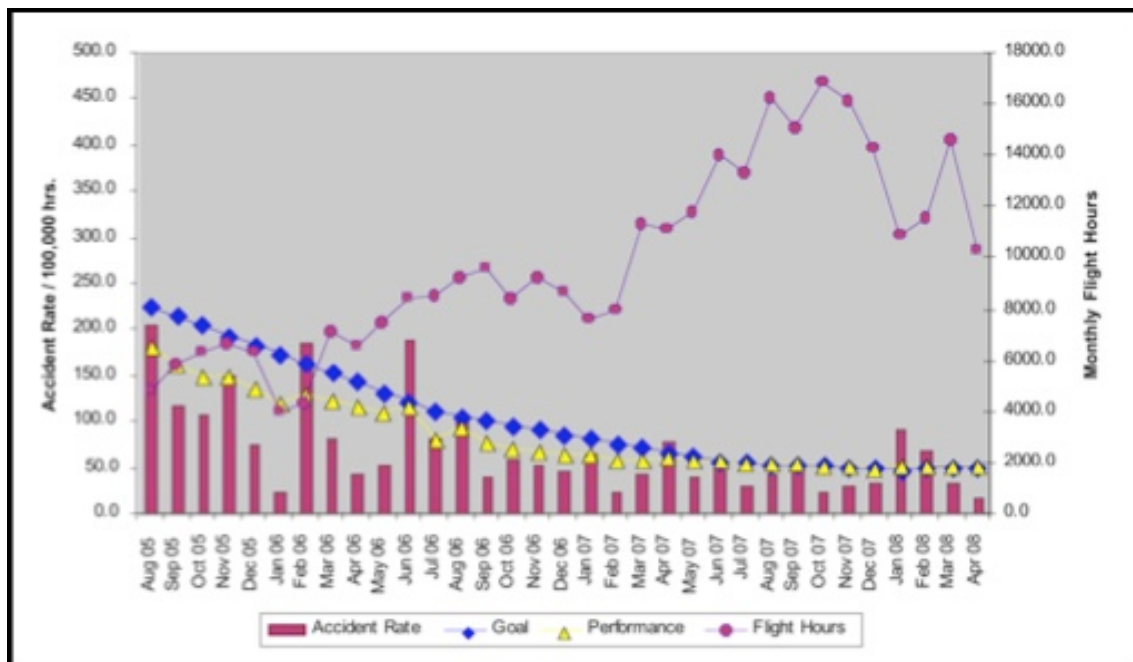


Fig. 2: UAS Accident Rate & Monthly Flight Hours April 2005 - 2008 [4]

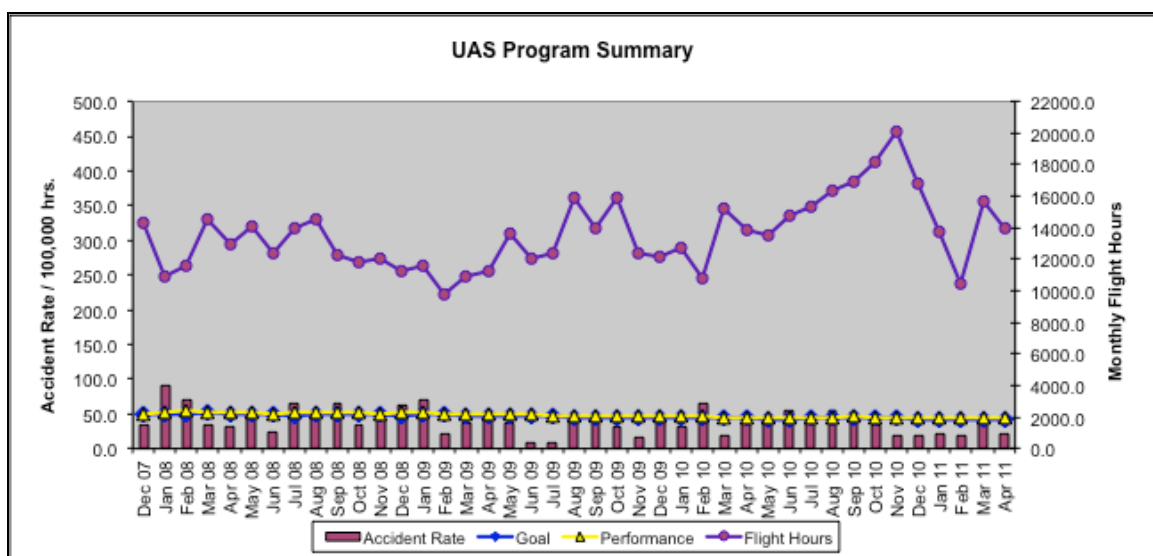


Fig. 3: UAS Accident Rate & Monthly Flight Hours December 2007 –April 2011 [4]

Issues Surrounding Unmanned Aircraft Systems

At issue is the fact that there is no FAA certification or regulatory standards for operating UASs in the US National Airspace System. Instead, the FAA issues Certificates of Authorization (COA) for each and every UAS operation. The COA establishes limitations and requirements intended to prevent accidents between UASs and piloted aircraft. However, many stakeholders within the enterprise feel that UASs need to meet the same certification and operational standards as piloted aircraft, and they must fit into the existing US National Airspace System without any negative impact on general aviation operations. With the exception of UASs, there is not an aircraft operating in the US NAS today that has not complied with strict Federal Aviation Regulations (FARs) governing its certification and maintenance. And again, with the exception of UAS operators, there is not a pilot operating today that has not undergone rigorous pilot certification training and testing. Pilots also comply with very strict FAA general operating and flight rules as outlined in the Federal Aviation Regulations (FARs), including the FAA's important *see and avoid* mandate. These regulations provide the historical foundation of the FAA regulations governing the aviation system. The challenges to UAS airspace integration are multi-dimensional. The three major issues that UASs fail to comply with in regard to the FAA regulation CFR91 include *See and Avoid*, *Command and Control*, and *Airworthiness* [5]. In the United States, the Department of Defense (DoD), Department of Homeland Security (DHS), and the National Aeronautics and Space Administration (NASA) formed a UAS Executive Committee (ExCom) with the FAA to focus on conflict and policy resolution, as well as technical and procedural challenges related to transitioning to routine UAS operations in the US NAS.

The introduction of UASs into the US NAS is a challenging enterprise for the FAA and the aviation community as a whole. The FAA understand the importance of working towards a global harmonization of UAS operations and has partnered with national and international groups focused on UAS safety, standards, and integration to include: Radio Technical Commission for Aeronautics (RTCA) for development of civil UAS standards, European Organization for Civil Aviation EuroCAE for the development of European UAS certification standards, International Civil Aviation Organization (ICAO) Study Group, EUROCONTROL, The University of Mexico under a Cooperative Research and Development Agreement (CRDA), AAI Corporation, GE Aviation, and General Atomics-Aeronautical Systems under a CRDA [12]. UAS proponents have a growing interest in expediting access to the US NAS. There is an increase in the number and scope of UAS flights in an already busy US NAS. The design of many UASs makes them difficult to see, and although *detect, sense and avoid* technology (vs. a pilot's *see and avoid* capability) is under development, the FAA is not quick to accept this as a substitute for the *see and avoid* requirement. Decisions being made about UAS airworthiness and operational requirements must fully address safety implications of UASs flying in the same airspace as piloted aircraft, and perhaps more importantly, aircraft with passengers.

Architecting the Enterprise

Strategic Objectives

The driving forces in the external environment of the US National Airspace enterprise include a very high operational tempo of the United States Army Aviation assets and subsequent aircraft maintenance. Additionally, as previously stated the demand for UAS technology as a fully integrated asset into daily combat and peacetime operations

is expanding and will continue to expand long into the future. In fact, UASs have become such a critical component of military operations, that they flew over 450,000 flight hours in 2009 in direct support of operations in both Iraq and Afghanistan [12]. Based on current guidance, this expansion will not result in a corresponding increase in access to additional civil airspace. This represents a significant challenge to the successful expansion of UAS operations for the military as they continue to expand the usage of UASs in Iraq and Afghanistan, then require additional airspace in the US NAS for sustainment and continuation training as units redeploy from the current conflict. Furthermore, as the civil and commercial demand for UAS usage increases, this is an additional group of stakeholders who will push for access to the NAS [5].

Enterprise Layout – U.S. National Airspace System

In today's US National Airspace System, air traffic control depends on voice communications to relay a wide array of critical information between aircrews and controllers. The use of voice communication is labor intensive and limits the ability of the US NAS to effectively meet future traffic demand. Much work has been done with ADS-B (Automatic Dependent Surveillance – Broadcast), which is a satellite based successor to the current radar system that makes use of GPS technology to determine and share precise aircraft location information and it also can stream additional flight information (i.e. advisories, weather) to the cockpit. It is an integral part of the NextGen National Airspace Strategy for upgrading and enhancing current Aviation operations in the United States.

With the rapid and continual advancement of technology in the areas of aircraft components and air traffic control capabilities, then coupled with the number of requests made to the FAA to fly UAS in the US NAS significantly increasing, the ExComm has developed the *NAS Access Plan* to allow timely expansion of NAS access while working towards viable long-term solutions. This plan establishes a set of recommendations focused on access needs through the assessment of policies, regulations, standards, and technologies that intend to enable more routine access to the US NAS for federal and public UAS operations. Currently, ExComm members are utilizing an incremental phased approach that focuses on the following:

- Near-term activities: high priority mission needs; consideration of technologies, procedures, and a safety and regulatory framework.
- Mid-term activities: focus on validating the safety and regulatory framework; validate standards that enable compliance with existing FARs and conform to existing air traffic control (ATC) standard operating procedures.
- Far-term activities: UASs certification and operating standards to permit routine access to the US NAS without a negative impact on safety and efficiency in the NAS; developing, certifying, and fielding UAS enabling technologies to approved technical standards and performance specifications [12].

“As is” Architectural View

In order to analyze the enterprise in its current state, the National Airspace System enterprise is individually evaluated based on the eight views of the enterprise: strategy, process, knowledge, product, service, IT, information, and policy (See Figure 4).

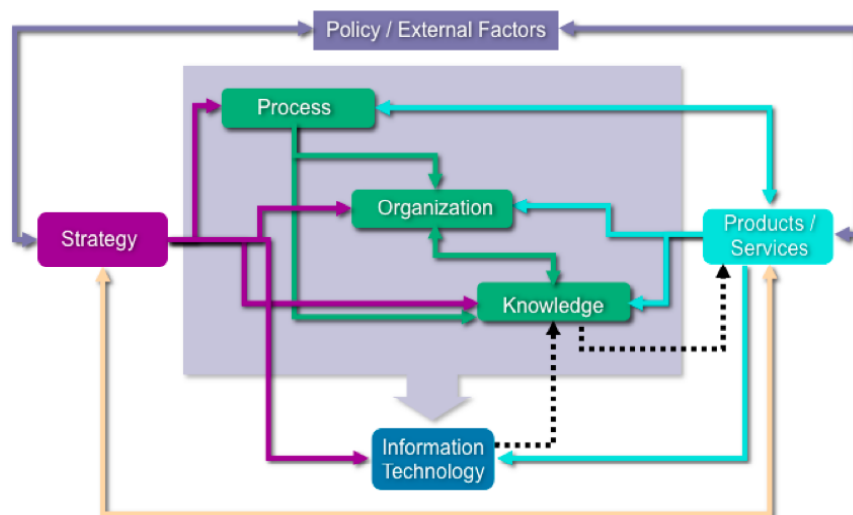


Fig. 4: Enterprise Architecture Views [7]

Through the consideration of issues from these respective *lenses*, one can best envision the enterprise from perspectives generally not considered from an individual stakeholder's analysis or even that from a group of stakeholders when together considering the issues at hand. The motivation behind utilizing enterprise architecting is the need for a sufficiently robust approach that can address the full-spectrum issues surrounding the National Airspace and the integration of UAS into this system. Enterprise architecture is a holistic approach capable of addressing the complexities inherent in the Aviation Community in a systematic manner. So what is enterprise architecture? As defined by Deborah Nightingale and Donna Rhodes: *"Applying holistic thinking to design, evaluation, and select a preferred structure for a future state enterprise to realize its value proposition and desired behavior"* [7]. This holistic approach fits within the broader value-creation framework and enables value capture of the structure, value, and behavior within the enterprise. In the current state of the US NAS enterprise, Policy greatly influences the Product, Process, and Strategy views, which ultimately drives the rest of the enterprise views and aligns other interrelationships. However, Policy seems to be the one view that remains unchanged in the current state. Although the ExComm members are moving forward with some analysis and plausible recommendations for policy in the near, mid, and far term, there are no current shifts in policy change. As a result, in order to comply with the current FAA Policies, one must view the entire enterprise from the perspective of the Product view in order to evolve into the Future State. The effect of applying this methodology is to understand what the enterprise should look like when viewing it from the Product view (followed by the rest of the Views), rather than how the Product is viewed from the enterprise.

A number of recent and current efforts to integrate UAS into the national airspace provide the context for the current enterprise activity. These efforts yield a significant degree of insight into the difficulties associated with creating a sustained effort for solving this issue. The primary views of concern include Policy, Strategy, Product, and Process. However, as demonstrated previously, Policy remains stagnant in the current state of the enterprise with existing standards in effect and no plan for creating separate regulations for UAS operations in the NAS in the near-term. As a result, the three most significant views of concern include Product and Process, which influence the Strategic View. The remaining views are heavily influenced by the aforementioned views and it is important to analyze the enterprise through all views because some are necessary for functionality while others are important for optimization (see Table 1). Enterprise

architecture requires a collaborative effort especially among Strategy, Policy, Process, and Product views in order to experience a successful transformation to the future vision of UAS flight in the NAS.

VIEW	CHARACTERISTIC	EXAMPLE VIEW INTERACTIONS
Strategy	Maintain the current level of safety with the integration of UAS into the NAS; enable increased capacity in the NAS.	Highly dependent on the Policy and Product views.
Policy	Conform rather than create; avoid separate policies for UAS.	Unchanged in the present and will most likely remain the same in the near term; Result: Strategy, Process, and Product highly coupled with Product most directly having to conform to the Policy view.
Process	Must link the process to the strategic goals and product specifications; eliminate communication gap and encourage cross-talk among and across organizations.	Strong relationship to Policy and Product architecture; complex processes exist for airworthiness, airspace operations, and integration of UAS in to the NAS.
Organization	Numerous interested organizations, research groups, and collaborative team members with holistic perspective.	Determines knowledge requirements and must be aligned with process architecture.
Knowledge	Requires a robust method for processing, accepting, verifying, and validating submitted data	Strong relationship with both product and org. arch.; both influences and is supported by IT arch.
Info Tech	Command and Control and security issues are highly important as the NAS continues to progress digitally	Highly coupled with Knowledge and supports relevant product/process information shared seamlessly across the enterprise
Product	Sense and Avoid equipage requirements: Modular vs. integral design; Need an integrative design with a large number of entrants to the market.	Strategy, Product, and Process views have high interaction; driving metric for all views
Service	Maintain safe airspace; increase capacity	Heavily drives product arch.; support requirements inherent in knowledge employed by teams in Process and Org. architectures

Table 1: NAS Enterprise – Stakeholder Value Exchange

UASs are the technology of choice in numerous government agencies and departments and there is a growing interest among commercial companies for UAS usage. They are used more frequently in the Global War on Terrorism (GWOT) effort both at home and abroad. The DoD, DHS, and NASA are developing plans to use UASs domestically. Unless these aircraft meet FAA certification standards established, large airspace restrictions are necessary to segregate piloted aircraft from UASs in the near-term.

Transforming the Enterprise

Vision and Design for the Future Enterprise

At the core of delivering value is the need to move the enterprise from its current architecture to the desired future state. An enterprise transformation plan describes in detail the actions and results to be achieved in order to move the enterprise from its current position to the one envisioned by the future enterprise architecture. So what does the future state look like for this enterprise? The strategic objectives for the US National Airspace System consist of *increased safety, greater capacity, international leadership, and organizational excellence*.

After a thorough analysis of these strategic objectives, the current enterprise architecture, stakeholder values, and an assessment of the constraints, the following characteristics of the future integration of UASs into the NAS emerge [9]: *Safety, conform to existing policy; Provide flexible airspace operations that enable mission execution and minimizes the impact on airspace capacity; Implement and remain within resource constraints; Integrate policy, procedures, and technology for all airspace operations; Reduce cost and training/operational overhead*

The future vision of success ultimately reflects routine UAS flights within the National Airspace that seamlessly operate without hindering safety or airspace capacity. However, it is a long road to reaching this vision and will require an phased approach to transition from the current “by exception” method of flight, to UASs fully integrated and compliant with airspace regulations and operations. A simple, incremental systems approach is essential to fulfilling the previously mentioned objectives and will drive rapid performance improvement with relatively minor changes. A UAS collision-avoidance system must cover many different types of operations. It is one thing for a remotely piloted Global Hawk to climb into restricted military airspace to altitudes above Flight Level 180, where all air traffic is under positive ATC control, and then climb above FL500, where there are very few aircraft. But it is more challenging to also support a wide range of UAS sizes when the aircraft are below 18,000 ft. Here, piloted aircraft will often be flying under visual flight rules (VFR) in a *see and avoid* environment. In order to capture UAS operational needs, the ExCom recently worked with the various stakeholders to identify each organization’s individual NAS access needs that are critical to meeting organizational missions. These needs are summarized in Table 2 below:

DEPT / AGENCY	REPRESENTATIVE MISSION NEEDS	PROPOSED ACCESS PROFILES
DoD / DHS / NASA	• Training • Development & Test • Maintenance & Checkout	Line of Sight 
DoD	• Tactical Surveillance & Reconnaissance • Pilot / Operator Qualification Proficiency	
DHS	• Border / Maritime Surveillance	
NASA	• Aeronautical Research	
DoD / DHS / NASA	• Training • Take-off / Landing Proficiency • Disaster Relief	Terminal Area 
DoD / DHS	• Surveillance & Reconnaissance • Aircraft and Payload Systems Testing	
DHS	• Border / Maritime Surveillance	
DoD / DHS / NASA	• Aircraft Deployment and Ferry	Lateral Transit 
DoD / DHS	• Transit to Training Airspace	
DHS	• Border / Maritime Surveillance	
NASA	• Aeronautical Research	
DoD / DHS / NASA	• Aircraft Deployment and Ferry • IFR Qualification & Proficiency	Vertical Transit 
DoD	• Orbit Operations	
DHS	• Border / Maritime Surveillance	
NASA	• Aeronautical Research	
DoD / DHS / NASA	• Research and Development	MOA 
DoD / DHS	• Training • Testing	
DHS	• Maritime Surveillance	
NASA	• Aeronautical Research	
All	• Operational Missions • Training Missions • Support Missions • Scientific Missions	Dynamic 

Table 2: Common UAS Access Needs [12]

Current Near Term Efforts

In order to achieve the vision and meet the strategic objectives previously discussed AND support the additional requirements of UAS operations in non-segregated airspace, Data Communications (Data Comm) will assume an increasing role in controller to flight crew communication, contributing significantly to increased efficiency, capacity, and safety of the NextGen National Airspace. Within the spectrum of the NextGen efforts also includes technological concerns and development in the areas of frequency and bandwidth, sense and avoid, and automation involving advanced algorithms.

The evolution of Data Comm in the operational environment will be based upon the incremental implementation of advanced communication capabilities. Data Comm represents the first phase of the transition from the current analog voice system to an ICAO compliant system in which digital communication becomes an alternate and eventually predominant mode of communication. Data Comm will enable Air Traffic Controllers to send digital instructions and clearances to pilots, provide precise visual messages that appear on the cockpit displays, and can then interact with the aircraft's flight computer system. As depicted in Figure 5, the operations and services enabled by Data Comm will allow air traffic controllers to manage more traffic, increase the capacity of the NAS, increase airspace user efficiency, enhance safety, and evolve into a high performance airspace – all strategic objectives of the enterprise.

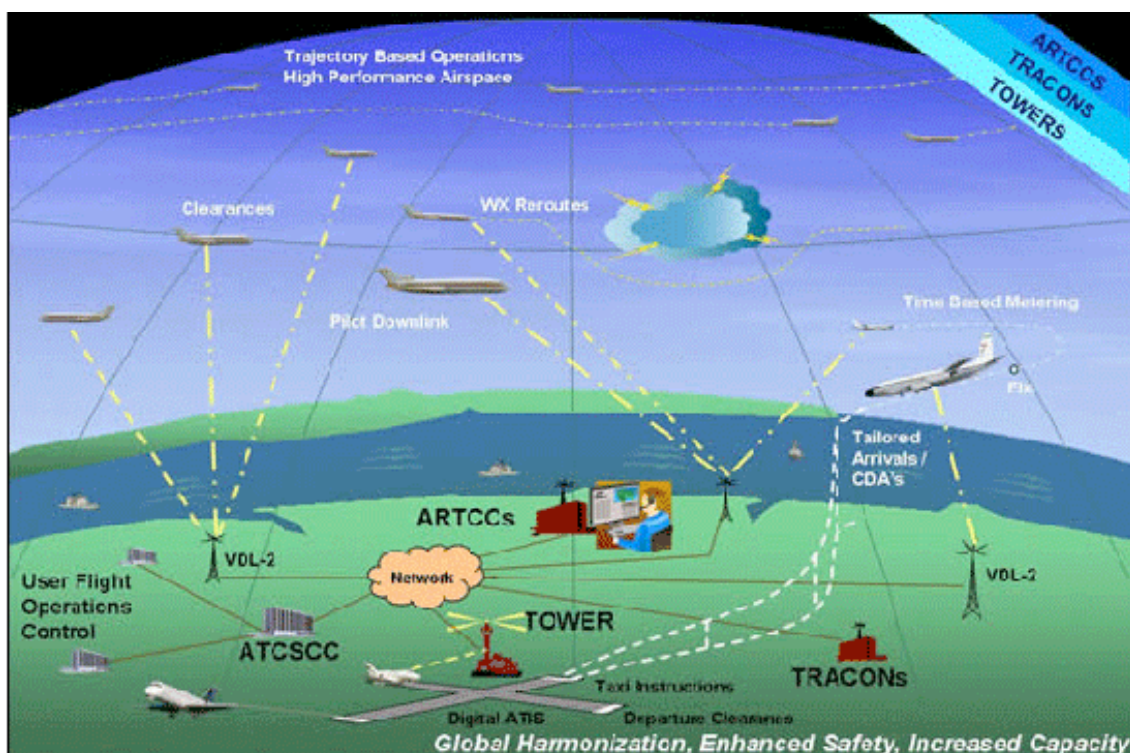


Fig. 5: Vision of a High Performance Airspace [6].

The Data Communication program is a key element in the implementation of Next Generation Air Transportation System (NextGen). It will improve and modernize the National Airspace's aviation infrastructure, which includes airports, airways, aircraft and the air traffic management system. NextGen Data Communications program will

allow the National Airspace System to handle more traffic, reduce flight delays, route aircraft more efficiently, and enhance safety all while reducing operational costs for airspace users. The majority of pilot-controller exchanges will be handled by Data Communications for appropriately equipped users, and eventually become normal operating procedure. The operations enabled by Data Communications will have the added financial benefits of reducing ground delays and significantly increasing fuel savings through more efficient routes and optimized profile descents. Reduced fuel use will have the important environmental benefit of reducing aviation carbon dioxide and other greenhouse gas emissions.

In 2006, the Project Manager for Project Manager Unmanned Aircraft Systems (PM UAS) described a potential early sensing system that integrated and fused radar data to provide accurate, real-time situational awareness to a UAS operator. The operator would make decisions to safely avoid other aircraft based on the sensor data being displayed in the ground control station. The US Army has worked with the FAA and Joint Unmanned Aircraft System Center for Excellence (JUASCOE) to identify the technical and operational needs, and capabilities for the development of standards and specifications for a *sense and avoid* system. As a result of efforts from the now dissolved Joint Integrated Process Team (JIPT), the FAA, and PM UAS this plan has now evolved into a solution called Ground Based Sense and Avoid (GBSAA) led by the Project Manager Air Traffic Control (PM ATC) [10]. PM ATC has formed a full-time GBSAA team to demonstrate a *system-of-systems* solution that can be tailored to various installations and missions to include deployable applications to serve the needs of all Military Branches of Service.

GBSAA is a “ground based means of detecting an airborne intruder and declaring a threat, in time to allow the UAS to adopt a safe state” [11]. It provides situational awareness information to UAS operators on the ground (*sense*) to enable them to maintain separation by maneuvering the unmanned aircraft away from the traffic (*avoid*). GBSAA functional evolution consists of using existing sensors to create airways, supplemented with fixed based air traffic control and military radars dispersed across the flight areas, and provides a fused and integrated picture of the airspace (See Figure 6). Creating these airways and integrating GBSAA with existing aircraft sensors may expand airspace operations, reduce restrictions, and assist in the development of requirements for future onboard *sense and avoid* sensors.

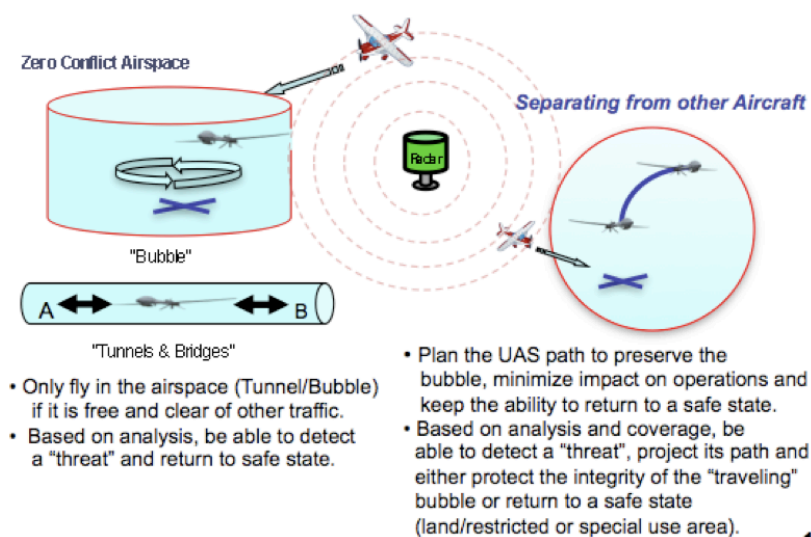


Fig. 6: GBSAA Functional Evolution [11]

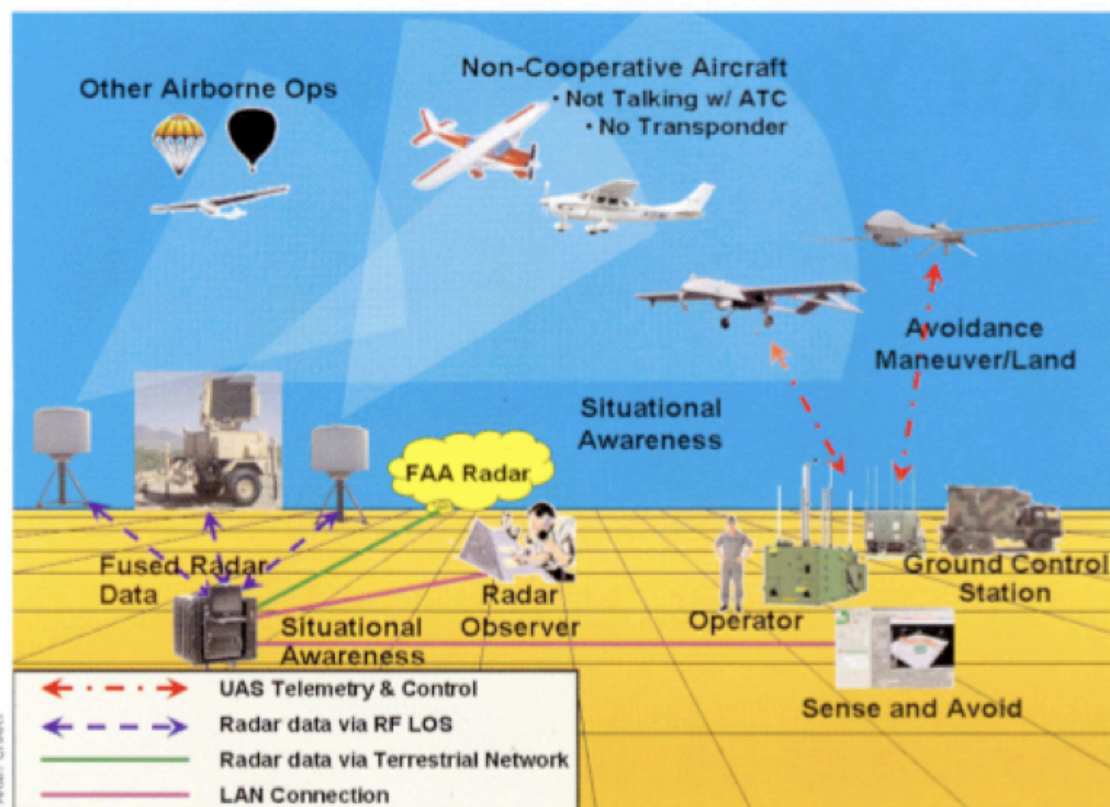


Fig. 7: GBSAA Concept for Safe UAS Operations [10].

The illustration in Figure 7 depicts several ground-based radars observing multiple targets with the radar feeds processed on the sensor fusion node. This process yields the consolidated air picture, which provides the UAS operator with situational awareness to avoid other air traffic in accordance with the FAA regulations. The US Army developed the GBSAA concept to provide a system of radars and other sensor technologies, sensor processing, and a command and control display to show a three-dimensional picture of all air traffic and protected airspace around the UAS. This provides the UAS operator visual and audio alarms to warn of impending conflicts with the UAS. The GBSAA mitigates some of the risks associated with flying UAS in the NAS and efforts are underway to prove that it meets a satisfactory level of safety. GBSAA is currently in use at El Mirage California and Fort Huachuca Arizona, with near term expansion to Fort Benning Georgia, Fort Bragg North Carolina, Fort Campbell Kentucky, Fort Hood Texas, and Fort Leonard Wood Missouri [10].

Until engineers can imbed sensors into UAS design and gain approval from regulatory agencies, GBSAA allows UAS operations without sensors on the actual aircraft and with existing technology, this reduces weight, drag, and fuel consumption and complies with FAA guidance. Integrating GBSAA with existing aircraft sensors will expand UAS operations and propagate the development of future on-board *sense and avoid* technology. Such technology combined with integrated flight and mission computers may yield a semi-autonomous UAS system, which enables a UAS to respond to hazards without human input. Although many efforts are underway, the US Army is leading in the integration of UAS operations into the NAS with its efforts surrounding GBSAA. The ExComm's near-term implementation products include Interagency Agreements, Site Transition Plans, and technical developments with the use of GBSAA. In the mid-term, the plan outlines certifying GBSAA equipment, standardizing procedures and

working the initial Airborne Sense and Avoid (ABSAA) capability [12]. The US Army's initiatives with *sense and avoid* ventures and research with autonomy, airborne sensor packages, and other payloads will help create a new horizon for UAS operations in the US NAS in both the near-term and sustainable long-term future beyond the military sector and into the civil and commercial markets.

Long Term Future State: Technology Strategy as the Preferred “to be” Architecture

There are three markets for UAS technology, which include the military, civil government, and commercial uses. UAS technology is mainly prospering in the military community versus other markets due to its successful use in the first Gulf War and its continued success, expansion, and value added in the current conflicts in Iraq and Afghanistan. The United States is leading in the UAS technological innovations and employment, with the Department of Defense, Department of Homeland Security, and the FAA as the primary organizations shaping the UAS domain, but ironically the current restrictions on flying UAS in the National Airspace greatly hinder further progression in the civil and commercial markets. In the far-term, the FAA must approve appropriate technical standards and performance specifications for enabling technologies. In addition, fully developed and certified technology and procedures, such as the ABSAA system with the appropriate level of automation is a MUST in order to provide a means for all certified aircraft – manned or unmanned - to fly dynamically in the US NAS (See Figure 8). Such dynamic operations satisfy those mission needs that require robust access to airspace – allowing flexibility in meeting rapidly changing contingency requirements, real-time scheduling of flights, and complete integration of piloted and non-piloted airframes in the same airspace.

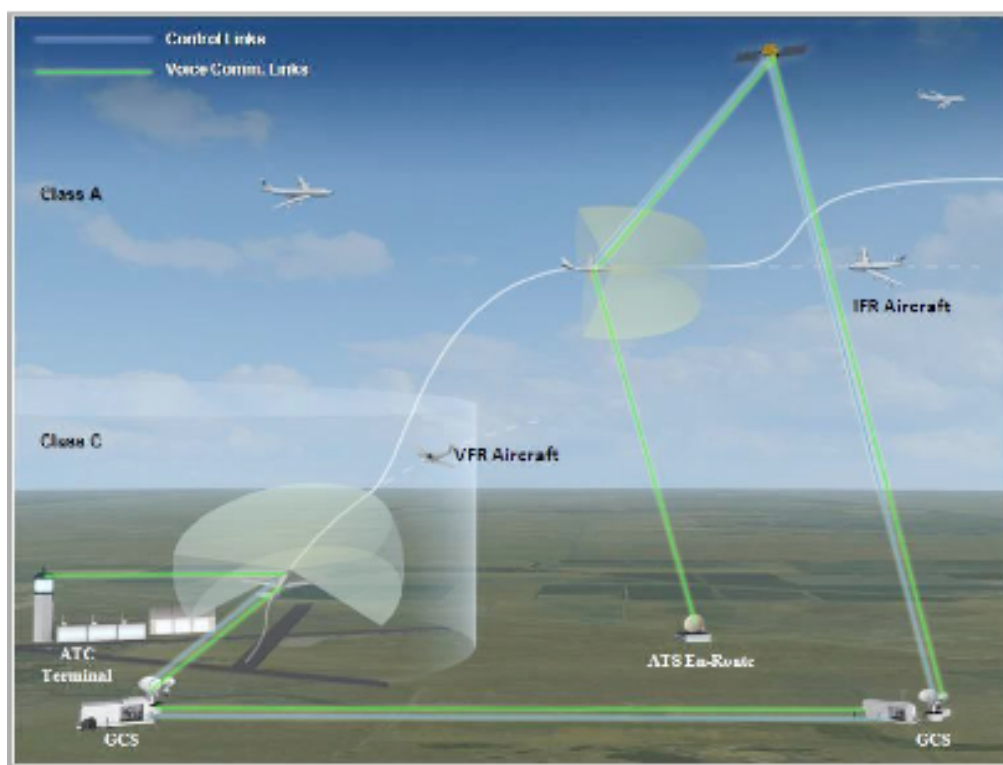


Figure 8: Dynamic Operations [12]

The integration of UASs into the NAS is a highly complex issue and involves a domain in which systems are important. UASs and the NAS are both part of larger and more complex systems and are comprised of systems themselves. Technology Strategy is a framework that enables the understanding of the structure and dynamics of high-tech

businesses, combined with an approach for their effective strategic management. Technology Strategy coupled with Engineering Architecture emphasizes the development and application of ways of thinking that bring clarity to the complex co-evolution of technological innovation, the demand opportunity, systems architecture, business ecosystems (See Figure 9), and decision-making and execution within the business.

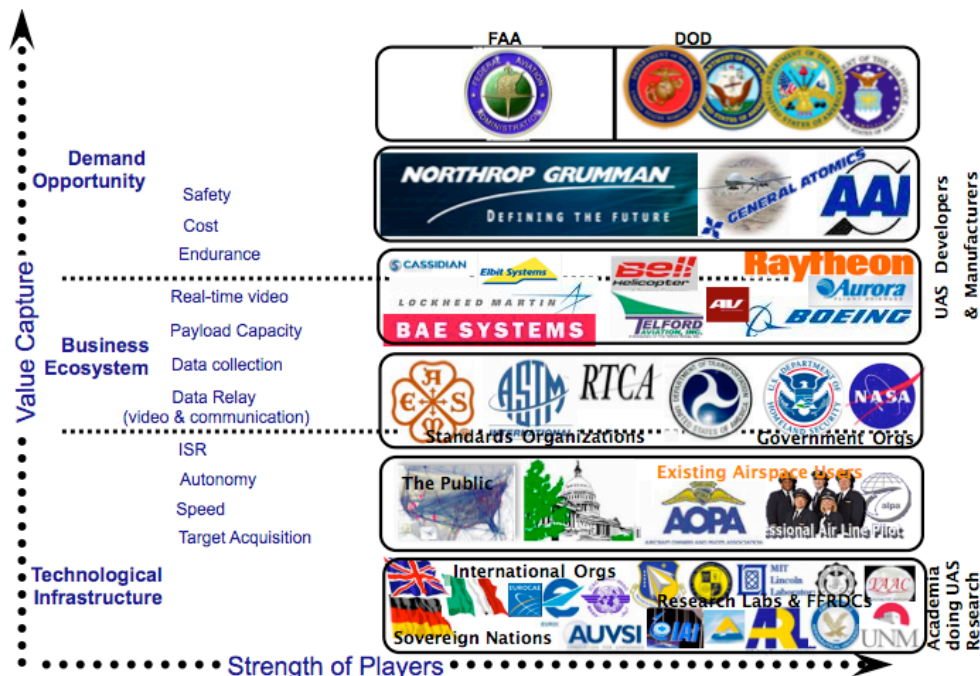


Fig. 9: UAS Ecosystem

Conclusion

History has shown that technological advances associated with military aircraft eventually make their way in the civilian sector [2]. The new UAS technologies under development today will have a profound impact on the entire aviation industry. Enabling routine access to the NAS by leveraging existing procedures for piloted flight operations, and using current guidance for unique military operations will yield a path for NAS integration and significant growth in the civil and commercial UAS market will immediately follow. Enterprise architecture is a holistic way of thinking which is essential to modern enterprises, such as the US National Airspace, that have highly interconnected systems. It is necessary to integrate management processes, lifecycle processes, and enable infrastructure systems. Furthermore, enterprise architecting balances the needs of multiple stakeholders working within and across boundaries and enables a full understanding of the value exchange, expectations, needs, and interactions. Technology in the UAS industry is advancing very rapidly and current military operations provide an optimal test bed for such innovation, which will assist the transition of UAS operations within the civil and commercial markets. Both Enterprise Architecture and Technology Strategy focus on a holistic approach and integrate enterprise strategic objectives, value capture and creation, in a systematic approach to achieve success in a complex, highly technical enterprise system. Architecting the current state of the NAS enterprise and then applying the technology strategy framework in an incremental systems approach to fully understand the future state of the NAS involves determining how to create and capture value, anticipating and deciding how to respond to the behavior of customers, complimentors and competitors, and develop and deliver technologies, platforms, and products.

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COMPARISON OF SOLAR SORPTION COOLING SYSTEMS USING TRNSYS SOFTWARE

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ABSTRACT

Since the Montreal Protocol set out a timetable for the phasing out of conventional refrigerants used in vapour compression systems, a lot of research has been undertaken into sorption cycles as an alternative. Absorption and adsorption use environmentally friendly fluids, such as water, as the refrigerant. The research in this area mostly focuses on improving the cycles, which currently have a lower COP than vapour compression systems. Few papers make a direct comparison between the two cycles for different applications.

This paper presents a numerical model of a sorption cooling system built in TRNSYS which uses real-world weather data at the given location. The model is run for absorption and for adsorption using three different working pairs and applied to human cooling and to food refrigeration. The results are assessed against a range of performance criteria and compared to determine the most suitable cycle for each application.

It is found that absorption systems have a higher cooling power per unit of absorbent and therefore are more suitable for small scale air conditioning systems. Adsorption systems are more suitable for low temperature applications, such as food refrigeration. Both systems studied rely solely on solar energy which makes them suitable for food preservation and air conditioning applications in countries where the power supply is unreliable but solar energy is abundant.

INTRODUCTION

Until the early part of the 20th century, sorption cycles were frequently used in refrigeration applications; however developments during the 1930s meant that vapour compression cycles became more widespread and have now become the conventional system used for refrigeration (Ziegler, 1999). Over the last few decades, there has been a revival of research into sorption technology, motivated by two main factors. Firstly, the Montreal Protocol and its subsequent amendments set out a timetable for the phasing out of ozone-depleting substances (UNEP, 2009), many of which are used as refrigerants in conventional refrigeration. Secondly, the Kyoto Protocol has set out targets for reductions in greenhouse gas emissions, which include carbon dioxide (UN, 1998). Traditional vapour compression systems require electrical power – usually produced with large carbon dioxide emissions, whereas sorption systems can be powered using waste heat or solar energy. Independence from an electricity supply also makes sorption systems attractive for use in areas where there is no reliable power supply but plenty of solar energy (Enibe, 1997).

Most recent research into sorption refrigeration considers either absorption or adsorption technology, and focuses on modifications to the cycles in order to increase the COP to make them more competitive with vapour compression systems (Demir *et al.*, 2008). Few papers present a comparison of the two cycles, and those which do rarely compare the cycles with identical loading and inputs (Deng *et al.*, 2011; Gupta *et al.*, 2008; Zhai & Wang, 2009). This paper aims to present a comparison of absorption and adsorption cycles applied to an air conditioning application and a food refrigeration application in order to identify the most suitable cycle for each application.

THEORETICAL BACKGROUND

This section details the theory behind the two sorption cycles, and gives the theory behind a traditional vapour compression cycle for comparison.

Vapour Compression Cycle

In a vapour compression refrigeration cycle, the refrigerant is used as the working fluid (see Fig. 1). Refrigerant enters the compressor as saturated vapour and the pressure and temperature are increased through compression (Rogers & Mayhew, 1992). The fluid then passes through the condenser where it rejects heat to the environment (Q_c) and through an expansion valve where the pressure is reduced. The fluid enters the evaporator as a low temperature, low pressure mixture of liquid and vapour. In the evaporator, the fluid extracts heat from the environment (Q_e) and evaporates. This produces the cooling effect in the system.

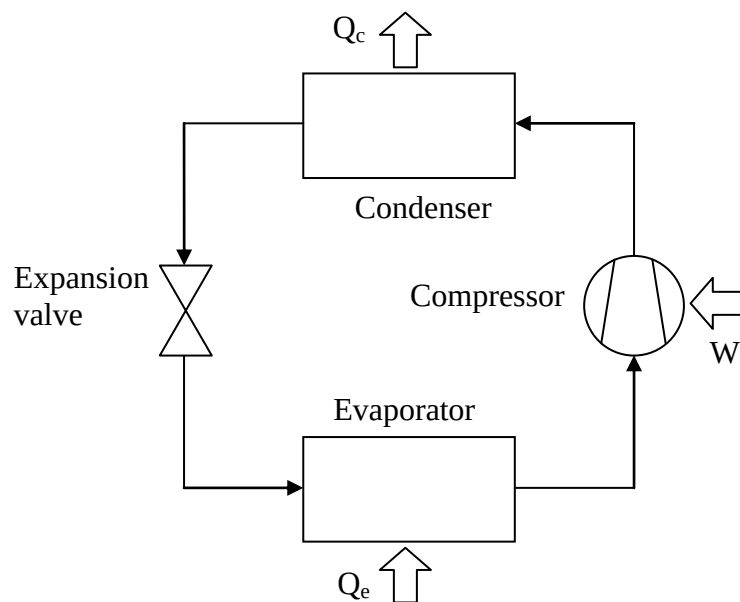


Fig. 1: Vapour compression cycle diagram

The coefficient of performance (COP) is a measure of how much cooling power is provided per unit of work input to the compressor. It is calculated as $COP = \frac{Q_e}{W}$ and is usually greater than 3.

Absorption Cycle

Absorption machines replace the compressor with a generator and an absorber (Fig. 2) (Rogers & Mayhew, 1992). The saturated vapour (refrigerant or absorbate) from the evaporator enters the absorber where it is absorbed into the absorbent. This process raises the pressure of the fluid and rejects heat to the environment (the heat of absorption) which is removed using cooling water. The mixture of absorbent and absorbate is then pumped to the generator (using significantly less electrical power than the original compressor) where heat from a solar or waste heat source is put in to the system and the absorbate is desorbed. The desorbed vapour flows to the condenser while the absorbent passes through an expansion valve to lower its pressure before returning to the absorber.

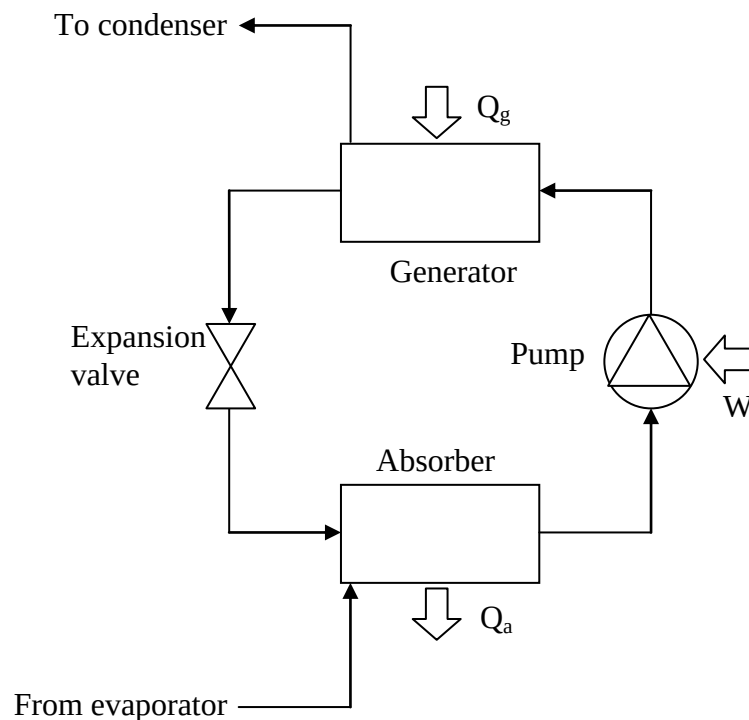


Fig. 2: Absorption cycle diagram

The cycle only requires minimal electrical power and a low-grade heat source such as solar thermal energy or waste heat. Typical absorbent-absorbate working pairs are water-ammonia and lithium bromide-water. The COP is calculated using

$$\text{COP} = \frac{Q_e}{Q_g + W}$$
 For a single-effect cycle, as described above, the COP is around 0.75 while a double effect cycle has a COP of around 1.2 but requires a higher temperature driving heat source (Ziegler, 1999).

Adsorption Cycle

Similar to the absorption cycle, the adsorption cycle replaces the compressor with a generator. The generator consists of a bed of a solid adsorbent which is in turns heated and cooled (Meunier, 1993). Cooling the bed increases its capacity to adsorb the refrigerant/adsorbate and decreases the pressure in the generator so adsorbate is vaporised in the evaporator, providing a cooling effect, and adsorbed. The adsorbent bed is then heated which increases the generator pressure and causes the adsorbate to be desorbed. Desorbed vapour is condensed in the condenser and rejects heat to the environment.

As the adsorption unit only provides a useful cooling effect during the adsorption phase of the cycle, a single bed cannot provide continuous cooling.

The heat needed for desorption in the generator is lower than that required for desorption in the absorption cycle, and no mechanical power is required. Typical working pairs are activated carbon-methanol, silica gel-water and zeolite-methanol. The

COP is defined as
$$\text{COP} = \frac{Q_e}{Q_g}$$
, typically between 0.3 and 0.4 for a one-bed adsorber and between 0.4 and 0.8 for a two-bed adsorber (Wang *et al.*, 2009).

MODELLING

TRNSYS (Transient Energy System Simulation) is a piece of software which allows the modelling of a system by linking together components from the pre-existing library of components (Wisconsin, 2011).

The system to be simulated consists of the chiller unit (either absorption or adsorption) connected to the required heat sources and sinks, a real-world weather data input file, and a building that simulates the cooling load either for air conditioning or food refrigeration.

Absorption

TRNSYS already has a component which simulates a single-effect lithium bromide-water absorption chiller (Type107), so this was connected to a heat source (to provide the driving heat energy for desorption), a cooling tower (to remove heat from the condenser and the heat from adsorption) and a building (to provide the cooling load) as shown in Fig. 3. In order to make the system totally independent from any electrical power supply, the heat source is provided by a solar thermal panel via a storage tank, and the pump necessary to pump the fluid between solar panel and tank is powered by a solar photovoltaic cell.

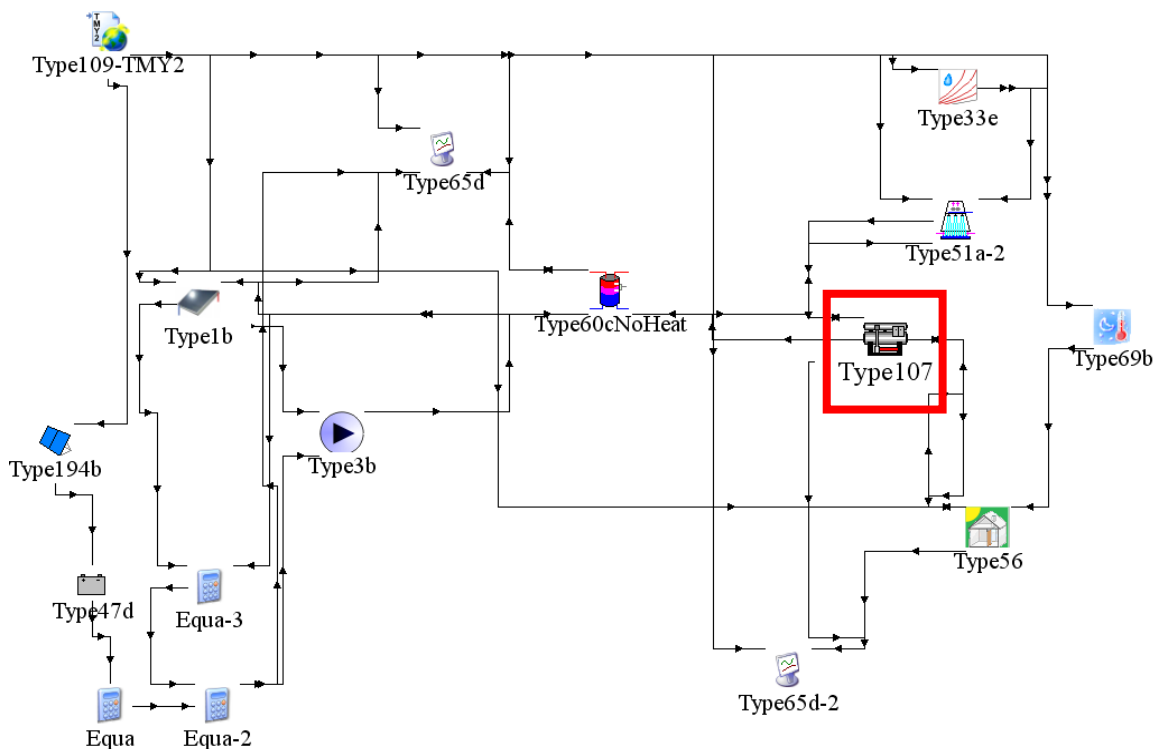


Fig. 3: Absorption chiller (Type107) and connected system

Adsorption

There is no pre-existing component that models an adsorption chiller, so a program was created in MATLAB and linked to TRNSYS using Type155. A two-bed unit was modelled in order to provide continuous cooling to the system.

Quasi-equilibrium conditions are assumed and therefore the effect of the rate of sorption is not included. The Dubinin-Astakhov equilibrium equation (Teng *et al.*, 1997) is used for activated carbon-methanol and zeolite-methanol working pairs and the Toth equilibrium equation (Chua *et al.*, 2004) is used for the silica gel-water equation.

Cooling Load

Type56 is used to create a building and define its characteristics. The cooling load depends on the external (ambient) conditions and the internal conditions. Internal conditions are set to simulate either the demands of an office environment or the demands of a refrigerated unit of the same size as the office. The building size is 10m x 10m x 2m. Windows are added to the office model, but not the refrigeration model.

TRNSYS uses ISO 7730 to calculate the rates of heat gain from occupants of an air conditioned spaces and provides a table of options, from which the option for 'Seated, light work, typing' is selected. Gains from five standard desktop computers and artificial lighting are also added. Adding these gains simulates an office environment.

There are no pre-programmed options for food refrigeration purposes, so new gains are defined for a range of foods. Values for the heat of respiration of various fruits and vegetables are shown in Tab.1 (Dossat, 1981) and the model assumes one tonne of each food is in the building.

Tab.1: Heat of respiration of various foods (at 10°C)

Food	Heat of respiration (W/tonne)
Apples	41-60
Bananas	65-116
Carrots	93
Oranges	35-40
Potatoes	20-30

RESULTS

The model was run for both applications (human and food cooling) using an absorption chiller and an adsorption chiller. The adsorption model was run using three different typical working pairs: zeolite-methanol; silica gel-water; and activated carbon-methanol.

The target temperatures for the building are 18°C and 6°C for human and food cooling respectively.

For adsorption, the required mass of adsorbent to provide sufficient cooling for each working pair and each application was manually optimised and is shown in Tab.2. (Densities are taken from (Waszkiewicz, 2003) and (K-TEK)).

Tab.2: Required mass of adsorbent and COPs

	Sorbent density (kg/m³)	Human cooling			Food cooling		
		Sorbent mass (kg)	Sorbent volume (m ³)	COP	Sorbent mass (kg)	Sorbent volume (m ³)	COP
Zeolite-methanol	641	130	0.203	0.69	130	0.203	0.62
Silica gel-water	670	130	0.194	0.65	100	0.149	0.64
Activated carbon-methanol	320	90	0.282	0.80	75	0.234	0.78
LiBr-water	3464	8	0.0023	0.73	5.5	0.0016	0.69

The volume of sorbent required to provide the necessary cooling power has a direct effect on the volume of the chiller unit, and should be as low as possible. The COP shows how much cooling power is being produced relative to the power supplied the chiller, and should be as high as possible. Considering adsorption, silica gel-water has the best adsorbent volume and activated carbon-methanol has the best COP for both applications considered. However, the absorption volume properties are considerably more favourable than the adsorption volumes, and the COPs are almost as good as the activated carbon-methanol COPs.

DISCUSSION

It was decided to use the ratio of COP to volume of adsorbent to identify the overall best working pair for adsorption chillers. The ratio for each working pair and each application is shown in Tab.3. This shows that zeolite-methanol is best for human cooling and silica gel-water is best for food cooling.

Tab.3: Ratio of COP to required adsorbent volume

	Human cooling	Food cooling
Zeolite-methanol	3.40	3.05
Silica gel-water	3.35	4.30
Activated carbon-methanol	2.84	3.33

Despite activated carbon-methanol having the highest COP and lowest required adsorbent mass, its low density means it is not the best all-round working pair for adsorption chillers. Likewise, zeolite-methanol does not have the lowest adsorbent volume or the highest COP, but when these two criteria are combined, this working pair becomes more attractive.

However, if the food cooling application requires a room temperature lower than 6°C, water is no longer suitable as a refrigerant as the temperature of the fluid entering the building would have to be lower than 0°C (the freezing point of water). For this application, activated carbon-methanol would be the most suitable working pair and absorption using LiBr-water would not be suitable.

Absorption chillers are widely recognised as having a higher COP and as being less bulky than adsorption chillers, and the results found here are in agreement with the literature. However, absorption chillers also require a higher grade heat source to drive desorption and have a higher complexity as pumps are required to pump the absorbent-absorbate solution around the chiller unit.

Other factors must be taken into account when deciding on which sorption system to implement, such as available space and ease of provision of maintenance. For example, in an office block in a city where the unit must fit into a restricted volume, absorption chillers would be more suitable. Providing cooling for a medication storage unit in a remote region would not have as many restrictions on space but access for maintenance would be more problematic, so adsorption chillers should be chosen.

CONCLUSION

A range of sorption systems have been modelled in TRNSYS and each has been optimised for food cooling and human cooling (air conditioning) applications. The results show that although absorption chillers require smaller volumes of sorbent than adsorption chillers, the latter are more appropriate in regions where simplicity is more important than the size of the system. Zeolite-methanol is the most suitable adsorption working pair for human cooling and silica gel-water is the most suitable for food cooling, unless the required room temperature is lower than 6°C, at which point activated carbon-methanol becomes more suitable.

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KINGSGROVE TO REVESBY RAIL QUADRUPLICATION – INNOVATIONS IN DESIGN AND CONSTRUCTION OF THE OVERBRIDGES

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ABSTRACT

This paper provides a high level overview of the Kingsgrove to Revesby Quadruplication Project. This project is being delivered by Transport Construction Authority (TCA) in an alliance with Leighton Contractors, AECOM (formerly Maunsell Australia), Sinclair Knight Merz, MVM Rail and Ansaldo STS (the K2RQ Alliance). The project scope includes constructing two additional fast tracks between Kingsgrove and Revesby (approximately 7.2km). It is currently under construction in NSW.

The site presents unique constraints necessitating the incorporation of many interesting innovations in the design and construction processes. This paper's focus is on those innovations adopted for extending the existing overbridge structures to accommodate the two additional tracks underneath. Examples include developing innovative overbridge pier design and steel strengthening solutions and adopting coordinated construction staging to ensure safe, flexible delivery of detailed bridge designs.

This paper also describes the Alliance Management team organisation which is incredibly diverse in its makeup. Not only are the team from a range of countries, they are also diversely skilled in their engineering backgrounds. The women of the team hold varying experience and have involved themselves in a very positive way on the project. Key roles occupied by women include, but are not limited to, Construction Manager, Engineering Manager, Structures Design Manager, senior project engineers and design team leaders as well as the Community and Stakeholder Relations Manager. The diversity in the leadership team plus the ongoing extensive interaction between the designers and contractor has contributed to the ongoing successful and sustainable delivery of this project.

INTRODUCTION

The Kingsgrove to Revesby Quadruplication (K2RQ) Project scope includes the construction of two additional tracks between Kingsgrove and Revesby (each 7.2 km long), construction of 11 new rail bridges, modification or replacement of five existing overbridges, upgrades to Revesby Station, new overhead wiring and associated civil and rail system works. The additional tracks will allow the complete physical separation of local and express services operating on the East Hills Line. The purpose of K2RQ was to:

- provide a more reliable rail service

- reduce conflicting train movements and potential for delay
- allow operations to be simplified to enable an increase in rail services to meet future demand
- increase capacity to terminate trains at Revesby Station.

In order to achieve these goals, the K2RQ Alliance undertook substantial multidisciplinary works within the constraints of an existing operational rail corridor and working alongside an ethane gas pipeline (EGP). Rather than attempt to describe all the multidisciplinary works and associated constraints in detail, the following sections will focus on the salient features of the bridgeworks, in particular the overbridge at King Georges Road. The paper describes how constraints were addressed and were overcome through careful planning and close collaboration between the Alliance and RailCorp and the Roads and Traffic Authority (RTA). This led to a number of innovative design and construction solutions.

KING GEORGES ROAD

King Georges Road Overbridge comprises two bridges, one accommodating the southbound carriageway and the other the northbound, abutted together but not connected. The southbound bridge structure is a 1930s two-span, concrete ‘jack-arch’ superstructure supported by a central brick pier and brick abutments. The newer northbound structure was constructed in the 1960s as a four-span, prestressed, concrete plank bridge supported on reinforced concrete piers and abutments.

The existing road is a key arterial route for the RTA into Sydney, with 70,000 vehicle movements per day. It was vital to ensure that two southbound lanes and three northbound lanes of traffic were maintained in each direction throughout the works whilst still having adequate room for construction and ensuring the safety of the general public, road users and construction team. To add to the complexity, the existing bridge also provides access to the existing station at Beverley Hills, with 1000 pedestrian movements at peak time. Access was via staircases off each side of the bridge to the platform and had to remain open at all times as well as providing disabled access. In addition, on the northbound carriageway, two streets exited King Georges Road at junctions just off the end of the bridge on the north and south.



Figure 1: King Georges Road Overbridge – Views from on top and under bridge

Key Challenges

The Alliance was presented with a number of challenges from site and operational constraints, the staging of the works and the linear nature of the works. The constraints relating to King Georges Road were:

- key arterial route – Five lanes to remain open at all times
- pedestrian access on both sides of the bridge and access to the station
- ethane gas pipeline - EGP
- rail corridor
- limited workspace in a densely populated urban environment
- existing bridge structures – limited existing drawings
- utilities – both at road level and at track level
- tight construction program.

Through close collaboration between the construction and design teams, a design and construction methodology was developed to address the constraints. The subsequent sections describe how in detail.

Design

King Georges Road Overbridge comprised two very different bridge structures which required two very different design solutions to be developed to satisfy the time and rail and road occupancy constraints, as well as to accommodate the construction staging.

As part of the design development for the southbound bridge, a detailed value engineering process was undertaken to consider the design options to settle on a preferred design. The criteria used to select the preferred design mainly comprised constructability, program, cost and minimising disruption to rail and road users. The preferred option was to retain and extend the existing bridges (refer to Figure 2). The key benefits achieved by retaining the existing bridge structure and extending in lieu of full replacement were:

- it allowed five lanes of traffic to remain open at all times during the bridgeworks which minimised impact on road users and
- it required a fewer number of rail track possessions during construction, which greatly facilitated the overall construction program and reduced costs.

The northbound bridge, although comprising a four-span configuration suitable for the four tracks, still required extensive modifications works, which were quite complex in design and construction (refer to Figure 3). The existing abutment founding levels were above the proposed new track levels. Therefore new abutments had to be constructed behind the existing abutments to support the existing bridge deck and enable these existing abutments to be demolished. These works were in very close proximity to the EGP and very tight controls were required on site to manage this risk. Other works included the construction of a new traffic barrier and installation of protection screens along the full length of the bridge.

The construction of both the northbound and southbound bridges is described in detail in the Construction section. Rather than describe the design process in detail, the remaining part of this section focuses on the key challenges relevant to the design and the subsequent design response and is summarised in Table 1.

Table 1: Key Design Challenges

No	Key Challenge	Design Response
1	Tight construction program	Retain existing bridge structure and modify to accommodate new tracks in lieu of demolishing and constructing a new bridge. This reduced the amount of works that needed to be done in a full track possession (shutdown) and facilitated speed of construction
2	Construction methodology – a top down method of construction was proposed whereby the deck is installed and excavation substructure works proceed underneath once the road is re-opened	Design was developed to accommodate a top down form of construction through careful detailing and consideration of construction staging in design checks with periodic reviews by construction team. Construction loading was considered in design. Close collaboration with the construction team throughout the design development as standard. The existing bridge structures were old with very limited drawings available so assumptions were made in relation to the dimensions of the buried parts of the structure. This could only be confirmed once construction commenced and details were amended accordingly. .
3	Traffic management and staging to accommodate four of the six lanes of traffic remaining open during construction works	Use of pre-cast elements in deck minimised the construction time and removed requirement for falsework. Careful consideration of staged construction was given in both the design and detailing to facilitate the staged construction for the abutments, piers, and deck. These all had to be constructed in separate stages and made continuous in the final design.
4	Limited workspace in a densely populated urban environment	Consideration by designers was given particularly in relation to the size of piles (limit size of piling rig) and to the weight of the individual pre-cast elements (to minimise the crane size for lifting). Pile size was kept to a minimum to maintain 2m clear zone around EGP.
5	Future replacement of existing bridge	The new design is detailed to facilitate the future replacement of the existing bridge superstructures. The abutment/pier strengthening works are sufficient to carry full design traffic loading along the full length of the bridge. The new deck is detailed to be completely separate from the existing deck structure, and the new protection screens can be re-used for the future replacement.
4	Southbound bridge - strengthening the existing piers to withstand the impact of train collision loads as	The existing masonry abutments are retained and utilised as the pier supports for the new end spans. Galvanised steel vertical anchor bars were installed from road level to provide an effective internal reinforcement system for strengthening the masonry piers from rail collision loads. In addition, the vertical anchors provide lateral restraint at the

	per current standards	base of the pier as the anchors are grouted into the underlying bedrock. An <i>in-situ</i> concrete headstock was constructed behind the old brick abutments to support the new deck. Dowel bars tie the two elements together.
5	Construction of new northbound abutments in close proximity to EGP	Minimise pile diameter to maximise the space between piles and the EGP – this was challenging because of the length of the pile cantilever and the associated pile design forces that had to be accommodated in the design. Detail new abutment headstock so it could be constructed from underneath the bridge deck and the load could be transferred to the new abutment under live traffic. Tight controls were put in place during construction to carefully monitor any movements. Design had to be flexible to accommodate construction tolerances and the difficult nature of the site (i.e. working with limited headroom).
6	Impact on adjacent bridge structure and embankment	The impact of the new end-span construction on the existing deck was considered in the design. The pier will be propped by both the new and existing decks. The existing deck is simply supported and once the frictional resistance between the deck and pier is exceeded the deck will act as a prop. The magnitude of the axial loading this will exert on the existing deck (from train impact loads) is estimated to be less than 1MPa, which is considered negligible. In addition the estimated deflection at the top of the pile when the existing deck is being replaced is expected to be 5mm which is considered acceptable.
7	Safety in design	Issues that were considered as part of the Safety in Design review at the outset of the design process and our design response included: working adjacent to the rail, working at height, heavy lifting, adequate working space. The construction team, as part of the Alliance, reviewed and provided input to the design process to ensure the design was safe for construction. This review and input occurred as part of the design development process in formal and informal meetings and at staged reviews of each design submission.
8	Sustainability in design	The detailed design has followed the Environmental Sustainable Development as defined in the <i>NSW Protection of the Environment Administration Act</i>. Examples of the outcomes include: ▪ minimising the footprint of the construction and permanent works ▪ specification of blended cement

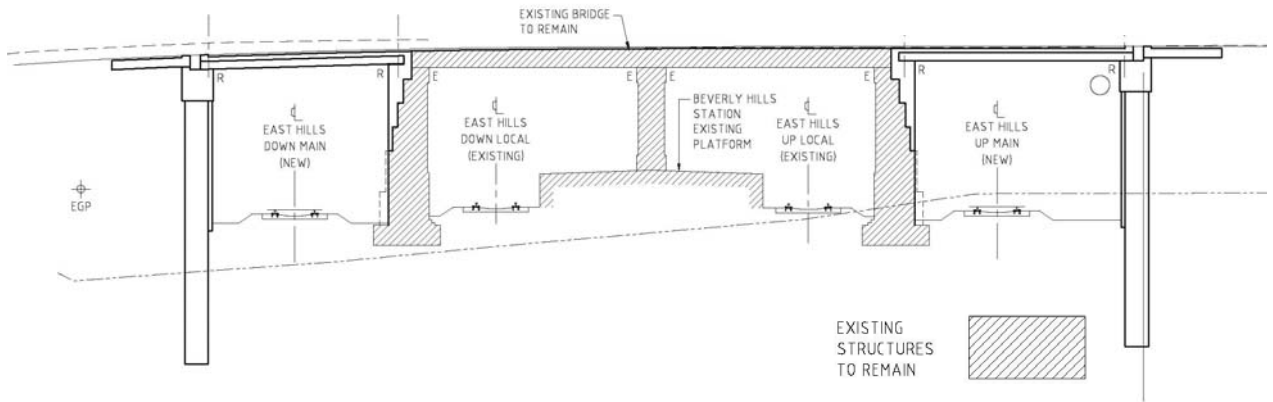


Figure 2: Longitudinal section through existing southbound bridge

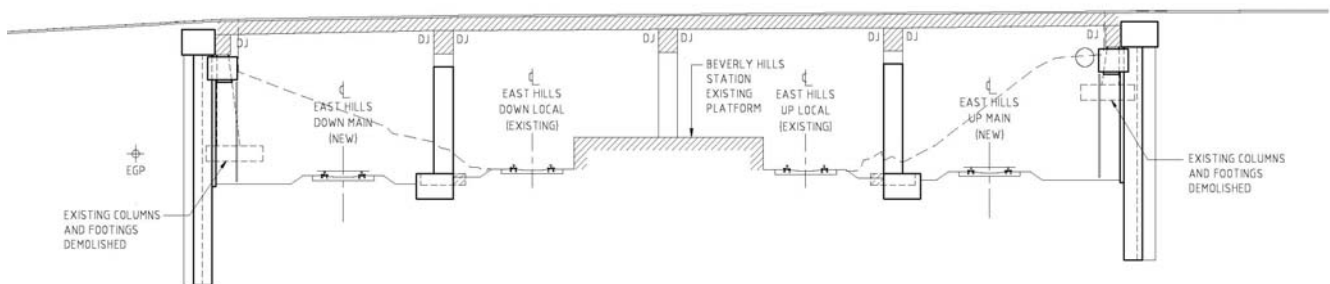


Figure 3: Longitudinal section through existing northbound bridge

Construction

Extension of the bridge at King Georges Road gave the construction team some enormous challenges, in particular the staging which was driven by limited track possessions, limited road closures due to the disruption this caused to the local community, and very limited area for works due to the proximity of live traffic, RailCorp boundaries and nearby buildings.

Before construction started, liaison was necessary between the construction team, RailCorp Station Liaison Group, RailCorp, RTA, buses and stakeholders (including local businesses) to consult on the proposed methodology and impact. Part of the scheme included the partial closure of the two adjacent roads, Morgan Street and Tooronga Terrace. New bus stops had to be provided and consultation undertaken on agreed bus diversions.

The team developed a proposal that required the works to be carried out in three key traffic management phases. This involved removing the existing median, including removal and storage of the palm trees, and surfacing this area to allow the traffic to be pushed to the west side of the existing bridges. A compound was then created on the east side of the bridge, allowing the bridge to be replaced below. Once complete, the traffic was then moved to the opposite side of the road and the process repeated. Finally, a compound was created in the central section of the bridge.

The utilities, including Energy Australia, Telstra and Optus Services, in the existing bridge deck, running north to south, needed to be diverted to allow for the construction of the deck extensions. These services were diverted to the northbound bridge to allow the southbound construction to proceed. In addition, running east to west just behind the new south abutment was the high pressure EGP. This represented a large risk to the project and site constraints meant that piling had to be carried out within three metres of the buried pipe. Potholing to locate the pipeline throughout the site was carried out to limit the risk and strict processes, including specific inductions for anyone working within five metres of the pipeline, were implemented.

The design had been detailed to minimise the impact on the operational railway. The constraints imposed on construction of the 1930s bridge (southbound bridge) and the 1960s (northbound bridge) were very different and the key points will be discussed below.

Southbound Bridge

The southbound bridge, as described in the design section above, is a two-span bridge, supported on a brick pier and brick abutments (refer to Figure 2). Piling for the new abutments was carried out from road level after the services had been diverted. Running parallel with the construction of the new abutment, alterations to the existing bridge abutment were required as this would be needed to support the new bridge deck and hence become a 'pier'. Tying in to this existing structure was particularly difficult for both the design and construction teams. Record drawings of the existing bridge had to be relied on for the initial design but when these elements were uncovered the design had to be refined to reflect what was currently there. Close liaison was crucial between the designers and constructors.

Lifting Planks into position



During excavation under deck

Figure 4: Views of southbound bridge during construction

The design allowed for pre-cast planks to form the deck for the new bridge. These were installed during partial closures of the road at night, reducing the number of lanes open and allowing a crane to be used for installation. The use of pre-cast planks as permanent formwork enabled a quicker program and overcame constructability issues as there was no easy access to install a traditional scaffold falsework. Once the planks had been installed the reinforcement could be fixed and the deck poured.

As soon as the new deck construction was completed, the earth fill under the new deck was excavated from track level and removed from site along the existing rail corridor (refer to Figure 4). As it was removed, the piles were exposed, trimmed and then shotcrete applied. The rear of the existing abutment was also exposed as the excavation works progressed. This revealed extensive cracking in the existing abutment. In order to

provide a 100 year design life and realise the design intent for the new structure, extensive stitching and grout injection of the new pier was required.

Northbound Bridge

The northbound bridge had very different challenges. The existing bridge, built in the 1960s was a four-span, pre-stressed, concrete plank bridge supported on reinforced columns founded on spread footings (Refer Figure 3). Although the existing abutments were set back with sufficient room to accommodate the new tracks, they were founded on the embankment above track level (See Figure 5) which meant new abutment supports had to be constructed.



Figure 5: Views of northbound bridge prior to construction

To protect the works from the operational railway the existing columns had a shutter erected during a weekend closure of the railway on the track side to provide a solid wall, enabling work to carry on behind it. This shutter served a dual purpose. Whilst it protected the workforce, it was also required to support the concrete between the columns in the final solution to enable the deflection wall to be constructed.

As mentioned above, the two end spans needed a new support in place of the shallow existing abutments. Bored piles were installed behind the existing abutment from road level with couplers in the reinforcement. Once the piles had been completed, working with limited headroom under the existing bridge span, the couplers were exposed and a reinforced cantilevered headstock was constructed tying into the piles. With the construction tolerances on the piles and the necessity to have dowel bars connecting the piles to the headstock, the buildability of this section of works was reviewed. Changes were made on site in conjunction with the design team to enable the headstock steel to be prefabricated, making it easier to install whilst still maintaining the design intent.

Once the headstock was completed, transfer of the load from the existing foundations to the new piled foundations was carried out, under live traffic conditions. This was done by injecting grout between the headstock and the existing bridge deck. Once transfer of load was complete the existing footing was removed and excavation could be carried out to track level.

Working within a Rail Corridor

Working in a rail environment and to help de-risk the program, it was important that the number of rail possessions required to carry out the bridgeworks were limited. These rail possessions, which are in effect closures of the railway, occur typically every few months and extend over a weekend period.

The design, which used parts of the existing structures, limited the amount of work that had to be carried out in track possessions to:

- installation of the catch fences across the bridge
- installation of new smoke screens (protection screen to the overhead wire)
- installation of the deflection wall and nosing at the face of the pier (a piled structure, precast moulds reinforced and filled with concrete).

The innovative design, combined with the construction methodology, allowed the works to be delivered to program with no impact on the operational railway and with limited disruption to road users and pedestrians.

PROJECT TEAM

The K2RQ contract was awarded to an alliance of key infrastructure and railway contractors, all of whom have a range of skills required to ensure the successful delivery of the full scope of the project.

The project organisation has been set up in accordance with a relatively traditional model with a leadership team made up of senior members of each of the alliance partner companies. The Alliance Project Manager was appointed by the leadership team to deliver the project in accordance with the scope of work, the applicable standards and to a high level of quality.

In order to successfully deliver such a large, diverse and complex project, the Alliance Project Manager is supported by a professional and experienced team. The members of this team have widely varying experiences, origins and qualifications and this diversity has ensured K2RQ is a leader in innovative applications, risk mitigation measures and discipline coordination.

Key roles within this very successful team are occupied by women. These roles include, but are not limited to, Construction Manager, Engineering Manager, Structures Design Manager, senior project engineers and design team leaders. In these roles, it has been possible for women to have a positive impact on the project and represent a good role model for all future works. In achieving this diversity, K2RQ has benefitted from the strengths associated with the various engineering skills and experiences of these staff and from the more subtle benefit of having a mixed and differing approach to dealing with any issues/challenges arising.

The women in these roles display strong leadership and professionalism and have played a significant role for the successful delivery of this project to date. Alongside these skills, a more open approach to problem solving has been developed throughout and improvements in team relationships have become the standard. In tackling issues and technical challenges, a diverse group has proved to be successful on K2RQ and sets a benchmark for future works.

A secondary achievement of the significant number of key engineering roles occupied by women on K2RQ may be seen as that of promoting women within the engineering workplace.

CONCLUSION

Construction of the King Georges Road Overbridge involved some innovative solutions to address time and rail and road occupancy constraints. It was a challenging design, due to the site constraints and the construction staging. Using parts of the existing structures limited the amount of work required and, combined with the construction methodology, ensured the works were able to be delivered to program with no impact

on the operational railway and with limited disruption to road users and pedestrians. The combination of pre-cast and cast *in situ* elements in the deck overcame the problem of limited road closures and facilitated faster deck construction. The success of the bridge structure was a breakthrough for the team, stemming from collaboration between the Alliance partners, RailCorp and the RTA during all phases of the project.

In addition, it is the opinion of the authors that a secondary contributory success factor to this project was the diverse makeup of the Alliance management team and the positive influence this created. This positive influence was exemplified by the team in general adopting a more open approach to problem solving and by way of the improvements in team relationships becoming the standard.



Figure 6: View of completed bridge from platform level and road level

TOWARDS A MORE SUSTAINABLE, RESILIENT INFRASTRUCTURE SYSTEM: REGIONAL RISK ASSESSMENT OF COASTAL BRIDGES DURING HURRICANE EVENTS

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ABSTRACT

Several hurricanes in the last decade have shown that bridge and roadway infrastructure systems in coastal communities are vulnerable to damage from hurricane induced surge and wave forces. Bridges represent vital links of the roadway system, connecting coastal communities to the mainland, and often experience significant loads due to their prevalence as water crossings. In order to mitigate the likely damage to the bridge network and promote actions that improve the sustainability of coastal communities, a viable approach is needed to measure hurricane risk to bridge networks across expansive regions.

This paper describes ongoing research to develop new models of bridge reliability under hurricane loads considering the common failure modes of bridges that were seen in Hurricanes Katrina and Ike, such as unseating of bridge decks or scour of foundations and approaches. These tools are then applied to a regional risk assessment of the bridge network in the Galveston, TX bay area, focusing on utilizing such research to create a more sustainable system. By analysing the failure probability of each bridge in the network for a set of scenario hurricane events, risk mitigation decisions can be supported such as prioritizing bridges for potential upgrade or identifying routes that will be viable for transporting emergency response and recovery personnel. This will help create a more sustainable and resilient roadway system by decreasing repair and rebuilding costs after an event, preventing the unnecessary use of additional materials and by providing an infrastructure system that facilitates rescue and recovery efforts in coastal communities.

INTRODUCTION

After a coastal storm event, access to the communities affected for rescue, recovery and re-entry is of utmost importance. However, as has been evidenced in past hurricane events, the roadway system is extremely vulnerable to storm induced damage; especially the bridge network where severe damage can limit or prevent access to coastal communities (Douglass et al., 2004, Padgett et al., 2008, Okada et al., 2006). Thus it is imperative to understand the effect hurricanes will have on coastal roadway infrastructure and to measure the risk to the system in order to mitigate possible damages and better plan rescue and recovery efforts.

Following recent hurricane events in the United States, research has been conducted on the performance of coastal bridges. Attempts have been made to quantify the wave loads on bridge decks and these research efforts have led to the first set of design specifications regarding bridges vulnerable to coastal storms (Cuomo et al., 2009,

Huang and Xiao, 2009, Schumacher et al., 2008, Douglass et al., 2006, Marin and Sheppard, 2009, AASHTO, 2008). Although such studies have focused on deterministic analyses, the recent development of validated wave load models allows for further research to assess the reliability of coastal bridges under surge and wave loading. This paper demonstrates a simple yet effective methodology to estimate the probability of deck unseating or shifting during hurricane events through case study application. During reconnaissance efforts after recent hurricanes, deck unseating was found to be the most prevalent failure mode in simply-supported coastal bridges (Chen et al., 2009, Meng and Jin, 2007, Padgett et al., 2008). This methodology for bridge deck unseating is then applied to the Galveston bay area for different hurricane scenarios to visualize the potential for structural damage and is also compared to inundation of bridges due to surge. The results of the regional risk assessment are then utilized to test for viable re-entry routes to Galveston Island and Bolivar Peninsula, with a focus on the implications for a sustainable roadway system. Additionally, this paper describes ongoing research to determine a feasible method for assessing another common failure mode at bridges; scour at piers and abutments (Padgett et al., 2008).

HOUSTON AREA BRIDGE INVENTORY ANALYSIS

In order to determine the capacity of a bridge deck to resist unseating as well as the wave and surge forces acting on it, specific data about that bridge must be known and quantified. Because of this, modelling wave and surge effects on bridge decks has been mostly limited to laboratory tests or a very small sample of existing bridges where field visits garnered the necessary data. Completing a risk assessment of the bridge network on a regional scale requires the same level of specificity in data; however field evaluations are not feasible due to the number of bridges in the region. With a base point of the 2008 National Bridge Inventory data (an online inventory record of every major bridge in the country inspected on a biannual basis), around 200 bridges are contained in the Galveston Bay Area. For the purposes of this study, the Galveston Bay Area is defined as all of Galveston Island and Bolivar Peninsula, as well as the interior of Galveston Bay, extending roughly one mile inland. Of these initial bridges, 155 are evaluated in this study with tunnels, culverts and movable bridges being discarded. With the help of the Houston office of the Texas department of transportation (TxDOT), the most recent field inspection files were obtained for each bridge along with as-built plans where available. The inspection files and plans were then mined for data relating to the size and reinforcement of both the superstructure and substructure of the bridge. The following table gives a list of the attributes that were collected and what they are used for.

Tab. 1: Table of Bridge Characteristics

Necessary for Assessing Bridge Deck Unseating	Necessary for Assessing Scour	Necessary for Assessing Both
- Material and Type of Bridge Deck - Number and Length of Spans - Width of Bridge - Reinforcement Details	- Pier Sizes - Soil Type - Abutment Type and Dimensions - Scour Vulnerability rating from TxDOT	- Deck Height above Water at Each Span - Water Depth at Each Span

From this data mining, 136 bridges had sufficient data to be included in this investigation. A database was set up so that all the pertinent data for any type of risk estimation (i.e. bridge deck or scour) could be ascertained as input to modelling.

In addition to merely serving as input to fragility (vulnerability) modelling, the inventory analysis provides insight to the distribution of bridges in the Bay Area as well as highlighting some critical facts. As an example, Figure 1 shows the percentages of bridges in the Galveston Bay Area as a function of the bridge deck height above mean water level. From this, it is seen that 68% of bridges in the study are less than 15 ft (4.6 m) above the water level, which is a disturbing statistic considering that the surge during Hurricane Ike reached 12 ft (3.7 m). Additionally, Figure 2 shows the classifications of bridges in the Bay Area and makes clear that the majority of bridges in this region are multiple span simply supported (MSSS) concrete bridges. In recent hurricane events, it was this type of bridge that suffered the most severe damage (Padgett et al., 2008). MSSS Concrete Bridges are among the most susceptible to deck unseating from wave and surge loading because they are simply supported, meaning adjacent spans act independently to resist uplift forces, and because they usually lack a strong connection between the super and substructure of the bridge.

Bay Area Bridges by Height above Water

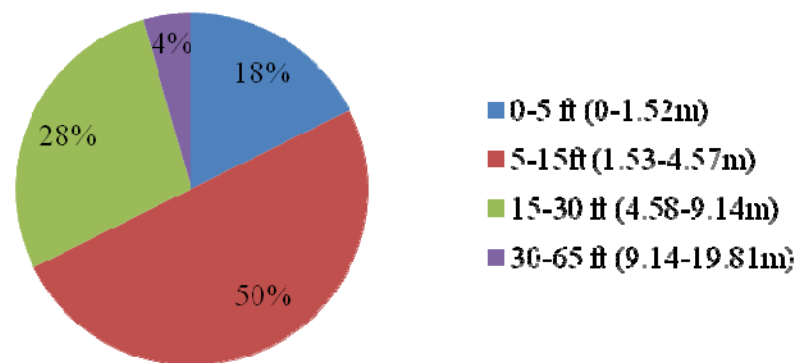


Fig. 1: Bay Area Bridges by Height above Water

Bay Area Bridges by Classification

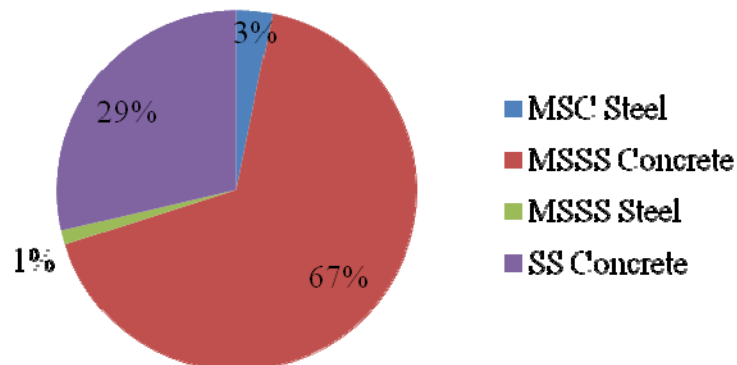


Fig. 2: Classification of Bridges in Galveston Bay Area

SS: Single Span, MSSS: Multi-Span Simply Supported, MSC: Multi-Span Continuous

FRAGILITY MODELLING OF BRIDGE DECK UPLIFT

Deck unseating or shifting was found to be the most common mode of long-term structural failure following recent coastal storms and thus is the first priority for conducting a reliability assessment of the bridge system. During a hurricane event, surge and wave forces exert upward demands on the bridge deck. Opposing those uplift forces is the capacity of the bridge deck, which includes the weight of the superstructure and any resistance from reinforcement that holds the deck to the substructure. For a risk assessment of full-scale bridges, variables pertaining to the demand or capacity are not known deterministically and so, instead of simply determining whether or not a bridge fails during a given event, a probability of failure is estimated based on a probabilistic distribution of both the demand and the capacity of the structure.

By introducing uncertainty modelling to the predictive equations for the capacity and demand of the structure and adding probabilistic distributions to the inputs of the models, a probability density function (pdf) can be obtained for both demand and capacity. This paper adopts the static fragility analysis approach proposed in Ataei and Padgett, 2010. For demand, the maximum surge and wave uplift forces are based upon the AASHTO Specifications for Bridges Vulnerable to Coastal Storm, considering maximum wave height and relative surge elevation at each bridge (AASHTO, 2008). The capacity was determined by estimating the weight of the structure and the yield or pullout strength of any vertical reinforcement that provides a connection between the deck and pier caps. Once probability density functions have been obtained for demand and capacity, considering the uncertainty in such parameters as material strength and density, the probability of failure for a single bridge deck is determined by conducting 1000 Monte Carlo simulations for each combination of wave and surge height. Failure, or unseating, occurs when the demand exceeds the capacity, and can be graphically observed by comparing where the pdfs overlap. This will yield a fragility surface for each bridge span, where a probability of failure is determined from any combination of maximum wave height and relative surge elevation. By considering each span in a multi-span bridge as being in a series (i.e. if one span fails, the entire bridge is considered failed), the probability of failure and fragility surface of each bridge can be obtained. Figure 3 shows this process in a flow chart form.

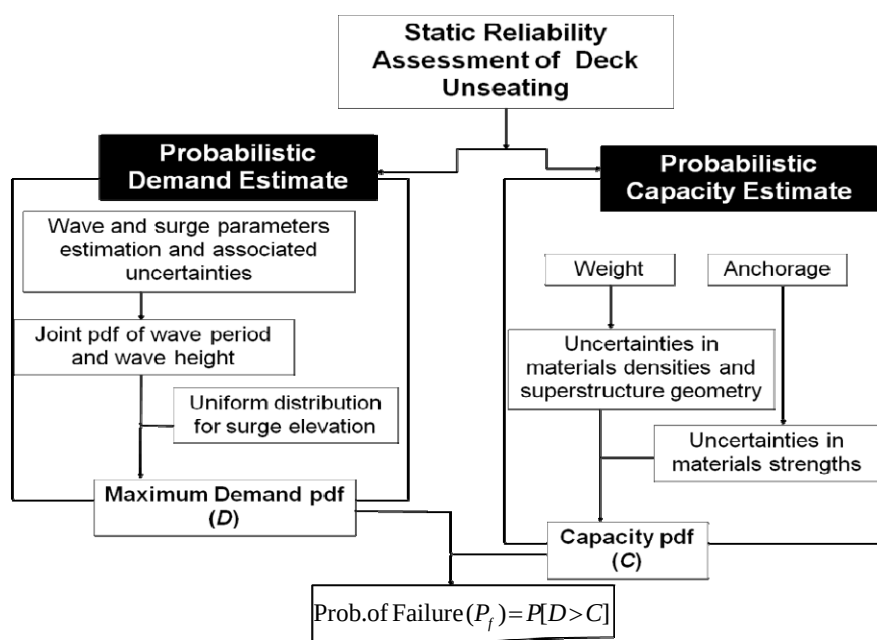


Fig 3: Flow Chart of Reliability Assessment Process

ASSESSMENT OF GALVESTON AREA BRIDGES FOR SCENARIO EVENTS

Bridge Deck Unseating

Using the methodology presented above, the Galveston bay area bridge system can be evaluated for a variety of coastal storm scenarios by collecting the maximum wave and surge height at each bridge location. This data was obtained from the Computational Hydraulics Group at the University of Texas at Austin (CHG, 2010) who used coupled ADCIRC (ADCIRC, 2010) and SWAN (SWAN, 2010) software to determine surge and waves at many points along a predetermined mesh for a variety of hurricane scenarios. Three scenarios were used in this study: 1.) a hind-cast version of Hurricane Ike; 2.) a storm that had the same landfall location as Hurricane Ike, but with 30% stronger wind speeds; and 3.) a storm that made landfall on the south side of Galveston island and had 30% stronger wind speeds as Hurricane Ike, known as “Mighty Ike”. These last two scenarios were chosen to try to reveal how the bridge system would fare during both a stronger Ike event and a “worst case” scenario because if Hurricane Ike had made landfall just south of Galveston Island, Galveston would receive the brunt of the storm forces.

In the Hurricane Ike scenario, only three bridges showed a probability of failure that exceeded 75%, and one of those bridges was Rollover Pass which was the only major bridge to fail by deck unseating during the storm. While this probabilistic methodology cannot be completely verified by empirical data because so little is available, the fact that the assessment of the bridges matches well with the limited empirical data lends more significance to the results from the other two scenarios. Table 2 shows the results from all three scenario events and it is evident that the bridge system could suffer significant damage if a storm of “Mighty Ike’s” magnitude hit Galveston, with over a third the study bridges exhibiting a high probability of failure. Figure 4 depicts the spatial arrangement of bridges in the Galveston Bay Area colour coded by failure probability.

Tab. 2: Number of Bridges in each category of failure probability for each scenario

Hurricane	Failure Probability (%)			
	0 - 5	5 - 25	25 - 75	75 - 100
Ike	127	5	1	3
Ike with 30% Stronger Wind Speeds	106	4	7	19
“Mighty Ike”	69	7	8	52

Bridge Deck Inundation

In addition to bridge deck unseating, which is a measure of long-term structural damage, determining inundation of bridge decks due to storm surge can offer insight regarding temporary functionality inhibition. Inundation here is taken as when the surge overtops the bridge deck, and, similar to deck unseating, each span in a bridge is considered to be in series, so that if one span is inundated, the bridge is inundated. In other words, bridges that are inundated are submerged for a period during the storm and could be impassable immediately following the storm, but do not necessarily exhibit long term damage associated with structural failure. In the three scenarios listed above, 28 bridges were discovered to be inundated during Ike, 53 in the stronger Ike scenario, and 82 in “Mighty Ike.” Figure 5 depicts the bridges inundated from the “Mighty Ike” scenario. While inundation information gives a sense of temporary functionality

problems, historically transportation risk assessment has been based upon either the mere existence of surge at a bridge site, or, at best, inundations maps that integrate surge height with land elevation. The inaccuracy of relying solely on inundation maps for long-term damage is seen by comparing Figures 4 and 5 closely, presented in Figure 6. Figure 6 shows that many of the bridges with a high probability of failure are also inundated during the storm, but not all of them. This could be explained by the fact that inundation maps do not take into account wave action on the bridge deck or the capacity of the structure to resist loads. To take a holistic approach to transportation risk, both inundation and deck unseating must be taken into account.

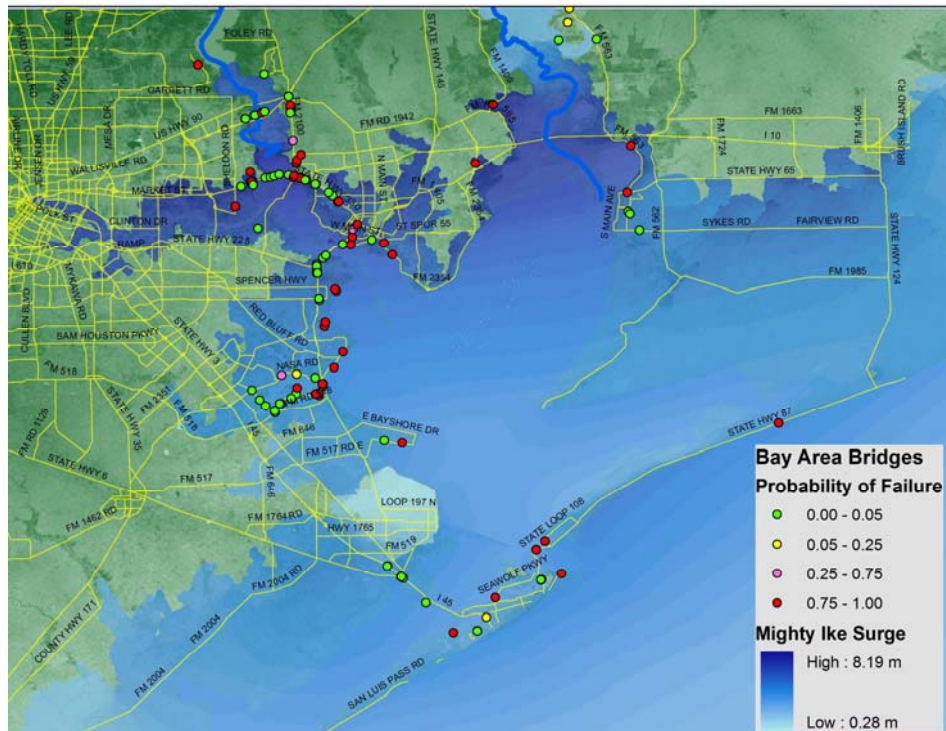


Fig. 4: Failure Probability of Bridges in “Mighty Ike” scenario

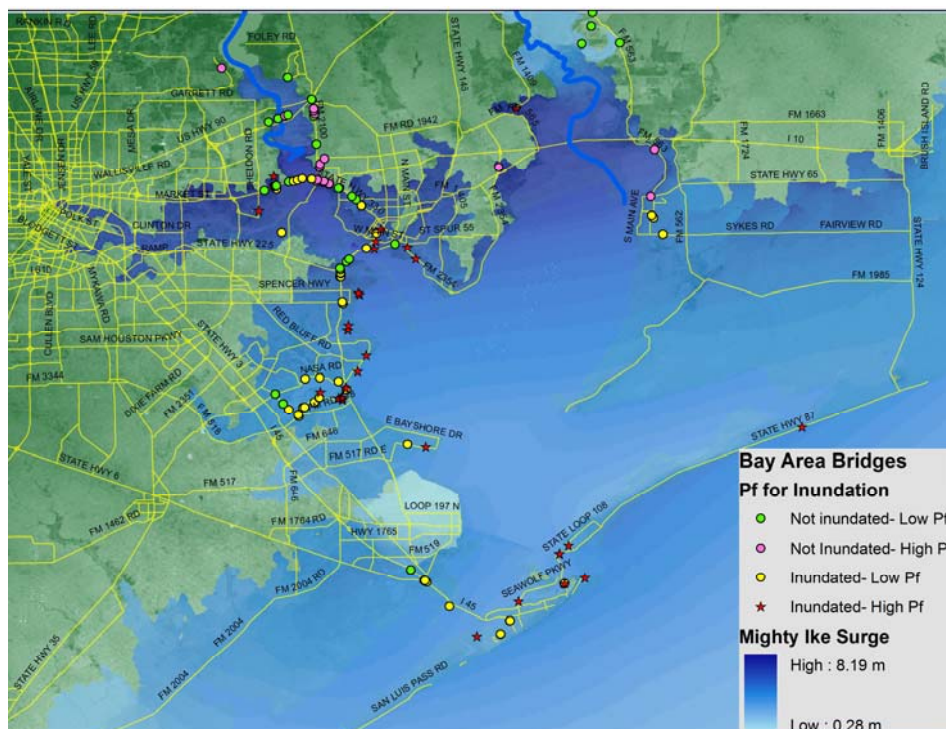


Fig. 5: Inundation of Bridges in “Mighty Ike” scenario

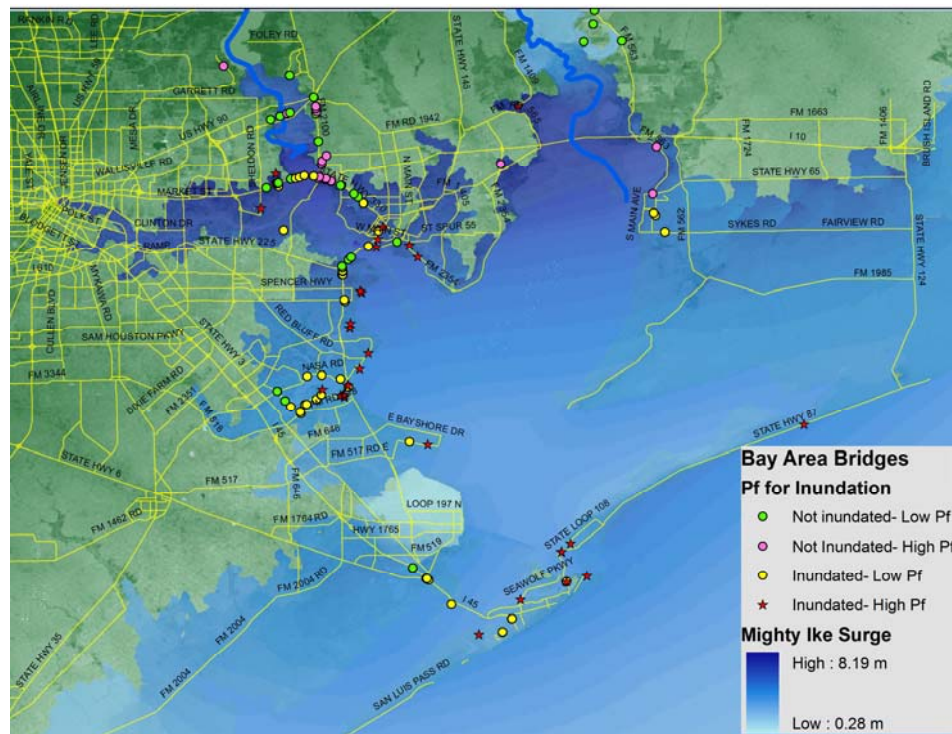


Fig. 6: Comparison of Inundation and Deck Unseating

APPLICATIONS OF REGIONAL RISK ASSESSMENT

Mitigation and Retrofit Efforts

With this new data on bridge deck vulnerability to storm surge, much can be learned both to prepare the bridge system to withstand the likely forces and to plan for rescue and recovery after the storm. For mitigation, there are several relatively low-cost options to increase the capacity of the bridge deck that are currently being used in areas prone to earthquakes; one such option is vertical tie downs. Vertical tie downs would provide a strong connection between the superstructure and the substructure of the bridge by increasing the vertical uplift resistance and with it the capacity of the bridge deck. The addition of these tie downs is currently being tested on the scenario events to see if they would indeed reduce the probability of failure due to bridge deck unseating and also to understand any negative consequences adding them would have such as increased forces on the columns and foundations of the bridge.

The application of a regional risk assessment and the use of some of these lower-cost mitigation efforts could lead to a more resilient transportation system because the system would be able to withstand larger hurricane forces while exhibiting lower failure probabilities and because officials would have a spatial understanding of possible failures, enabling a quicker recovery. Lowering the probability of failure, the consequences of failure and recovery time are all characteristics of a resilient system (Tierney and Bruneau, 2007). Additionally, these efforts could also help lead to a more sustainable bridge system because damages after the storm would be less and replacement of bridges would not necessarily have to occur after each hurricane. Finally, the use of these mitigation techniques could assist in post-event recovery by allowing more routes to be viable entry points to the Island and thus facilitate quicker rescue operations.

Post-Event Recovery

Additionally, the use of these scenario events can aid in risk mitigation, including selecting which routes emergency officials plan to take onto Galveston Island. By comparing bridge deck unseating and inundation of roads and bridges, the planned emergency routes can be assessed for their viability into the city. For example, there are two main land routes onto Galveston Island or Bolivar Peninsula: Rollover Pass at the north end of Bolivar and I-45 Causeway onto the east side of Galveston Island. As was seen in Hurricane Ike and the other two hurricane scenarios, Rollover Pass is at high risk; however, the Causeway is not in significant danger from any of the scenarios, making it the most likely entry point to the Island. However, with the land route to Bolivar Peninsula at high risk, the next option to get there is by the ferries between Galveston Island and Bolivar. From the scenarios, it can be seen that at least one of the ferry slips on the Galveston side is at high risk of structural failure and all of them will have been inundated at some point during the hurricane.

With this general information in hand, it can be seen that land access to Bolivar Peninsula is questionable after a hurricane event and any rescue teams will likely have to enter Bolivar by helicopter or by ferry. The I-45 Causeway gives reliable entry into Galveston Island according to the scenarios, and once on the Island, there are many routes available to navigate to where help is needed. In order to have a clearer picture of the viable post-event entry routes into Galveston, the case study must be extended to include damage to roadways, which is the next step in this research.

ONGOING AND FUTURE WORK: FAILURE DUE TO SCOUR

The current work on this study focuses on understanding bridge failures from a second common failure mode; scour at abutments and piers. This is a national problem notwithstanding coastal storm events, but hurricane events complicate the matter and scour at bridge sites leading to closure or repair has been observed after hurricane events (Padgett et al., 2008, Briaud, 2006). Scour arises when the force of the water is greater than the force holding the soil particles together around a bridge pier and soil starts to wash away creating a hole around the pier or abutment (Briaud et al., 2001). Hydraulic Engineering Circulation (HEC)-18 describes a deterministic methodology for estimating the maximum scour depth at a bridge pier (Richardson and Davis, 2001). Also, J. L. Briaud proposed a method called SRICOS for calculating a time dependent scour depth based on a soil sample from the site and the maximum scour depth (Briaud et al., 2004, Briaud et al., 1999). In this research, the SRICOS method will be adopted for estimating scour depth potential from hurricanes, where uncertainties in both the model and the input parameters will be treated probabilistically to assess the likelihood of exceeding various scour depth limits (Bolduc et al., 2008). This work is still ongoing.

After understanding scour at the bridge site, the last phase of this study will be to incorporate risk to roadways from soil erosion into the transportation risk assessment. This includes understanding how the process of soil erosion works in soil that is both heavily compacted and not usually in contact with water, as well as obtaining data on the soil type under each roadway in the Galveston Bay area. However, with this knowledge and data obtained, a model will be developed to estimate soil erosion potential under roadways, incorporating the velocity of the surge across the roadways, inundation maps of the entire transportation system and erosion rates of various soil types. By including scour at bridges and erosion under roadways, a more complete view of risk to coastal transportation systems during hurricane events can be arrived at.

CONCLUSIONS

This paper introduces research to conduct a regional risk assessment of coastal transportation systems vulnerable to coastal storms. A simple methodology is presented to estimate the failure probability of bridges due to bridge deck unseating or shifting, the most common structural mode of failure during hurricane events. To facilitate a region wide assessment of bridge, a detailed inventory analysis of Galveston Bay Area bridges was undertaken to obtain data that would otherwise only be found through field visits to each bridge site. This proposed method was then applied to several case studies of the Galveston Bay Area based on three hurricane scenario events. Results from this initial case study reveal that one, the model of the hind-cast Ike event correlates very well with the empirical evidence from Hurricane Ike and two, that the Galveston bridge system is highly vulnerable to stronger hurricane events as many bridges had a high probability of failure in “Mighty Ike.” Furthermore, in all three scenario events, many bridges could be susceptible to short term functionality inhibition due to inundation, with more bridges being inundated as the scenario events grew in intensity. Also, inhibition due to inundation and failure due to unseating were compared to illustrate the dangers of relying solely on inundation maps for regional risk assessment.

Applications of the three scenario events to pre-event planning and post-event recovery were proposed, with an emphasis on how utilizing a risk assessment of this type can assist in building a more resilient transportation network and a more sustainable bridge system. Finally, the two ongoing and future phases of this study were introduced, focusing on other common failure modes, scour at bridges and the undermining of soil at roadways. The continued development and refinement of probabilistic models for bridge, roadway, and hazard potential can provide decision support to owners and emergency managers based on risks from hurricanes to the transportation infrastructure. Its application can help to enhance the safety, sustainability, and resilience of transportation systems across coastal communities.

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IMPROVING THE THERMAL PERFORMANCE OF FRAMED WINDOW SYSTEMS

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ABSTRACT

The drive toward sustainable practice in building engineering has seen the inception of regulatory bodies, whose purpose is to provide direction for industry development in the face of climate change. One such organisation is the Australian Building Codes Board (ABCB), responsible for producing the Building Code of Australia (BCA) to which all buildings must conform.

In 2006, Section J was introduced into the BCA. This section outlines measures to reduce greenhouse gas emissions through energy-efficient design. In 2010, these provisions became more stringent, with Section J calling for thermal properties of vision glazing to be based on the combined or 'total' system: glass plus frame. Historically, designers have relied on glass manufacturer's advice for thermal values of individual components.

This paper examines the thermal performance of glass curtain walls as guided by the National Fenestration Rating Council (NFRC) procedures and subsequently as adopted by the ABCB. Combined glazing and frame systems are analysed using NFRC-approved thermal simulation software (Optics5, WINDOW5.2, and THERM5.2) developed by the Lawrence Berkley National Laboratory (LBNL). The results demonstrate that the thermal performance of a typical framed window system within a curtain wall is considerably reduced when all frame components are considered, as per new BCA 2010 requirements.

The paper also discusses potential improvements for curtain wall systems that are commonly available within the Australian façade industry by focusing on enhanced thermal performance due to reductions in thermal transfer.

INTRODUCTION

The world is experiencing a change in climatic conditions due to increasing average global temperatures. Climate change has provoked many governments and communities worldwide to move toward a more sustainable pattern of inhabitancy. Regulatory bodies have begun transforming the building industry with the intention of arresting an increase of greenhouse gas emissions through considered environmental policy design. One such organisation is the Australian Building Codes Board (ABCB) which produces the Building Code of Australia (BCA).

In 2006, the ABCB introduced a section into the BCA that relates to non-residential construction: Section J – Energy Efficiency. Section J is underpinned by an objective to reduce greenhouse gas emissions in buildings through increased energy efficiency (ABCB 2006, p341). Since its inception, Section J has sought to change the ways in which façade designers calculate thermal transfer into and out of a building. Prior to

Section J, calculations of the thermal properties of glass did not include the highly conductive metal frame that in many façade types encases and supports the glazing.

As such, the building industry has underestimated the actual thermal transfer through the window system. Research in the area of window systems has been led by developments in the United States by the National Fenestration Rating Council (NFRC), which produces standard procedures, methods, data, and thermal software analysis packages. Conformance with NFRC systems and standards is endorsed by the ABCB.

This paper studies the effects of Section J with reference to non-residential vision glazing applications in ‘typical’ curtain wall construction (refer Figure 1). The purpose of this paper is to highlight the effects of Section J and to promote greater industry awareness in this area through a guided explanation of how the glazing system is thermally analysed. Three case studies presented in this paper demonstrate that with only marginal improvements to existing typical framed window systems in accordance with NFRC procedures, the overall energy efficiency can be greatly improved at low commercial cost.

REGULATING TO IMPROVE ENERGY EFFICIENCY IN NON-RESIDENTIAL APPLICATIONS

Thermal transfer and its effect on energy consumption

Energy consumption in commercial buildings accounts for approximately 10 per cent of Australia’s greenhouse gas emissions (COAG 2009; CIE 2007). The façade of a building plays an integral part in determining the quantity of energy consumption within a building. Thus, any solution that seeks to increase energy efficiency in buildings must consider the role of the façade. In the majority of cases, the glazing forms a large portion of the façade, and is assumed responsible for a considerable amount of heat loss and gain (Lyons 2004; IPCC 2007).

The introduction and repercussions of the BCA, Part J2: Glazing

The BCA is updated annually in May and at this time each year each Australian State and Territory can consider one of the following options: adopt the BCA in full, elect not to adopt certain sections, or vary the requirements of a section through the relevant Appendix. State and Territories also have the opportunity to delay the implementation date beyond 1 May within their own legislation.

In 2006, the ABCB introduced a new section on energy efficiency pertinent to non-residential construction. Since its inception, the BCA has sought to tighten the regulations surrounding energy use in buildings, with the BCA 2010 presenting the most stringent requirements to date (ABCB 2010b, p1). It is noted that the BCA introduced Section J in 2005 with limited applicability. For simplicity, this paper only considers Section J as having appeared in 2006 as this was when it first applied to non-residential construction.

Part J2 of the BCA 2010 relates to the performance of the glazing which forms the conditioned envelope in most non-residential buildings. Part J2 provides guidance for the assessment of the glazed areas on each orientation of a building and provides limitations to the extent and performance of the glazing.

The BCA 2010 defines glazing as: “a transparent or translucent element and its supporting frame located in the envelope” (ABCB 2010a, p24). Reference made to the supporting frame infers that consideration must be made for the thermal contribution of the frame.

This arrangement of glass plus frame is referred to in this paper as a ‘framed window system’. Thermal analysis of this system yields values referred to as ‘Whole of System’ (WoS) or ‘Total’. Before the BCA 2006 introduced Section J, façade designers calculated the thermal properties of the window system purely on the ‘Centre of Glass’ (CoG) values. Analyses were driven on the assumption that the glass extended to the edges of the window system and thus disregarded any effect of the frame.

It is noted that the BCA definition of glazing limits designers in determining the performance of the transparent vision areas of glazing only. Part J2 does not include any allowance for inclusion or averaging with the opaque spandrel areas of a building. Consideration of spandrel areas currently lies with Part J1 – Building Fabric.

While the BCA 2010 (ABCB 2010a) does not propose a suitable procedure to analyse framed window systems, the BCA 2010 Deemed-To-Satisfy (DTS) ‘Energy Efficiency Glazing Calculator’ (ABCB 2011) and the ‘Guide to BCA 2010 – Volume 1’ (ABCB 2009) do provide some support for the designer. Both the tool and document refer to the Australian National Fenestration Rating Council (AFRC) and National Fenestration Rating Council (NFRC), the “Australian operator of the NFRC” (AFRC 2010, p1). The façade designer is directed toward these organisations via a ‘tip’ which appears when one hovers the cursor over the thermal property fields in the Glazing Calculator and through reference made in the BCA guide (ABCB 2009, p487).

The NFRC and its role in promoting an understanding of thermal transfer

The NFRC is a not-for-profit organisation which was established in 1991 by the window, door and skylight industries in the United States (US). The NFRC was founded after the US Department of Energy (DoE) “announced [in 1989] that the oil and gas reserves ... were 40 percent less than projected” (NFRC 2003, p5). At the time it was approximated that, “compensating for heat loss through windows accounted for 25 percent of all heating dollars spent in the US” (ibid.). Many in the building industry acknowledged the need for ‘self-sufficient’ or energy efficient buildings, yet they did not know how to effect such a change. For these reasons, the DoE demanded that an organisation be created by stakeholders; if an agreement could not be made, it threatened to legislate over the top of the glazing industry (ibid.). Thus the primary objective of the NFRC is to provide a sound base of information on glazing and its thermal properties.

NFRC-approved thermal simulation software has been developed by the Lawrence Berkeley National Laboratory (LBNL). The LBNL is an official DoE Laboratory that is operated by the University of California. The suite of software programs includes THERM5.2, WINDOW5.2, and Optics5. These interact with one another to model and simulate components of glazing systems. This software is developed in accordance with the international standard, ‘ISO 15099 Thermal performance of windows, doors and shading devices - Detailed calculations’ (2003) and procedure documents developed by the NFRC; it incorporates material properties, temperature conditions, and boundary conditions set out in these documents in order to generate accurate thermal properties.

THERMAL PROPERTIES OF GLAZING: U-VALUE AND SHGC

Heat is transferred through the window system via a mixture of conduction, convection, and radiation. The two thermal properties considered pertinent to this paper are: U-Value and Solar Heat Gain Coefficient (SHGC).

The first law of thermodynamics states thermal transfer is always from a hot environment toward one that is cold. Thus, U-Value represents the loss of heat to the external atmosphere or heat gain to the internal space. U-Value is affected by the temperature differential on each side of the glazing system, the air movement around the system, and the ability of materials within the system to resist thermal transfer. The lower the U-Value, the better it is at preventing the transfer of heat. Typically, glass manufacturers supply glass with its nominated U-Values obtained from thermally analysing the glass. Values can range from 5.0 W/m²K to 5.5 W/m²K for single clear glazing to below 2.0 W/m²K for double-glazed systems with high performance coatings.

The second thermal property, SHGC, measures the amount of solar heat that passes through the glass in the form of radiation. SHGC values are supplied by glass manufacturers and range from 0.0 to 1.0; 1.0 denotes maximum solar gain through the glass.

AN ANALYSIS OF THREE DIFFERENT WINDOW SYSTEMS

Aim

The intent of this paper is to depict the effects that the inclusion of different materials in a window system has on its thermal properties. Three case studies have been chosen:

- (1) The glass-only system considered by building designers before the introduction of Section J into the BCA.
- (2) The framed window system typical of current curtain wall construction.
- (3) The framed window system with minor thermally enhancements, considered to provide potential gains in energy efficiency.

As this paper directly relates to the use of glazing in commercial applications, a 'unitised curtain wall' façade system has been adopted for each of the framed window system analyses. Curtain wall façades are typically made up of a vision area and spandrel area (refer Figure 1). The façade panels are constructed from vertical and horizontal aluminium frames and are 'hung' from the building base structure. They do not support the building in any way and their load is transferred back to the base structure.

Curtain wall façade systems are common in the commercial construction as unitised systems can be prefabricated off-site to a high construction standard. They are then transported to site where they can be swiftly assembled.

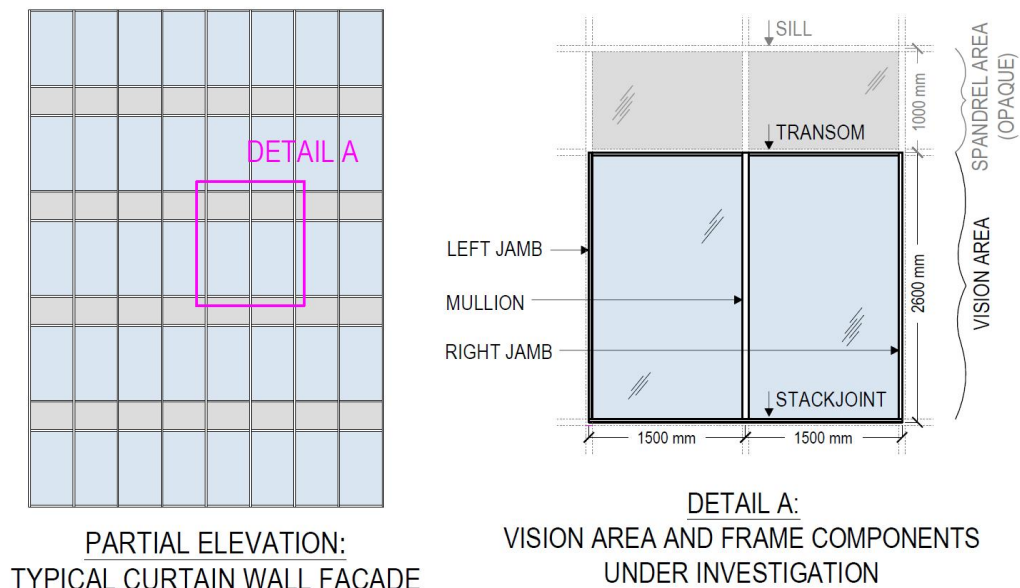


Fig. 1: ‘Typical’ curtain wall: partial elevation, the vision area, and frame components

To increase the solar and thermal performance of the curtain wall glazing, insulating glass units (IGU) coupled with low emissivity (Low-E) coatings are commonly used. Low-E is a high performance metallic coating applied to the surface of the glass. It is used primarily to stop any solar heat gain through the glass and is becoming more commonplace on commercial building façades as energy efficiency requirements become more stringent.

The glass which is utilised for this case study is an IGU with nominal thicknesses of 6mm glass/12mm gap/6mm glass as depicted in Figure 2. The outer light of 6 mm is a monolithic glass with a Low-E coating applied to surface two of the system. The gap between the outer and inner light has been modelled in each case study alternatively with an air and argon gas infill (Ar). Argon is a relatively inexpensive gas in Australia. It is also an inert gas acting to improve the thermal efficiency of the glass without affecting light transmission or compromising aesthetics. These arrangements are considered typical of curtain wall construction in Australia.

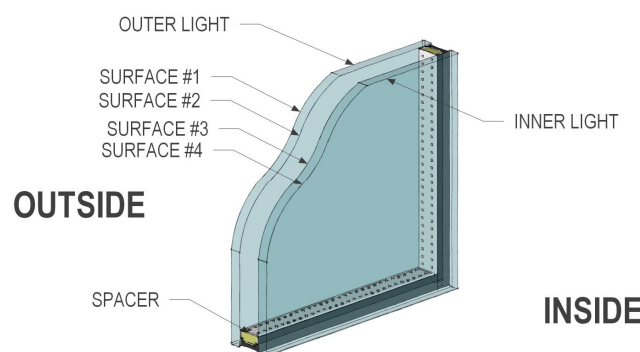


Fig. 2: The components of an insulating glass unit (IGU)

This assessment is only concerned with the transparent or vision areas of the façade in accordance with Part J2 of the BCA 2010 (ABCB 2010a). No allowance is made for the inclusion or averaging with the opaque or spandrel areas of the façade.

Method – the software and its use

The NFRC requires the glazed frame in a curtain wall system to be modelled as two side-by-side windows (LBNL 2006, p8-96). Figure 1 details the different horizontal and vertical components of this window system.

Step 1

WINDOW5.2 is first used to create and analyse the centre of glass properties (CoG) of single or multi-layer glazing assemblies. Glazing is selected from the software's glass library which has integrated links to the International Glazing Database (IGDB). The IGDB "provides glazing layer (peer-reviewed) optical data for over 1000 commercially available products" (LBNL 2011, http://windows.lbl.gov/win_prop/Default.htm); it is generally updated by the LBNL every six months. If a product is not listed in the IGDB, the user can create generic or modified glazing options in Optics5: support software to WINDOW5.2. These user-customised glazing systems are unendorsed by the NFRC. As such, Optics5 has not been used for this paper.

This glass is analysed in isolation, yielding the first set of results for case study one.

Step 2

Next, a typical frame section is produced in THERM5.2. This involves accurately recreating the section via importing a scaled '.dxf' file and tracing over it to create a 'mesh' of components (refer Figure 3). When the mesh is finalised, the IGU that was created in step one, is imported into THERM5.2. Once the materials are appropriately allocated and the boundary conditions are set, the extrusion is simulated to produce thermal values associated with the edge of glass and frame.

This step is repeated until all extrusions are analysed.

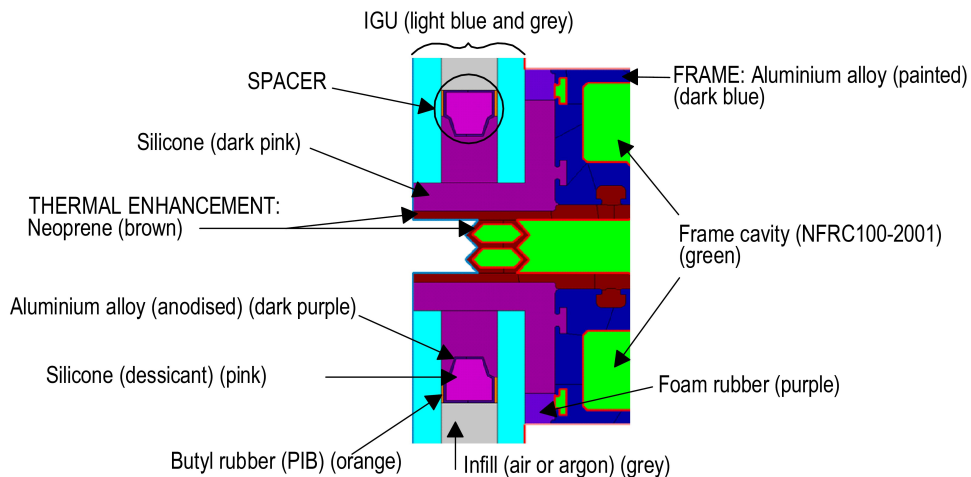


Fig. 3: Materials and components of the frame analysis from THERM5.2

Step 3

With the thermal transfer across each extrusion determined in isolation, they are imported back into WINDOW5.2 and into their appropriate place within the window system (refer Figure 1). The entire framed window system is finally simulated, yielding the WoS thermal properties for case study two. Steps two and three are repeated to determine the results of case study three.

Case Studies

Case Study 1

This case study investigates the results of the glass-only system when the infill is air and argon alternatively. The thermal properties produced by this analysis will be CoG values. In this case study no allowance is made for the frame of the system.

Case Study 2

Curtain wall systems normally expose frame elements such as trims and legs to the outside conditions. These components, due to the high conductivity of extruded metal alloy, provide a thermal bridge between the inside and the outside of a building through which thermal transfer can occur.

This case study shall examine a ‘typical’ structurally glazed and framed window system and relies upon the glass thermal values that were determined from the first analysis. The thermal properties produced by this analysis will be WoS values. The cross sections of the frame produced in THERM5.2 are shown in Figure 4.

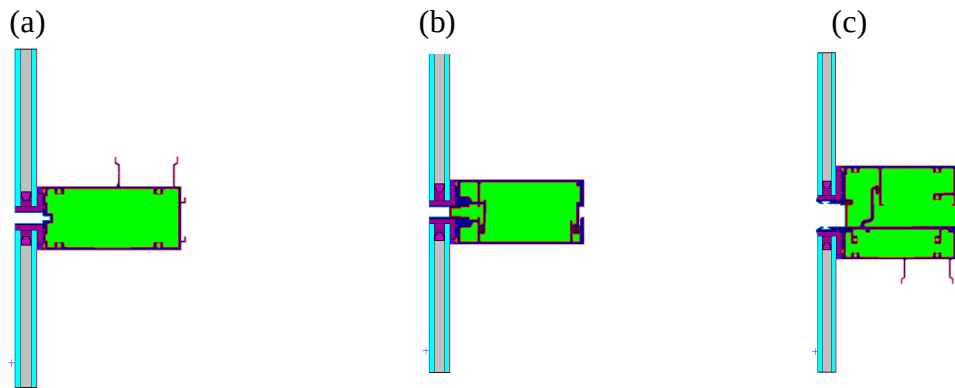


Fig. 4: THERM5.2 Aluminium extrusions: (a) Transom, (b) Mullion, Left Jamb, and Right Jamb, (c) Stackjoint

Case Study 3

This case study shall examine the effects of thermal enhancements incorporated into the typical framed window system. It is expected that the thermal enhancements incorporated into the total system analysis for the third set of results shall provide a marked improvement in the WoS U-Value and Total SHGC. The cross sections of the frame produced in THERM5.2 are shown in Figure 5.

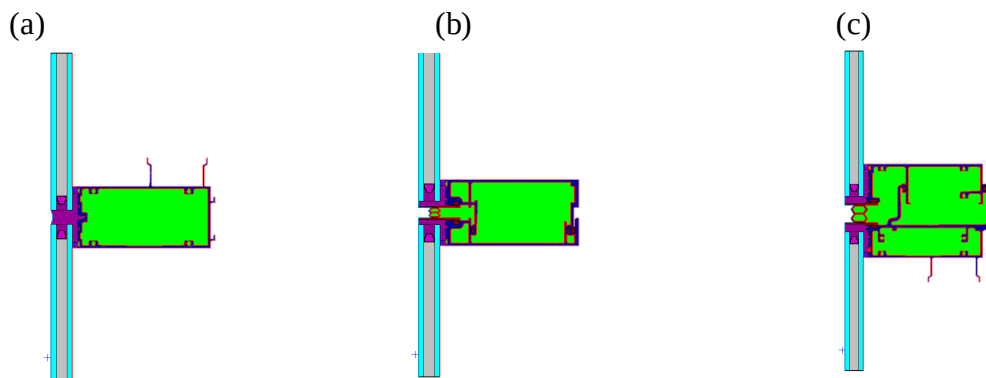


Fig. 5: THERM5.2 Aluminium extrusions with thermal enhancement: (a) Transom, (b) Mullion, Left Jamb, and Right Jamb, (c) Stackjoint

Results

Tab. 1: Results of thermal analyses

Case Study	Type of System (Thermal Properties)	IGU Glass Type & Arrangement	Infill	Thermal Properties	
				SHGC	U-Value W/m ² K
1	Glass-only system (CoG)	VNE19-63 6/12/6	Air	0.24	1.7
			Argon	0.23	1.4
2	Typical framed window system (WoS)	VNE19-63 6/12/6	Air	0.23	2.9
			Argon	0.23	2.7
3	Thermally enhanced framed window system (WoS)	VNE19-63 6/12/6	Air	0.23	2.1
			Argon	0.22	1.9

Discussion

The results of the three different case studies demonstrate the variance in thermal properties when different materials are taken into consideration. As expected, the CoG values derived from the primary analyses are the lowest of all systems considered. Prior to examination of the effects of the frame upon the U-Value, it was hypothesised that increasing the performance of the glass alone would yield gains in thermal performance (NFRC 2003, p5).

The results of the second case study indicate that in line with BCA 2010 Section J regulation, the inclusion of the frame in the analysis leads to a higher rate of thermal transfer across the system. The U-Value increases due to high conductance of heat that travels through the framed window system.

It is observed from the results that the SHGC decreases slightly when the frame is introduced into the framed window system analysis. CoG analyses assume the edge of the glass extends to the frame extents, whereas in reality, the frame accounts for a relatively large proportion of the area of the total window system. Therefore, a reduced area of glass leads to a smaller glass area available to transmit solar heat as depicted in WoS analyses.

Overall, the most interesting of these results is the combined effect of the neoprene gaskets and argon gas infill on the thermal performance of the typical framed window system. It is clear that such a system could present a simple solution to the energy efficiency issues of glazing to the façade. It appears from this analysis that merely covering the metal alloy frame elements such as trims and legs against outside conditions can improve the performance of these systems quite substantially.

FUTURE RESEARCH: THERMAL PROPERTIES OF SPANDREL AREAS

Spandrel panels are an increasing area of interest for further investigation using thermal modelling. At this stage, we are some way behind understanding and modelling accurately the behaviour of these systems. This is due to the complex construction of the panels which often includes many different types of insulating materials.

Part J2 – Glazing, of the BCA 2010 is concerned with vision areas of glazing only. A spandrel is defined as a: “panel of a wall located between vision areas of windows which conceal structural columns, floors and shear walls” (CMHC 2004, pA-12). As spandrel panels are generally opaque, they are considered in industry to fall under the requirements for Part J1 – Building Fabric. The method of analysis used to determine the thermal performance of these areas differs greatly from vision glazing accounted for in Part J2. Part J1.5 assumes the opaque glazed areas as ‘walls’; there is no mention of the supporting frame nor of the effects the frame on its overall thermal properties.

As such, the thermal performance of these areas is merely determined by hand calculation of the R-Value of each material through the centre of the panel. Over time, it is probable that the method of analysis of these opaque areas will become more sophisticated and therefore thermal assessment of spandrel areas will include the contribution from the supporting frame.

CONCLUSION

Energy efficiency is an important aspect of buildings and accounts for a large proportion of greenhouse gas emissions. In Australia, the government increasingly seeks to tighten regulation on these emissions through the provisions detailed in Section J of the BCA, with the BCA 2010 presenting the most stringent requirements to date. This paper considers the effects of Part J2 of the BCA in reference to the vision area of a typical curtain wall in non-residential applications.

Through results obtained from an analysis of a simple glass system, a framed window system and a thermally enhanced window system, it is illustrated that the frame accounts for a great proportion of heat loss and gain through the façade glazing. Further, these analyses demonstrate that with only marginal improvements to the framed window system, its overall energy efficiency can be greatly improved. All of the methods used in this paper to increase the thermal performance of the window system can be achieved relatively simply and with low commercial cost.

The Intergovernmental Panel on Climate Change (IPCC) acknowledges that the obstacles to reducing greenhouse gas emissions and achieving energy efficiency in buildings are great and many (IPCC 2007, p390). By accounting for at least part of the thermal transfer through increasingly accurate glazing modelling and simulation, we can begin to see positive developments to the ways in which our buildings perform in hot and cold climates.

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CHALLENGING DESIGN: FOUNDATIONS FOR TALL BUILDINGS

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ABSTRACT

The design of foundations for tall buildings is a challenging task for geotechnical engineers as they are required to consider all geotechnical aspects of the project, with the aim of identifying and managing the geotechnical risks. In the design of foundations for tall buildings, lateral loadings are of great importance as are the vertical loadings. A small rotation at the foundation will be magnified to a very large magnitude at the top of the structure due to the height of the building, which will affect the serviceability and functionality of the building.

This paper presents the foundation design process for two cases - the 1km high Nakheel Tower in Dubai and the 151 storey Incheon Tower in South Korea. The role of the authors as an internal reviewer of the analyses and an engineer undertaking the numerical analyses during the different project phases will be discussed. Analyses of the proposed foundation were carried out by computer programs using the boundary element method and 2D & 3D finite element methods based on the limit state approach. Key issues, in particular the overall performance of the foundation, will be addressed. The paper concludes with a summary of the design processes and the basic design criteria for tall buildings.

INTRODUCTION

In the design of foundations for tall buildings, engineers face a challenging task as a conventional design approach may not be able to address all the key design issues. The foundation design team has to employ innovative approaches to tackle the problem. Due to the size of the tall building, it is necessary to design a cost-effective foundation system that meets the long term performance requirements.

This paper will describe the involvement of female engineers in tall building projects. Details of the design approach and its application to the Incheon Tower in South Korea and Nakheel Tower in Dubai will also be discussed.

FOUNDATION DESIGN TEAM

Organisation Chart

The major tasks of the tall building geotechnical designers are to provide professional recommendations for the foundation design, undertake geotechnical review services and independent analysis of foundation performance. The tall building design team will often comprise a project principal, a project manager and design engineers as shown in the organisation chart in Figure 1.

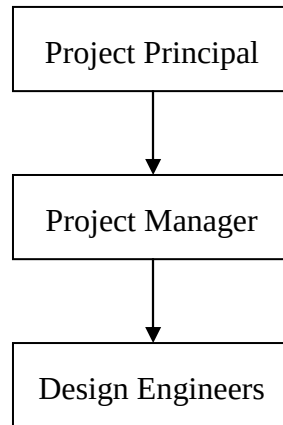


Fig. 1: Organisation Chart for Tall Building Foundation Design Team

The major roles for each member of the team are outlined below:

- Project Principal – supervision of the design team and review process and providing technical advice to the design team and the clients.
- Project Manager – preparation of proposal and cost estimation of the design services, liaison with the clients and supervision of design process.
- Design Engineers – development of geotechnical models and parameters and undertaking foundation analyses.

Roles and Responsibilities of Authors

Coffey Geotechnics have been appointed as the geotechnical designer for Incheon Tower and as geotechnical peer reviewer for Nakheel Tower.

The second author, Frances Badelow, was acting as the project manager for the Incheon Tower and also the peer reviewer for Nakheel Tower. The first author, Helen Chow, was acting as the design engineer for Incheon Tower and the peer reviewer for Nakheel Tower.

Project Manager – Frances Badelow

As a project manager, Ms Badelow was involved in the preparation of the proposal and estimation of the design and peer review services costs based on the scope of services provided by the clients.

For Incheon Tower, she set out the design steps for the design process, provided guidance to the design engineers in the development of geotechnical models and parameters, which were then used to carry out the design and reviewed the foundation design at various stages of the design process. She also liaised with the client and the structural engineers. As the superstructure and the foundation are interacting components of a single system, it is important that the geotechnical design engineers work closely with the structural design engineers to provide an effective design of the foundation for the client.

For Nakheel Tower, she set out the steps for peer review process and was part of the geotechnical peer review team for the foundation design provided by the foundation designer.

Design Engineer– Helen Chow

As a design engineer for Incheon Tower, Ms Chow was involved in the interpretation of ground conditions and assessment of foundation performance for different pile layouts and load combinations using different numerical methods. For Nakheel Tower, she

undertook independent analyses of the foundation system proposed by the foundation designers.

Prior to becoming a design engineer, Ms Chow carried out extensive research and developed a computer program for numerical analysis of piled raft foundations at the University of Sydney. The computer program employs the finite layer and finite element methods in the analysis. Upon the completion of this research, Ms Chow began work as a design engineer and has been involved in projects such as foundation design for bridges, buildings and embankments, soft soil ground treatment design, and retaining wall and slope stability analysis which allowed her to apply the knowledge she acquired through research to design work and further developed her design skills through the exposure to different kinds of project.

FOUNDATION SYSTEMS AND DESIGN ISSUES

Piled raft foundations are a cost-effective form of foundation for tall buildings and have been extensively used by geotechnical engineers in the past two decades. For most piled raft foundations, the primary purpose of the piles is to act as settlement reducers. The proportion of load carried by the piles is considered to be a secondary issue in the design.

Unlike the conventional piled foundation design in which the piles are designed to carry the majority of the load, the design of a piled-raft foundation allows the load to be shared between the raft and piles and it is necessary to take the complex soil-structure interaction effects into account.

The performance of a piled raft can be influenced by several factors such as the conditions of the supporting soil, relative stiffness between piles and soil, loading conditions, size and length of the piles, and pile arrangement. Therefore, the design has to take account of these factors to achieve the objective of economic construction with satisfactory performance.

In the design of foundations for tall buildings, design engineers have to understand the mechanism of load transfer from the raft to the piles and to the soil and then to address the following issues (Poulos, 2009):

- Ultimate capacity of the foundation subjected to vertical, horizontal and moment loading combinations.
- Influence of the cyclic nature of wind and earthquake on foundation capacity and movements.
- Overall settlement of the foundation.
- Differential settlements, both within the high-rise footprint and between high-rise and low-rise areas.
- Load-sharing between raft and piles and load distributions along the piles.
- Possible effects of externally-imposed ground movements on the foundation system, for example movement arising from excavations for pile caps or adjacent facilities or movements arising from ongoing consolidation settlement of soft soils.
- Earthquake effects, including the response of the structure-foundation system to earthquake excitation and the possibility of liquefaction in the soil surrounding and/or supporting the foundation.
- Dynamic response of the structure–foundation system to wind-induced forces.

DESIGN PROCESS

Prior to the commencement of a project, it is necessary to have a well planned design process. The design process should include several phases as follows:

- Phase 1 – Subsurface exploration
 - o Carry out a ‘desktop’ study of all the geotechnical engineering data and work available from previous investigations and geotechnical engineering recommendations in the vicinity of the site.
 - o Perform site specific geotechnical investigation to explore the soil strata profiles and groundwater conditions across the site and carry out in-situ and laboratory testing to obtain the properties of each soil strata.
- Phase 2 – Foundation Design
 - o Develop geotechnical models and parameters based on the available geotechnical information obtained from Phase 1.
 - o Preliminary selection of a foundation system using simplified geotechnical profiles and analysis methods.
 - o Detailed design of a foundation system based on detailed geotechnical models and structural loads provided by the structural engineers to predict the performance of the foundation including the ultimate capacity of the foundation and anticipated settlement of the foundation under loading combinations.
 - o If excavation is required, design the retention system. The design has to consider a system of controlling groundwater inflow during construction and for the completed project.
 - o Assessment of seismicity of the site including changes in soil and rock conditions during earthquakes and possible effects on the foundation system.
 - o Assess the effects of construction on adjacent properties and on other facilities within the site.
- Phase 3 – Foundation testing and monitoring
 - o Perform a pile load test for the verification of design assumptions in Phase 2. If necessary, refine the foundation design based on the interpreted test results.
 - o Monitor the performance of the foundation and compare the measured performance with the predicted performance.

INCHEON TOWER, KOREA

Incheon Tower is a super high rise twin tower, where each tower consists of 151 storeys with a height of 601m and is connected by three skybridges as illustrated in Figure 2. The tower is proposed to be constructed on reclaimed land underlain by soft marine clay in Songdo, Korea. Coffey Geotechnics was appointed as the geotechnical designer.

Ground Conditions

The Incheon site is located within an area of reclaimed land and as such is subjected to variable ground conditions. Detailed geotechnical aspects of the site are described by Badelow *et al* (2009).



Fig. 2: 151 Incheon Tower (artist's impression)

The reclaimed land is comprised of approximately 8m of loose sand and sandy silt which is constructed over approximately 20m of soft to firm marine silty clay (Upper Marine Deposits – UMD) underlain by approximately 2m of medium dense to dense silty sand (Lower Marine Deposits – UMD), followed by residual soil and a profile of weathered rock.

The lithological rock units present under the site comprise granite, granodiorite, gneiss (interpreted as possible roof pendant metamorphic rocks) and aplite. The rock materials within about 50m from the surface have been affected by weathering which has reduced their strength to a very weak rock or a soil-like material. This depth increases where the bedrock is intersected by closely spaced joints, and also sheared and crushed zones that are often related to the existence of the roof pendant sedimentary / metamorphic rocks. The geological structures at the site are complex and comprise geological boundaries, sheared and crushed seams - possibly related to faulting movements, and jointing.

The inferred contours of the 'soft-rock' surface within the tower foundation footprint were developed based on the available borehole data. It was found there was a variation in level of the top of soft rock of up to 40m across the foundation as presented in Figure 3.

To take into consideration the variation of ground conditions, the footprint of the tower was divided into eight zones with the appropriate geotechnical models and parameters developed based on field and laboratory tests and experience of similar soils on adjacent sites. As the performance of the UMD under vertical and horizontal loadings is of great importance in the design of the tower foundation, the selection of parameters for this stratum has to be carefully considered. Table 1 presents the typical parameters adopted for the foundation design.

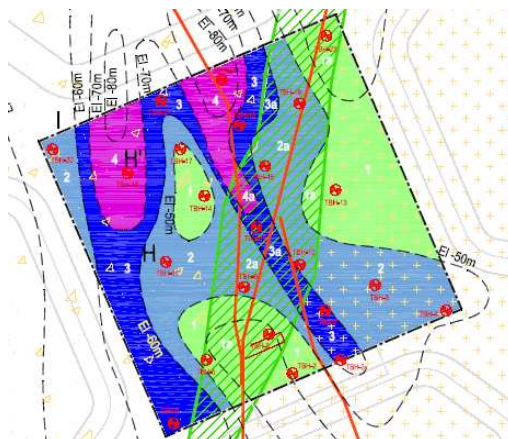


Fig. 3: Inferred Contours of Soft Rock Surface

Tab.1: Summary of Adopted Geotechnical Parameters

Stratum	E_v (MPa)	E_h (MPa)	f_s (kPa)	f_b (MPa)
UMD	7 - 15	5 -11	29 – 48	-
LMD	30	21	50	-
Weathered Soil	60	42	75	-
Weathered Rock	200	140	500	5
Soft Rock (above EL-50m)	300	210	750	12
Soft Rock (below EL-50m)	1700	1190	750	12
E_v = Vertical Modulus f_s = Ultimate shaft friction E_h = Horizontal Modulus f_b = Ultimate end bearing				

Foundation Layout and Load Combinations

The tower foundation consists of a 5.5m thick raft supported by 172 no. bored piles socketed into the ‘soft rock’ stratum. The pile arrangement and pile sizes were obtained from a series of trial analyses conducted by the geotechnical and structural engineers.

The primary purpose of the piles is to control settlement of the foundation. The pile lengths were determined by the geotechnical designers based on the pile settlement performance as the first priority and pile capacity as the second priority.

The final design adopted a diameter of 2.5m as the pile diameter with a minimum socket length of two pile diameters into soft rock. The pile lengths vary from 36m to 66m, depending on the depth of the founding soft rock stratum. The raft is embedded into the ground with the base of the raft located at about 14m below the ground surface level. The pile layout of the foundation is presented in Figure 4.

Load combinations used for the foundation design were provided by the structural engineers. The typical loads of the tower are summarised as follows:

- Vertical Load (Dead Load + Live Load): $P_{z(DL+LL)} = 6622\text{MN}$
- Horizontal Load (Wind Loads): $P_{x(WL)} = 146\text{MN}$, $P_{y(WL)} = 112\text{MN}$
- Horizontal Load (Earthquake Loads): $P_{x(EQ)} = 105\text{MN}$, $P_{y(EQ)} = 105\text{MN}$
- Moment due to Wind Loads: $M_{x(WL)} = 12578\text{MNm}$, $M_{y(WL)} = 21173\text{MNm}$
- Torsional Moment: $M_{z(WL)} = 1957\text{MNm}$

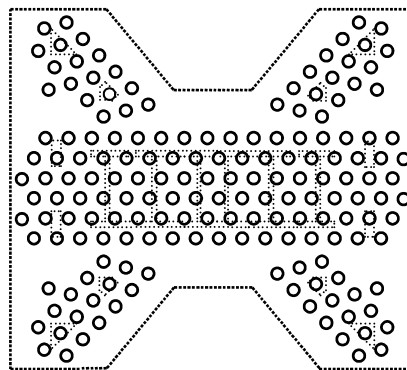


Fig. 4: Pile layout Plan for Tower Foundation

Foundation Performance

The performance of the foundation has been assessed using the following computer programs:

- CLAP (Combined Load Analysis of Piles) – for the assessment of overall stability under ultimate load combinations
- GARP (General Analysis of Rafts with Piles) – for the assessment of foundation settlement under vertical and moments loading
- PLAXIS 3D – for the assessment of the foundation under vertical and horizontal loading

Vertical Loading

Computer program GARP was used as the main design tool. In the GARP assessment, the piled raft is in contact with the underlying soil but not with the surrounding soil. The predicted maximum settlement for the load combination of dead load + live load was about 67mm with a differential settlement of 34mm. In the analysis, the resistance provided by the soil surrounding the raft has been ignored.

The commercially available program PLAXIS 3D Foundation was used to provide an independent check of the foundation settlement. Analyses have been carried out for two cases:

- Case 1: Similar to the GARP analysis, the piled raft is in contact with the underlying soil.
- Case 2: The piled raft is in contact with the underlying soil and the soil surrounding the raft and basement walls is included (the soil above the base of the raft).

The finite element mesh used in PLAXIS 3D for case 2 is shown in Figure 5 with basement walls supporting the sides of the excavation. The soil layers are modelled as Mohr-Coulomb materials to allow for non-linear behaviour. Figure 6 presents a plot of percentage of applied load versus vertical displacement at the centre of the raft which shows that the deflection of the foundation is reduced when the resistance provided by the surrounding soil is considered.

Horizontal Loading

The performance of the foundation under lateral loading is a critical issue in the foundation design for tall buildings. Computer program CLAP was used to assess the lateral stiffness of the pile group (assuming no contact between the raft and underlying soil) and a separate calculation was carried out to assess the lateral stiffness of the raft and basement walls. The predicted lateral deflection of the pile group from CLAP was about 22mm.

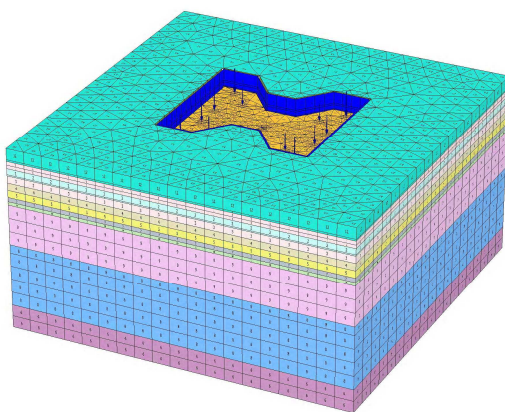


Fig. 5: Finite Element Mesh for PLAXIS 3D

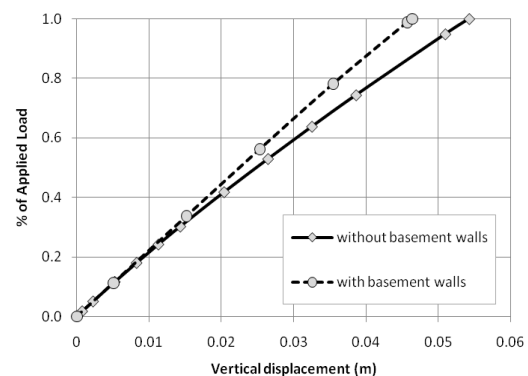


Fig. 6: Load Deflection Behaviour at Centre of Piled Raft (Vertical Loading)

PLAXIS 3D was used to assess the overall lateral stiffness of the piled raft foundation. Three cases were analysed by PLAXIS which included cases 1 and 2 as above and an additional case 3 that is similar to the CLAP analysis which considers the pile group only.

The lateral displacement predicted by PLAXIS 3D agreed well with the CLAP results. Figure 7 presents a plot of percentage of applied load versus horizontal displacement of the raft which shows that the lateral deflection decreases when the raft is in contact with the underlying soil and decreases further when the surrounding soil resistance is considered. In this case, because of the large number of piles, the effect of the raft burial on lateral deflection is small.

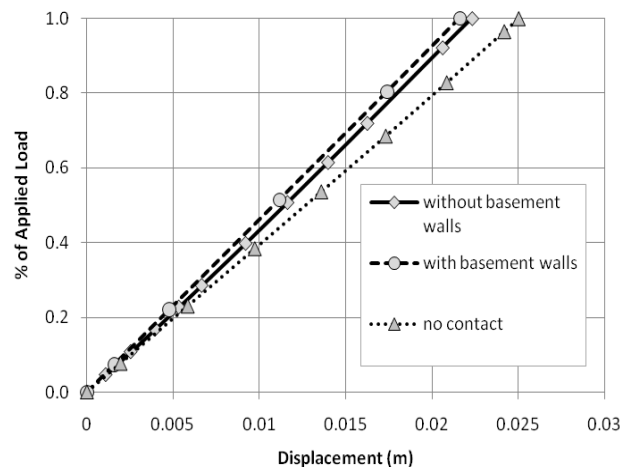


Fig. 7: Load Deflection Behaviour at Centre of Piled Raft (Horizontal Loading)

THE NAKHEEL TALL TOWER

Nakheel Tower, one of the multi-billion dollar projects in Dubai, will be one of the centre-pieces of Nakheel Harbour. The tower is proposed to have a height in excess of 1 kilometre with more than 200 floors and will be the tallest structure in the world when completed.

Golder Associates have been appointed as the foundation designer and Coffey Geotechnics appointed as the geotechnical peer reviewer.

A brief summary of the foundation design is described below, detailed analyses have been presented by Haberfield *et al* (2008)

Ground Conditions

The geotechnical profile consists of a 20m thick sand layer, underlain by cemented carbonate siltstone (calcsiltite) with gypsum layers up to 2.5m thick occurring at depths in excess of about 75m below ground level. Laboratory and in-situ tests were carried out to estimate the properties of the soil materials.

One of the features of the foundation materials was the existence of a 'bond yield strength' which controls the compressibility of the materials. If the imposed stress on the ground is less than the 'bond yield strength', the soil will behave as a very stiff material, otherwise, the compressibility would increase by an order of magnitude. In the foundation design, it is necessary to limit the stresses on the ground to be below the bond yield strength to avoid excessive settlement.

Foundation Layout

The foundation system consists of a raft with a thickness that varies up to a maximum of 8m supported by a total of 392 barrettes. The barrettes have sizes of 2.8m x 1.2m and 2.8m x 1.5m and extend to depths of 37m, 42m and 72m below the carbonate cemented siltstone where the base of the raft is to be founded. Figure 8 presents the foundation layout for Nakheel Tower.

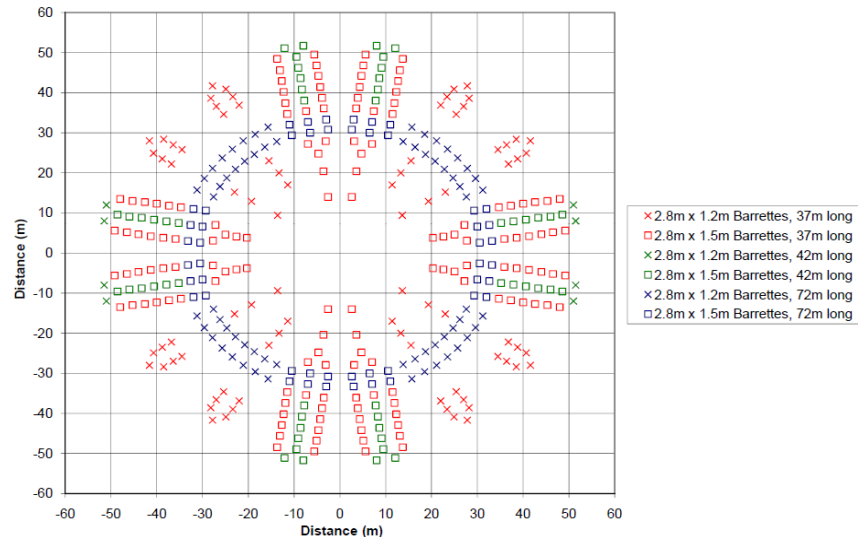


Fig. 8: Foundation Layout for Nakheel Tower

Geotechnical Peer Review

Geotechnical peer review involves the tasks of reviewing the geotechnical designers' report and the foundation design method, and then developing independent geotechnical models based on the available geotechnical information and then undertaking independent analyses for the foundation for different loading conditions.

The independent geotechnical model adopted for the foundation design was developed based on the available information and the barrette test results. Computer programs PIGS and CLAP were used to assess the overall stability of the foundation under the ultimate limit state load combinations in which the foundation capacities were reduced by a factor of 0.65. The assessment has shown that the foundation satisfied the ultimate state limit design criterion.

Computer program GARP was used to carry out the settlement assessment of the foundation system. Simplified finite element analysis using the commercially available PLAXIS 2D was carried out to check the GARP results. As the pile layout is symmetrical, a quarter of the foundation was modelled in GARP and an asymmetric model was used in PLAXIS 2D. The barrettes were modelled as equivalent circular rings in PLAXIS 2D.

From the GARP analysis, the maximum settlement was 95mm which was in good agreement with the computed settlement of 92mm obtained by Golder (designer) using a three-dimensional finite element analysis (PLAXIS 3D).

CONCLUSION

In the past few decades, there have been an increasing number of females choosing engineering as their career. Female engineers have been involved in many different

aspects of engineering works from academic research to working in industry. They are often given the opportunity to undertake different roles in major projects.

This paper outlines two of the super-tall building projects that the two authors have been involved with. Key design issues and design processes have been discussed. Ground conditions should be well understood in the development of geotechnical models and parameters. In the design, the performance of a foundation under lateral loadings is a critical issue, therefore special consideration has to be given in the evaluation of parameters for the assessment of lateral response.

For the Incheon Tower where the raft is embedded, it is necessary to consider the resistance provided by the soil beneath and surrounding the raft in the design.

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ACCELERATED DRAINAGE IN SAND PILES BY SUCTION THROUGH CONVOLUTED PERFORATED PIPE

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ABSTRACT

In most sand quarries a wet process is used to obtain sand and separate it from minerals. The final wet product with 20% of moisture content is stockpiled to dry, since it can not be sold unless reaching the required 5-6% of moisture. Quarries keep the sand in the plant for about two weeks to dry. Space limit and delays in production process are the problems quarries are facing these days. Water among sand particles gradually drain through the particles spaces and remains in the base of the pile. A drainage system consisting of a perforated pipe and a suction pump has been designed to remove water out of the sand pile base. The moisture reduction trend is monitored. Results show the system can be an improvement in the drying process.

INTRODUCTION

One of the fundamental parts of the concrete is sand. The majority of sand quarries use the same production procedure. The raw material is excavated from the mines and then crushed, washed, dewatered and aggregated.

Since the moisture is vital in concreting for having a high quality concrete, it is essential to have the basic material with specific moisture content. The desirable moisture content for sand is about 5-6%.

The quarries final sand product usually contains about 20% of moisture. Sand is piled in the plant for 7 days and is kept there for another 8 days to dry. During this period, the quarries can not produce sand often due to lack of space. After 8 days the sand moisture content is reduced to 5-6% and can be sold and removed from the plant and the quarry production cycle starts again.

With the aim of optimizing the production in quarry, a personal communication from Boral Quarry in Bacchus Marsh conducted a study to investigate the drying process in the sand piles and offering a solution to an enhanced drainage and drying process of the piles and eventually optimizing the production. In this regard, a moisture probe placed at 2 meters above the base of a 25m pile in the quarry plant. The probe recorded moisture contents continuously for the whole period; starting from piling to the time sand reaches the saleable moisture (Fig. 1). No specific drainage system is considered in the plant and under the sand piles.

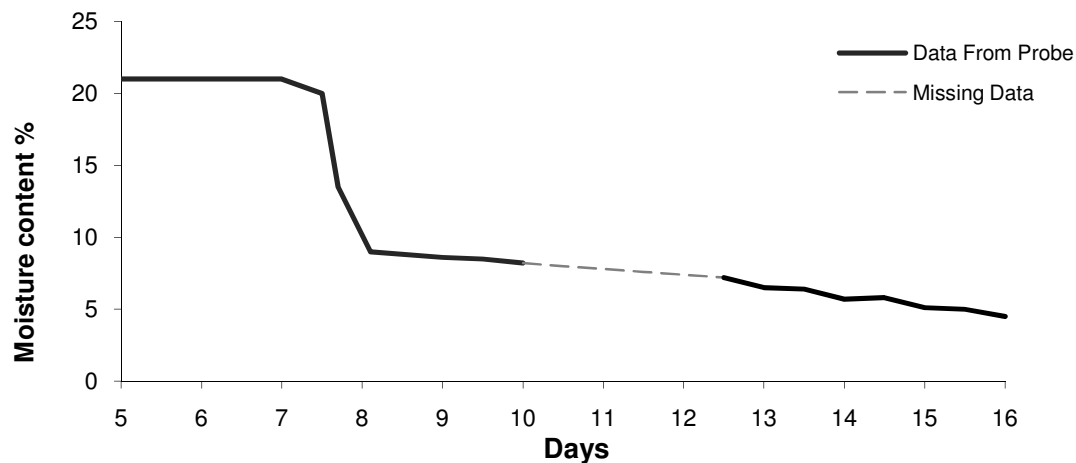


Fig 1: Drying trend of sand pile on quarry plant (Boral Quarry at Bacchus Marsh)

The sand moisture when the sand is first piled is more than 20%. The moisture is constant during the time when the production is still in process. Wet sand is being added to the pile until day 7. As soon as the pilling stops (day 8), the moisture content drops quickly due to gravity drainage of excess water between sand particles. The moisture drops from about 21% to 9% within a few hours. But the drainage rate decreases as the excess water has drained and what remains can not leave the system smoothly since capillary pressure and the surface tension resist the gravity (Bear and Verruijt 1987). From this point, the drying process with drainage or evaporation happens very slowly. It takes 7 days for the moisture content to decrease from 9% to 5%.

A patented method (McGarry 1984) suggested a suction system at the base of the pile can be very effective in the drying process of granular materials. The system consists of a convoluted spiral perforated pipe placed at the base of the pile and attached to a suction pump through a connection pipe.

The objective of this study was to find a quantitative rate of drainage from the sand stock pile. In this regard, a sample sand pile was made at the RMIT laboratory and the process of the drying was monitored, using a suction pump.

Experimental materials

Concrete Sand: supplied by Rocla Pty Ltd, with specific gravity of 2.55g/cm³.

Moisture sensors: MP 406 Moisture probe. Supplied by ICT International. Sensors were connected to a logger and set to read the moisture for every minute. The sensors were calibrated with the sand used for the experiment based on the oven dry method (AS1289.2.1.1-2005) and separately for each sensor. The out put of the sensors was in millivolt which had a linear relation with moisture content (VWC). The temperature calibration of the probes has been ignored since the temperature effect on probes in sandy system is negligible (Merlin et al. 2007).

Suction Pump: Sparmax TV 701 Diaphragm vacuum pump supplied by Dynapumps. Maximum suction capacity 80 kPa. The pump is equipped with a container that removes the water, since the pump is sensitive to water and basically is an air suction pump. The dish volume is 1 litre, therefore during the first few hours of working the pump was

stopped several times to empty the filled-container and also let the pump motor to cool down.

Perforated pipe: 20mm in diameter and spongy material.

A metal box: $70 \times 70 \times 70$ cm, modified with 16 holes with 30mm diameter on the bottom for drainage. To stop the sand from pouring outside through the holes, they were strained with fine mesh.

EXPERIMENTAL PROCEDURE

Free drainage

The sand was mixed with water and placed on to the metal box in a way to shape a pile with 600 mm height and 700 mm diameter at the base. The probes were buried inside the pile. The first probe was placed at 150mm from the bottom and the second one at 350mm. The probes were connected to a data logger that read and recorded the moisture of the sand for every minute for several days. (Fig.2)

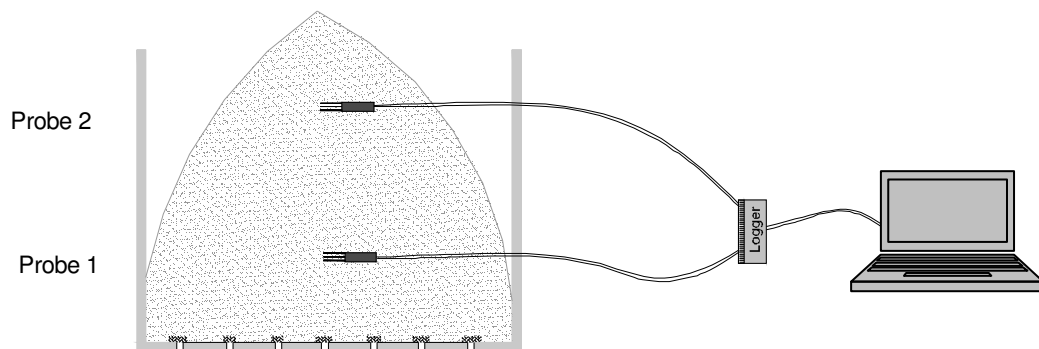


Fig. 2: Experimental setup

The drainage was rapid for the first few hours. Water started draining out of the base holes as the wet sand was placed in the box. The moisture content of the sand was about 22% at the starting point of the experiment. The moisture dropped down gradually with time. The rapid drainage during the first few hours is more obvious for the probe 2 that was placed on the top (Fig.3). Probe 1 showed a near constant drying process due to the water gathered at the base and drainage through the holes happens relatively slowly (Fig. 4). The holes in the metal box are designed to let the excess water out.

The sand stayed in the box and in the lab condition for 14 days. On day 14 the moisture decreases to 8% (at the second probe point). Since after day 2, no water had trickled out from the holes, therefore, it has been concluded that the moisture has decreased due to evaporation only and the lab conditions (no fresh air, wind or sunlight) made the process even slower.

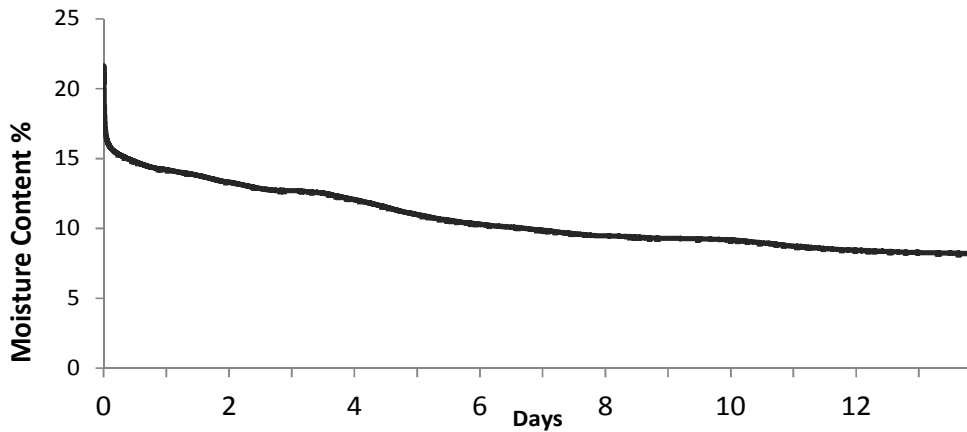


Fig.3: Monitoring of moisture content at the point of probe 2

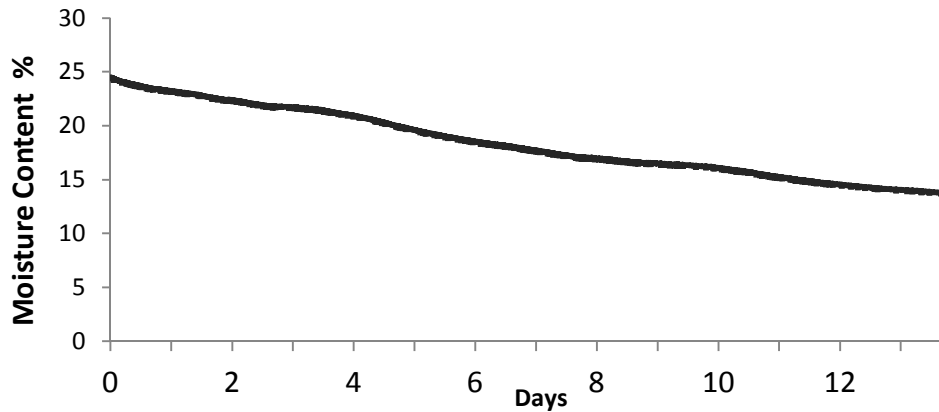


Fig.4: Monitoring of moisture content at the point of probe 1

Drainage by using perforated pipe

A suction system consisting of a perforated pipe and a suction pump was prepared (Fig. 5). The perforated pipe was fixed with convoluted shape on a wooden board and placed on the bottom of the box. It is worth mentioning that the holes are covered and no drainage is possible through them.

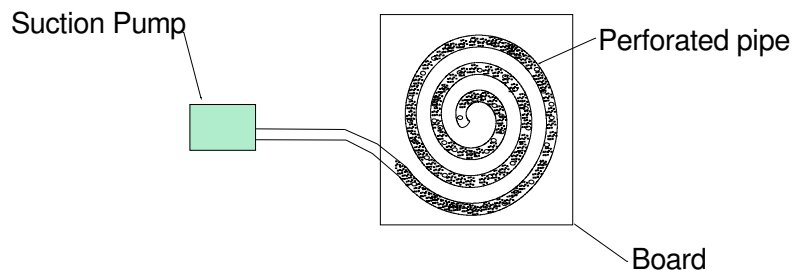


Fig. 5: The perforated pipe attached to the pump

The perforated pipe was attached to the suction pump with a connecting pipe. The sand was placed over the perforated pipe and probes were situated in the same positions. The pump was working for the majority of the first few hours except for short intervals

needed for emptying the water collected and cooling of the pump. The amount of the water coming out was considerable but decreased with time. The sharp drops in the graphs show the periods that the pump was working.

RESULTS AND DISCUSSION

The moisture content reduction at the point of probe two is fast and obvious for the first few hours with pump working. No fluctuation is obvious due to the distance between probe and the perforated pipe comparing to the first probe (Fig. 7). The moisture content decreased to about 4% after 3 days.

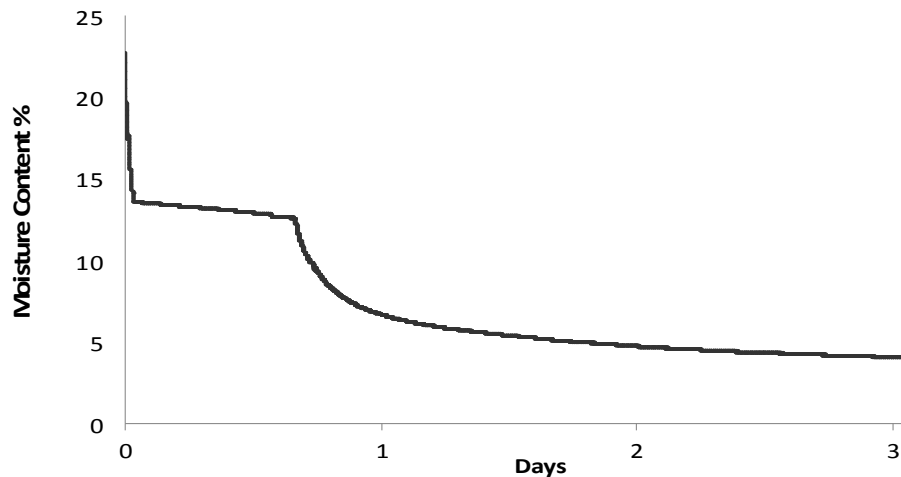


Fig.6: Monitoring of moisture content at the point of probe 2

Probe 1 show fluctuations with pump started and stopped working (Fig. 7). The negative pressure increase in the stock pile affects the drainage behaviour. The water moves toward the perforated pipe when the negative pressure created with the pump working, but as soon as the pump stops, the water moves back to the areas with lower moisture content and caused the probe shows a slight increase in moisture. The moisture content of the sample decreased to 10% in just one day and after 3 days probe shows about 8% of moisture. The pump was not working continuously during this period.

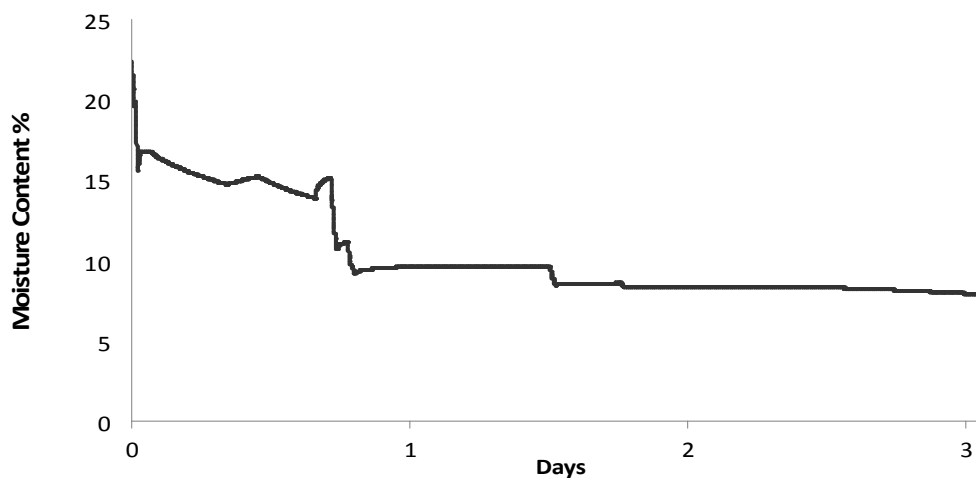


Fig.7: Monitoring of moisture content at the point of probe 1

The suction capacity of the pump was 50kPa at the start of the experiment and it decreased with moisture reduction in progress. On the third day no water was drained through the pipe and the pump could get air and the pressure decreased to less than 20kPa (Fig. 8).

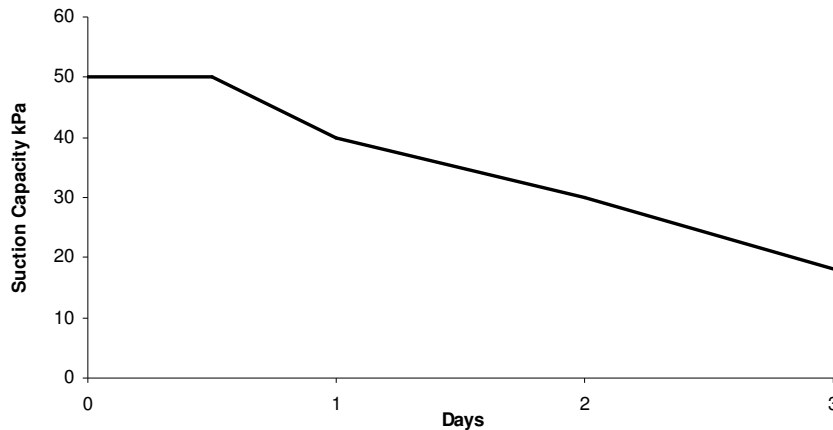


Fig. 8: Pump suction capacity

The drainage system worked very effectively on the sample sand pile and it happened in one third of the normal period. However, the size of the sample pile and the capacity of the pump used for it should be compatible. The drying trend in the plant is quit different and is under the influence of weather conditions.

CONCLUSION

By using the suction system, the moisture reaches to 4-8% in just 3 days while with no suction system it took more than 2 weeks. This is a preliminary study and more investigation is needed in the future.

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RULES FOR THE PROVISION OF EARTHQUAKE RESISTANCE IN SMALL BUILDINGS IN GHANA

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ABSTRACT

Although earthquakes do not occur frequently in Ghana, damaging earthquakes with magnitudes greater than 6.0 on the Richter scale have been recorded in the past. Attempts to ensure that buildings are provided with adequate seismic resistance have generally been directed towards the provision of a modern seismic code for the design of reinforced concrete structures. This approach however does not address the problem posed by the majority of buildings which are one and two storey structures constructed by craftsmen and other individuals. These buildings are essentially non-engineered and this paper examines building practices used in the construction of such buildings. The paper finds that many of these buildings will not be able to withstand levels of seismic action that lead to peak ground accelerations greater than 0.25g without excessive damage. The paper proposes simple rules for the construction of one and two storey buildings based on observed behaviour of similar buildings in earthquakes. The rules are intended for use by builders and those responsible for enforcing building regulations.

INTRODUCTION

The seismicity and geology of Ghana shows that there are two major sources capable of producing large earthquakes, the Coastal Boundary Fault and the Akwapim Fault Zone.

The Coastal Boundary Fault runs parallel to the coast and intersects the land at a number of places. Accra, the capital of Ghana lies at one of these points of intersection. A number of smaller faults which form part of the Akwapim Fault Zone can also be found in Accra. These faults extend in the direction of the Akwapim mountain range into Togo (Fig 1).

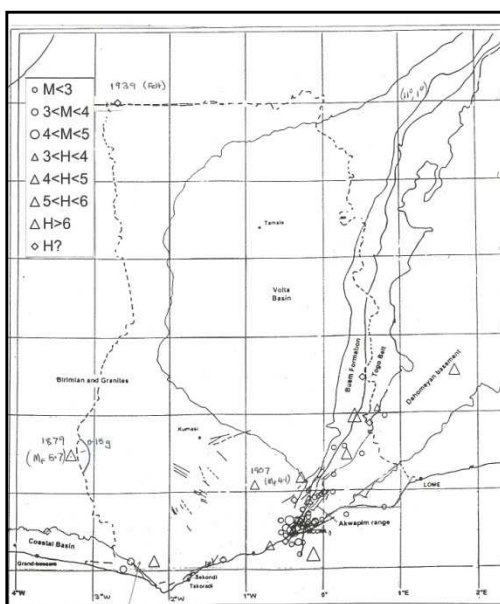


Fig. 1 Map of Ghana Showing
Fault lines and Historical and
Recent Seismic Events

A number of destructive earthquakes have been recorded in Ghana in the past. The largest one, a magnitude 7.1 earthquake, occurred in 1862 (Ambrayes, 1988). It destroyed most coastal areas of Ghana as well as some inland areas. Occasional minor events serve as a reminder that the potential for a major earthquake exists. In spite of this, very little has been done to prepare buildings for the effects of an earthquake.

The advice given to persons who want to provide earthquake resistance in their buildings

is that they should employ professional engineers. Unfortunately there is very little expertise in earthquake engineering amongst professional engineers. For one and two storey buildings, most engineers will undertake gravity load design with no special detailing for seismic effects. Engineers have perhaps been lulled into a false sense of security by the statement that during the last major earthquake in June 1939, no well designed reinforced concrete framed building failed in Accra (Deakin, 1941).

Although attempts are underway to update the seismic code for Ghana, this will not provide a satisfactory solution. Building development is often far ahead of planning. Many buildings are put up without the required permits. Even where engineers are employed for the design of a building, they will often not be involved in the supervision of construction. The laws currently rely on a few building officials who are expected to monitor building construction at various stages. This is virtually impossible considering the number of buildings and the rate of new development. It is also not feasible to ensure that builders employ professional engineers for every little building.

Unfortunately in Ghana many craftsmen receive little or no formal training. Although the structures exist for trade testing, very few craftsmen actually take the tests because it is not a legal requirement. In the past, formal apprenticeships were undertaken and this ensured proper training of craftsmen but these systems are also breaking down. In a random survey of 100 buildings in Accra, over sixty five percent of the one and two storey buildings showed signs of failure mainly caused by poor construction practices (Bou-Chedid, 1993). The numbers reduced for buildings three storey and above possibly because developers of such buildings are more likely to employ the services of professionals.

In order to effect a real change, it is proposed that every individual involved in the construction process should be empowered with the knowledge of the right way to build. This is to be done by present engineering rules in the form of clear simple guidelines that are well illustrated. Construction costs in Ghana are very high and it is believed that most people would want to ensure that their investment is well protected. The current situation puts them at the mercy of ill trained craftsmen.

Public education will be required to promote the use of the guidelines. Craftsmen will need to be properly trained. An Engineering Council Bill proposed by the Ghana Institution of Engineers has recently been passed by parliament. This law will require the registration of all craftsmen. Craftsmen can now be made to take trade tests before registration to ensure that they have the requisite knowledge and skills before they practice. With education, individuals will demand evidence of registration before they entrust their hard earned money into the hands of any craftsman.

CURRENT CONSTRUCTION PRACTICE

Architectural forms, structural forms, methods of construction and materials all play an important role in determining the performance of buildings under seismic action. A variety of construction methods and materials are used in Ghana. The ones described in this section are those commonly used in non-engineered structures.

Architectural forms

In Ghana today a great variety of building designs can be found particularly in urban areas. With the exception of recent housing developments by estate developers, the most noticeable feature of any estate area is the distinct lack of uniformity. Each house is individually designed. Many modern residences are not only built for function. They also act as a status symbol. Because the pace of building far outstrips infrastructure planning and development, several buildings are put up in areas where water supply is

inadequate or non-existent. Water is often stored in water tanks on top of the roof. Ghana has a warm tropical climate. Whilst some houses may be provided with large window and door openings for proper ventilation, others may be given small window openings and air conditioners will be installed. Typical architectural features are listed below.

- An irregular plan and distribution of internal partitions
- Storage area for water tank at roof level
- Unsecured Gable walls sometimes with openings
- Concrete Fascia's and gutters
- Large window and door openings in walls
- Front porch and kitchen courtyards
- Carports and attached or detached garages
- Balustrades, decorative fin walls etc.

Structural forms

Two basic types of structure are common. Unreinforced masonry structures and reinforced concrete frame structures with masonry infill. Sandcrete block work is used in both. Unreinforced masonry structures are mostly tied at lintel level with a lintel beam. In a few cases, lintel beams may be placed over door and window openings. In such cases, a roof beam may be introduced at eaves level to run throughout the building. In other cases, the building is left without any form of tie beam. Two storey buildings are more likely to be provided with a reinforced concrete frame. A survey conducted in 1993 of a hundred buildings in Accra showed 43% with a reinforced concrete framework, 41% with tie beams at lintel or roof level and 16% with lintel beams only. (Bou-Chedid, 1993). The study was made up of 88% one and two storey buildings.

Materials

Cement

Ordinary Portland cement is produced in Ghana. It comes in 50kg bags and it is used in practically all construction work.

Reinforcement

Steel reinforcement is also produced in the country. It is generally mild steel with a characteristic strength of 250N/mm^2 . Currently bars of 10mm diameter and above are mostly deformed bars. Standard sizes available are 6mm, 10mm, 12mm, 16mm and 20mm. Unfortunately non-standard sizes can also be found on the market and they serve as a source of confusion as for example a 14mm bar may be passed off as a 16mm bar.

Aggregates

Fine aggregate comes in different grades. Rough sand which is mostly used in concrete works and mortar is dredged from riverbeds. It is not processed in any way and can be seen to contain some twigs, roots or other vegetable matter (Fig 2 a). Smooth sand is used in final finishes. Quarry dust is used in the production of concrete blocks but because of its relatively high cost, it is not used in concrete production.

Coarse aggregate can either be machine crushed from quarries or hand-broken. Machine crushed stone is very expensive so many developers use hand broken stones. Different grades and qualities are available. One particular type is quarried from shales. The stones are flat and can easily be broken. For reinforced concrete work, 20mm aggregate is generally sought but more often than not, the stone presented as 20mm aggregate, has a majority of pieces that are much larger than 20mm. Although it is possible to buy well-graded angular and clean hand broken stones, they can cost twice as much.



Fig. 2 (a) Rough Sand and Quarry Dust (b) Sandcrete Block work

Masonry unit

The sandcrete block is the main unit for construction of walls. It is made from a cement and sand mixture that is pressed into a mould and compacted whilst damp (Fig 2 b). Several small operators are involved in its production and there is a wide variation in strengths. Larger operators tend to produce concrete blocks using quarry dust in place of sand. These blocks are much stronger but because they are also much more expensive, many developers will not use them.

Typical dimensions of sandcrete blocks in production are:

- 100mm x 200mm x 400mm (4" x 8" x 16")
- 125mm x 200mm x 400mm (5" x 8" x 16")
- 150mm x 225mm x 450mm (6" x 9" x 18")

The 125mm (5inch) block is currently the most widely used for external walls and partitions. Both solid and hollow blocks are produced but the solid block though slightly more expensive is more popular. Other forms of block work such as hollow clay blocks and cement stabilised lateritic blocks are only rarely used. The use of bricks has not proved popular possibly because the skill of bricklaying is known to relatively few artisans and because bricks are not as readily available as sandcrete blocks.

Methods

The methods described below are typical for structures that have no engineering input in their design or construction.

Concrete

The quality of concrete used in construction is highly variable. Some artisans determine the proportions of materials to use by eye whilst others determine them by volume using a headpan (A metal bowl with handles on either side) for measurement. Fine and coarse aggregate is done with a headpan. Cement is not normally measured as one 50kg bag of fills two standard headpans to the brim. Fine and coarse aggregates are often measured heaped rather than level resulting in a mixture that is weaker than expected.

Foundations

Foundations for walls and columns are usually shallow. A depth of 750mm is considered sufficient by many artisans. There are several instances though where footings are placed at smaller depths. Soft soils, expansive clay soils, waterlogged soils or other problem soils receive no special treatment. Walls are founded on strip footings of mass concrete.

Columns are mostly founded on isolated bases. They are not always reinforced. Many artisans would prefer to keep the base size of column footings in line with the wall footings so a size of 450mm x 450mm is used. These bases are usually placed at the same level as wall footings. Sometimes column footings are placed at slightly lower depths than beams.

Reinforcement is normally 12mm diameter bars placed at intervals, which may vary from 150mm to 300mm. For columns that are placed within walls, block work is constructed to the level of the underside of the ground floor slab. Column footings are also constructed to this height by placing formwork on either side of the block walls. After filling with gravel or sand, the ground floor slab is cast. The column footing is continued by providing a 50mm kicker on top of the slab. At this stage, any mistakes in original alignment of footings are corrected. The length of longitudinal reinforcement left to provide a lap for column bars can be as little as 150mm.

Columns

Sometimes columns within walls are formed by first constructing the walls, then attaching formwork on either side and pouring concrete. This means that where 125mm blocks are used, the columns end up being 125mm X 125mm in cross-section.

In two story buildings, columns are sometimes made bigger. Longitudinal reinforcement used in columns of 150mm width tends to be twelve millimetre bars. For larger columns 16mm bars may be used.

Stirrups of 6mm or 10mm are used. Very often, stirrups are widely spaced at 300mm centres and more. They are anchored at the ends in 90-degree bends. The extension of bars beyond the final bend varies but it is often extremely short.

At beam column joints, stirrups are not continued through the joint. Sometimes, developers purchase already prepared reinforcement for column and mat foundations. These are prepared in much the same way as described above.

Beams

Beams are constructed by first building the walls to the level of the underside of the beam, positioning the reinforcement, then fixing formwork on either side of the wall, before casting concrete. Lintel beams used in single story buildings normally have depths of about 230mm (Fig 3b). Beams for two storey buildings are usually 450mm deep. Beams in single story buildings can be reinforced with two, three or four 12mm longitudinal bars. In two storey buildings, 16mm diameter bars may be used.

Links for beams are formed using 6mm or 10mm bars at a spacing of around 300mm. Like the column stirrups, they end with a 90-degree bend and the extension beyond this can be quite short.

Slabs

The thickness of ground floor slabs on fill can be anything between 100mm and 150mm. Suspended floor slabs would generally be of reinforced concrete. Typically they would be 150mm thick. Reinforcement is usually 12mm diameter bars but some artisans may use 10mm diameter bars. In recent years, slab systems employing precast prestressed beams and precast concrete slabs with a have been introduced. A thin layer of concrete is applied on top of the prestressed beams and slabs. The prestressed beams are supported on existing reinforced concrete beams but they are not tied to the existing structure (Fig 3a). These systems are beginning to gain in popularity as they represent a significant saving in cost.



(a)
Fig. 3 (a) Precast Floor Slab System

(b)
(b) Roof Rafters & Typical Lintel

Roofs

Asbestos cement, iron and aluminium corrugated roofing sheets are the most widely used forms of roofing. Concrete and micro-concrete roof tiles, felt based tiles, and metal tiles are all in use particularly in the more expensive residential areas. Flat concrete roofs became popular during the 1970s however problems due to leakage etc were experienced and their use declined. Concrete roof slabs are now used in some portions of roofs to support water tanks.

Often sloping roofs are supported on gable walls formed from block work. Parts of the block work are broken to receive purlins. Purlins are nailed on both sides. Formwork is placed on either side and filled with mortar or concrete to hold the purlins in place. Where there is no intermediate block work to support a gable, rafters or some form of truss may be used (Fig 3b). Trusses may be tied with reinforcement from columns or embedded in beams.

ASSESSMENT OF VULNERABILITY OF BUILDINGS

In the most recent proposals for a seismic risk map of Ghana, the country is divided into four seismic zones. Zones 3, 2, and 1 are located in the southern part of the country and they are assigned horizontal peak ground accelerations (pga's) of 0.35g, 0.25g, and 0.15g respectively (Amonoo-Neizer, 2010). Seismic Zone 0, covers the north of the country and it is assigned a pga of 0g. The values are based on a maximum expected earthquake of 6.5 on the Richter scale.

In order to assess the vulnerability of the current building stock, a Damage Probability Matrix developed from accounts of damage to buildings after the 1939 Accra Earthquake is used (Bou-Chedid 2002). In the Matrix, buildings are grouped according to their structural form and construction material. Three categories are identified, reinforced concrete framed structures with infill walls of sandcrete block or clay bricks, sandcrete wall structures which may or may not have a tie beams and adobe buildings. Table 1 shows relevant values for building types under discussion. Expected damage levels are related to the Modified Mercalli Scale.

According to a correlation given by the US Geological Survey, a pga of 0.15g corresponds to Modified Mercalli of VI, 0.25g to VII and 0.35g to VIII. Table 1 indicates that 25% of sandcrete block buildings in seismic zone 2 and 55% in seismic zone 3 will be severely damaged in event of the design earthquake. The buildings will require costly repairs and some evacuation. Reinforced concrete buildings are expected to experience mainly non-structural damage such as cracks in the walls etc. Considering the fact that the Capital City Accra, two main port cities and two other regional capitals all lie within seismic zone 3, the potential for loss is considerable.

Damage State	% of Buildings Reaching Each Damage State (Modified Mercalli Intensity)							
	Sandcrete Block				Reinf. Concrete			
	VI	VII	VIII	IX	VI	VII	VIII	IX
0 – None (No Damage)	15	0	0	0	95	90	50	20
1 – Minor(Very little non-structural damage)	55	50	15	5	5	10	25	25
2 - Moderate (Widespread non-structural damage)	25	25	25	15	-	-	25	55
3 - Severe (Extensive non-structural & some structural damage)	5	25	55	55	-	-	-	-
4 – Very Severe (Completely destroyed)	-	-	5	25	-	-	-	-

Table 1 Extracts from Damage Probability Matrix

It must also be noted that the p_g values indicated for the seismic zones are those expected at stable rock sites. Values may be amplified considerably in certain circumstances, eg. where soft soils are encountered. A study of the Greater Accra Metropolitan Area found low velocity sediments that gave rise to p_g 's as high as 0.57g in a 1939 scenario event (Amponsah et al). The areas covered by these sediments are now developed and more destruction can be expected. In the event of a Magnitude 7.1 earthquake as happened in 1862, much greater damage can be expected.

At the time of the 1939 event, many areas that are currently developed were either not inhabited or were villages with adobe, thatch and other such buildings. In general reinforced concrete construction was not widespread and most such structures were well built government buildings.

Buildings that are not well constructed can expect to experience much more damage. An examination of current construction practice reveals several areas that are likely to lead to poor performance of buildings in earthquakes. The architectural forms described are known to have performed badly in past earthquakes. Features such as irregular plans and distribution of internal partitions can create stiffness or mass eccentricities. Carports placed at the ground floor of a storey building and create a soft storey which will attract larger forces leading to damage and possible collapse. Large window openings in walls can lead to weaknesses in a load resisting system that is dependent on the stiffness of these walls. Water tanks at roof level and concrete fascias and gutters can create a top-heavy structure. Unless carefully positioned, this may also lead to eccentricities in mass. Features such as balustrades and decorative fin walls although they may not directly affect the performance of the structure, nevertheless will still have to be adequately detailed if they are not to fall away from the structure and injure people in the process. Several unconfined gable walls were known to have collapsed in 1939.

The quality of materials used plays an important role in determining the performance of buildings under seismic action. Current methods for producing concrete may lead to a weak product. Sandcrete block work that is weak will not provide additional resistance to the structure.

DISCUSSION

Structural forms currently used are a mixture of reinforced concrete frame construction with some elements of confined masonry construction but the confined masonry system is not sufficiently developed to be able to perform adequately in an earthquake.

In confined masonry systems, walls are built first before the confining reinforced concrete elements of tie beam and tie column are cast. The function of these tie

elements is to confine the masonry and ensure that it works together with the concrete ties. The walls are securely connected to the tie column through teeth like indentation at the point of connection. The connection may also be achieved with steel dowel bars placed at intervals in horizontal mortar joints that protrude into the columns. The confined masonry wall thus forms the lateral load resisting system. It also supports gravity loads and a key feature is that the masonry units are load bearing. One of the main advantages of the confined masonry system is that tie columns and beams do not require any special detailing. Reinforcement used is generally 4No 10mm bars with 6mm links.

One element in confined masonry construction that does not generally feature in current practice in Ghana is the plinth band. The plinth band is required to transmit loads from the wall to the foundation. It has the added advantage of protecting the wall from excessive settlement in soft soil conditions.

In reinforced concrete construction the frames are built before infill walls are constructed. Beams and columns are usually larger than the walls and isolated footings must generally be provided under each column. The frame forms the lateral load resisting system and special detailing is required to ensure that it behaves in a ductile manner during an earthquake. Infill walls are not load bearing.

From the above descriptions, it is clear that a number of difficulties will have to be overcome in order to ensure that buildings are provided with adequate resistance to earthquakes. In the implementation of the confined masonry system, the main hurdle is the fact that the sandcrete block in common use is not load bearing. The introduction of a plinth band and several tie columns will introduce some extra cost but the need for pad foundations will be eliminated and it is believed that the extra cost will not be excessive. The main advantage of the system is that no special skills are required and the current workforce should be able to implement the system without much difficulty.

With regards to reinforced concrete framed construction, the main drawback will be the need for larger columns and beams and greater skill and care in detailing members. This will mean that its implementation cannot be left in the hands of the unskilled.

RECOMMENDED GUIDELINES

In view of the difficulties outlined above, it is proposed that engineering rules are presented in two separate guidelines. One guideline for the construction of single storey buildings based on the confined masonry system and the other for the construction of two storey buildings based on the reinforced concrete frame system. It is envisaged that walls in a single storey building will not be required to carry any significant gravity load and therefore sandcrete blocks currently available should be able to perform adequately in a confined masonry system.

A necessary requirement in the construction of two storey buildings will be the involvement of a technologist. With clear guidelines, technologists as opposed to professional engineers should be able to ensure adherence to engineering rules in design and supervision of construction of two storey buildings. In Ghana, there is currently only one university training civil engineers but ten Polytechnics training technologists. The number of technologists available is thus far more than Professional Engineers.

General Notes

- In view of the wide variability of sandcrete blocks, it will be necessary to give guidance on the selection of good quality blocks. This may include visual inspection to ensure blocks are not breaking off at the edges, dropping the block from a height, diving the block to see if it is of uniform consistency throughout or any other such

simple tests. There will also be a need to provide proportions by volume of cement and sand for producing good quality blocks.

- Simple processing methods for fine aggregates should be recommended including sieving of sand to remove vegetable matter.
- Characteristics of good quality stones must be indicated with the aid of pictures.
- Guidance notes on concrete mixing will be essential. Construction of a gauge box that takes one 50Kg bag of cement should be advocated. Pictures should be shown to indicate that measurements are to be made level and not heaped.
- Wire brushing of rusting reinforcement should be advised.
- The bending of stirrups and links is very important. Education will be necessary to let developers understand that they are to be bent at 135° and not 90° .
- Guidance will be required on depth of footings. A minimum of 0.9m depth is recommended for Ghana. Soils above this depth are subject to effects of the weather such as repeated wetting and drying and leaching of fines.
- Where expansive clays are encountered, foundations may be taken deeper to 1.2m so that they lie within an area where moisture levels are fairly constant.
- It will be necessary to show pictures of how vertical reinforcement is to be placed at ground floor level. The reinforcement is not to be spliced and this must be well illustrated as it goes against current practice.

Guidelines for single storey buildings

There are a number of publications that give guidance on the construction of confined masonry structures (Eurocode 8, 2004) and (Arya *et al*, 2010). It is proposed that these should be well illustrated and adopted for use in Ghana. The following features are to be included.

- It is proposed that the guidelines indicate a minimum wall thickness of 125mm as opposed to 100mm suggested in some documents (Arya *et al*, 2010) for masonry elements. This is in view of the variable quality of the sandcrete block. It is also noted that Eurocode 8, 2004 recommends a minimum tie column and tie beam section of 150mm width.
- In line with the minimum wall thickness selected, Tie Columns and Tie Beams are to have a minimum width of 125mm.
- The use of steel dowels should be recommended for ensuring a good connection to the column. This is because the size of sandcrete blocks makes it possible that some pockets of honeycombed concrete will be created when casting columns.
- A minimum wall density of 5% is recommended. This is to reflect the uncertainties associated with the sandcrete block.

Guidelines for two storey buildings

The publication “Guidelines for Earthquake Resistant Non-Engineered Construction” (Arya *et al*, 2010) provides rules for the construction of reinforced concrete framed structures. It is proposed that these should be adapted for use in Ghana. The following features are to be included.

- Cover to steel in Columns and beams should be 30mm rather 25mm. This is to reflect the very aggressive atmosphere experienced in Ghana.
- Fixing details will be required for the prestressed precast concrete systems in current use. This is to enable the slab act as an integral part of the structure and prevent the precast beams from slipping off their reinforced concrete supports during an earthquake.

CONCLUSION

Ghana's experience of seismic activity indicates that its structures must be able to accommodate strong earthquakes without excessive deterioration. Current building practices however show that many buildings may not respond favourably. The construction of many small buildings lies in the hands of unskilled labour and the methods being used are sometimes a mix between Reinforced Concrete framed construction and Confined Masonry construction. It is likely that in the event of an earthquake such buildings will behave like poorly designed Reinforced Concrete structures. Based on the availability of materials and personnel, the following has been proposed.

- Engineering rules are to be presented in simple clear and well illustrated guidelines for use by builders in the construction of one and two storey buildings in Ghana.
- Guidelines for single storey buildings are to be based on Confined Masonry Construction, whilst guidelines for two storey buildings are based on Reinforced Concrete construction. The reason for the difference is that the sandcrete block commonly used in Ghana is mostly non-load bearing and of very variable strength.
- Registered Craftsmen can be given the responsibility for implementing guidelines for one storey buildings as the requirements will be simple but those for two storey buildings must be left to Registered Technologists.
- Training in the use of the guidelines should be given to building professionals. It is recommended that Craftsmen and Technologists in the building sector are tested for knowledge of the rules before they are certified to practice.

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PERCEPTIONS AND EXPERIENCES OF THE WORKPLACE AMONG CANADIAN COMPUTER SCIENCE AND ENGINEERING STUDENTS – A GENDER ANALYSIS

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Abstract: This paper presents an overview of selected results of a national survey on the career intentions of upper-year Canadian undergraduate students in computer science and engineering programs. The survey was conducted in spring and summer, 2010, by the regional Chairs for Women in Science and Engineering and included approximately 600 respondents. The paper offers gender and discipline-based analyses of the survey results, with particular attention paid to students' perceptions and experiences of the workplace. In designing the study, it was hypothesized that a higher proportion of female students might choose not to pursue employment in the field after completing their undergraduate program because of negative educational experiences and/or workplace expectations. While survey results reveal some gender differentiation in terms of educational experiences, similarly high proportions of male and female students intend to either pursue employment (~69%) or graduate programs in their field of study (~20%). However, a significant proportion of female students (63.3%) expect to face gender-based discrimination in the workplace, while only 5% of male respondents indicated similar concerns. An analysis of survey responses paint a concerning picture of experiences and expectations of hiring practices and workplace climate, one which warrants attention.

INTRODUCTION

Women continue to be underrepresented in the fields of engineering and computer science, both in post-secondary studies and in the workplace. In Canada, the most recent census data indicated that women represented 25.9% of the professionals in computer and information science and 12.2% of engineers (Statistics Canada, 2006). This study focuses on the experiences and career plans of those students who have chosen to pursue and complete post-secondary education in these fields. In designing the study, it was hypothesized that a higher proportion of female students might choose not to pursue employment in the field after completing their undergraduate program because of negative educational experiences and/or workplace expectations. While survey results reveal some gender and discipline differentiation in terms of educational

experiences, overall, respondents described their experiences in similarly positive rates. Further, similarly high proportions of male and female students intend to either pursue employment (~69%) or graduate programs in their field of study (~20%). At the same time, however, a significant proportion of female students (63.3%) expect to face gender-based discrimination in the workplace. While academic environments remain far from perfect, responses regarding the workplace paint a more concerning picture of expectations and experiences of gender discrimination in hiring practices and workplaces. This suggests that hiring practices and workplace climate may be significant barriers to attracting and retaining women who have completed post-secondary programs in computer science and engineering into employment in these fields in Canada. As such, attention to making further changes in these areas is vital. This paper provides an overview and analysis of selected survey results.

METHODS

The survey tool combines quantitative and qualitative measures, which assess educational experience, perceptions of personal strengths, skills and confidence, career motivations, and field and workplace expectations and experiences. The survey, which included both closed and open-ended questions, took approximately 15-20 minutes to complete and was made available in both an online and paper version. 604 students completed the study. However, as respondents were able to skip questions while remaining in the study, the number of responses analyzed for different questions varies somewhat. Respondents that indicated themselves to be students of a science other than computer science or engineering were excluded from this analysis, as were those that did not provide sufficient information to allow for a gender and discipline-based analyses. 586 respondents provided responses sufficient for the intended analysis. Approximately two-thirds of respondents were from engineering programs, while slightly more than a third came from computer science.

Tab. 1: Gender and Discipline

	Computer Science (CIS)	Engineering (ENG)	Total
Female	33.5% (68)	50.4% (193)	44.5% (261)
Male	66.5% (135)	49.6% (190)	55.5% (325)
Total	34.6% (203)	65.4% (383)	100% (586)

Participants included students with a wide range of traditional and newer engineering specializations. Solicitation of respondents involved a mix of approaches meant to include as many upper-year Canadian undergraduate students in engineering and computer science as possible.

Tab. 2: Location of Respondents

	Respondents (n=590)
Ontario	331
British Columbia	152
Open University	63
Atlantic Provinces	31
Prairie Provinces	13

Particularly because of the small number of women in some areas and programs, a random sample was neither feasible nor appropriate. As is evident in Table 1, the method used allowed the incorporation of 44.5% female respondents, which is significantly greater than the proportion of female students in either computer science (13.6% 2007-2008) or engineering (17.4% in 2009) programs, overall (CAUT, 2011/Engineers Canada, 2009). Students across Canada were informed of the study via emails to departments and student groups, and in-class announcements. All participation was voluntary. Respondents were entered in a draw for the chance to win 1 of 3 prizes of \$100. Data analysis involved comparative gender and discipline-based analyses using qualitative and quantitative approaches.

RESULTS

Educational Experiences

Respondents from both disciplines and genders indicated generally high levels of satisfaction with their educational experiences. When asked how they would rate their experience in their current academic program, the most common response was positive, with over 50% in each group indicating this response. Additionally, greater than 20% of respondents described their experience as very positive, with a slightly higher proportion of female respondents selecting both positive and very positive. A relatively small number of respondents, 6.1% of male and 4.3% of female respondents, indicated their educational experience to be negative or very negative. In comparison, when asked as part of the National Survey of Student Engagement (2009-10): “How would you evaluate your entire educational experience at this institution?”, on a four point scale, 44% and 29% of the 338 engineering student respondents answered good and excellent, respectively.

Tab. 3: Overall, how would you rate your experience in your current program?

	All Male (n=314)	All Female (n=256)	All CIS (n=193)	All ENG (n=381)
Very Negative	1.6% (5)	0.4% (1)	2.6% (5)	0.3% (1)
Negative	4.5% (14)	3.9% (10)	2.1% (4)	5.2% (20)
Neutral	19.4% (61)	17.6% (45)	21.2% (41)	17.3% (66)
Positive	51.3% (161)	52% (133)	53.9% (104)	50.4% (192)
Very Positive	23.2% (73)	26.2% (67)	20.2% (39)	26.8% (102)

This similarity in educational experience is dominantly reinforced by responses to the question of whether respondents would select the same field of study were they given the choice to do so again. As shown in Table 4, a majority of all respondents indicated an affirmative response.

Tab. 4: Given the choice to do it again, would you select the same field of study?

	Female CIS	Female ENG	Male CIS	Male ENG
Yes	57.8% (37)	70.5% (134)	71% (88)	69.7% (131)
No	14.1% (9)	10% (19)	12.1% (15)	10.6% (20)
Unsure	28.1% (18)	19.5% (37)	16.9% (21)	19.7% (37)

While overall satisfaction levels were generally similar, some variation in more specific areas of educational experience by gender and discipline were evident in the sample, as is suggested in Table 4. There was no clear gendered pattern that was consistent across responses on this subject, other than female respondents appearing more likely than male respondents to select the most positive response on a Likert scale, while male respondents were more likely to select the second most positive response. What did become apparent, however, was a discipline difference. In the case of Table 4, above, female CIS students were less likely than other respondents to state that they would choose the same field of study again, were they given the chance. Others responses of both male and female CIS students, when compared to those of male and female engineering students, suggest that the climate in CIS programs is less positive for both genders, when compared to engineering programs. This difference was evident on questions regarding the social environment, and friendliness and respect from other students. In addition to illustrating a disciplinary difference, Table 5 underlines the similar level of satisfaction with educational experience across gender.

Tab. 5: Gendered Similarity and Disciplinary Difference in Educational Experience (%)

	Strongly Agree or Agree			
	Female CIS	Female ENG	Male CIS	Male ENG
I find the social environment to be a positive one.	63.5*	80.4*	57.8	72.4
I feel like I fit in.	50*	74.9*	50.4	72.2
Extracurricular activities are important to me.	44.8	70.5	39.4	64.4
Support from friends and family is important to my academic success.	67.3	78.7	61.1	63.3
I find it difficult to balance school and other activities.	51.8	37.3	42.2	44.2
Students in my department respect my ideas.	47.3	71.6	60.5	68.5
Students in my department are friendly.	55.1	81.9	67.9	77.3
My department treats people equally regardless of gender, race and socioeconomic status.	84.5	78.7	67.9	81.2

*Female engineers were more likely to Strongly Agree with the statement than female CIS respondents.

This section has highlighted both areas of difference and similarity in educational experiences of undergraduates in engineering and computer science across Canada. In contrast to the expectation of significantly gender differentiated experiences, overall, the data suggests similar experiences across genders and a high level of satisfaction across respondent groups. The most significant differences seen appear when comparing students in engineering to those in computer science, regardless of gender.

Educational and Employment Plans

Not surprisingly, considering the generally positive educational experience described by both male and female respondents in both disciplines, a significant majority indicated the intention to seek employment in their field of study or to pursue graduate studies in their field. Across fields and disciplines, respondents' plans are quite similar, with 88.1% of male respondents and 90.1% of female respondents intending to seek employment or pursue further studies within their field. The intentions of the surveyed Canadian undergraduate students differ significantly from the actions of equivalent

students in the United Kingdom. Kirkup, Zaleyski, Maruyama and Batool (2010) noted that, “[i]n 2006/07, twice the proportion of men graduating with undergraduate qualifications in STEM entered SET professional or associate professional occupations (41.8 per cent) compared with women (21.0 per cent)” (12).

Tab. 6: Summary of Plans for First Year After Graduation

	All Male (n=269)		All Female (n=233)	
	#	%	#	%
Employment or studies in field	237	88.1	210	90.1
Employment or studies outside field	20	7.4	15	6.4
Unknown/Other	12	4.5	8	3.4

When Canadian respondent’s plans are broken down into more detail, it is evident that female engineering students are more likely to choose to pursue graduate studies in their field than their male counterparts, who were slightly more likely to pursue employment in their field. However, both male and female respondents frequently noted that they felt they needed more education to succeed in their field.

Tab. 7: Plans for First Year After Graduation

	All (n=502)		Male ENG (n=168)		Female ENG (n=177)		Male CIS (n=101)		Female CIS (n=56)	
	#	%	#	%	#	%	#	%	#	%
Pursue additional undergraduate education	10	2	3	1.8	4	2.3	2	2	1	1.8
Pursue graduate studies in your field	99	19.7	30	17.9	41	23.2	19	18.8	9	16.1
Pursue graduate studies in another field	18	3.6	6	3.6	6	3.4	4	4	2	3.6
Seek or continue employment in your field	348	69.3	119	70.8	119	67.2	69	68.3	41	73.2
Seek employment outside your field	7	1.4	2	1.2	1	0.6	3	3	1	1.8
Other	20	4	8	4.8	6	3.4	4	4	2	3.6

When the plans of the small group that stated an intention to leave their field of study are examined in more detail, the data show that only a small minority expressed dissatisfaction with their program or field as a reason for changing fields. Additionally, of those who indicated that they intend to pursue employment or studies in another field, 77.8% of females, compared to 22.2% of male respondents, who specified their plans further, plan to stay in a science field. This includes a number of respondents who pursued biological or biochemical engineering programs as preparation for medical school. Male respondents intending to leave their field indicated plans to pursue business, law, aviation and a master of divinity.

In spite of the discipline differences in educational experiences, a corresponding difference is not borne out in respondents' plans for after graduation. Contrary to the initial hypothesis, male and female respondents are choosing to stay in their field at high and near equal numbers, suggesting that whatever differences in educational experiences exist are not leading to different career intentions. While not taking into account those who have chosen to leave these programs, the results still offer a positive picture of the educational environment, suggesting less women may be lost from the field at this stage than previously expected.

Expectations and Experiences of Gender Discrimination in the Workplace

In contrast to generally positive educational experiences of female students in engineering and computer science programs, responses to questions of experiences and expectations of the workplace in these fields, particularly around the issues of challenges due to gender, raise significant concerns about the workplace climate and hiring practices. As indicated in Table 8, a fairly high proportion of respondents have worked in their field in the past, many through cooperative education programs.

Tab. 8: Have you worked in your field in the past? (%)

	Female CIS	Female ENG	Male CIS	Male ENG
Yes	77.6	65.7	70.3	80.6

When asked how their workplace experience impacted their interest in pursuing employment in their field, a majority said that it made them more interested. However, a larger proportion of female computer science students indicated that they were less interested based on their experience. Almost double the number of female computer science students indicated that there were less interested in pursuing employment in their field based on their experience in the workplace than any other group.

Tab. 9: Did your experience in the workplace make you more or less interested in pursuing employment in your field of study? (%)

	Female CIS (n=52)	Female ENG (n=128)	Male CIS (n=81)	Male ENG (n=151)
More interested	50.0	62.5	59.3	66.9
Less interested	23.1	10.2	12.3	9.3
Unsure	26.9	27.3	28.4	23.8

Tab. 10: Female Expectations of Challenges in the Workplace Due to Gender (n=196)

	#	%
Yes	124	63.3
No	70	35.7
Unsure	2	1.0

When asked: Do you expect to face challenges in the workplace based on your gender, a majority of female respondents indicated the affirmative. Many of the issues noted in Roberts and Ayre's (2002) review of implicit and explicit discrimination in engineering

workplaces in Australia aligned with respondents' expectations of gendered challenges in the workplace.

Although female engineering students appeared more satisfied with various aspects of their programs than female computer science students, they were more likely indicate that they expect to face gender discrimination in the workplace. 66% of female engineering students, compared to 55.1% of female computer science students, indicated this expectation. 84 female engineering students specified the reasons that they expect to face gendered challenges in the workplace. Their reasons are described below in Table 11. The most common reasons relate to male dominance in the field and women being underestimated and needing to work harder to earn respect. Several times the notion of the 'Old Boys Club' was raised.

Tab. 11: Explanation of Expectations of Gender Based Challenges in the Workplace – Female Engineering Students

Yes (n=84)	#	%
It's a male dominated field/women are the minority	32	38.1
Women have to work harder to earn respect, are not taken seriously, are underestimated	30	35.7
Have experienced such challenges in work or school in the past.	10	11.9
If outside of the office (on site) or certain fields (construction/mining)	10	11.9
Concerned that I will be paid less, get less favourable jobs and advance less	7	8.3
Because of having children	6	7.1
I can handle it.	5	6
Yes, but it's improving, it's more with the older generation and varies with the company and specific people.	3	3.6

In explaining the reasoning behind their affirmative response, there were repeated comments such as, "Since it is still a male dominant field I'm sure I will encounter cases where my ideas may not be 'correct' on the basis that I am a female" and "I do believe there will be challenges because I am female in a male dominated industry. I am worried that people will assume I am not as smart so I feel like I will need to work harder than others to earn respect". Several respondents indicated, however, that they felt they were strong enough to deal with it. While some respondents indicated they felt being female to give them an advantage, stories like the one provided by another student, raise the issue of whether female engineering graduates are discriminated against in the hiring process:

We have all heard that overall women makes proportionally less than men in engineering and in business. Closer to home, when applying for internships last year, my good friend was actually told by someone in our career centre that although she was one of the strongest candidates, probably didn't receive an offer from a specific company because she was female. This was based on years of looking at the rankings the company provided of the candidates, and how they rarely ever (relative to the number of females in the program) made offers to women.

A few respondents even indicated that they have changed their career plans based on this expectation. For example, one female engineering student said, I "[p]refer [an]

office setting since there is lower chance of sexual harassment.” Both among those who indicated and did not indicate an expectation of facing gender-based challenges in the workplace, several respondents noted that they believe things are improving, particularly with the increased number of women in the field, supporting the *critical mass theory* (Danon-Schaffer, Dykeman, Bogan, Bennett, & Croft, 2006; Mattis, 2007).

Female CIS students expressed similar concerns to female engineering students. However, a higher proportion had experienced or heard of such issues in the past and, also, a greater number expressly identified that women were assumed to be technically weaker and job tasks were given accordingly.

Tab. 12: Explanation of Expectations of Gender Based Challenges in the Workplace – Female Computer Science Students

Yes (n=24)	#	%
Male dominated field/Women in the minority	10	41.7
Experienced in past or heard other's experiences	9	37.5
Women are assumed to be technically weaker and given jobs accordingly	6	25
Women have to work harder to earn respect, are underestimated	4	16.7
I can handle it	2	8.33
Yes, but it depends on the specific people	1	4.17
Women are paid less	1	4.17

The comment by one female computer science student duplicates the concerns expressed by several others:

I am afraid to work in an environment where there are few women for a number of reasons. I do not feel as comfortable asking questions of male colleagues for fear that I will be viewed as less competent than a man would be. I am afraid of working in a less professional environment of younger men where I may not be fully viewed as a team member because I do not play certain video games or have many of the same interests. I am concerned that I will have to work harder than a male colleague who has the same skill level because any mistake or lack of progress in my work might be seen as a weakness. I am afraid to work in an environment where they do not adequately address gender concerns as legitimate, but rather that I am a woman who does not know how to behave in a man's world.

In spite of this fear, others indicated, as among female engineering students, their belief that they could cope with the challenge. For example, one respondent wrote, “There are occasionally gender-based challenges in the workplace, but I stand up for myself if I feel gender is a potential barrier. I also work in a team that creates a culture that doesn't allow gender-based barriers to doing our work.”

Few male respondents, 6.7%, expect to face challenges in the workplace due to their gender. Those that expressed concern cited issues of reverse discrimination linked to gender equity programs and issues surrounding their sexuality as the causes for concern.

When asked if they had any concerns about pursuing employment in their field, male and female respondents gave generally similar responses, including the economy, high

expectations in terms of hours of work and so forth. However, female respondents did raise concerns about gender. Overall, this concern was less prevalent among responses by female computer science students. However, it was still evident. For example, one respondent stated, "It took years in my department to get to the point where my opinions are somewhat respected by male peers. I am not looking forward to starting from scratch somewhere else." Others expressed concern about whether they would not be hired because they were female and about how they would fit in to a male dominated environment. One female computer science student, for example, stated, "men are generally given preference over women for any specific computing science related job". The issue of a "male culture" has long been recognized as a potential challenge for females employed in the sciences and engineering in the literature (eg: McIlwee and Robinson, 1991).

Work-life balances issues have been identified in the literature as key challenges (eg: Ashraf, 2007). Engineering students were more likely to raise the issue of having a family, with one respondent stating, "I feel that if I have a family, I won't be considered as a serious worker because of it." Work-life balance and family issues were also raised by a few male respondents who indicated concern about the potential to need to move for a job and balancing spousal careers and proximity to family. Another respondent expressed concern about whether they would receive the training and mentorship that is desirable. Ghazzali and Myrand (2009) examine such issues of a lack of institutional and/or organizational support in their review piece. Responses across disciplines indicate a significant majority of female respondents expect to face, and many have already faced, challenges in the workplace because of their gender. These results suggest that hiring practices and the workplace climate remain barriers to attracting and retaining women to jobs in the fields of computer science and engineering and, thus, areas where change is necessary.

CONCLUSIONS

The survey data presented here suggest that, overall, the educational experiences of female students are similarly positive when compared to male students' experiences, though some gender differences and challenges remain. The positive experience helps to explain the high proportion of female students that intend to pursue further studies or employment in their field. However, an examination of expectations of, and experiences in, the workplace raise concerns about both hiring practices and workplace climate, as a majority of female respondents in both fields expect to face gender-based discrimination in the workplace. This suggests additional work needs to be done to address these issues. To that end, additional research is underway which seeks to better understand the intricacies and realities of these concerns. Incorporating the lessons learned from this study, an additional round of surveying is scheduled for the spring of 2011. This round seeks to incorporate a larger sample of students from across Canada and to delve further into issues surrounding gendered workplace concerns. Additionally, comparing these results to recent workplace studies will provide further insight.

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CAN LABOUR SAVING TECHNOLOGIES HELP RURAL WOMEN IN UGANDA? THE CASE OF THE MANUAL FORAGE CHOPPER FOR SMALLHOLDER DAIRY FARMERS.

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ABSTRACT

Labour-saving technologies have been prioritized in reducing household labour requirements. They are particularly important during peak production seasons when labour requirements run high to reduce production costs for hand and hired labour. Women have been specifically targeted in the development and dissemination of most of these technologies. The aim is to help them divert time from farming and domestic activities into more productive income generating activities. The forage chopper is one such technology that was developed with the assumption that it will save labour for rural women. It was hoped that this would give women control over their own labour, freeing them for other income generating activities. With a technographic approach, this research evaluated the effectiveness of the technology as a labour saving device for women in Masaka district. The study evaluated how the forage chopper consolidated or transformed existing gender relations among smallholder dairy farm households. The focus was on how existing gender relations influenced the nature, use and ultimately the impacts of the forage chopper technology. The study showed that targeting women in technology development in itself is not enough to guarantee that women will benefit, let alone that it will lead to their empowerment. The use and impacts of technology are in part determined by intra-household behaviour and individual's bargaining power. Exploration of how gender relations are negotiated and transformed is therefore a pre-requisite if labour saving technologies are to have the desired effects for women.

INTRODUCTION

In agriculture-based countries, development efforts to reduce rural poverty have prioritized labour saving technologies in reducing household labour requirements (Carr and Hartl, 2010, MAAIF, 2005, NARO, 2001). These technologies are mainly important during the peak production season when labour requirements run high to reduce production costs for hand and hired labour. According to Carr (2010), women have been specifically targeted in the development and dissemination of these technologies because they are central to overcoming rural poverty. I, however, argue that targeting women with technology development in itself is not enough to guarantee that they will benefit, let alone that it will lead to empowerment. This is because the use and impacts of a technology are partly determined by household organization of activities. Most development interventions focus on improving the welfare of women but, women's welfare is based on complex interactions within households. Moreover, households are not fixed entities in terms of composition and activities either.

The household organization of activities bears significant importance in understanding the potential gender empowerment of labour saving technologies. It is the different activity organization strategies that constitute an important context for the introduction of new technology. In understanding the potential gender empowerment of technology we have to explore how technology intertwines with this complex setting. Gender-development and gender-technology debates have all emphasized the importance of gender targeted interventions for sustainable development (FAO, 2010, UNFPA, 2008, United Nations, 1995). Equitable access to, use of and benefit from economic resources; and equal participation in decision making fora for both men and women have been the focus. However, this is rarely the case when interventions are introduced due the gender dynamics triggered off by the interventions. According to Doss (2001) gender relations are dynamic and respond to economic incentives and opportunities. This makes it difficult to understand how they will respond to the introduction of new technology. It also makes it difficult to even predict, *a priori*, what the dynamics of technology use will be within households and communities.

Doss (2001) further argues that it is usually assumed that women would benefit if project designs would simply take into account women's roles and responsibilities. As such, many development interventions have focused on women and very often used "woman" as a label without understanding women's setting. Neither has there been a clear understanding of how men and women are often assigned certain traits and attributes that may or may not be limiting to their development. Simply taking women into account is not sufficient. It is necessary to understand how women operate in different activities of the socio-technical setting. Developing technologies that will improve women's wellbeing poses much more difficult challenges. This is because women are part of a socio-technical system, with other social entities. Understanding the way the different elements of the socio-technical system combine or intertwine with the technology is important to determine use and impact of technology.

Hence, although labour saving technologies have been prioritized for women's empowerment, a detailed understanding of the interaction of technology with other social entities is important. This is what creates an understanding of the gender potential empowerment of technology. Technology users are not fixed entities in terms of composition. Although women are frequently singled out in empowerment strategies, they are not stand-alone individuals. They are part of the domestic groupings which are not fixed entities in composition. The activities that determine the use of technology are not fixed either. Understanding the way technology intertwines with changing users' compositions and activities is key in assessing potential gender empowerment of technology.

Methodology

The technographic approach was used to examine activities within the household and the community and how technology interacted with them. Some scholars of technology-human interactions (Jansen and Vellema, 2011, Kien, 2008, Richards, 2003) have proposed technography as an interdisciplinary methodology for the study of technology in everyday social situations. Technography is ethnography of technology (Jansen and Vellema, 2011); a perspective for describing "socially active technology" (Kien, 2008); or an attempt to map out actors, processes and client groups (Richards, 2003). The analyst should see beyond the technology itself and the problems technological applications are supposed to solve (Richards, 2003). This approach reveals how technology dynamically works with human actors (Kien, 2008, Kien, 2009), with an

understanding of what parties and interests are being mobilized in arriving at solutions (Jansen and Vellema, 2011, Richards, 2003). With the case study of the forage chopper among smallholder dairy farmers, this research explored how the technology interacted with different social entities and how these determined its use and impact. The introduction of the forage chopper was part of the interventions developed by NARO to address forage processing constraints in the zero grazing livestock production system. Forage materials for zero grazing animals require chopping for ease of consumption by the animal and increased palatability of forage. Hand chopping is the common practice by most farmers. Besides its low output capacity and lack of uniformity in length of cut, the method is tedious, time consuming and quite dangerous to operators. In an effort to address some of these constraints, NARO developed a manual forage chopper for farmers owning not more than five animals.

The technographic approach was used to map out the different social entities and gather information on domestic groupings, individuals/task groups and activity profiles of smallholder dairy farmers. This was for understanding what and how resources were being mobilized to determine use of the forage chopper. The study employed an in-depth qualitative realistic evaluation (Pawson and Tilley, 1997) to explore how the technology interacted with different social entities when it was introduced among farmers. The qualitative approach allowed for describing, understanding and explaining complex interrelated and/or changing phenomenon of gender relations and how these impacted on the forage chopper introduction. The gender analysis included activity profile for smallholder dairy farmers (what men, women & children do); resource access and control profile (who has access to and control of what type of resources and decision making); and an analysis of the socio-economic context. In the absence of own derived quantitative verifiable indicators to support the research, the study relied on interview data and technographic observations to strengthen collected data.

The study was conducted in Masaka district of Uganda, in four sub-counties of Kkingo, Kabonera, Mukungwe and Bukulula. The study population were the smallholder dairy farmers, owning 1-5 animals, grazed in the back yard of their homesteads. Two groups of farmers were selected: smallholder dairy farmers with forage choppers (study group) and smallholder dairy farmers without the improved forage chopping technology (control group). The study group was purposively selected to provide information-rich cases that could be studied in depth for gender-technology relations that emerged from technology uptake and use. The control group was randomly selected to find out what is typical of smallholder dairy farmers. The forage chopper was introduced as part of the interrelated zero grazing technologies that were needed to allow women to effectively benefit from zero grazing animals. In the remaining sections I examined the way NARO framed the “virtual” users of labour saving technologies in comparison to the “actual” users. I focused on organization of household activities and how the introduced technology eventually interacted with these to determine its use and impact.

Constructing the “virtual” user

The zero grazing livestock production system is associated with high feed requirements due to the genetic capacity of stall-fed cattle (Kabirizi and Nanyeenya, 1998). A diagnostic survey, carried out by the Livestock Systems Research program (LSRP) project of NARO among the smallholder dairy farmers of Masaka (LSRP, 1999), two priority needs were identified. (1) Reducing drudgery presented by high farm labour demands. (2) Increasing farm productivity particularly in the intensive zero feeding dairy production system. Primarily, there was lack of sufficient land for forage

production, coupled with forage scarcity for dry season feeding. Secondly, there were labour shortages. These necessitated the efficient use of the available forage by minimizing its wastage. The role of NARO's first project was to increase feed resource availability as the project leader explained:

The two interventions targeted to increase feed availability were establishing fodder banks and leguminous forage, focusing on the grass used whereas forage processing and conservation were envisaged for the efficient forage utilization role. (key informants interview, 2008)

She went on to explain how the project targeted their technologies:

The project targeted smallholder dairy farmers on zero or semi-zero grazing system of livestock production. Participating farmers had to have animals of course, land, and at least 0.5 acres of forage. (key informants interview, 2008)

NARO's second project of the forage chopper followed immediately after the first phase of establishing fodder banks. Among the constraints identified by the farmers during the LSRP survey was the drudgery associated with forage processing. Secondly, one of the roles of the first project was to promote efficient utilization of fodder. This entailed forage chopping for conservation of forage especially for dry season feeding as well as reduce forage wastage for the fresh one. After addressing the first constraint of feed shortage, the forage chopper then became relevant to farmers as the team leader explained:

For one of the project technologies where farmers had to conserve the forage, we later introduced the forage chopping technology. We required these farmers to chop forage to very small pieces and we realized this was going to be very strenuous on them when using the traditional hand chopping method. (key informants interview, 2008)

The initial efforts of NGOs that introduced zero grazing animals had already framed the user of the animals (the woman) by the time NARO set in with the forage chopper. Land size grown with forage was another criteria framing the NARO user and the number of animals. Furthermore, NARO framed the user as the overburdened woman with the zero grazing system who had to be assisted to improve her welfare. Such focus on women as individuals extracts them from their work place or context. But users are not fixed entities in terms of composition and activities. The way they interact with other socio-technical elements will determine use of the introduced technology. The organization of different activities in the household matters if zero grazing livestock production technologies are to work for women. And among the activities necessary to make the enterprise work is chopping of forage. So this points to the need for examining the way activities are organized and intertwine with introduced technologies to determine their use.

The context of the actual user

The introduction of labour saving technologies has implications for labour allocation patterns for different activities. This also spills to economic resource distribution and allocation among farmers. The way different activities are organized is bound to influence the use of technology. The data presented in the following sections is based on 65 farmer interviews I conducted among smallholder dairy farmers (35 farmers with forage choppers and 30 farmers without forage choppers), FGDs and observations.

The labour patterns among smallholder dairy farmers

Labour allocation patterns have implications for the introduction of labour saving technologies. The gender division of labour and access to family or hired labour in a

household are some of the aspects that influence technology uptake and use. This study, focused on livestock production activities of the zero grazing enterprise. Gender division of labour across different domestic groupings (male headed, female headed and female managed) showed that although some activities were initially prescribed to men or women or children, many times most of these activities were shared. Over and above family labour, there were activities for which hired labour was contracted, especially forage processing. Sharing of roles points to the unfixed nature of households in terms of activities as well as composition. A role could be performed by a number of household members and, with enrolment of hired labour, household composition was a variable. From the farmers' interviews, diverse explanations existed for this divisions of labour. With Universal Primary Education (UPE) and Universal Secondary Education (USE), the time available for children to assist their parents was limited; forcing children to work in the early hours of the morning on week days and over the weekend.

Unlike the crop activities where labour demands went down during the dry season, livestock labour demands were almost a constant throughout the year. Whereas forage was readily available in the wet season, there were other activities (e.g. hay/silage making) that required farmers to prepare for the next dry season. Strict animal health practices were also needed as this season presented high occurrences of animal diseases. In the dry season, farmers were hit with feed scarcity. With stall-fed animals, the search for forage was at its peak in the dry season. However, milk yields were low to afford non-conventional feeds. This implied a constant labour demand for zero grazing animals. However, the organization of these different activities required more than just family labour to make zero grazing work. Irrespective of household category, there was a shortage of family labour that necessitated the enrolment of hired labour. Looking at the livestock production labour, labour was drawn from family, hired or a combination of both family and hired labour (Fig. 1). There was an overall dependence on family more than hired labour. This could have been explained by the constraints farmers experienced with hired labour. Hired labour was usually unreliable, expensive and scarce/competitive, especially during the peak production period when labour demands were running high.

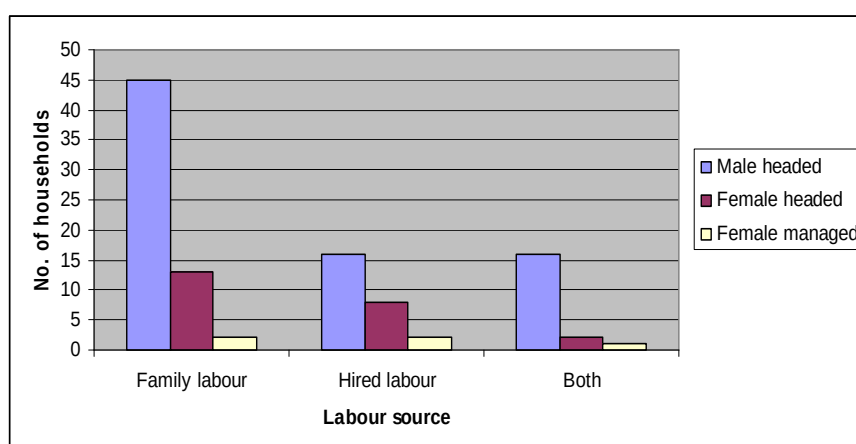


Fig. 1: Household division of livestock production labour

Although farmers enrolled hired labour for production activities, several households worked closely with hired labour. Farmers still attributed this to the constraints associated with hired labour. Furthermore, the high labour demanding zero grazing system caused a high labour turn-over in many households. The issue of hired labour was not confined to a particular household category. This shows that neither households

nor a notion of gender relations is enough to understand the labour issue. Another point this shows is that farmers' ability to mobilize community resources, like the labour force, was important to cope with labour demands of the zero grazing enterprise. Decision making for division of labour varied in different domestic groupings but, largely involved men, women and the older children. It was observed that hired workers were not key decision makers that influenced the allocation of household labour/activities. All interviewed farmers only pointed to household head, spouse and children as the people involved in decision making.

Whereas female headed and female managed households presented less dynamics in decision making for women, the same could not be said for male headed households. In these households, there was high involvement of men in most decisions. Joint labour allocation decisions were mainly observed under two circumstances. (1) Where men relied on farming as the main source of income and using family labour more than hired labour. Their wives' involvement in labour allocation was necessary to adequately access family labour. (2) Where men had formal employment. This was because their financial support was often required to enrol hired labour. Equally important was the women's support for effective management of the family's production. Different people were involved in production and decision making in different households. Furthermore, there was varying availability of school going children and hired labour. This shows that division of tasks is a complicated process. It differs over domestic groupings and can change over different periods. Therefore, the way activities are organized in different households, for different task groups around the production seasons, and the way these intertwine constitute the process that makes zero-grazing technologies work.

Gender relations of economic activities

Agro-pastoral activities were the main economic activity in the study area, growing both annual and perennial crops and, keeping both local and exotic livestock. Annual crops doubled both for home consumption and as non-traditional cash crops. Men generated income from large livestock, traditional and non-traditional cash crops. Women generated income from small livestock animals and food crop enterprises. Women's crops were predominantly similar across the different household types, the difference only being realized in the scale of production. Women in male headed and female managed households mainly generated their income from the sale of surplus food crops. However, there was less sale of food crops in female headed households. Irrespective of household type, zero grazing animals formed an important economic resource for women (Fig 2).

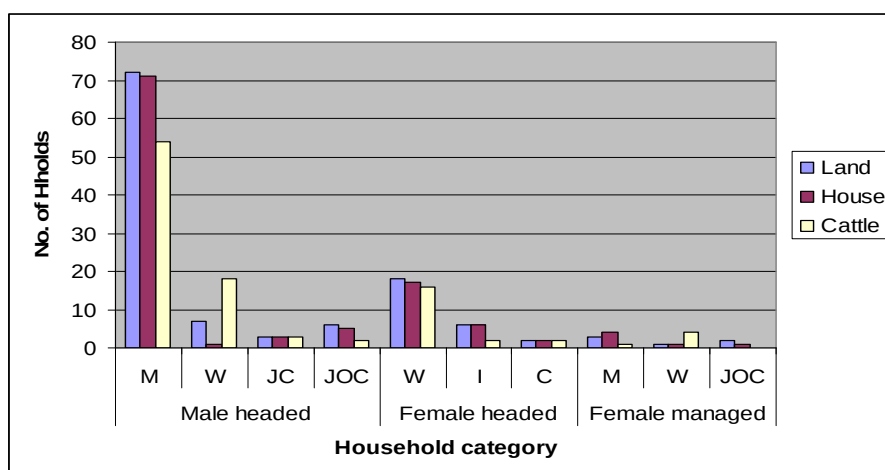


Fig 2: Distribution of main economic assets (**M**: owned by men; **W**: owned by women; **JC**: owned by men but jointly controlled; **JOC**: jointly owned and controlled; **I**: Inherited from spouse or parents; **C**: Children)

It was rated as their number one economic asset (assets that individuals could use as collateral). This data further points to the fact that households are not fixed in terms of activities. People engage in different activities, some shared and others not. The way different activities are organized and interact with other social entities in the socio-technical systems is important to determine use of labour saving technologies. Moreover, users and households are not fixed social entities in composition and activity in the socio-technical system. Drawing from this data, in the next section I explored how the introduction of the forage chopper intertwined with the users in the different households.

Impact of the forage chopper on household organization of labour

Of the 35 households selected with forage choppers, only 24 were still actively using the technology when this study was conducted. Data presented here was based on interviews of only user households. The forage chopper was developed with the assumption that it will save labour for the rural women. It was hoped that this will give women control over their own labour and free them for other income generating activities. In the users' rating of the forage chopper they concurred that the technology eased the chopping operation. It saved them time and labour which they could utilize to perform other production activities. But, whose labour did it save? Having targeted a women's role in the development of the forage chopper, it was necessary to examine the outcomes of technological change for the women.

The analysis of activities of smallholder dairy farmers showed that households and farmers were not fixed in terms of activities. This implies that the introduction of the forage chopper saved different people's labour, not necessarily women's labour. The chopping activity was not only restricted to women. Beyond freeing labour, other things had to be in place for women to benefit from labour saving technologies. The introduction of one labour-saving technology did not imply that women necessarily had control over their saved labour. Women experienced differences in household decision making powers. This influenced their ability to benefit from labour-saving technologies. The female headed and female managed households presented less challenges. However, in male headed households, the decision making process for labour saving technologies showed men's heavy involvement. Consequently, the way this is organized and also interacts with livestock production activities matters if women are to benefit from labour saving technologies.

Comparing allocation of livestock production labour for using households and non-using households (Fig 3), there was more use of a combination of family and hired labour in the users male headed households. Non-users on the other hand relied more on family and hired labour. Since no baseline data existed for the "before" situation of the labour patterns in the users households, two possible interpretation can be made from Fig 3. (1) The use of the forage chopper allowed a redefinition of roles altering the balance between family and hired labour. (2) The decision to adopt the forage chopper depended on relative availability of family labour for livestock production activities shown in Fig 1. However, users and households were not fixed entities in activities and composition. Hence, the way the forage chopper intertwined with these mattered for the gender potential empowerment of technology. With the unfixed nature of users and households in terms of activities, the forage chopper did not ease the chopping activity

solely for women but for the entire household. What carried meaning for the women though was their ability to reallocate saved labour to own benefit.

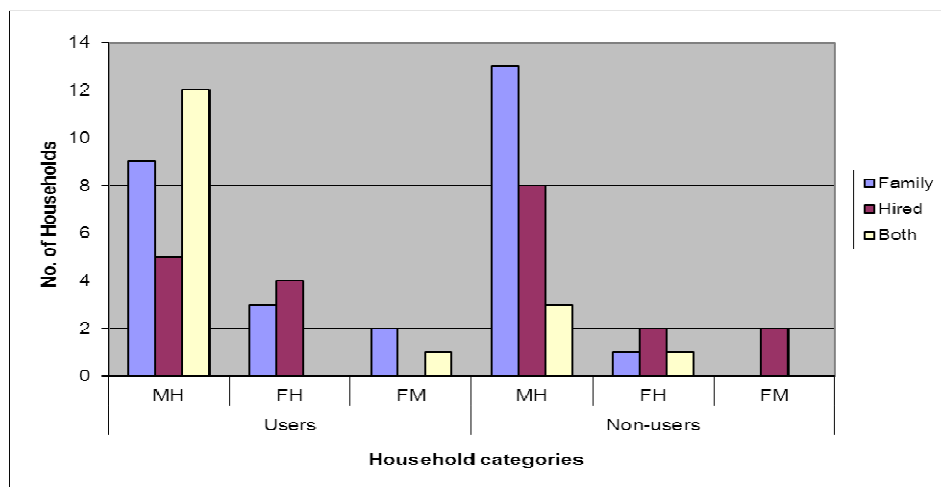


Fig 3: Household allocation of livestock production labour (FC: Forage chopper users; WFC: without forage chopper. MH: male headed; FH: female headed; FM: female managed)

With the labour allocation decision making dynamics discussed earlier, the reallocation of saved labour varied in the different household types. It depended on the person who controlled the household division of labour decisions. In female headed households where labour decisions were entirely to the woman's discretion, saved labour was redirected to own benefit. Although men influenced labour decisions in female managed households, their absence allowed women to make labour allocation decisions to own benefit. On the other hand, very few women in male headed households could utilize the saved labour to their own benefit. With the differing control over household labour allocations, the introduction of one labour saving technology did not necessarily liberate women's labour for other income generating activities that could directly benefit them.

The use of the forage chopper did not necessarily reduce women's overall labour burden nor did it provide control for women over their labour in all households. The forage chopper only carried meaning for women's empowerment in two circumstances. (1) In households where women controlled or could influence the allocation of saved labour to own benefit. (2) In households where saved labour was used to increase incomes whose allocation women could influence. In households where women had no control over labour allocation decisions, the introduction of the forage chopper was seen yet as another production technology. In this regard, it simply saved women's labour for one production activity, redirecting saved labour to still supporting their husbands to generate more income they (men) controlled.

Impact of the forage chopper on household economic resource

The introduction of new technologies always has implications on household economic resources. The introduction of the forage chopper had two implications on the household economic resources. On one hand, there was a possible indirect income increase from effective utilization of the machine. On the other hand, there was an economic expense on the cost and maintenance/repair of the machine. The contribution of the forage chopper to the increase of household incomes was twofold: saving on labour costs and more income from milk production boost. Altering the balance between family and hired labour implied a reduced dependence on hired labour. This meant a decrease in cost for hired labour. Furthermore, with properly chopped forage, reduced

wastage for forage was reported which implied reduced labour for processing forage as a result of efficient utilization of the chopped forage. From the farmers' ratings of the forage chopper, there was a notable increase in forage intake by the animals attributed to well chopped forage. This had implications of increased milk production and a possible income boost from the sale of milk. This was only beneficial to women who controlled livestock-generated incomes or influenced the allocation process.

On the down side, the first economic expense of the forage chopper was the initial cost of the technology. The initial cost of the NARO forage chopper was high which prompted farmers to seek other alternative sources for the technology. Even with the other technology sources, some farmers still found the cost prohibitive. The persistent use of the traditional hand chopping method even after introducing the forage chopper was mainly a result of the high cost of purchase of the technology. As it emerged with further analysis of non-users, the cost of the technology largely defined the farmers who never managed to use the forage chopper. Only a few farmers had received machines as incentives for their participation in the NARO forage conservation project or NGO projects. Not only was the cost implied in the purchase of the machines but, subsequent maintenance and repairs of the machines also had a cost implication. This was one of the constraints farmers sighted with the technology. For the forage chopper to carry meaning for women, their control over economic resources or ability to influence the allocation process was important. This influenced their use of the machine in terms of affording the initial cost and sustaining the maintenance.

What these impacts show is that there were several elements of the socio-technical system that had to be mobilized for the forage chopper to carry meaning for the women. The users, the households and the gender relations were not fixed entities. The idea of freeing women's labour for other income generating activities through the introduction of the forage chopper requires clear understanding of several things. The technology, household composition or gender relations and how these intertwine with the different activities women are engaged in are all necessary to determine use of technology.

Conclusion

This paper analysed the importance of understanding the organization of household activities and the ways in which women-targeted technologies interact with these. I argued that targeting women with technology development in itself is not enough to guarantee that they will benefit (let alone that it will lead to empowerment). This is because the use and impacts of technology are partly determined by household organization of activities. I conclude that it is important to put emphasis on women individually in technology development in the bid to increase their access to technology. However, a detailed understanding of the social construction of gender within households is essential in developing technologies for women's empowerment. Increasing women's access to technology in itself is not empowering and may even just increase women's workload. The way women are organized and interact with other social entities of the socio-technical system is important to determine technology use.

Households and users are not fixed entities in terms of composition and activities. When technology developers focus on women as individuals, they risk targeting "virtual" users instead of "actual" users. Understanding the context of the actual user is important when targeting individuals with technology interventions. This study showed that the overall gender ideology simply provides a general normative and ideal frame of reference for guiding and judging men and women behaviour and activities. However, this ideology

does not actually determine, prescribe or strictly guide what men and women do. This is very much a function of the specific situation they find themselves in. It is this that forms the context of the actual user. Anthropological research can help close the gap between “virtual” users and “actual” users in technology development.

Over and above reconfiguring the user, the process of making a technology work entails understanding what resources or parties have to be mobilized by users to arrive at workable solutions. Beyond the technology, there are other elements or social entities in the socio-technical system. This study showed that the way different activities are organized in households and the composition of users (family labour, hired labour or both) are both not fixed entities of the socio-technical system. This implies that a range of interests can be mobilized to arrive at solutions. Developing technologies that will improve women’s wellbeing requires understanding the way different elements intertwine with the technology to determine use and impact of technology. Gender relations are dynamic. People also respond differently to introduced technology. This makes it difficult to predict beforehand what the dynamics of technology use will be within households and communities.

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THE PRODUCTION OF BIODIESEL FROM OILS AND FATS

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ABSTRACT

The feasibility of biodiesel production from non-edible oils and waste oils as oil sources was investigated. The acid values of tung oil, trap grease, and acid oil were 9.55, 102.9, and 99.8 mg KOH/g, respectively. Because these oils had high content of free fatty acids, their free fatty acids were removed by the esterification using Amberlyst-15 or sulfuric acid as an acid catalyst prior to transesterification. After transesterification of oils using potassium hydroxide as an alkali catalyst, the properties of biodiesel produced were analyzed. Based on the compositions of free fatty acids, biodiesel showed different characteristics. Tung oil biodiesel and acid oil biodiesel showed good cold temperature behavior. The viscosity of tung oil biodiesel was still high. Because the oxidation stability of three biodiesels was low, the properties improvement by an antioxidant was required.

INTRODUCTION

There has been an increased interest in the use of the biodiesel produced from triglycerides as an alternative fuel for diesel engines, due both to the instability in the price of petroleum and to environmental concerns related to the air pollution generated by vehicles. The biodiesel production has typically focused on edible oils such as soybean oil, rapeseed oil, and palm oil. Recently, waste oils and fats such as used frying oil, trap grease, soapstock, acid oil, and tallow has been proposed and used as biodiesel resources. As the supply of biodiesel increases, the interest in the use of non-edible oils such as jatropha oil, tung oil, and algal oil as an alternative feedstock for the production of biodiesel has grown.

The alkali process for biodiesel production can achieve high purity and yield of biodiesel in a short time. However, oils and fats that are high in free fatty acids result in the production of soap and the loss of catalyst in the alkali process. To overcome this, the free fatty acids should be removed before the transesterification reaction.

Tung oil is non-edible woody plant oil (Shang *et al.*, 2010). Tung oil is pressed from the nuts of the tung tree and the nut has an oil content of 30 to 40%. The productivity of tung oil varied from 300 to 450 kg/ha. Tung oil has been used as a protective coating or drying agent and as the composition of oil paints and printing inks. It usually contains more than 80 wt% of α -eleostearic acid, a long chain fatty acid with three conjugated double bonds.

Trap grease is waste oil that is intercepted in the greased trap of restaurants to prevent it from entering the sewage system. It has free fatty acid content ranging from 40% to 100%, and is plentiful in supply. For example, in Guangzhou, the third largest city in China, 20,000 tons of water-free trap grease is produced annually (Wang *et al.*, 2008). As the Chinese government has banned the use of trap grease as animal feed, trap grease expected to become an attractive feedstock for biodiesel production.

Soapstock, a by-product of the refining of vegetable oils, is a potential biodiesel feedstock. It is a heavy alkaline aqueous emulsion of lipids containing about 50% water, with free fatty acids, phosphatides, triglycerides, pigments and other minor non-polar compounds. Soapstock is generated at a rate of about 6% of the volume of crude oil refined. Its market value is about one-tenth the price of crude vegetable oil (Hass, 2005). Acid oil is also a possible feedstock for biodiesel. Acid oil is prepared from typical industrial processing of soapstock by acidulation, wherein sulfuric acid and steam are employed to achieve partial acid hydrolysis or removal of the triglyceride and phosphatide ester bonds of soapstock. The heavy emulsion of soapstock is destroyed, resulting in spontaneous separation of two phases, an aqueous and an oil layer. The oil layer is termed acid oil. It is used as an animal feed ingredient and as a source of industrial fatty acid.

In this study, biodiesel was produced from different sources of oils through a process involving esterification by a solid acid catalyst, followed by transesterification by potassium hydroxide. The fuel properties of biodiesel produced were analyzed.

EXPERIMENTAL METHODS

Materials

Tung oil and trap grease were kindly supplied from Guangzhou Institute of Energy Conversion and Guangzhou Environmental Protection Agency in China, respectively. Acid oil was kindly supplied by CJ Corporation in Korea.

Esterification and transesterification of oils and fats

Each 200g unit of oil was esterified in a pressurized stainless-steel reactor of a 500 ml equipped with two tanks. One is a tank for adding methanol. The other is a buffer tank, through which the pressure of the reactor can be maintained with nitrogen. When the temperature of oil and a catalyst introduced into the reactor reached at the setting value, methanol was fed to the reactor by the pressure of nitrogen. The pressure of the reactor was kept at 4kgf/cm² during the reaction. Agitation speed was 200 rpm. There was a filtering net inside the sample port at the bottom of the reactor, and samples were withdrawn with the specified interval.

For the pretreatment of tung oil, the mixture of oil, methanol, and Amberlyst-15 was mixed by a magnetic stirrer at 80°C for 2 h. After the reaction, the acid value of the sample was determined. Pretreated tung oil was used for the transesterification. Oil was mixed with methanol and potassium hydroxide at 80°C for 20 min. After washing with distilled water and centrifuging at 15,000 rpm for 15 min, biodiesel properties were analyzed. For the production of biodiesel from trap grease and acid oil, the optimal temperature was 95°C in an acid catalyst esterification, and 80°C (30 min of reaction time) in an alkali catalyst transesterification.

To improve the purity of the biodiesel, a simple distillation system was used. The vacuum was adjusted to 65 cmHg. The temperature was in the range of 160-220°C, and the distillate was collected.

Analysis

The acid value of oil was measured by titration method, following AOCS official method Cd 3d-63. The water content was measured by Karl Fischer Titrator (Mettler Toledo model DL31 Volumetric KF Titrator, Columbus, OH, USA) in accordance with AOCS official method Ca 2e-84.

The oxidation stability measurements were carried out with the model 743 Rancimat (Metrohm, Herisau, Switzerland). Sample was analyzed under constant air flow of

10L/hr at 110°C heating block temperature. The temperature correction factor ΔT was set to 1.5°C.

The cold filter plugging point (CFPP) measurements were carried out with the model FPP5Gs (ISL, Carpiquet, France). Sample was cooled following EN 116 method. At intervals of 1°C, a 200 mm H₂O vacuum was applied to draw up the sample into a pipette through a filter. The temperature at which either the sample ceased to flow through the filter within 60 seconds or failed to return into the test jar was recorded as the CFPP.

The fatty acid methyl ester (FAME) content was analyzed by Gas Chromatography equipped with an auto-injector (Agilent 6890A, Santa Clara, CA, USA). The INNOWax (Agilent) column (30mm×0.32mm×0.5μm) was used for the analysis of FAME. The oven temperature was started at 50°C for 1 min, increased to 200°C at a rate of 15°C/min, held at the temperature for 9 min and again increased to 250°C at a rate of 2°C/min and then held at the temperature for 2 min. Methyl heptadecanoate was used as the internal standard.

RESULTS AND DISCUSSION

Biodiesel from tung oil

The feasibility of biodiesel production from tung oil was investigated. The esterification reaction of the free fatty acids of tung oil was performed using Amberlyst-15.

Optimal molar ratio of methanol to oil was determined to be 7.5:1 and Amberlyst-15 was 20.8 wt% of oil by response surface methodology. Under these reaction conditions, the acid value of tung oil was reduced from 9.55 to 0.72 mg KOH/g. After the transesterification reaction of pretreated tung oil, the purity of tung oil biodiesel was 90.2 wt%. The molar ratio of methanol to oil was 6:1 and KOH was 0.9% of oil (Tab.1).

The high viscosity of crude tung oil decreased from 109.4 to 9.8 mm²/s at 40°C. Due to the presence of eleostearic acid, which is a main component of tung oil, the oxidation stability as determined by the Rancimat method was very low, 0.5 h, but the cold filter plugging point, -11°C, was good. The distillation process did not improve the FAME content and the viscosity.

Tab.1: Properties of tung oil biodiesel

Properties	Before distillation	After distillation
FAME (wt%)	90.2	90.4
Total glycerol (wt%)	0.046	0.016
Oxidation stability at 110°C (h)	0.50	0.17
Water content (vol%)	0.23	0.01
Acid value (mg KOH/g)	0.59	0.46
Viscosity (mm ² /s) at 40°C	9.8	8.7
CFPP (°C)	-11	-9

Biodiesel from trap grease

The feasibility of the production of biodiesel from trap grease containing 51.5% free fatty acids was investigated. The esterification of free fatty acids by an acid catalyst followed by the transesterification of triglycerides by an alkali catalyst was examined.

The esterification of trap grease by sulfuric acid as a homogeneous catalyst or by Amberlyst-15 as a heterogeneous catalyst was optimized through a response surface

methodology. After the two-step esterification of trap grease by sulfuric acid, the acid value decreased from 102.9 to 2.75 mg KOH/g. When the molar ratio of methanol to oil was 9.31:1 and sulfuric acid was 1.95wt% of oil, the acid value of trap grease became 7.6 mg KOH/g after 1h. And then, when the molar ratio of methanol to oil was 9:1 and sulfuric acid was 0.5wt% of oil, the acid value of trap grease became 2.75 mg KOH/g after 1h. Through the transesterification by potassium hydroxide, the FAME content reached 92.4%. The molar ratio of methanol to oil was 6:1 and KOH was 0.8% of oil.

In the esterification of trap grease by Amberlyst-15, when the molar ratio of methanol to oil was 8.37:1 and Amberlyst-15 was 21.04wt% of oil, the final acid value became 3.23 mg KOH/g after 3h. With the transesterification by potassium hydroxide, the FAME content increased to 94.1%. The molar ratio of methanol to oil was 6:1 and potassium hydroxide was 1.2wt% of oil.

After the distillation of the produced biodiesel, the FAME content increased again, to 97.6% (Tab.2). The oxidation stability of the trap grease biodiesel was 0.17 h, and its cold filter plugging point was 4 °C. As the FAME content of the trap grease biodiesel satisfied the Korean Biodiesel Standard, the trap grease biodiesel seems to be applicable for use as an engine fuel after properties improvement.

Tab.2: Properties of trap grease biodiesel

Properties	After distillation
FAME (wt%)	97.6
Acid value (mg KOH/g)	0.40
Water content (wt%)	0.01
Oxidation stability at 110 °C (h)	0.17
Total glycerol (wt%)	0.012
CFPP (°C)	4

Biodiesel from acid oil

The feasibility of the production of biodiesel from acid oil containing 49.9% free fatty acids was investigated. Optimal molar ratio of methanol to oil was determined to be 8.4:1 and Amberlyst-15 was 21.0 wt% of oil by response surface methodology. Under these reaction conditions, the acid value of oil was reduced from 99.8 to 2.45 mg KOH/g. Through the transesterification by potassium hydroxide, the FAME content reached 93.5%. The molar ratio of methanol to oil was 6:1 and KOH was 1.2% of oil.

After the distillation of the produced biodiesel, the FAME content increased again, to 98.1% (Tab.3). The oxidation stability of the acid oil biodiesel was 1.49 h, and its cold filter plugging point was -3 °C after distillation. The FAME content of the acid oil biodiesel satisfied the Korean Biodiesel Standard and its low temperature properties were good.

Tab.3: Properties of acid oil biodiesel

Properties	Before distillation	After distillation
FAME (wt%)	93.5	98.1
Oxidation stability at 110 °C (h)	1.31	1.49
CFPP (°C)	-3	-3

CONCLUSIONS

Biodiesel was produced from different sources of oils. For the pretreatment of oils, Amberlyst-15 as a solid acid catalyst showed a good esterification efficiency. Due to the

high content of unsaturated fatty acid, tung oil biodiesel showed very low oxidation stability and very good cold temperature behavior. The FAME content of trap grease biodiesel and acid oil biodiesel satisfied the Korean Biodiesel Standard after distillation. Following the properties improvement of it, the biodiesel produced from non-edible oil or waste oil can be used as a blend component of an alternative engine fuel.

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MORE WOMEN IN ENGINEERING: A 21ST CENTURY CULTURAL IMPERATIVE ?

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ABSTRACT

Under representation of females in the engineering profession has been a topic of intense discussion for many years and the myth that women are excluded because of perceived inabilities or intellectual deficiencies has been well exposed. There have been many initiatives adopted to recruit and retain women in Engineering, including the introduction of new disciplines such as Environmental Engineering, where a significant increase in female student numbers was expected. Whilst we succeeded in attracting female students into the early years of the Environmental Engineering degree, the numbers have recently been on the decline and we again have low female participation in most Engineering undergraduate programs.

We explore the history of integration of females into the work force, analyse barriers that have been identified in earlier research and discuss many of the solutions developed and implemented. We present current numbers and trends in engineering undergraduate programs for three diverse regions in the world. On the basis of this, observed best practice will be utilised to develop a better understanding of the recruitment and retention of females in Engineering.

INTRODUCTION

In most developed and developing cultures the number of female students in Engineering remains approximately at about 20% of the student cohort (Beraud, 2003). Pearce (2011) reports that in 2008, only 14% of Engineering students in Australia are female. Early initiatives to attract females into the profession can date back to the 1960s with the majority of Australian Universities celebrating around 25-30 years of women in Engineering initiatives (Holland, 2007). Targeted advertising campaigns, scholarships, school based Women in Engineering activities and general careers fairs are some of the initiatives adopted to attract female students into the profession. Family work life balance, paid maternity leave, return to work programs are some of many initiatives that have helped to retain women in engineering. However, a significant improvement in numbers in the Engineering programs and the profession is yet to be seen.

The work presented here, conducted at the School of Civil, Environmental and Chemical Engineering at RMIT University in Melbourne was aimed at developing a

marketing program to attract female students in to the three degree programs offered in the school: Civil and Infrastructure Engineering, Environmental Engineering and Chemical Engineering. A history of integration of females into the workforce was examined to obtain hard evidence of what attracts females to a professional career. The research then focussed on analysing the attempts made to attract female students to the profession of Engineering in Australia and three other regions: Europe, Sri Lanka and Iran. The student numbers in these countries are then compared to understand the effect of these programs on the number of female students recruited linking with the findings of previous studies. Based on these findings, essential elements of an effective marketing program are identified.

PREVIOUS STUDIES ON WOMEN IN ENGINEERING

In analysing previous research conducted on the topic, two detailed studies provide significant insight into the issue. Analysis of data from six countries in Europe demonstrated that the academic performance of girls and boys in secondary schools is quite similar in mathematics and sciences (Beraud, 2003). However, the proportion of female students in Engineering ranged from 11% in Austria to 28% in Greece in 2000. After analysis of the student numbers in different programs, Beraud (2003) concluded that increasing the socio-economic subject matter (management, business, economics, languages, cultural studies, sociology, politics, psychology, ethics, arts, technology and society, communications, law, history, design, gender studies), at least up to 25% of the course content, would improve recruitment of female students into Engineering. Further, he observed that project based teaching which includes team projects would appeal to female students. Both these observations have been made by Armstrong (1995) as well. This aligns with the graduate attributes of Engineers Australia and would not compromise accreditation of Engineering programs, and perhaps explains the attraction of female students to new programs such as Environmental Engineering. The very masculine concept of Engineering and the perception that difficulties arise in balancing a professional career with family life have been identified as the reasons that discourage females entering the profession.

More detailed research program reported in Goodman et al (2002) focussing on the USA identified the main reasons that hinder recruitment of female students in Engineering programs as:

- Low self confidence in mathematics and science
- Lack of pre-college experience (Margolis & Fisher, 2002)
- Curricula, focus and pedagogy
- Lack of female peers as role models
- Gender and social issues

From this, Goodman (2002) identified the reasons why girls choose engineering as:

- Job prospects, 68.4%
- Interest in content, 57.7%
- Personal fulfilment, 46%
- Benefit to society, 20.2%
- Pride and achievement, 16.4%
- Reasons external to Engineering, 13.3%

- Influence of parents or others, 10%
- Women in Engineering programs at schools, 8.7%
- School social climate, 2.3%

Key reasons for females leaving engineering programs are identified as lack of interest in engineering content (53.9%), Program structure (49.8%), work load (37.2%), external reasons (30.8%), school social climate (30.8%), personal fulfilment (27.3%), pride and achievement (26.9%). A most interesting finding is that Women in Engineering programs do not appear to have a significant influence on the decisions made by female students to enter an Engineering career. This raises the question of whether the current women in Engineering programs target the appropriate pressure points.

Cohen and Deterding (2009) argue that the retention of female students is not a major issue, rather recruitment is where effort needs to be concentrated. They emphasized the need for widening the net to attract female students into Engineering.

Another strong factor identified in literature as influencing female students to consider a career is the cultural environment which affects the decisions of secondary students selecting tertiary programs (Blum et al, 2006). Donohoe *et al.* (2008) identifies the culture contributing to the decision can be institutional or community/societal. The programs that perform best are small in size and have committed institutional support. Historically Black Colleges and Universities show 32 to 50% of Engineering students as females. Trenor *et al.* (2007) supports the above with data that shows that a larger proportion of female Engineering students in USA come from ethnic minority backgrounds.

The review of literature therefore brings up several key issues as dominant in influencing a female student's decision to select Engineering as a career:

1. Job prospects
2. Interest in mathematics and science
3. Confidence in mathematics and science
4. Proportion of interdisciplinary content in the Engineering program
5. Project based learning incorporating team projects
6. Cultural factors – both institutional and societal

The following attempts to establish the validity of the above key issues so that a marketing program can be developed with understanding of dominant areas of focus needed. Whilst the study is qualitative in nature, it provides a good basis for a more comprehensive quantitative study to further explore the most effective methods of enhancing recruitment of females in to Engineering programs.

INTEGRATION OF FEMALES INTO THE WORK FORCE

The roles of women and men in society have, until the twentieth Century, been very strictly delineated. The reasons for this were originally biological – for irrespective of physical disparity, it was the female that ensured the survival of the species. Over millennia, this division become enshrined in religious, cultural and legal tradition. Not surprisingly, an outcome of this inequality was the economic dependency of women on men; the lower socio-economic status that this engendered further restricted the entry of females into much of the workforce, especially the professions.

Even in countries such as England, where a somewhat “enlightened approach” to women’s emancipation had recently occurred, it was as late as the mid 20th Century before universities such as Cambridge validated degrees for women (Goldin, 2006).

Most of us are aware of Plato’s observation (in *The Republic*): “necessity, who is the mother of invention”, and necessity was certainly pivotal in the journey for females to enter the engineering profession, with a most rigorous driver for the necessity being the Second World War. The early 1940s was a time when there was an acute shortage of men for the manufacturing industries in Australia, Britain and the United States. A very large portion of the male workforce was overseas on military service, and commensurate with this there was a growing need to feed and equip them. Although some men were retained and directed to undertake war support at home, more than 16 million left their employment to take up military service, as such the remaining manpower was insufficient, necessitating a mobilisation of the women’s workforce (Green, 1992).

As well as new roles in industry, many of which were “engineering”, opportunities began to open up to female students in engineering and technology at tertiary level.

A half-century has now passed, and in an enlightened society, one could perhaps have anticipated parity (or close to it) with at least enrolments into engineering at Australian Universities. But even with the impetus of the war, and growing acceptance of gender equality, the numbers of women in engineering in Australia is still very much a minority. Armstrong (1995) reported that between 1988 and 1995 the percentage of female students entering undergraduate engineering degrees in Australia rose from only 10% to 15%. Kaspura (2010) reports that the number of female students completing Engineering degrees in Australia peaked at 17.4% in 2003 and reduced to 16.5% in 2008 (less than in 2001). Mills et al (2010) shows that in USA completions in 2007-8 were 18.1%, lowest since 1996, in Canada completions peaked at 21.8% in 2003, decreased each year since then to 18.9% in 2007 and in UK completions were 15.4% in 2007-8.

In another study, Buckeridge *et al.*, (2000) showed that there were programmes that had special appeal to women, e.g. Environmental Engineering. They then tried to assess why engineering has traditionally been a male domain and concluded that although the reasons are complex, they certainly include the social, technological, economic and developmental values that have been adopted by a society. Australia has evolved through a developmental stage that was originally perceived as a period where “taming of the land” was the priority, i.e. the focus of engineering was man’s battle against nature (Buckeridge, 1999). The language tells us much about public attitude.

The numbers of women in environmental engineering at RMIT University was as high as 51% in 1997 and as low as 23% in 2009. The reasons for this decrease are still not yet fully understood, but anecdotal evidence suggests that there may have been frustration with career prospects for women engineers, and there has certainly been increased concern at the apparent inability of engineering (as a broad profession) to mitigate a rapidly degrading natural environment. Further, there are still too few female academics – Armstrong (1995) reviewed the numbers of faculty members who are female academics – in 1980 there was only one female at lecturer level or above in the whole country.

Based on the foregoing discussion, history brings up three further factors, which appears to influence women in Engineering:

- Gender equality, which can be considered as a cultural issue
- Necessity of females in the profession of Engineering

- Low number of female academics

CURRENT NUMBERS OF FEMALE STUDENTS IN DIVERSE CULTURAL ENVIRONMENTS

Tables 1 to 4 present data sourced from four cultural environments that were used to gain an insight into the applicability of the key issues identified through our analysis of the literature. Data from RMIT University were captured from student enrolments in compulsory first year courses of single degree programs in Civil and Infrastructure, Environmental and Chemical Engineering. Data from Sri Lanka were obtained via personal communication with Dr. D.Nanayakkara from University of Moratuwa. Data from Iran were obtained from communication with Dr. Sara Moridpour. Interviews conducted among Iranian postgraduate students at RMIT University and interviews of Sri Lankan female students and senior female Engineers contributed to establish the cultural background of the profession in each of the countries. Each set of data is considered with respect to the cultural and economic background of the students.

Table 1: Proportion of commencing female students in three programs at RMIT University in Melbourne (based on enrolment data of compulsory first year courses)

	2011			2010			2009		
	Total	Fem.	% Fem.	Total	Fem.	% Fem.	Total	Fem.	% Fem.
Civil and Infrastructure Engineering	156	15	9.6	162	22	13.6	170	21	12.3
Environmental Engineering	56	21	37.5	39	14	14	39	9	23
Chemical Engineering	42	7	16.7	69	20	28.9	44	10	23

Job prospects

Job prospects in engineering were excellent in the four regions of the world investigated. At RMIT University, graduate employment data in 2010 indicate that the employment rate upon graduation is over 80% in all three programs. However, Engineering is not considered as a top profession in the country and most high achieving students are attracted to law or medicine. In Sri Lanka, engineering and medicine are the two top professions in the country, attracting the highest starting graduate salaries. The data from Europe were scarce, the European commission study (2010) indicated that if female graduates are seeking employment, they will secure employment, inferring 100% employment for female graduates. In Iran, Engineering is identified as one of the top professions sharing equal status with medicine. Therefore employment prospects are quite attractive for female Engineering graduates in all the regions explored. Perhaps the issue could be whether a high school student making a career decision is fully aware of the prospects.

Interest in maths and science/confidence in maths and science

Australian data indicates that this is an area where the performance can be improved. Shortage of competent and passionate mathematics teachers in secondary schools is a well identified issue which has been identified as a priority area by many schools

(Jorgensen, 2006). In Sri Lanka, the female students undertaking the mathematics stream which leads to Engineering as a career choice is approximately 10% based on analysis of data from four leading schools in Colombo. Iran on the other hand offers data which supports equal participation of female and male students in physics and mathematics entrance exams to Universities (Table 4).

Table 2: Proportion of completing female students in Engineering programs at University of Moratuwa, Sri Lanka (personal communication from Dr. D.Nanayakkara, 18/12/2010)

	2010	2009	2008	2007
Civil Engineering	19%	11%	16%	15%
Mechanical Engineering	5%	4%	4%	5%
Electrical Engineering	20%	15%	18%	17%

Table 3: Proportion of female students in different areas of study in Europe in 2000 (Beraud, 2003)

	UK	Austria	Germany	France	Greece
Total enrolments	53%	48%	45%	55%	57%
Natural Sciences	46%	52%	35%	43%	45%
Engineering	15%	11%	20%	23%	28%

Interdisciplinary content in the Engineering program

Data from RMIT University strongly supports the claim that the perceived socio-economic content of the curriculum has a direct correlation with the proportion of female students in the three Engineering programs. European data also strongly supports this as demonstrated by Beraud (2003). In Sri Lanka programs are quite traditional in nature with high technical content and low interdisciplinary content. Iranian data obtained from the program structure of University of Tehran indicates that religion and cultural studies form about 10% of the curriculum which increases the socio-cultural content of the programs.

Table 4: Data from Iran (Personal communication – Dr. S. Moridpour, 15/2/2011)

	2006	2003
Proportion of female students in the maths and physics entrance exam in Tehran	46.4%	48.1%
Proportion of female Engineering students in Isfahan City	50.1%	Not available

Cultural Factors

The most important finding of this preliminary study is that culture is a dominating factor influencing the decision of females to select Engineering as a career. Iran has the highest success in attracting female students into Engineering compared with other regions surveyed. Iranians do not invest in “Women in Engineering Programs” to encourage females to consider a profession in Engineering. Iranian female students perceive a career in Engineering as an excellent method of obtaining independence in a society which has many constraints for females while male students prefer entering careers in business which offers better financial gain. Both Australia and Europe have been concentrating on Women in Engineering activities and many studies have been undertaken to address the issues. However, the numbers of female students have stagnated at around 20%. Sri Lanka is also not keen in enhancing the number of female students in Engineering where numbers remain around 20%, without any significant effort.

Proportion of Female Academics in Engineering

At the school of Civil, Environmental and Chemical Engineering 9 out of 38 academic teaching staff are female giving us 24% which is well over the historical figures reported by Armstrong (1995). In Sri Lanka the proportion of female academics is around 18% in Civil Engineering, 5% in Mechanical Engineering and 12% in Electrical Engineering, which follows the trend of the student numbers. At the Isfahan University where the undergraduate female student number matches that of males, only one out of 52 academic staff is female. Obviously, the number of female academics is not a factor which has influenced the decision of Iranian female students to take up Engineering.

ANALYSIS OF THE EVIDENCE GATHERED TO DEVELOP A RECRUITMENT INITIATIVE

Whilst many studies have been conducted and led to initiatives for female recruitment into Engineering programs, the outcome remains unchanged. On the other hand, studies which reported back on the effectiveness of the measures are limited in literature.

It is clear from the current tertiary entrance scores published by the Victorian Tertiary Admissions Centre that engineering is not the program in highest demand in Australia amongst tertiary students of both genders. In general there is a need to increase high quality recruitment to the profession and it makes sense to target the 51% of the population which is under-represented in the profession.

Culture appears to be the most dominating factor affecting the decision of a female student to undertake Engineering based on the comparisons of the data presented in previous section. Iranian example provides strong evidence to support this. The second prominent factor is “socio-economic” content of a program, which appeals to the female students. Larger proportion of female students in Environmental Engineering supports this observation. The other prominent factor is the interest and confidence in maths and science. The lesser take up of mathematical subjects by female students in Sri Lanka, Australia and Europe indicates a lack of confidence rather than capability, since obviously there is no evidence to support a major difference in the ability in

mathematics between the genders (Beraud, 2003). We should also not forget that employment potential is a prominent factor affecting the decision of female students to take up Engineering as a career.

In any recruitment initiative these factors must be considered. We have thus explored possible activities to be included in an effective marketing campaign which captures the attention of female students.

Creating a Culture where Female students are encouraged to take up Engineering

Females are expected to make a set of selected career choices. This expectation has been largely dissipated due to world-war 2 where females did step up and contributed in traditionally male vocations. In a subtle fashion, the methodology of Engineering has moved from a physical approach to an intellectual approach. Judy Brennan, who is among the 25 most influential female Engineers identified by Engineers media in 2007 quotes “methodical problem solving can compensate for lack of experience”. Good role models who increase the awareness of the profession should be used in marketing initiatives.

After analysis of data from marketing web sites and other promotional material in Europe, European Commission (2009) concludes that most material reflect a masculine image of Engineering and technology fields.

Increasing Awareness of Interdisciplinary Nature of Engineering and new teaching methodologies

Advertising material targeting females should focus on the benefits to society and demonstrate to the prospective students “why and how they can make a difference”. The general association of Engineering to “nuts and bolts” should be changed to a broader vision such as “our graduates will lead the sustainable transformation of resources into products and infrastructure for the benefit of mankind” or “taking the dreams hopes and desires of humanity and making them a reality” currently adopted by the school of Civil Environmental and Chemical Engineering at RMIT University.

The observations made in project based teaching courses support the previously raised thought that team projects would appeal to female students. Thus the marketing material should make the best of these activities and include samples in promotional materials.

Activities to Enhance Engagement and Confidence in Mathematics and Sciences

This is an action to be explored by schools. Maintaining a good relationship with careers teachers and sending recent graduates and current Engineering students for school based presentations are the activities that can be explored. Most of the mathematical concepts are easily demonstrated through application and small projects. Perhaps offering schools the sponsorship for competitions could be attempted to cover this aspect.

CONCLUSIONS

The paper attempted to identify the major factors influencing recruitment of female students in to Engineering and develop some strategic marketing activities. Major factors perceived by other researchers have been identified and considered in

comparison of data presented in the paper. From the evidence gathered, the dominating factor which influences a female student to select Engineering as a career is identified as the “culture” of the society or the school, followed by interdisciplinary content in Engineering, project based teaching, interest and confidence in mathematics and job prospects. Possible marketing activities are identified as:

- Developing an awareness of the Engineering methodology, which has changed from a physical approach to an intellectual approach.
- Scrutinising advertising material to ensure that the language and the images do not project a masculine image of the profession.
- Engaging good role models who can promote Engineering and use their profiles in marketing materials.
- Taking the focus from “nuts and bolts” to benefit to the society, how Engineering can make a difference.
- Promoting the interdisciplinary content in Engineering.
- Developing school based programs that develop interest and confidence in mathematics in schools.

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ENGINEERING SUSTAINABILITY – A SYSTEMS APPROACH

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ABSTRACT

Over the last fifty years, engineers have made important contributions to improved environmental outcomes, through design and implementation of containment and control measures which have evolved with community expectations. In the past, engineers have operated under an assumption that there is no real limit on resources – our mandate has been narrowly focused on providing the best technical solution for our clients over the short term at least cost. However, in more recent times, we have come to understand that we live in a global community whose finite resources are not sufficient, with current technology, to provide everyone the standard of living to which they aspire. A shift in thinking is required, and engineers are rising to the challenge of leading the community through to a new paradigm.

Looking to the future, engineers should demonstrate leadership in environmental management beyond compliance – not just implementing ‘end of pipe’ solutions to achieve environmental standards but seeking to design or implement new processes or technologies which: avoid environmental impacts as part of the process design; reuse/recycle wastes to achieve higher value products; and reduce consumption of water, energy and materials. As engineers, we have a responsibility to challenge ‘business as usual’. Moreover, the community’s expectation has increased beyond local environmental management towards more sustainable outcomes over the long term which include social and economic considerations on a global as well as local scale. This paper discusses a ‘systems approach’ to engineering more sustainable solutions, with engineering ‘excellence’ as a key platform for delivery.

THE ROAD TO SUSTAINABILITY...

Where have we been? Where are we going?

The following is an engineering perspective of where we are on the road to sustainability, where we have been, where we are going, and how we might get there. In the more distant past, engineering design has typically reflected the relaxed community attitudes towards environmental management which were prevalent at the time.

Going back in time, personal anecdotes by a relative of one of the authors include a number of stories about the old mining operations and cement plants that he was exposed to as a young Canadian mining engineer in the 1950s (Jones, LW; pers.com.). He recalls flying over one mine site in northern Quebec and seeing lakes and rivers the colour of ‘tomato soup’ – the red colour being due to the dumping of iron oxide (known as ochre) from the iron ore concentrator. ‘From the air, the tomato red colour was visible for hundreds of miles...’

Air pollution control was also rudimentary at that time, and this particular relative tells his favourite anecdote of an iron ore concentrator where, despite a dust collection efficiency of 98%, the large tonnage throughput resulted in the fallout of particulates being so thick that the roof almost collapsed. The cement industry is another example of evolution. Water was previously seen as plentiful, and used freely to mix ingredients, requiring long kilns and high energy to remove the water later in the process. As the

cement industry evolved in the seventies, the industry converted to a dry process with shorter kilns, heat recovery and reduced water and energy use. As this particular relative continued along his engineering career, the new plant designs that he was involved with included better containment measures and increasingly efficient dust collection and use of resources.

Environmental pollution and waste management concerns in the sixties created a vibrant environmental movement in the seventies which raised community expectations and led to increased regulation in the eighties. These legislative requirements are now reflected within mainstream business management systems and operational controls.

Over the last fifty years, engineers have made important contributions to improved environmental outcomes, through design and implementation of containment and control measures which have evolved with community expectations. Tailings containment dams and highly efficient bag houses and dust precipitators (i.e. 99.9%) are now ‘business as usual’ in developed countries.

‘Business as usual’ is no longer sufficient...

Although tailings containment in mining operations is now considered ‘business as usual’, the potential environmental and safety risks are significant – only last October we have seen the catastrophic failure of tailings dam walls from bauxite mining following flooding events in Hungary resulting in injuries and loss of life. A recent article (Boger, 2010) notes that resource industries are the world’s largest producers of waste, much of this waste being produced as a fine particle suspension which is pumped to tailings storage dams at low concentration – this was the case in Hungary. As engineers, we have a responsibility to challenge ‘business as usual’.

Boger notes that simply removing, recycling and reusing water from the suspension represents a step towards more sustainable practice in the mining industry. The failure of the wet residue storage dam in Hungary is as ironic as it was unnecessary, as it is the alumina industry (bauxite processing) that has led the way in the move from wet to dry disposal. The dry stacking design (such as is used by Alcoa World Alumina in Western Australia) reduces dam failure risks, reduces the footprint of the tailings area, and facilitates water recovery and reuse.

There are limits to growth...

In the past, engineers have operated under an assumption that there is no real limit on resources – our mandate has been narrowly focused on providing the best technical solution for our clients over the short term at least cost. However, in more recent times, we have come to understand that we live in a global community whose finite resources are not sufficient, with current technology, to provide everyone the standard of living to which they aspire. A shift in thinking is required and engineers must rise to the challenge of leading the community through to a new paradigm. Society has coined the phrase “sustainability” to reflect the new paradigm.

Looking to the future, engineers must demonstrate leadership in environmental management beyond compliance – not just implementing ‘end of pipe’ solutions to achieve environmental standards but seeking to design or implement new processes or technologies which: avoid environmental impacts as part of the process design; reuse/recycle wastes to achieve higher value products; and reduce consumption of water, energy and materials. Moreover, the community’s expectations have grown beyond

local environmental management towards more sustainable outcomes over the long term which consider environmental, social and economic considerations on a global as well as local scale.

Take a global perspective...

We need to tackle sustainability issues from a global perspective. For instance, while responsible corporate environmental management is today taken for granted in Australia, environmental and safety controls are not necessarily of the same standard in developing countries – this raises potential ethical issues, as Australian engineering companies increasingly seek advantage from sourcing cheaper components (i.e. steel) from overseas suppliers. As engineers, we should be asking ourselves the following questions:

- Are we satisfied that these overseas components have been made without compromising workforce health and safety, or the local environment?
- How shall we as engineers respond to these dilemmas and other leadership challenges?
- What tools, skill sets and personal attributes will engineers require to deliver more sustainable outcomes?

Take a long term perspective...

We need to take a long term perspective on what is achievable. Last year, the Australian Federal election was in full swing. Climate change and water shortages dominated the media headlines across Australia. The Peak Oil Theory was also getting significant air time. Nuclear power as an energy option for reducing our dependence on conventional greenhouse gas intensive fossil fuels was also part of the media debate. Once the election was over, media coverage of these issues dwindled with the public's interest and enthusiasm similarly waning. More recently, the carbon tax debate has brought climate change back into the headlines. How do we maintain momentum and convert public sentiment into consistent policies and actions which set the foundations for a more sustainable future? Real behavioural change will take generations: our challenge is to sustain the public's interest and enthusiasm over the long haul. Long timescales will be required to achieve positive change. *Patience, persistence* and *persuasiveness* are the attributes that engineers will need to break through the 'business as usual' barrier.

Forty years ago, in the late sixties, the conservationist movement sparked (grass roots) local community recycling campaigns to lobby for municipal governments to implement glass recycling depots. Today it is commonplace for householders to separate waste at source, and most municipalities provide dual bin curb pickup with central processing facilities to recycle glass, paper, plastics, metal and green waste.

Thirty years ago, during the late seventies and early eighties, rising oil prices sparked grave concerns that easily accessible oil reserves would soon be depleted. As engineers and scientists scrambled to find alternative fuels, there was a renewed interest in hydrogen technologies (such as fuel cells) that could facilitate the harnessing and use of renewable energy and advance the '*hydrogen energy economy*' (Jones et al.,1985). This concept reflected a large body of American and European research into hydrogen generation, storage and handling, and propulsion systems that had been ongoing for at least thirty years prior. Eventually however, the high oil prices stimulated additional petroleum exploration and production leading to a decline in the price of oil. Simultaneously, the stock market crash in 1982 caused a severe recession leading to

reduced oil demand. These two factors contributed to a reduction in funding of renewable energy efforts.

Over the last decade, community expectations have broadened to embrace sustainability and concerns about climate change are at the forefront. The Peak Oil Concept has resurfaced in the public consciousness (Deffeyes, 2005) and the concept of the '*hydrogen energy economy*' is back in fashion. Realistically, the hydrogen energy economy has been a long time coming (over sixty years) and is unlikely to become a practical option for some time yet.

Long timescales are required to achieve positive change and we need to be patient, persistent and persuasive. The positive signs are, however, that government corporations and businesses are seizing the imperative of addressing climate change, and internalising sustainability principles into their business systems – these will become key drivers for positive change in the way our society manages water, energy and resources. Engineers and scientists will need to respond to these drivers and lead our global community along the road to sustainability.

More interaction and communication is required to develop a common vision and agree on fundamental sustainability principles, to establish a platform for achieving more sustainable outcomes – and this interaction is required at all levels, amongst individual practitioners, professional associations, private industries, government corporations, and sovereign nations. There is a role for professional organisations such as Engineers Australia to influence more sustainable outcomes by fostering communication and facilitating knowledge transfer.

THE ROLE OF ENGINEERS AUSTRALIA

Engineers Australia is the largest engineering association in Australia with over 90,000 individual members nationally and over 11,000 members in Western Australia (including students). Engineers Australia has an international sphere of influence through affiliated engineering organisations in other countries. Through its technical societies, Engineers Australia also embraces non-engineering professions such as scientists, planners and architects and, through its broad-based membership, is well positioned to collaborate with kindred professional groups to bring forward our sustainable future.

Agenda 21, a historic document endorsed at the Earth Summit in Rio in 1992, explicitly addressed the important role of engineers in achieving sustainability and identified two broad programme areas:

- Improving communication and cooperation between the scientific and technological community and decision-makers and the public; and
- Promoting codes of practice and guidelines related to science and technology.

Following on from Agenda 21, the then Institution of Engineers passed a motion at the 1993 Annual General Meeting '*that Council acknowledge the leadership role the engineering profession must provide in attainment of sustainable development and that Council develop special plans to achieve this leadership role and report progress regularly to the members*'. As a result of this motion, the Institution set up a Task Force on Sustainable Development. The Council adopted a **Policy on Sustainability** (in October 1994), and the **Code of Ethics of the Institution** issued in 1994 stated that:

*“Members of the Institution of Engineers, Australia are bound by a common commitment to promote engineering and facilitate its practice for the common good based on shared values of: ethical behaviour; competent performance; innovative practice; **engineering excellence**; equality of opportunity; social justice; unity of purpose; and **sustainable development**.*

Over the intervening years, Engineers Australia has contributed to the sustainability debate through its Learned Groups, and has included sustainability as a key attribute of accreditation for undergraduate engineering education. The **Sustainability Charter** for Engineers Australia was formally launched at the *International Conference on Engineering Sustainability* hosted by the *Society for Sustainability and Environmental Engineering (SSEE-2007)*.

The current **Code of Ethics** (Engineers Australia, 2010) states that ‘*As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future*’. To paraphrase, the Code says that ‘*Furthermore, in the course of engineering practice we will promote sustainability through:*

- *Engaging responsibly with the community and other stakeholders;*
- *Practising engineering to foster the health, safety and well being of the community and the environment; and*
- *Balancing the needs of the present with the needs of future generations’.*

A ‘WHOLE SYSTEMS’ APPROACH TO ENGINEERING SUSTAINABILITY

For some engineers, sustainability remains a ‘fluffy’ word with no substance; a nice ‘motherhood’ sentiment with no defined process for delivery. In the face of these conventional attitudes, how do we ‘engineer’ sustainability? The most effective means of achieving sustainability outcomes for a project may be to embed a ‘sustainability framework’ within existing core engineering processes, including:

- risk workshops;
- safety-in-design workshops;
- concept planning workshops;
- options evaluation, analysis and assessment (using SA, LCA, TBL, ecological footprint analysis, etc); and
- value for money workshops.

As an overarching project delivery platform, we propose a ‘whole systems’ approach, which entails defining the boundaries of the system, identifying the key stakeholders, and optimising to achieve integrated design objectives. This strategic approach places a heavy emphasis on team work and communication skills. Key elements of a ‘systems approach’ are described below.

Take a more strategic view

A ‘systems approach’ takes a more strategic view of a project, ideally at the initial concept stage, when all of the options are still on the table. If we consider the stages of a project’s life cycle, from its initial formulation at a conceptual level (strategic or policy) through to the project-specific construction and operational stages, it is not difficult to imagine that careful decision-making earlier in the life cycle would result in more sustainable outcomes.

At the project-specific stage (design, construction and operational), engineers and scientists are often charged with the task of refining projects that are already well advanced (most notably in terms of site allocation or design assumptions), consequently the scope for realising high magnitude, large-scale sustainable outcomes is minimised.

Engineers and scientists typically employed to work at the project-level should endeavour to become increasingly valued at the conceptual stage of project formulation. There is arguably no one better placed to identify the constraints and opportunities associated with various project options than those people responsible for the more tangible aspects of project delivery.

Multi-disciplinary teams incorporating engineers, scientists, contractors and other parties more typically associated with project delivery should ideally be involved in high-level strategic visioning workshops at the conceptual stage when all options (including whether the project/process is really required) are still on the table.

Review the purpose and objectives

A ‘systems approach’ can incorporate a ‘sustainability framework’ to facilitate the achievement of project effectiveness and sustainability outcomes (i.e. what to consider and how to do it). A ‘sustainability framework’ establishes: an overarching project vision and objectives; opportunities and design challenges; key performance indicators (KPIs); knowledge gap priorities; and tactics (i.e. how it will be achieved).

Workshops are excellent forums to develop a ‘sustainability framework’ and can facilitate: sharing of systemic views of the project to explore linkages; backcasting to identify project success factors; exploring ‘drivers for change’; developing project objectives and principles; developing key performance indicators beyond ‘business as usual’; identifying knowledge gaps and key risks; managing project risks/challenges; and managing project interfaces.

Consider whole of life

A ‘systems approach’ considers the sustainability aspects of a project over its full life cycle. This requires:

- Engagement with maintenance and operational staff during the design stage, to incorporate relevant experience and ‘lessons learned’.
- Clarity of design scope in EPCM contracts.
- Review of project options using appropriate sustainability assessment techniques such as multi-criteria analysis (MCA), Lifecycle Cost Analysis (LCA), Triple Bottom Line (TBL) or other expanded financial analysis, ecological footprint analysis, etc.
- Consideration of sustainable supply chain aspects during procurement of contractors, materials, technologies, plant and equipment.
- Establishing a monitoring and evaluation framework, to anticipate future monitoring/ compliance requirements.

Define the boundaries of the system

A ‘systems approach’ considers the project footprint within a broader context (both in terms of geography and time horizon) and then defines the boundaries clearly. This requires a broader, more integrated approach during the up-front planning phase of the project. As regional and global issues may have a bearing on the project, there is a need to step back from the localised view. It is necessary to maintain a long term project horizon (ie. design life and beyond). Having considered the broader context, it is

important to define the project purpose and scope from an early stage, so as to ensure clarity and maintain focus during options optimisation. The goal is to optimise the entire system, not just the component parts.

Ask the right questions - communication is the key

A 'systems approach' recognizes the importance of communication in achieving more sustainable outcomes. People have different frames of reference, reflecting their language, culture, vocabulary, technical disciplines and skill sets. Engineers and scientists must master the art of communication and make sure that our messages are understood. Key strategies for project communication should include:

- Seek multidisciplinary input across all project phases (engage with operational and maintenance staff).
- Develop an integrated and early approach to social planning - strive for community engagement in the broader region (as appropriate), not merely information dissemination to local residents and affected landowners.
- Determine strategies for dealing with workforce/community issues early.

Communication, consultation, integration and innovation can all be fostered through a multidisciplinary team approach, and will lead to more sustainable outcomes.

SO WHAT DOES SUSTAINABILITY LOOK LIKE?

From an engineering perspective, many attributes of engineering 'excellence' also reflect aspects of sustainability. Some of the recent Engineering Excellence Awards championed by Engineers Australia provide a glimpse of what can be possible with a collaborative approach and the right design environment. Judgement is based on seven mandatory and fourteen elective criteria, with sustainable development being specifically mentioned as one of the mandatory criteria (Criterion 6). Overall, of the 21 judging criteria, sixteen of them reflect elements of 'sustainability thinking' (although the term 'sustainability' may not be specifically mentioned) as shown below:

- **Attention to occupational health and safety (Criterion 1):** The increasing focus on 'safety in design' has application to delivering more sustainable outcomes through better engineering design (Jones, 2008).
- **Use of sound engineering practices and principles (Criterion 2):** This offers the potential to integrate *sustainability objectives and principles* within the project **design principles** and to implement **quality systems** which can demonstrate continuous improvement.
- **Originality and ingenuity of the solution (Criterion 3):** This provides a platform to demonstrate **innovations** *which can lead to incremental or step changes towards more sustainable outcomes*.
- **Contribution to the economy** through more **efficient use of resources** and improvements on the **quality of life (Criterion 4)** – self evident.
- **Benefits to the community through positive contributions to employment, environment, conservation, amenity and quality of life (Criterion 5)** – self evident.
- **Contribution to sustainable development through managing, protecting or conserving the natural environment (Criterion 6)** – self-evident.
- **The simplicity of the engineering solution (Criterion 8)** – self evident.

- **Use and development of innovative design, construction, maintenance or management practices (Criterion 9)** – self-evident.
- **Cooperation with other disciplines and professions and/or effective use of community government or industry consultation (Criterion 11)** – self evident.
- **Attention given to the needs of users (Criterion 15)** – self evident.
- **Environmental implications (Criterion 16)** – self evident.
- **Quality and extent of research (Criterion 17)** – (i.e. looking for new and better solutions, rather than accepting ‘business as usual’).
- **Skills transfer and team development (Criterion 18)** – (i.e. development of ‘human capital’).
- **Integration and innovative use of computer automation...modelling systems (Criterion 19)** (i.e. could by extension reflect a ‘whole systems’ approach).
- **Maintenance efficiency and effectiveness (Criterion 20)** – (i.e. consider ‘whole of life’ aspects).
- **Heritage value (Criterion 21)** – (i.e. maintain a ‘sense of place’).

The point is that engineering ‘excellence’ provides a platform for sustainability, particularly when all stakeholder needs are considered from a ‘whole systems’ perspective. It is noteworthy that two of the judging criteria recognise positive team behaviours such as cooperation with other disciplines and professions, skills transfer, and team development. These positive team behaviours also reflect a sustainability approach. A review of the WA Engineering Excellence Award winners and finalists over the last few years provides a glimpse of the range of sustainability outcomes that can be achieved through engineering ‘excellence’. A small selection is provided below, representative of various market sectors including buildings, mining, power and water. One of the case studies (Case Study No. 4) is expanded to evaluate the success of a ‘systems approach’ as a delivery platform for sustainability.

Case Study No. 1: Condor Tower - Pritchard Francis Pty Ltd (2010 WA Award Winner and National Award Winner)

Condor Tower is a mixed-use 28 storey building at 22 St Georges Terrace, just across from the Perth Concert Hall. Condor Tower exemplifies leading engineering innovation by adding 18 storeys on top of a 10 storey abandoned building. Reusing the existing concrete structure reduced concrete consumption and building waste to landfill. Unique in Australia and possibly worldwide, a building extension of this magnitude required innovative engineering solutions and involved four years of research at the University of Western Australia. Condor Tower pushes the boundaries of building adaptability and sustainable design by demonstrating how obsolete structures with remaining design life and inherent strength can be recycled and transformed.

Case Study No. 2: A Mobile Mining Unit plant – RCR Mining (2010 WA Award Winner)

RCR Mining designed, manufactured, installed and commissioned a fully integrated track-mounted mobile unit plant (MUP) for the client, Iluka Resources. The MUP is installed at the Jacinth Ambrosia mine pit in South Australia. Heavy mineral concentrate from the Jacinth Ambrosia mine is treated at Iluka’s upgraded processing facility near Narngulu in Western Australia. The innovative MUP incorporates an ore recovery and full in-pit primary processing unit and sophisticated relocation system. The advanced technology for the customised hydraulically driven track module enables

the 1000 tonne machine to raise and drive itself to the next mining position via remote control. The MUP features lower infrastructure and operation costs, improving efficiencies and reducing waste, energy and emissions. Sinclair Knight Merz provided structural design support, and electrical design was provided by Overflow Industrial. Delivered within nine months with an outstanding incident-free safety record, the key to the project's success was passion, innovation and team work.

Case Study No. 3: Eneabba to Moonyoonooka Transmission Line Corridor Selection Process – Western Power and Sinclair Knight Merz (2007 WA Award Finalist)

The Perth to Geraldton transmission line is the largest project of its type for Western Power in 20 years, securing power in the region and facilitating sustainable energy projects such as wind farms. The high capacity 330kV transmission line will run from the existing Eneabba substation to a new substation at Moonyoonooka (approximately 15km east of Geraldton). Sinclair Knight Merz (SKM) undertook the corridor selection process which has received acclaim from government authorities and stakeholders. The study employed a novel approach to spatial planning, an unprecedented level of community consultation and sustainability assessment to identify a 1km corridor regarded by the community, stakeholders and Western Power as the best environmental, social, technical and economic option. Workshops were held with Special Interest Groups to fully understand their issues and concerns. Western Power's field officers liaised closely with farmers and landowners to fully understand the constraints and opportunities of each corridor option. Upon referral, the EPA was satisfied with the level of public consultation and a formal public review was not required, thus saving two years.

Case Study No. 4: Woodman Point Odour Control Facility – Water Corporation and W2W Alliance (2009 WA Award Winner)

The W2W Alliance, comprised of partners Black & Veatch, Sinclair Knight Merz, Thiess and the Water Corporation, formed in 2006 to manage a five-year, \$352 million program of works to upgrade Perth's metropolitan wastewater treatment plants. The new Odour Capture Facility at the Water Corporation's Woodman Point Wastewater Treatment Plant has significantly improved the quality of life for local residents living or recreating around Lake Coogee. One of the largest of its kind in Australia, the Woodman Point Odour Capture Facility utilises a unique odour treatment system combining biological scrubbers followed by traditional chemical scrubbers to achieve outstanding odour reduction and reliability. The project was initiated as a result of community complaints of odour emissions, which led to a Ministerial condition to reduce odour emissions by 50%. The W2W Alliance accepted the brief to upgrade the plant. There were a number of initial barriers to the project including: capital budget limitations; institutional barriers and prejudices; organisation goals and projects not being connected; and organisational 'silos'.

The *Problem Definition Phase* led to the following key outcomes: stakeholders were identified (community, operators, asset managers, designers, planners, capital investment managers, etc); requirements and constraints were elicited during workshops with key stakeholders and design staff; an understanding of perceived values was established; and project objectives and boundaries were defined.

During the *Analysis Phase*, a Return on Investment (ROI) model was established. Capital cost was seen as a major driver, and therefore significant design

innovation/optimisation was required to meet capital cost constraints. As a minimum, the target cost had to be met while meeting stakeholder expectations and performance requirements (i.e. Ministerial Conditions). A range of technology options were ranked according to the sustainability performance criteria as defined by stakeholders. This involved quantification of environmental impacts (i.e. GHG emissions due to embodied energy of chemicals used in processes).

The *Design Phase* led to an innovative concept design being developed to meet the ROI model and performance/community expectations. Once capital funds were made available, the detailed design progressed, vendor specifications were developed and procurement proceeded. The *Construction and Commissioning Phase* was completed in 2010 and the *Validation Phase* has recently been completed.

Evaluating the effectiveness of the ‘systems approach’ to Case Study No. 4, while economic sustainability was considered (in itself a milestone), it became apparent that environmental and social considerations were not true elements in the actual capital spend decision-making. Nevertheless, key improvements beyond ‘business as usual’ were made in the process through:

- considering, quantifying and weighting the environmental and social impacts, through broad stakeholder and team discussion; and
- breaking down internal stakeholder barriers (i.e. lack of communication, lack of coordination, resistance to new technology).

IN CONCLUSION - HOW CAN WE ‘ENGINEER’ SUSTAINABILITY?

Climate change, water shortages and environmental degradation – the issues confronting our global community are daunting. How can we make a difference, both as individuals and as professionals in our work place? We propose:

- be ingenious - work smarter and innovate;
- expand your ‘spheres of influence’;
- breakdown the silos;
- seek involvement at the conceptual stage of projects;
- take a ‘whole systems’ approach; and
- strive for engineering ‘excellence’.

As engineers and scientists we have the skill sets to make a significant difference, and society is relying on us to find solutions to these problems.

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DEMONSTRATING CARBON DIOXIDE CAPTURE THROUGH PILOT PLANT OPERATION

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ABSTRACT

Capture and storage of carbon dioxide (CO₂) can have a significant role in the near-term reduction of CO₂ emissions and thereby reducing the impact of global warming. Demonstrating capture of CO₂ from emission sources on a pilot plant scale is a significant step towards commercialisation of carbon capture and storage (CCS) technology.

As part of the Victorian Government's Energy Technology Innovation Strategy (ETIS), and the Federal Government's Low Emission Technology Demonstration Fund (LETDF), successful capture of CO₂ from synthesis gas and boiler flue gas has been demonstrated using solvent absorption pilot plants located at HRL's coal gasification facilities in Mulgrave, Victoria and International Power's Hazelwood Power Station in the Latrobe Valley, Victoria, respectively.

Performance results and operability issues associated with the pilot plants are presented.

CO₂ CAPTURE AND SEQUESTRATION

CO₂ capture and sequestration shows promise to significantly reduce greenhouse gas emissions from stationary sources such as power stations burning fossil fuels.

The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO₂CRC) was established in 2003 and is a collaboration of research participants, government and industry partners working towards commercialisation of CO₂ capture and sequestration in Australia.

The CO₂ capture and sequestration process as shown in Figure 1 involves (i) capturing CO₂ from the source, (ii) pressurising CO₂ so that it forms a dense phase, (iii) transportation of the CO₂ to a storage site (via pipeline) and finally (iv) storing the CO₂ underground in an existing geological formation such as an oil and gas or saline reservoir.

Referring specifically to CO₂ capture from power generation, there are two major types of CO₂ emission sources to the atmosphere that are likely to be of industrial relevance in the near future. The first emission source comes from the production of synthesis gas using fossil fuels. CO₂ capture from this emission source is referred to as pre-combustion capture. The second emission source is the flue gas from electricity power stations that use direct combustion of fossil fuels. CO₂ capture from this emission source is referred to as post-combustion capture.

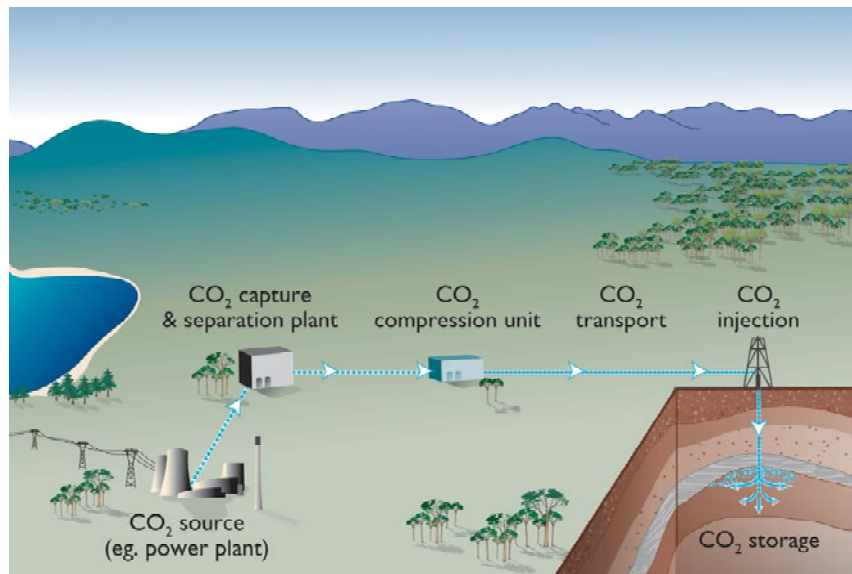


Figure 1: CO₂ capture and sequestration process.

PILOT PLANT FACILITIES

In 2007, the CO₂CRC obtained financial support from the Victorian State Government, as part of ETIS, to build and operate pilot plants demonstrating pre- and post-combustion CO₂ capture. Pre-combustion pilot plants demonstrating solvent absorption, gas adsorption and membrane separation were located at HRL in Mulgrave. Post-combustion pilot plants demonstrating gas adsorption and membrane separation were also located at Hazelwood Power Station in the Latrobe Valley in addition to International Power Hazelwood's solvent carbon capture plant.

Of the three technologies tested, a discussion of the operability issues and results pertaining to the solvent absorption pilot plants will be presented here. In both the pre- and post-combustion solvent pilot plants, the solvent tested was potassium carbonate (K₂CO₃). Potassium carbonate reacts with CO₂ to produce potassium bicarbonate (KHCO₃) according to the following reaction.



The synthesis gas (syngas) in the case of pre-combustion and the flue gas in the case of post-combustion come into contact with the solvent in the absorber column, where the reaction occurs. The transfer of CO₂ from the gas to the liquid results in a CO₂-lean gas stream exiting the top of the absorber column. The solvent rich in bicarbonate exits the bottom of the column and proceeds to a regenerator column where heat is applied and the CO₂ is liberated from the solution giving a very pure CO₂ gas stream ready for sequestration. There was no geological storage component of the ETIS projects.

The standard potassium carbonate process is well established for removing CO₂ from synthesis gas, where the absorber operating pressure is high (Benson et al., 1954, Benson et al., 1956, Buck and Leitch, 1958(Savage et al., 1980). However, due to the low pressure of the flue gas and lower rate of reaction compared with traditional amine-based solvents, the potassium carbonate process is not generally considered for post-combustion capture. The CO₂CRC has been developing alternative potassium carbonate processes that are applicable to high temperature pre-combustion capture and also to low pressure post-combustion capture. These processes promise to have the benefits of lower energy usage and being more environmentally benign when compared with the

standard amine-based solvents. The primary objective of the pre- and post-combustion solvent pilot plants has been to obtain operating data for benchmarking the ASPEN PlusTM simulations for the continued development of the alternative potassium carbonate processes.

Simulation of the pre- and post-combustion pilot plants was completed using ASPEN PlusTM (Version 7.1, AspenTech, USA). Within ASPEN PlusTM, the Electrolyte-NRTL (ENTRL) model was chosen as most appropriate for modeling ionic liquids like potassium carbonate. In addition, the RadFrac unit operation in rate-based mode was chosen for modeling the adsorption and regeneration columns given that the reaction of CO₂ with K₂CO₃ is rate limited.

Pre-Combustion

The pre-combustion solvent pilot plant was operated over three campaigns at HRL in Mulgrave from May 2009 until July 2010, taking syngas from the HRL air-blown brown coal research gasifier. The solvent pilot plant has a capacity to remove 1 tonne/day of CO₂ from the synthesis.

The typical composition of the syngas supplied from the Mulgrave research gasifier to the solvent pilot plant is provided in Table 1. The synthesis gas provided was at a lower pressure and at higher carbon monoxide content than that from a typical commercial gasification plant after water gas shift.

Table 1: Typical syngas composition from an air-blown coal research gasifier as part of the CO2CRC/HRL Mulgrave Capture project.

Gas Species	Mol %
CO ₂	16.2
H ₂	9.8
N ₂	63.2
CO	6.7
CH ₄	2.8
H ₂ O	0.25
H ₂ S	~ 0.05
Heavier hydrocarbons (propane, ethane etc.)	~ 1

Details of the process configuration of the pre-combustion solvent pilot plant are published elsewhere (Anderson et al., 2011).

Post-Combustion

The post-combustion solvent pilot plant was operated using two different solvents at Hazelwood Power Station from July 2009 until September 2010. The pilot plant was designed to be used with a commercial amino acid based solvent known as BASF PuraTreatTM F. However, the CO2CRC also trialled the potassium carbonate solvent process and the results from this test campaign are presented in this paper. The pilot plant was designed to remove up to 50 tonne/day of CO₂ (but nominally operates at 25 tonne/day) from the flue gas produced by Hazelwood's brown coal fired power station.

The composition of a typical flue gas supplied from Hazelwood's Power Station to the solvent pilot plant is provided in Table 2.

Table 2: Flue gas composition from Hazelwood Power Station

Gas Species	Mol %
CO ₂	13.0
N ₂	62.0
O ₂	3.5
H ₂ O	20.5
Ar	0.8

Details of the process configuration of the post-combustion solvent pilot plant are published elsewhere (Qader et al., 2011).

PILOT PLANT OPERATION AND RESULTS

Pre-Combustion

Various operational issues were encountered and overcome during the operation of the pre-combustion solvent pilot plant. These included avoiding solvent precipitation, maintaining solvent liquid levels through managing the absorber temperature profile and handling syngas impurities absorbed into the solvent, such as coal dust. These types of issues can not necessarily be accounted for in simulation or engineering design and as such operating experience provides invaluable input for future design and operation of larger-scale capture facilities.

A snap shot of the pre-combustion pilot plant results for a typical day is presented in Table 3. Also presented in Table 3 are the ASPEN PlusTM simulation results for the same day using aspects of the plant data for input as indicated. The simulation results match the experimental data well and therefore provide confidence in using ASPEN PlusTM for full-scale design of the pre-combustion potassium carbonate process developed by the CO2CRC. Various other trial days were simulated in ASPEN PlusTM and resulted in similar outcomes with plant data matching simulated data within +/- 5%.

Table 3: Comparison of plant data and ASPEN PlusTM simulation results for a typical day of solvent plant operation – (pre-combustion capture).

Parameter	Plant Data	Simulation Result	Error (%)
Flow (kg/hr)			
Syngas In	299	Input	N/A
Regenerator CO ₂ Out	34	33	-4
Lean Solvent	1702	1697	-0.3
Rich Solvent	1673	1714	+2
Pressure (kPag)			
Absorber	752	Input	N/A
Regenerator	60	Input	N/A
Temperature (°C)			
Syngas In	63	Input	N/A
Absorber Gas Out	87	91	+4
Absorber Lean Solvent In	90	Input	N/A
Absorber Rich Solvent Out	83	84	+1
Regenerator Bottoms	119	116	-3
Condenser Outlet	80	Input	N/A

The performance of the pre-combustion pilot plant cannot be compared directly with existing facilities for pre-combustion CO₂ removal, such as those that facilities that use

the Benfield Process, as the pressures and temperatures of the syngas are lower than that typically observed in gasification processes. However, adjusted calculations have shown that pilot plant results are within the expected range.

Post-Combustion

Various operational issues were also encountered during operation of the post-combustion solvent pilot plant. The precipitation of solids in various parts of the plant resulted in operating problems which led to plant shutdown for maintenance tasks such as cleaning out equipment as the solid precipitates blocked filters and level transmitters. Large fluctuations in the steam supply occurred due to a fault in the steam pressure transmitter to the reboiler and a steam leakage from the reboiler were also observed during the testing period, resulting in some instability in the regenerator and the tripping of the plant on one occasion. Various instrumentation items such as indicators and pressure control valves were also found to be out of range due to the change over to the potassium carbonate solvent resulting in difficult analysis of plant data and operational problems. It is also worth noting that the post-combustion capture plant was specifically designed to be operated with BASF PuraTreat™ F solvent. Therefore, upon operating the plant with the solvent potassium carbonate, issues such as solvent precipitation were encountered.

A snap shot of the post-combustion pilot plant results using potassium carbonate solvent is presented in Table 4. Also presented in Table 4 are the ASPEN Plus™ simulation results for the same day using aspects of the plant data as input as indicated. Generally the simulation results match the experimental data well and therefore provide confidence in using ASPEN Plus™ for full-scale design of the post-combustion potassium carbonate process developed by the CO2CRC. Other trial days were also simulated in ASPEN Plus™ and resulted in similar outcomes with plant data matching simulated data within +/- 5%.

Table 4: Comparison of plant data and ASPEN Plus™ simulation results for a typical day of operation (post-combustion capture).

Parameter	Plant Data	Simulation Result	Error (%)
Flow (kg/hr)			
Flue Gas In	6617	Input	N/A
Regenerator CO ₂ Out	N/A	230	N/A
Lean Solvent	45030	Input	N/A
Rich Solvent	44400	45169	-2
Pressure (kPag)			
Absorber	3	Input	N/A
Regenerator	42	Input	N/A
Temperature (°C)			
Flue Gas In	42	Input	N/A
Absorber Gas Out	46	47	-3
Absorber Lean Solvent In	47	Input	N/A
Absorber Rich Solvent Out	47	47	-1
Regenerator Bottoms	113	113	+1
Condenser Outlet	46	Input	N/A

There are presently no post-combustion pilot plants or larger scale facilities operating worldwide using a K₂CO₃ solvent. On comparison with other more traditional solvents,

such as amine or amino acids, the amount of CO₂ absorbed is lower when using a K₂CO₃ solvent due to the slower rate of reaction.

CONCLUSIONS

The CO₂CRC, HRL (pre-combustion capture) and International Power Hazelwood (post-combustion capture) have successfully operated two CO₂ capture pilot plants demonstrating pre-combustion and post-combustion capture using solvent absorption. The operation of the pilot plants presented challenges that have provided valuable experience for the design and operation of larger scale capture facilities. In addition, the data collected from the operation of the pilot plants have enabled simulation models to be benchmarked for further development of the potassium carbonate processes by the CO₂CRC.

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BARELY SURVIVING OR TRAILBLAZING? PROFESSIONAL LIFE OF WOMEN ENGINEERS IN SHIPBUILDING, MECHANICAL AND CONSTRUCTION INDUSTRIES IN TAIWAN

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ABSTRACT

Even though much effort has been given to attracting female students to engineering in Taiwan, they only consist about 12 % of all college engineering students. Never the less, we know very little about how women engineers start and thrive in engineering professions; or leave after all. In this research, we focus on the professional experiences of Taiwanese women engineers in three extremely masculine industries: shipbuilding, mechanical and construction. In-depth interview were conducted to gain understanding of their work life balance, professional performances, dealing with workplace culture and self-imaging. Interviewees' education backgrounds, family status, work years, job requirements are also taken into consideration when analysing. The interviews reveal women engineers who work in an office setting feel marginalized by the workplace culture, which worships field experiences and male perspectives. A common thread among many of them is the non-existence of passions for engineering. They separate work and personal life definitely, some spend great effort in pursue personal interests. Other field women engineers tell different stories. They immerge in the harsh field conditions using their own feminine ways for protections, or non-protection at all. They eagerly seek opportunities to be involved and interact with colleagues and subordinates of both genders. Attitude towards dealing with field practical work is clearly one of the key factors, among many found in this research, for women in engineering seeking a pleasant professional life. The result can be used to design a greater scale study in the near future.

BODY OF PAPER

Background

According to the statistics from The Ministry of Education, the total number of college students in Taiwan raised from 910,000 to 1,320,000 between 1998 and 2007. Number of male students increase in Science and Engineering (S&E) department as well as non-S&Es. It is very surprising that there have not been more female students entering S&E departments, roughly 13% of all students now. Nevertheless, female faculty only consists of 6% of entire engineering faculty. This is the first glance of the traditional segregations — “male science and engineering, female humanity and social science”.

Being a female engineering faculty, I am very aware of the gender imbalance in education institutes and industry, therefore inspired to study gender and engineering issues. This Research focus on women engineers, based on interview manuscripts, we draw understanding of their professional experiences. Being the minority in the workplace,

what's their career development? What kind of challenges do they face? What kind of adjustments and counter-actions they take under the influence of engineering culture?

▪ Engineering Industry and Career Choices

In sociology, there has been a changing concept of “career”. Slocum (1966) defined career as an occupation in a period of time, which consists of a series of developing responsibilities. Later, researchers were interested about “career path”, constructed by changes of occupational positions. Stebbin (1970) believed, subjectively, an actor can define a series of events to be successful in career. This definition of career allows it to be non-restricted by working for salaries.

Generally, the aim of engineering education is to teach students to apply engineering theories, and to have the abilities to work with natural materials. Engineering is a practical discipline. Physical implementation is a key element (Feisel *et al.* 2005). But in a rare research about female engineers in Taiwan, 謝宜家(Hsieh, 2000) points out female partitioners in civil engineering have higher education, mostly work in design fields, have very limited involvement with field work. Some claim to have no passion about engineering, and they tend to be conservative and deliberately avoid field assignments. This seems to resonate with McIlwee and Robinson (1992) about the unique “engineering culture”, stating the culture was dominated by male engineers showing off their exquisite practical skills. This culture intimidates female engineers who are less confident about practical experiences. No matter how excellent their mathematical abilities and professional knowledge are, they are strongly excluded from it. Some sacrifice their feeling of engineering and switch to more humane posts like managers. Those who do stay are constantly questioned, implying that they do not belong to, do not fit into engineering society. As a result, most women and some men are coldly moved to the outskirts of engineering (Tonso, 2007).

Western Studies about work and gender often mentioned about “retention rate”, meaning the rate of target parties stay in the occupation or department. However, in Taiwan, college students rarely change major or choose to leave school early, hence the education statistics do not reflect the possible “pipe leak” of female engineering students. Presently, local studies on gender and engineering are rare (陳芬苓Chen, 2004; 林玉萍 Lin, 2001; 嚴祥Yan, 1998); western studies still provide great value of references (Hoeffel, 2007).

▪ Female in Non-traditional Career

From some common statistics, we learned over 60% of female college graduate choose to enter the fields of humanity and social science, there is less than 10% join engineering workforce, the lowest in all disciplines. It is reasonable to assume that, this wide gap affect the percentage of women joining engineering, and what fields in engineering they join.

謝宜家(Hsieh, 2000) points out, in a workplace dominated by male, women face more problems and pressure related to their multiple roles and female body. Dainty *et al* (2000) shows 20% employer feels women are not suited for construction, based on study of female employees in England. They encounter the following eight difficulties: 1, Entrance to industry; 2, Entrance to Companies; 3, Subsequent Promotion; 4, Structural; 5, Culture Organization; 6, Individual Characteristics and Circumstances as Determinants of Careers; 7, Career Strategies; and 8, Future Expectations, Opportunities, and Threats. Therefore, women need to evaluate and make choices in more aspects than men in male-dominated industry.

In the book 〈Gender〉, Connell mentioned gender is not viewed as a solid state. In fact, it changes with time and environment fluently. Those are dynamic processes of configuring practice through time, which transform their starting points in structures. Therefore, female career experiences are unique and active. This research are interested in how female engineer's experience different from that of male engineers? Here, we discuss some studies about women in non-traditional careers for inspiration and comparison.

王月喬(Wang, 2005) studies how female deck officers in container vessels interact with male colleagues in a closed and masculine environment; how she situates herself risking being seen as invaders; how she finds her way and strategies. 謝宜家(Hsieh, 2001) points out in the studies of female in construction, even though the number of female entering construction has increased, but there are still significant differences in work environment, salary and promotion. Issues related to adjusting to male culture and establishing peer friendship are still challenging. Study by 崔艾湄(Tsui, 2004) on female military officer found, they are constantly in a dilemma of guarding or rejecting their femininity. We want to find, I are these aspects universal for other male dominated workplace, like engineering.

▪ Research Method and Layout

This research try to enter rarely studied field of gender — engineering industry. We want to do preliminary analysis on gender situation on female engineers. Because of their uniqueness and diversification, we use the in-depth interview approach. We interview 5 female engineers work in extremely male dominated traditional engineering industry such as shipbuilding, construction and mechanics. The detail differences of these industries are not the focus of this paper.

We noted these engineers with years in this career, office or field work and their personal status. Following are the basic information about the five engineers:

Name	Amber	Betty	Cindy	Debra	Emma
Years	0-7	0-7	14-	7-14	7-14
Company	A. Manufactu ring	B. Ship Yard	C. Shipbuilding related	D. Construction Consulting	E. Mechanical Testing
Position	office	field	office	office	field
Education	M.S.E.	B.S.	M.S.E.	M.S.E.	M.S.E.
Family Status	Married w/ children	Single	Married w/ children	Married w/ children	Married w/ children

In the following chapters, our analysis is divided into the structural restrictions, gender challenges and female experiences of adjustment and reaction. This Research focus on women engineers in engineering industry, based on interview manuscripts, we draw understanding of their professional experiences. What's their career development as minority? What kinds of challenges do they face? What counter-actions they take to adjust to engineering culture? In the following chapters, our analysis is divided into the structural restrictions, gender challenges and female experiences of adjustment and reaction.

Because the aim for this paper is to understand engineering profession from women's prospective, we do not include male engineers' stories in analysis (unless mentioned by

the interviewees), nor do we try to give a complete description of gender situation in engineering.

Structural Restriction

This chapter we focus on women engineers under the restriction of the greater engineering environment. We are interested in learning the reality of engineering industry, and what kind of restrictions and troubles women engineers have to face being the minority in this fields. We try to answer these questions from two points of view: entering the profession and marriage and family issues.

▪ Entering the profession

In the higher education institutes in Taiwan, female students in the engineering departments consist of only 12 % of the total students. However, currently there are not enough data and research to help us understand, the real percentage of these female engineering graduates taking their first job as engineers. Western's studies of gender and Science and Engineering (S&E) education, commonly talk about the retention rate of female students in S&E departments, meaning the percentage of then finishing college education in these departments. But Taiwan has a different culture. Most college students "stay" for the graduation even though they encounter conflicts and frustration during this learning process.

We reason, post-graduation may be the first critical timing a female student exams her experience in the engineering department and consider whether she will pursue an engineering career. Therefore, understanding how and why women engineers obtain their first engineering job can shed some light on how engineering education help in training future (women) engineers.

According to studies in many countries, general public has a stereotype image of engineering industry like laying bricks, welding, painting... that kind of mechanical, outdoor work (Tonso , 2007 ; Phipps , 2002 ; Fielden 、 Marilyn , 2000). They also indicate that engineering requires mathematics and logics. Some researcher argue that low participation of women in engineering is due to the lack of confidence in technical skills among women (Wolffram, Gabriele, 2004 ; Fielden, Marilyn, 2000) . Third, the interviewing process: engineering industry often do require some degree of labour, this becomes one of the obstruction for women (Fielden 、 Marilyn , 2000). Forth, male dominated work culture and environment: women may concern about being excluded and/or not fitted (Fielden 、 Marilyn , 2000 ; Miller , 2004 ; Dryburgh , 1999).

If the above assumptions are true, the "pipeline leak" happens at this critical time. Twisted and biased stereotype imaging of engineering and the traditional view of career choices, limit the opportunities for women to enter engineering industry. Those who do enter will be affected by "female socialization", subject to disadvantages and negative impacts. This motivates us to exam in detail the career experiences of female engineers.

When Amber looked for her first job in a manufacturing company, the (male) manager of company A was not positive about hiring female. He thought male is more versatile, like handling some rough work in the shops. But Amber got the position anyway because she was highly recommended by her college professors. For company A (a shipbuilding company), Betty's (male) manager was pretty positive about hiring female engineer. He was impressed by a female engineer in a previous hiring, even though she failed to enter the short list owing to poor test result. So he was very open about hiring Betty this time.

Right after hiring Amber, her manager turned down another female college graduate because he did not want equal number of both genders in that division (2male 1female at

that time). However, he did hire another female engineer owing to labour need. Right now, there are equal numbers of male and female in the design division in company A. Cindy and Debra have similar stories, they are also in the design division in their company, being the only female.

Based on their experiences, and male managers' attitudes about recruiting female engineers, our observations about female entering engineering industry are: 1, Female engineering graduates feel pretty natural about entering engineering choosing career. This may come from a "genderless" working environment. It is still uncertain if these apply to most female engineers. 2, Managers do consider gender when hiring. They feel uncomfortable for female become the majority in the office. Some will also prefer male because of working conditions in traditional engineering industry.

▪ Marriage, Childbirth and Family

「getting married, having kids, and taking care of family」 seems to be the stereotype images of female nature in our society. Being an administrator of masculine engineering, are female engineers given these expectations at workplace? Is this a protection? Caring action? Or killing of professional interest and development? When it comes to real childrearing needs, what are the employer's reactions?

After one year on her post, Betty was transferred to an office position. Betty was upset:

I didn't want to go at all. ...I was still very enthusiastic, the you just transferred me. I got very upset. ...It's the new manager ...He told me, ...because I am a woman, I will get married or pregnant someday. Then it becomes inappropriate to work in the shop. Now here we have this office position open, you just follow the flow and take it. Don't have to do shop work. (translated into English by author)

Actually, Betty was not even in a relationship, nor had any plan about marriage and pregnancy. Never the less, she has great confidence in her workplace:

For me, it's too early. As of my work place, when I worked there long enough, I know where the dangers are. I can avoid them. Also, my chief of staff (male) also felt no difference, no difference for pregnant ladies.

Betty got to stay in here post in the shop. She had not only had chief of staff but also higher position officer on her side.

Amber had a different experience with her manager of the same issue. When she applied for half-year parental leave,

When I applied for parental leave, I wanted it to be half a year. ...My boss was upset and criticized me. ...Yes, I thought, our company keep telling us we are a decent company that we follow the Labour's Law. I kind of believe that. Now, I feel, if I have another child, I would not apply (for parental leave).

Amber is the second female to take maternity leave (6 weeks for Taiwan), the first to take parental leave. She did not consult with her manager in advance because she believed her company's self portrait of following the laws. Her manager was in shock and furious about it. But she took the leave anyway but for a shorter period.

When Debra was pregnant with her twin, she applied for maternity and parental leaves. Her manager told her coldly that she will have to find someone to take her job, and she may not be welcome after the leave. She was angry but did not take further action even

though the manager clearly offended current laws. However she had since then made clear cut between personal life and work.

Emma shared her experience:

I feel, the entire workplace, not only engineering, are not very friendly to women after all, no matter your priorities is family or having children. ...About half of the ladies in my company envy me. They only let this idea flash by but took no action about it. One woman had her baby about the same time with me. She was rejected by her boss, then she left

Even female engineers administrate the commonly believed masculine engineering in their workplace, the expectation of them getting married and having children seems to be rigidly in place. The master statuses for female engineers are still “female body”. Never the less, when it comes to dealing with these issues, what the system and some supervisors concern are the projected negative effects caused by the limitation of female baby.

However, notice not all managers are open nor close to the family needs of female engineers. We are at the turning point of the new ways to accommodate even support working women in their needs of family caring. More understanding and respect of gender values and issues can bring better future.

Female engineers are often the first pioneer into the male dominated engineering industry. They face being labelled, spotlighted, questioned at all time. However, Amber and Betty are very positive about their work. Amber like the stability of her job, Betty wants to stay in the shop and have confidence she has gained respects and approvals from her supervisor, colleagues and subordinates.

The Gender Challenges: a Single Red in the Midst of Thick Foliage

▪ Gender’s Social Roles

According to Padavic and Reskin(2002), “We define work to include activities that produce goods and services for one’s own use or in exchange for pay or support.” Work shapes personal identity, also affects power play and gender reproduction. Through the allocation of social value, both genders are expected to play their roles, to pursue careers appropriate for their images. Looking back at history of human development, “male make houses, women make homes” have already in-placed since the hunting and gathering era. Male are considered suitable for “dangerous”, “labour intensive” work. And female are excluded from those rough work. Cindy is a senior manager in a company handles shipbuilding affairs. She told us:

When you go to the field, it’s dirty, it’s messy, it’s dangerous and tiring. You don’t really have the physical strength of a man. ...In addition, the administration will get someone to accompany you anyway, because of safety concerns ... plus woman needs someone as company.

Debra mentioned an unforgettable story. “When we were ready to enter the tunnel (during graduate school years, visiting tunnel construction site), my instructor suddenly turned to me and say: go to my car to take care of my child.” After this incident, it becomes clear for her that field work is not for women.

Amber also said: “Our CEO preferred men. He can ask them to do rough work.” Here we found that gender quality has profound impact to the work contents. Male are perceived as strong and tough, are more suited for risky and challenging work.

While female are recognized as fragile and tender, therefore are excluded in the extremely masculine workplace like shipbuilding industry. Under these social expectation and gender stereotype influence, gender work segregation is very obvious in our labour market. In the traditional single sex shipbuilding industry, what are the female engineers' experiences?

- Occupational sex segregation

What is Occupational sex segregation? Bergmann (1974) called when male and female are extremely gathered up in some certain occupations. Entering single-gender occupation being a pioneer, one will be examined by dominating male culture. The system and people involved have to re-negotiate a new way to accommodate female engineers.

Senior engineer Cindy mentioned: *"Sometimes it feels like a congenital defect. ...There is an area that we are not fitted to be a part of it. But we are good in research, examination, and design."* — being weak or fragile is rejected by the traditional engineering industry. Those female who enter may face gender identity impacts.

To conclude, after same education and professional training, it is still very difficult for female to enter traditional engineering industry. Many of engineers we interviewed mentioned, one of the first questions they encounter was *"What are you doing here?"* We can then conclude that there exists a clear gender demarcation in this professional career.

In addition to the obvious segregation, being in the man's world make female engineers the focal points. However, these spotlighting may also cause neglect of their professionalism. Betty remembers vividly during her early days:

Now I remember, one of the first things is how they mentioned me. ...They would say, for example, that girlie (in Taiwanese dialect). ...Or someone may called to discuss work, they would said, oh, you guys have a girl here right? ...My supervisor would correct them, she is Engineer Chen.

It took the field workers about half a year to lose the habit of calling her *girlie*. We learn there exists an occupation segregation of "male engineering, female others" in engineering industry. Entering of female engineers challenges this boundary and forces the system to negotiate new roles for them. Something worth mentioning is, Amber and Betty both have a supervisor who defends their professional identities.

When these minorities makes their way to the company ladder, they are subjected to criticism and gossip. Now a senior manager, Cindy made a comment about her advancing: *"I am one special case. I have not had field experience but now I am in a senior manager position. I knew some are not convinced. They would look at you differently. It's all because you have a better relationship with the boss."*

For these women in non-traditional fields, they have to bear the barrier and pressure coming from the social stereotype, behave carefully in this unbalanced social structure. Just like what Moss-Kanter (1977) called the "token group", whereby a small number of people of a previously excluded gender are allowed entry into an occupation but remain in a minority. They are examined under a magnifying glass, therefore need to act extremely cautiously.

Summary

This research interviewed 5 female engineers who work in a male-dominated engineering workplace. We try to analysis and compare special events and experiences of their professional career. We found engineering graduates feel very natural about getting into engineering industry. It is possible the past education experience did not sprout any questions. But work, interpersonal interactions and life-changing events like marriage, childbirth and promotion change their viewpoints and self-images. While there are clear “man engineering, women others” segregation in engineering, the entrances of female engineers challenges this decoration. Female engineers still possess the master status as woman. However, attitude towards dealing with field practical work is clearly one of the key factors, among many found in this research, for women in engineering seeking a pleasant professional life. We hope this preliminary research shed some lights on understanding gender in engineering. The result can be used to design a greater scale study in the near future.

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STRUCTURE, HYDROGEOLOGY, AND THE GEOTHERMAL SYSTEM OF MOUNT UNGARAN AREA, CENTRAL JAVA, INDONESIA

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ABSTRACT

Indonesia is well known as a country of volcanoes. There are hundreds active and dying volcanoes, one of which is namely Mount Ungaran. It is a Pleistocene age volcano, located in the Semarang region, Central Java Province. In the present time the volcano is identified being in its post volcanism stage. Some observable fact related to the stage of the volcano is there has been no more volcanic eruption record for a thousand year. In contrary, there exist fumaroles and sulfuric hot steam through fissure on the flank of the volcano. The geologic structures obtained at the surrounding area are reverse faults, strike slip faults, and normal faults. On the other hand, the hydrogeologic system is compiled of fractured complex aquifer system, containing volcanic breccias, sandstones, and lava deposits of andesitic to basaltic composition. Due to the high density of fractures, cracks, and faults, the aquifers are able to transmit surface water and groundwater down to contact with such hot plutonic bodies in the volcanic environment to perform geothermal system. This geothermal system is expressed by the occurrence of side and fissure sulfuric fumaroles eruption. Therefore it can be stated that structures and hydrogeologic condition play important role to the occurrence of the geothermal system in the study area.

Introduction

Mount Ungaran is located at Central Java province, belonging to the Semarang region, Indonesia. The volcano is Pleistocene (about 1 to 1.8 million years) age, and in post volcanism phase, indicated by the existence of fumaroles on its side vent. Ancient Mount Ungaran volcanism was the source of Notopuro Formation, comprises of andesitic to basaltic breccias, sandstones and agglomerates. Geothermal system is generally influenced by geologic structure, and hydrogeologic condition. Therefore, based on the rationales mentioned above, this paper is intended to assess the geologic structures and hydrogeologic condition those control the geothermal system of Mount Ungaran environment.

The area being studied is situated on the southeastern slope of Ungaran volcano, administratively belonging to the Semarang region, Central Java Province. It is astronomically bordered by 7°10'00" to 7°15'39" latitudes, and 110°22'30' to 110°28'32" longitudes, able to be reached from Semarang, the capital city of Central Java province, of about 27 km to the south, and from Yogyakarta about 70 km to the Northwest (Figure 1).

Method applied in order to complete the objectives of this study is geologic and hydrogeologic mapping, geologic structural and hydrochemistry analyses. Some rock and groundwater samples were taken for either in situ or laboratories testing.

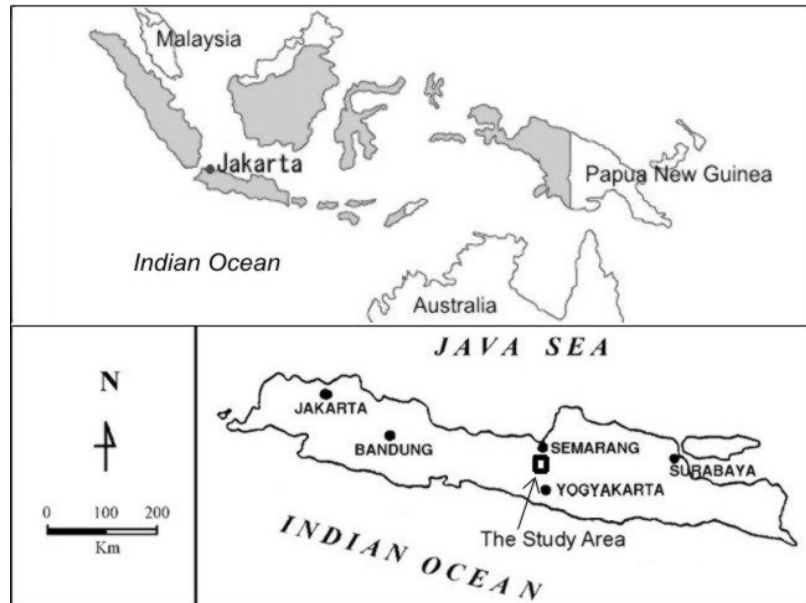


Figure 1. The location map of the study area

Geology

Van Bemmelen (1949) divided the physiography of the Central Java into several zone, respectively from the north to the south are alluvial plain of Northern Java, North Serayu Anticlynorium, South Serayu Mountains, Central Depression and Quaternary Volcanoes Zone, and Southern Mountains. The study area that is situated on the southeastern slope of Mount Ungaran, physiographically includes in the North Serayu Mountains (Figure 2). The Ungaran volcano stands on the eastern most edge of uplifted mountains, and separates North Serayu Mountains in the west from Kendeng Ridge in the east (East Java). Both the North Serayu and Kendeng Mountains are folded ridges, built of predominantly plastic sedimentary rocks of Tertiary Neocene ages (Van Bemmelen, 1949). Because of occupying such foot slopes of a volcano, landforms in the study area are generally expressing hills and wavy planes.

The oldest lithology outcropped in the study area is Penyatan formation, comprises of andesitic breccias with lava interbedding, calcareous sandstones, and marl, Middle Miocene to Late Miocene ages (Van Bemmelen, 1949, Genevraye & Samuel 1972, Markam 1998). Penyatan Formation is unconformably overlain by Notopuro Formation. Notopuro formation consists of andesitic to basaltic breccias, lavas, volcanic sandstones, and tuff layers. The breccias were deposited by both laharic and pyroclastic mechanism. This volcanic formation at some locations was intruded by igneous rocks of either andesites or basalts. The age of Notopuro formation is Late Pliocene to Pleistocene (Van Bemmelen,

1949). The youngest lithology of the study area is alluvial deposits, consists of unconsolidated sediments of clay, granule, pebble, cobble, to boulder grain sizes. The alluvial have been produced from fluvial sedimentation of some rivers, such as River Panjang, River Garang, and River Santritlung.

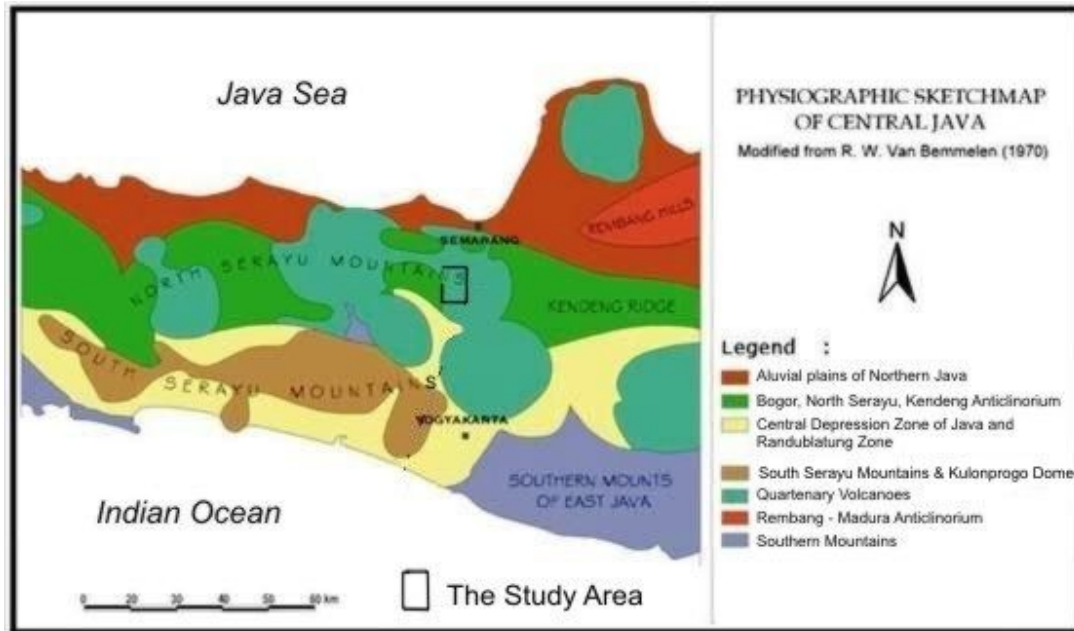


Figure 2. The Physiographic map of Central Java (Van Bemmelen, 1949)

Structural Geology and Hydrogeology

The study area shows a complex geologic structure of folds and faults. Formation of Tertiary period is strongly folded, while litologic unit of Quaternary period is in general dissected by faults. In spite of being controlled by regional tectonic regime of Java island during Tertiary to Quaternary period, the geologic structures in the southeastern slope of Mount Ungaran is also influenced by local gravitational tectonic processes of Pleistocene to Holocene (Van Bemmelen, 1949). The Quaternary gravitational phenomenon created the collapse of Ungaran volcano, and reactivated some faults those already sliced the plastic formations underlain by the massive volcanic deposits of Notopuro Formation (Van Bemmelen, 1949).

Three great faults crosscutting the study area are the Ungaran reverse fault, Jimbaran normal fault, and Getas left strike slip fault. Beside the three faults, there are normal faults as the impact of gravity force with relatively north – south strikes. On the other hand the reverse fault is west – east strikes, and the left strike slip faults is northeast – southwest orientation. Fault type determination was done by using field data and joints analysis, referring to Rickard classification (Billing, 1979). Field data used to determine the classification of the faults are written in the Table 1, while the geologic condition of the study area can be seen in the Figure 3.

Table 1. Field supporting data to fault classification of the study area

Fault Name	Classification	Field Supporting Data
Getas Fault	Left strike slip fault	- Scarps along the Santritlung river - Fault breccias at river Santritlung, Begajah, and river Klampok - Lithologic offset, and shear & gash fractures
Jimbaran Fault	Normal fault	- Fault plane with slicken sides - Fault breccias, shear and gash fractures - Lithologic offset
Ungaran Fault	Reverse fault	- Fault plane with slicken sides - Scarps, water fall, and fault springs - Brecciated zones, - Lithologic offset, - Minor faults, and drag folds

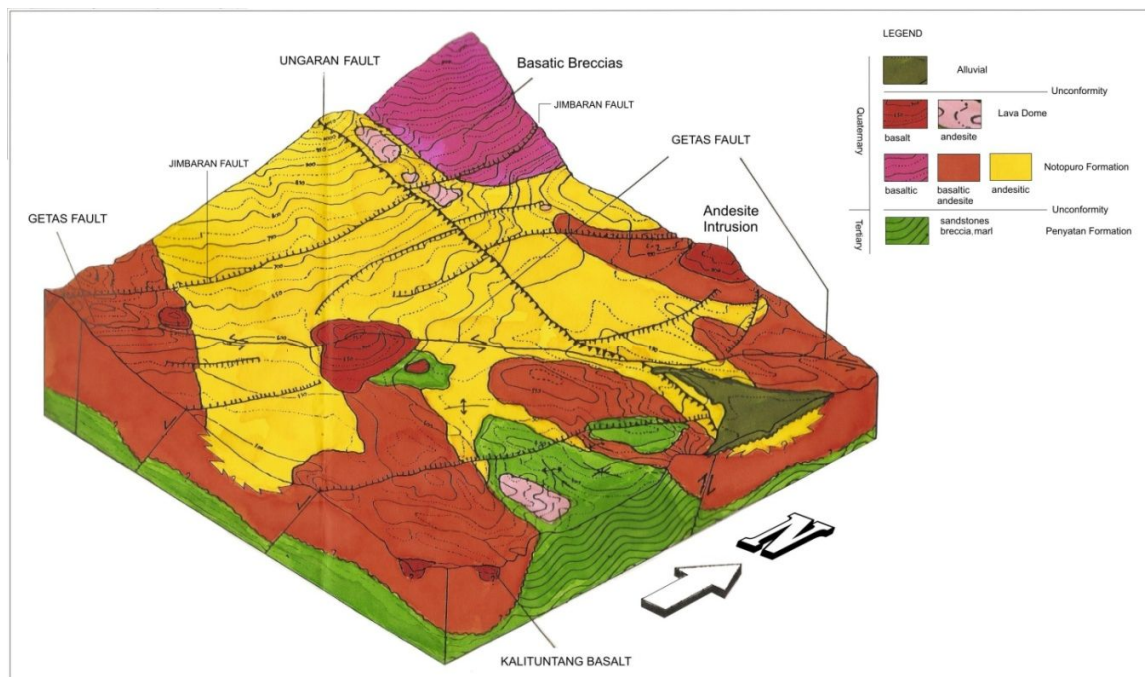


Figure 3. Geologic block diagram of the southeastern slope of Mount Ungaran (Markam, 1998 revised by Kusumayudha et.al, 2011)

There are some normal ring faults surrounding the cone of the volcano (Figure 4.). By the control of these faults, the summit part of Mount Ungaran was subjected to gravitational subsidence (Van Bemmelen, 1949, Zen, 1969, vide Zen, et.al, 1983). Impact of this collapse, magma extruded out to the surface forming some lava domes around the summit of the volcano (Figure 5a.). Despite of the existence of ring faults, there are radial

faults which play as the vent of side or flank eruptions. Up to now, fumaroles, sulfuric hot steam and geyser extrude from the flank vent as geothermal energy potency (Figure 5b.).

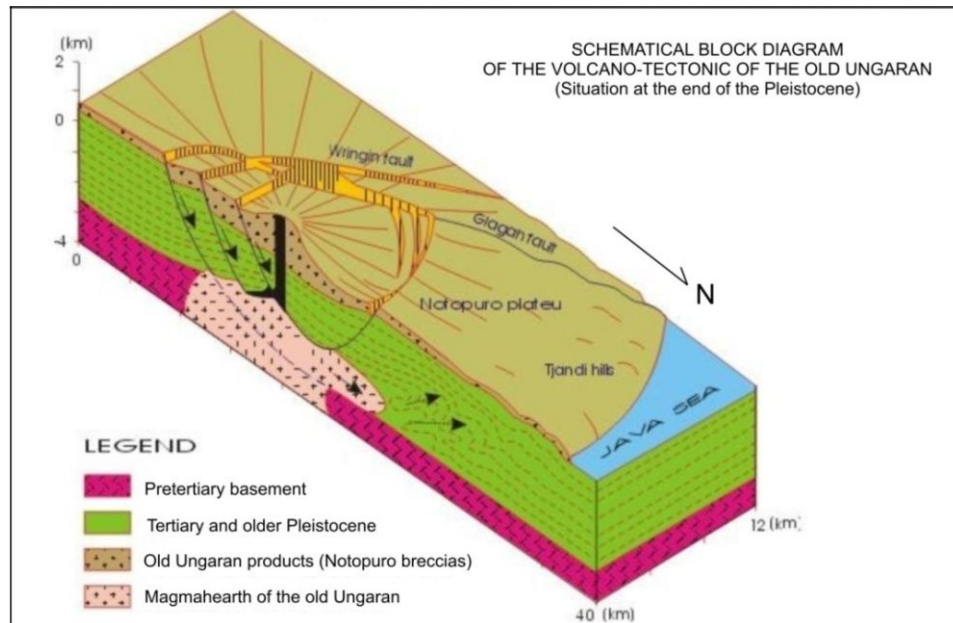


Figure 4. Schematic block diagram of Ungaran volcano–tectonic (Van Bemmelen, 1949)



Figure 5. a. Lava dome, b. Fomarole, at Gedongsongo, southern flank of Mount Ungaran

The hydrogeologic system of Ungaran area is built by aquifers comprises of volcanic deposits especially andesitic breccias, lava, and sandstone, predominantly forming fissure type of water bearing formation. In this system, Penyatan formation plays as the basement. Based on their stratigraphic position, Ungaran aquifers can be classified into

unconfined and semi confined aquifers. Groundwater dynamics in the Ungaran aquifer is very complex, because it is conducted by crack and intergranular porosity systems combination. Under the hydraulic gradient, groundwater moves in general relatively from west to east direction by complex diffuse and cracked flow type.

Recharge zone occupies almost all parts, while the discharge zone lay on the eastern parts of the study area. There are many springs, and some of them are containing sulfur of moderately high concentration, and relatively high temperature. The existences of some hot and sulfuric springs show that the volcanism of Ungaran in the present time is progressing for post volcanism stage. Figure 6 displays the hydrogeologic conceptual model that is controlling the geothermal system of the southeastern slope of Mount Ungaran.

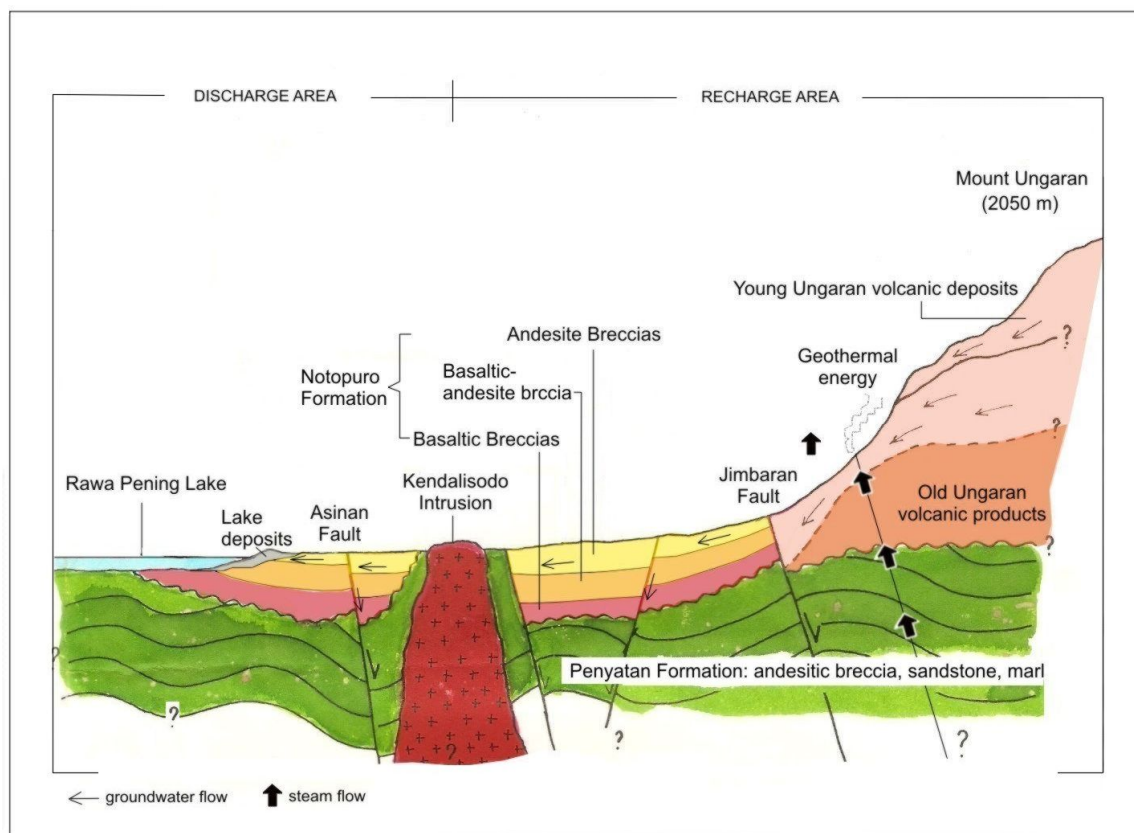


Figure 6. Hydrogeologic conceptual model of Mount Ungaran southeastern slope area (Markam ,1998 revised by Kusumayudha et.al, 2011)

The properties and groundwater chemistry of the aquifers are shown in the Table 2 and Table 3. The data were obtained from field measurements, field sampling, and laboratory testing. Result from hydrochemistry analysis using Aquachem software show that groundwater of Ungaran aquifer belongs to various water types. Based on cation content, it can be classified into calcium dominant water, on the other hand according to

anion content the water includes in bicarbonate water, although some samples indicating chloride water (See Table 3 and Figure 7, the Piper plot of groundwater chemistry).

Table 2. Properties of the Ungaran aquifers

Hydraulic Conductivity (m/sec)	Transmissivity (m ² /sec)	Effective Porosity	Storage Coefficient
$0.9 \cdot 10^{-5}$ to $1.9 \cdot 10^{-5}$	$1.3 \cdot 10^{-4}$ to $3.3 \cdot 10^{-2}$	10% – 25%,	$1 \cdot 10^{-3}$ to $1.7 \cdot 10^{-1}$

Table 3. Groundwater chemistry of the Ungaran aquifers

Sample ID	Location (Village)	Hydrochemistry Concentration (Mg/l)						Water Type
		Ca	Mg	Na	HCO ₃	SO ₄	Cl	
U1a	Jimbaran 1	56.12	14.59	27.59	256.25	19.21	14.18	Ca-Mg-Na-HCO ₃
U1b	Jimbaran 2	56.14	14.58	27.58	256.25	19.20	14.19	Ca-Mg-Na-HCO ₃
U2a	Karangjoho1	24.05	14.60	62.07	189.14	9.61	56.72	Na-Mg-Ca-HCO ₃ -Cl
U2b	Karangjoho 2	26.05	13.38	48.28	192.19	9.61	35.45	Na-Ca-Mg-HCO ₃ -Cl
U3	Pakopen	24.05	19.45	50.57	231.84	19.22	24.81	Na-Mg-Ca-HCO ₃
U4	Kalikembar	36.07	17.02	34.48	247.11	4.80	14.18	Ca-Na-Mg-HCO ₃
U5	Sruwen	76.15	13.37	29.89	317.26	19.20	10.64	Ca-Na-HCO ₃
U6	Coblong	26.05	13.38	20.69	167.78	9.60	7.09	Ca-Mg-Na-HCO ₃
U7a	Diwak 1	28.06	13.37	29.88	184.26	9.61	17.72	Ca-Na-Mg-Cl
U7b	Diwak 2	36.07	17.02	41.38	222.69	9.60	35.46	Ca-Na-Mg-HCO ₃ -Cl

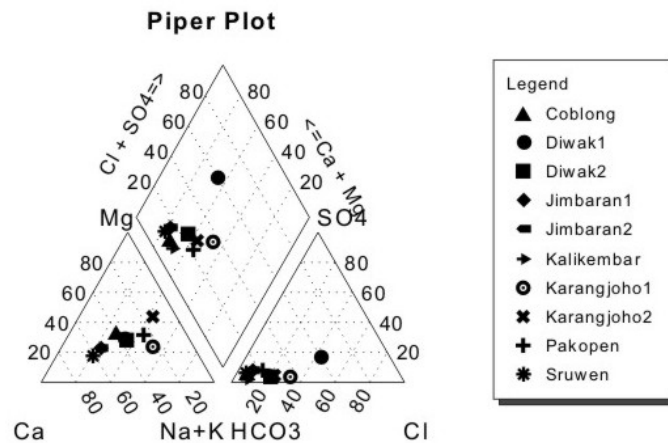


Figure 7. Piper diagram plot of groundwater samples of Ungaran aquifers

Geothermal System of Mount Ungaran

The earth anatomy from the outer to the inner is composed of crust, mantle, and core respectively. It owns and yields natural heat. Increase of the temperature layers with depth toward the earth core is called geothermal. The temperature of the geothermal has been resulted from heat residue of the initial earth material, and decay of radioactive

compounds. The rate of the temperature change in the earth crust per km deep is known as geothermal gradient. Geothermal gradient causes the melting rocks to form such very hot and melted materials in the earth mantle. When hot and melted materials of the earth mantle rise to intrude the crust, it is called magma. If the magma extrude the surface, it becomes change its name to lava.

When water from the earth surface infiltrate subsurface penetrating soil layers reaching the saturated zones, it will forms groundwater. Due to high permeability of the rock formation and particular favorable condition, the groundwater will gravitate down to enter deeper formations, contact to such a high temperature rock body. The water then will be heated, changing its phase to be steam. When the surrounding rock formations are fissured intensively by joints and cracks, the condition will be able to function as a regulation for the steam out flowing from its traps. The steam mixed with such volcanic gases is potentially flushed up and out of the land surface, known as fumaroles that can be geothermal energy resource. The model of geothermal system is shown in the Figure 8 bellow.

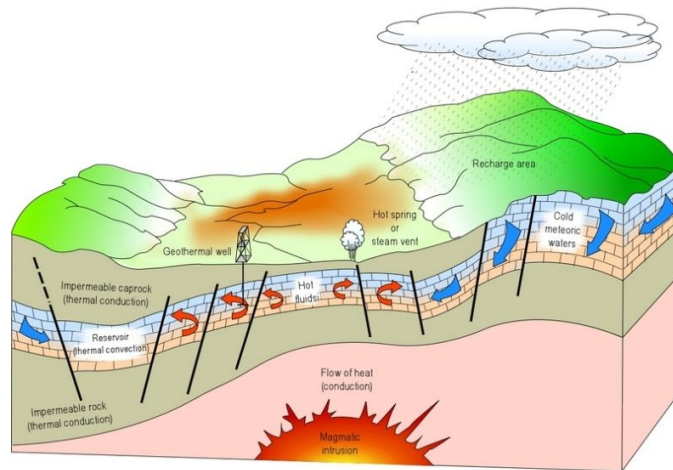


Figure 8. Geothermal system model (<http://www.indotoplist.com/info>)

On the south flank of Mount Ungaran, i.e. Gedongsongo area, there is fumarole through fissures, composed of water vapor and such gases as CO_2 , H_2S , H_2 , and CH_4 (Wahyudi, 2006), with temperature of about 85°C . Water samples taken from Gedongsongo in general show very low $\text{pH} < 4.0$. This high acidity of the water is caused by geochemical reaction of water with some gasses such as CO_2 , and Sulfur. Source of the erupted steam is groundwater in the hydrogeologic system of Ungaran volcano and surrounding area, including the southeastern slope parts of the volcano which strongly controlled by cracks, fissures, and faults.

Due to the influence of geologic condition as has been discussed earlier, there are weak zones performed from the existence of reverse Ungaran Fault, strike slip Getas Fault, Jimbaran Fault, and other normal faults with all of their secondary order structures of joints and fractures. The weak zones cause the aquifer more permeable. The existence of such a caprock makes the steam accumulated, causing its volume and pressure increase. Lithology that able to function as a caprock is clay or marl. As it was mentioned above, there are marl layers in Penyatan formation. When there is crack system able to be

the regulator, the steam will be sprayed out, known as fumaroles. The geothermal potency of Mount Ungaran is assumed to be sustainable, because it is supported by the relatively high precipitation in the surrounding area, i.e. 2,247 mm/year average (www.esdm.go.id).

Conclusion

Based on the analysis and assessment written above, the conclusions are as the following:

1. Geology of the study area is composed of Tertiary Penyatan Formation, unconformably overlain by Pliopleistocene Notopuro Formation. Penyatan Formation comprises of sandstone, breccias, and marl, Notopuro formation consists of andesitic to basaltic breccias, lavas, volcanic sandstones, and tuffs. The formations are intruded by andesites and basalts.
2. Geologic structures in the study area are folds and faults. The folds exist in Penyatan Formation, while the faults cut up Notopuro Formation. The three main faults are Ungaran reverse fault, Getas left strike slip fault, and Jimbaran normal fault.
3. The hydrogeologic system of the Ungaran southeastern slope is built of complex fissures aquifer system composed of volcanic rocks of Mount Ungaran. Types of groundwater are variation of Ca-Mg-Na-HCO₃, Na-Ca-Mg-HCO₃-Cl, Ca-Na-HCO₃, and Ca-Na-Mg-Cl. The structural hydrogeologic system let groundwater of the surrounding area to contact with magmatic and plutonic bodies of the volcanic environments to perform geothermal system.
4. The geothermal system of Mount Ungaran southeastern slope is expressed as flank and fissure fumaroles eruption. The fumaroles consist of water vapor, CO₂, H₂S, H₂, and CH₄ with 85°C temperature.

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