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Management skills for professionals - are they required? A case study on the needs of engineering

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Management Skills for Professionals - Are They Required?

A Case Study on the Needs of Engineering Undergraduate Students.

A thesis submitted in partial fulfilment of the requirements for the award of the degree

Doctor of Business Administration

from

University of Wollongong

by

Peter W Childs MBA, MSc

Sydney Business School

2012
Thesis Certification

I, Peter W. Childs, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctor of Business Administration, in the Sydney Business School, University of Wollongong, is wholly my own work unless referenced or acknowledged.

This document has not been submitted for a qualification at any other academic institution.

Peter W. Childs

30/9/2012
Abstract

For more than thirty years the world’s economies have become increasingly oriented towards a more diverse set of objectives, including a focus on sustainability, stakeholder management and the effective motivation of staff for competitive advantage.

The need for engineers to be educated in business and management skills has been addressed to some extent, by the development of the Master of Business Administration (MBA), Master of Engineering Management (MEM) and similar courses. These have been offered as supplementary qualifications to engineers holding undergraduate degrees. However, the need to develop undergraduate engineering courses that integrate such aspects as business strategy, entrepreneurship, leadership, team work and economic/financial applications, has not kept pace with current industry requirements.

A study of the relevant literature over the past three decades has highlighted two major gaps. Firstly, little is known about the management skills required of newly graduated engineers who may be considered for early promotion to a line or staff management role and secondly, there is no general agreement on what management skills are required.

This research has confirmed by surveying a wide cross-section of employers of engineers that there is a definite need for graduate engineers to possess specific management skills. Those most in demand are Communication and Human Resource Management. Other attributes highlighted in the survey responses were Entrepreneurship, Ethics, Sustainability and Leadership. Also, this survey uncovered that the management skills being taught at present by the various institutions are not adequately equipping engineers to undertake their duties in many engineering enterprises. They may possess some of the defined skills through work experience and further studies.

Whilst the relative importance of each skill surveyed may differ, the list of skills considered (plus Finance) forms an excellent platform from which to review current engineering curricula. Management skills are classified for the purpose of this research as Decision Making, Human Skills, Communication, Interpersonal, Conceptual, Diagnostic, Flexible, Administration, Entrepreneurship, Leadership and Sustainability. The respondents indicated strongly that the
need for management skills of graduate engineers are required now and will only increase even more so in the future.

Responses to the survey indicated attempts to provide the required management skills by compulsory “Engineering Management” subjects have been ineffective. There is evidence students gain little from this approach because they are not integrated into technical engineering subjects. Without direct professional engineering experience they fail to see its relevance.

The majority of responses to the questionnaire were from the Manufacturing and Consulting sectors. After statistical analysis of these sectors it was confirmed employers’ perceptions of the desired management skills were similar through all sized organisations.

In order to complete the views of all stakeholders Engineers Australia, Deans of Engineering and the Australian Council of Engineering Deans were also consulted.

Recommendations are provided on how management skills should be integrated into an undergraduate engineering course and by whom those skills should be taught. Opportunities for further research are identified.

The survey also shows that teaching these additional management subjects has so far been ineffective. There is evidence to suggest students gained little from the current approach as they find it difficult to identify with the relevance and context of management.

Key Words

Engineering Management, Communication, Human Resources, Ethics, Entrepreneurship, Leadership, Sustainability
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PMS  Professional Management Skills
SAE  Society of Automotive Engineers
**Publication and Conference Presentations**


Childs, Peter, Gibson, Peter. (2005) International Graduate Engineering Education - The ethical challenges for Universities, 9th Baltic Region Seminar in Engineering Education Gdynia, Poland


Childs, Peter, Gibson, Peter, (2009), Management Education for Engineers, Proceedings of the 20th Annual Conference for the Australasian Association for Engineering Education, December, Adelaide Australia


The “hits” for the above last three papers now stands at 308 with 31 downloads in June (including 13 full text downloads). This indicates a strong interest in this subject by the wider academic community (Author Dashboard (2011))

**Comments about the Author**

The author graduated in 1966 with a BSc in Metallurgy, in 1976 with a Master of Science (Ceramic Engineering by Research) and in 1991 with an MBA. He commenced his industrial career with junior management positions moved to Technical Manager of the Australian arm of both American and English refractory companies and later to General Manager of a specialised refractory plant.
He was involved in all facets of management and technical activities including product development, manufacture, marketing, problem solving, installation and quality management.

During the four decades spent in heavy industry he worked with many engineers in management roles and anecdotally all expressed the opinion that engineers should have had more management training in their undergraduate years. This mirrors the views of the author.

The final decade of his career was as a lecturer in the Supply Chain Management stream of the Sydney Business School, University of Wollongong, where he taught many graduate engineers who had chosen to undertake a specialist engineering management degree to cover the deficiencies of their undergraduate training.
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CHAPTER 1  INTRODUCTION

1.1  Engineers and the Economy

Because engineers are at the core of a large part of a country’s economy, professional engineers, regardless of their speciality, need a basic understanding of business skills. All enterprises that employ engineers do so in the belief those employed as engineers will need to have some understanding of management skills, such as financial, human resources and administration. This includes clear logical, verbal and written skills. This applies to all engineering activities from the multi-nationals down to sole researcher.

During his career the author spent approximately 8 years as an academic during which time he helped develop and teach engineering management subjects in the Engineering Faculty, UOW. In addition he had an industrial career spanning four decades in the manufacturing, product development and installation spheres, in various parts of Australia and internationally. Observations made during this career have reinforced his view that professionals need to be exposed to management techniques early in their careers or training. Graduate engineers do not always commence their graduate careers in engineering per se but often start in peripheral areas such as marketing of technical products or are promoted to non-engineering or managerial positions reasonably quickly after graduation (within one to five years). In recent times, undergraduate engineers have had “management skills” added to their curricula, but these skills are generally viewed as an adjunct to the current curricula and are not fully integrated into the engineering knowledge base. In addition, these skills are generally taught by engineering academics whose primary interest is engineering.

In the heavy industrial area of Port Kembla, near Wollongong, Australia this is evident in the large number of engineers, of all disciplines, that hold management positions ranging from senior management levels through to first line supervisors. A large number of these have graduated from the various courses offered by the University of Wollongong (UOW) and other tertiary institutions.

Anecdotally, the comment that most of these engineers and employers make concerns the need for basic management skills, primarily communication (both verbal and written) and costing (financial).
Traditionally, from the beginning of the industrial revolution, these management skills, latent or otherwise were developed in engineers by mentors, work experience and by “on the job training”. This was in general considered adequate for those particular times. The discipline of engineering management was boosted by the development of a formal management qualification, the Master of Business Administration (MBA) by Harvard Business School) in 1908. This Masters Degree was considered the correct career path for engineers into management. With the explosion in industrial and engineering technology following World War II (WWII) it was recognised that engineering training needed to change and engineers required management training at some stage of their education or career. This need was filled over the three decades from about 1950, by a rapid expansion in the area of post graduate management education for engineers and the development of engineering management specialist degrees.

Kocaoglu (1980, 1984, 1994, 2009) surveyed the development of engineering management courses from 1980 through to 2009. This survey was carried out within the USA as well as internationally. His survey showed steady growth in these courses albeit that they were primarily post graduate courses. His summary in his 2009 paper was

“Those who manage technology will be the winners in the coming generations, those who are managed by technology will be left in the footnotes of history. The challenge awaiting us is to make sure that our societies will be among the winners”

The Masters Degree route continued to progress into the 21st century with a vast number of tertiary institutions introducing specialist Masters Degrees in Engineering through an association between the Engineering Faculty and their Business School. The University of Wollongong’s Engineering Faculty, for example offers the following Masters Degree courses.

- Master of Engineering (Asset Management)
- Master of Engineering Management
- Master of Professional Engineering
- Master of Engineering Practice

These degrees typically entail 5 subjects taught by the Engineering Faculty and 3 by another faculty, usually the Sydney Business School or the Faculty of Commerce. Some of the Engineering subjects do contain elements of management theory.
The rapid growth in communication and technology over the last two decades of this century has highlighted the need for professionals, not only engineers, to develop management skills.

However the above courses are postgraduate degrees. Graduate Engineers or even those on cadetships or trainee positions and who study part time are usually promoted to junior management positions early in their career without the benefit of formal management training. Because of these reasons this thesis hypothesises there is an urgent need for graduate engineers to be competent in a number of management areas during their undergraduate study. These include communication (written and verbal), human resources management, and an understanding of the financial ramifications of their activities and the broader organisational picture.

This makes for a compelling case for management to become part of the undergraduate courses and not an adjunct. There is a need to enthuse undergraduate engineers with this new balanced approach to their career future and not consider themselves solely technical experts in the workplace.

1.2 Development of Management Training

There is a long history of teaching management skills to graduate engineers since the Harvard Business School developed the Master of Business Administration. In addition, this shortfall in management training has been largely covered by “in house short courses”. Tertiary institutions also developed a variety of sandwich courses, as well as additional Master Degree courses to cover this gap.

However, the huge changes that have occurred in technology and communications, particularly following World War II have meant that the training of professionally qualified graduates (in particular engineering professionals) has needed to change.

This Post Graduate approach has escalated with the establishment of a large number of Post Graduate degree courses for engineering throughout the world. In 1983 Flowers pleaded for a greater involvement in management training for engineers (Flowers, 1983). His comments were primarily aimed at the development of management skills in undergraduate engineers.
Since World War II a wide range of tertiary institutions have developed a range of specialist Master Degrees to address this shortfall. The University of Wollongong (UOW), for example, has the following degrees available as outlined above. The MBA has continued to be a valued access to management training for a wide range of professionals.

From the 20th Century onwards the rapid and ever increasing development of electronic communication has seen the development of the “global village”. This change of pace has affected industry as a whole and in particular engineering.

The 21st Century has brought even greater changes in technology and communications, especially in industry, where even recently graduated engineers may be called upon to take an active part in the management of their particular firm, e.g. as a team leader of a group of professional and non-professional workers. This calls for not only excellence in engineering skills, but also skills in the management of others, communication skills both written and verbal and knowledge of cost analysis.

It is generally agreed that about 50% to 60% of graduate engineers will become managers to some degree during their career. About half of these engineers will assume management roles within 3 - 5 years of graduating.

Even engineers who chose a research career will need finance, writing and presentation skills to be able to develop research proposals that will be clear, coherent and correctly costed for presentation to the various bodies that allocate research funding.

This thesis looks at the problem of engineering management skills, in particular those that will be needed by recently graduated engineers.

Many researchers have commented on the need for engineers to attain management skills, either at university, during their initial degree course, or later by undertaking a Masters degree (either a specialist degree or an MBA).

Research has identified that engineering management is considered an integral part of the skills and attributes that a graduate engineer should possess. This comment is backed by a large body of scholarly literature including the works of - Aldridge (1990), Brisk (1997), McCahon and Lavelle (1998), Carmichael and Gibson (2001), Nambisan and Wilemon (2003), Wilkinson and Schofield (2002), and others.
The two disciplines, engineering and management generally have pursued independent paths. Whilst each has need of the other there is still a certain amount of reluctance by engineering academics to fully commit to the importance of management skills for engineering graduates. Midwinter (2000), who espoused the traditional view, raised concerns over the value of management teachings. He commented that engineering is a rigorous and scientific education where the scientific method is paramount and all research is subject to rigorous review. He believes that management is not a fully developed discipline and with a large proportion of knowledge based on anecdotes, opinions and case studies “is totally devoid of rigour”.

Management, according to Midwinter, is a “new” study discipline and the established body of knowledge is generally limited and unproven. Also he highlights the fact that there is no level of knowledge or qualifications that allow a practitioner to claim status as a professional manager. This can be sharply contrasted with the stringent requirements of an engineer’s professional body for admission to the various grades of “engineer”.

There is a need to develop the ability of engineers to see the importance of and to accept the “softer” aspects of management. A subject such as “Operations Management”, which allies both a scientific aspect as well as a management aspect, could provide a bridge between some of the softer issues of management and the more scientific style with which engineers regularly identify. In addition the field of Operations Management allows practitioners to become fully professionally certified (http://www.apics.org/careers-education-professional development courses/preparation), (2013). Currently the University of Wollongong’s Faculty of Engineering is incorporating an Operations Management subject into its undergraduate engineering curriculum.

There has also been considerable discussion as to whether the teachers of engineering management should be management specialists. They may have dual roles as employed engineer/teachers or full time engineering teachers who have work experience in management. The qualifications required to teach these various skills will need to be determined.

The above comments reinforce the realisation that engineers need to have a greater understanding of management principles and be able to incorporate them into their work responsibilities as more and more engineers take on management roles. Much has been written over the last three decades concerning engineering business (or management) education and whether it is required as an integral part of an engineer’s formal education.
1.3 Engineering Management Definitions

There are several definitions for the term Engineering Management; the two listed below are the most succinct and applicable to the work.

a. The All Engineering Schools (USA) (2012) defines engineering management as follows,

“Engineering Management is a career that brings together the technological problem-solving savvy of engineering and the organizational, administrative, and planning abilities of management in order to oversee complex enterprises from conception to completion.”

b. The National Centre For Education Statistics (USA) (2012) defines engineering management as follows,

“Engineering/Industrial Management. A program that focuses on the application of engineering principles to the planning and operational management of industrial and manufacturing operations, and prepares individuals to plan and manage such operations. Includes instruction in accounting, engineering economy, financial management, industrial and human resources management, industrial psychology, management information systems, mathematical modelling and optimization, quality control, operations research, safety and health issues, and environmental program management.”

1.4 Problems and Hypotheses

Within this area the fundamental concerns or problems that need to be identified are whether management education is a requirement for an engineer and if so, what attributes are needed.

In general, when the term ‘engineering management’ is used there are two views. These are:

1) This is the skill required to manage engineers, engineering skills and engineering equipment.

2) This is the skill required to manage both engineers and other non-engineering employees in either a commercial or non-commercial environment. The
additional skills that will be needed for engineers to successfully manage in this environment will include human resources, financial, operational, marketing etc..

This thesis supports the second definition and will use the term Professional Management Skills (PMS) to describe the skills believed to be necessary for engineering undergraduates to participate fully in the management of an organisation and to be able to successfully manage disparate groups of both professional and non-professional employees in a timely and efficient manner.

Thus the following potential hypotheses have been identified and will be refined and form the basis of the final research hypotheses and sub-hypotheses listed in Chapter 3.3 (page 94).

1. That the current Australian University engineering professional management education processes and content (at undergraduate level) does not prepare graduate engineers for rapid integration into management roles in commercial and industrial workforce in Australia.

2. That the skills and attributes required (of engineering graduates) by industry and business have not been adequately discussed, identified or documented.

3. That the effect of the lack of these skills on business performance and profitability have not been identified or addressed.

4. That there are strong elements of negative reactions and poor motivation within some groups of undergraduate engineering students to business/management subjects and that they have difficulties in understanding the relevance of engineering management education.

5. That due to lack of research in this area the Australian professional engineering body, Engineers Australia (EA), whilst recognising that management studies are important, does not appear to be fully cognisant of the management skills that industry require and hence is unable to ensure that the required professional management skills are addressed in the various accredited engineering courses within Australia.
6. That there is a lack of knowledge of the skills that employers believe should be taught to undergraduate engineers so that they will be able to undertake junior management roles upon graduation or very shortly thereafter.

1.5 Management Skills

Little has been discovered to date on the needs and perceptions of employers as to the skills and attributes that they perceive as being either essential or desirable for recent postgraduate engineers to possess and the resulting influence this has on business performance. The scant literature covering this aspect and the limited scholarly research on the management attributes and skills required by an engineer generally are mostly discipline based and are covered by a small range of authors such as Peterson and Van Fleet (2004) and Robinson et al. (2005). Some authors have attempted to define these general skills without a particular reference to managerial skills e.g. Plonka et al. (1994), Chisholm & Burns (1999), Holfield and Thomas (1999), Rifkin et al. (1999), Edum-Fotwe and McCaffer, (2000), Gibson and Carmichael (2001), Editorial (2004).

Engineers are also finding they need to take on more complex tasks that include very significant managerial issues (The Royal Academy of Engineering) and (National Academy of Engineering). These roles include strategic focus, financial management and control, quality management, human resources, stakeholder management and industrial relations. In more recent times, due to the nature of their technical knowledge and education, engineers are also finding themselves leading the crucial thrust towards sustainable engineering business.

Muster and Weekes (1983) questioned the failure of the major Western countries to maintain productivity gains when compared to Japan, in particular, and Western Europe. Their analysis of the situation indicated that they believe there has been a systematic failure in the education of engineers initially and then a failure of engineering management education as well, although this has been addressed to some extent recently.

Liyanage (2001), Gibson and Carmichael (2001) and Thilmany (2004) have all reviewed the needs and dimensions of postgraduate engineering courses. They have all highlighted the need for engineers to study and absorb ‘management concepts’. The areas that these authors have highlighted are;
Gibson and Carmichael (2001) commented that:

“Financial restraints and exploding technological complexities are affecting universities’ ability to offer universal solutions that will allow engineers and technologists to fully cover [the] breadth and depth in their undergraduate programs.”

Leading firms are working with universities to develop innovative ways to progress and develop their staff throughout their careers. The divide between working and learning is becoming increasingly blurred. The global dimension adds further challenges that will probably result in strategic alliances and networking capabilities that allow even greater degrees of customisation and just-in-time delivery.

There are enormous challenges for engineering and technology schools in how they develop future profiles of their academic staff.

Wei (2005) has also posed the question ‘what type of engineering management education will be needed in a post-industrial world?’ In reviewing current education he comments:

“…. expert enough to practice engineering, all in 4 years of education. It has always been a point of tension to achieve both breadth and depth in 4 years, and the engineering accreditation process has accepted the notion that between one-eighth and one-quarter of the engineering curriculum should be devoted to humanities and the social sciences.”

Wei continues to review the changes in both the developed and developing world in which the former is moving rapidly to become a service economy and then on to a knowledge economy, whilst the developing countries will still need traditional engineers for some time. However, he believed this time frame is shortening rapidly.
University engineering education has tended to rely on the knowledge of technical experts who have little inclination towards the business and commercial challenges of the 21st Century. These needs can no longer be described as basically scientific and technical in nature, and these needs must be integrated within a knowledge base associated with the Commerce and Business Faculties. Some engineering faculties (e.g. University of Wollongong) have attempted to include managerial skills in their undergraduate engineering curricula. However, these have often been approached as secondary and have involved a ‘bolt-on’ to the technical skills and hence do not fully encompass the integrated range of skills needed. Anecdotal evidence and the author’s experience in teaching these subjects to engineers, has shown that they are not motivated (at least in their early years) to become interested in and committed to the management aspects of their future profession.

All authors reviewed thus far have identified problems with engineering management education. The varied topics taught in management education across the papers reviewed and what constitutes this discipline, require clarification including:

- By which faculty should this discipline be taught?
- The qualifications of the teacher/lecturer who will teach it, and
- At what level will the courses be offered?

Underlying this dilemma are the questions

- How can engineers be trained to satisfy tomorrow’s requirements?
- What skills will these engineers need?
- What attributes will the academics need to teach these skills?
- What various skills will be taught?

As far back as 1997 Brisk (1997) attempted to forecast the type of engineer who may graduate in 2010 and made some interesting comments, particularly regarding the gender split that he believed would occur. He also commented on the differing directions that engineering education would take regarding sustainability and environmental issues. He also commented that engineers must obtain vastly improved communication skills and he highlighted the need for engineers to be capable of working in teams and becoming ‘multi-discipline generalists’. Comments on his predictions on attributes will be discussed in the next chapter.
Holfield and Thomas (1999) made the comment, with regard to the UK scene, that British management and managers have ……

“been castigated for an apparent lack of professionalism. This has been equated with the lack of relevant professional qualifications. By this we mean that people who end up in managing a team, department, or even a division, usually have (in industry, for example) a first degree in Mechanical Engineering, but by implication, know nothing about, say, motivation or the mystique of managing other people.”

Engineers tend to be uncomfortable with management aspects of their profession because engineering is considered a rigorous, scientific discipline whereas management can be considered an unscientific discipline. In addition whilst engineers have a binding set of knowledge that allows them to call themselves engineers there is no similar system to claim the title of manager. This thesis reviews the managerial skills that will be needed by graduate engineers to allow them to perform at a satisfactory level within the current multiskilled work environment. The history of management skill identification is reviewed from the work of Katz (1955) through to the present and a list of the identified managerial skills needed of a manager has been developed and then this list is modified to highlight those skills that the author suggests as being relevant to the training of a fully rounded and competent graduate engineer.

1.6 Methodology

The basis of the research is to ascertain (by questionnaire) what Professional Management Skills (PMS) employers’ desire in their graduate engineers and to assess what skills they have and what activities they are capable of undertaking.

For those who follow the first definition of engineering management as outlined by the author (see page 24) the current engineering curricula should suffice. However for those who expect their engineering employees to become professional managers (at any level and at some stage in their career) the skill set required will be different. It will also be different for different applications as well as for different phases of the economic cycle.

From the data bases available, the Australian Bureau of Statistics web site was searched and the Australian and New Zealand Standard Industrial Classification (ANZSIC) was used. This was chosen as the most suitable data base for a satisfactory source of firms that were likely to employ engineers in engineering plus management roles. A perusal found this to be the case and the industrial sections and sub-sections were satisfactory. This was the method chosen to be the
basis for the Australian Questionnaire. The Segments and sub groups chosen are listed in Appendix 5 (page 280).

The contact details of the potential respondents firms were located on the data base – www.onesource.com (2010).

It is proposed that in this research the work of Katz (1955 etc), Peterson and Van Fleet (2004), and the work of Robinson et al. (2005), be considered as they reviewed management skills from the ‘commerce’ side of an organisation. It can be assumed that currently a graduate engineer will possess the necessary engineering skills taught within the engineering discipline curriculum.

The varied topics taught or recommended for management education across the literature reviewed, and what constitutes this discipline, requires clarification. Where this discipline will be taught, by whom and at what level remain unanswered.

Underlying this dilemma is the question:

What special skills (both technical and managerial) will future engineers need?

No specific research has been identified that has been carried out in conjunction with Australian engineering employers that has identified which particular professional management skills are deemed necessary by the employers of graduate engineers. There appears to be a significant gap in the literature and the research proposal aims to rectify this in part or whole.

This research aims to identify those professional managerial skills that industry and commerce require of graduate engineers. These professional management skills are generally recognised as skills covering areas such as human resources, financial, marketing and conceptual skills.

In the context of this review, PMS (for Engineers) are considered to be those skills as typically taught in a Commerce faculty or a Graduate Business School: that is, the ‘softer skills’ of management.

Due to the geographical dispersion of industries in Australia, it was decided a questionnaire would be the most effective means of gathering data from such a diverse range, both geographical as well as by industry segment, of organisations.
The questionnaire was submitted to a randomly selected group of organisations. These organisations were chosen using both the ABS (ANZSIC (2006)) and onesource web sites, www.onesource.com. The groups and sub groups are as listed in Appendix 5 (page 280). They were categorised into six separate activity groupings, with each group divided into three sub- groups according to size. The range of sizes was as follows:

- Small 1 - 20 employees
- Medium 21 – 99 employees
- Large 100 plus employees

The respondents were chosen at random, using the Excel random number generator. The number of respondents chosen for each group was proportional to the number of firms identified in each group. Each group was then culled to remove firms that were considered to have little chance of employing engineers. The results were subjected to statistical analysis to ensure that the conclusions were statistically valid. For a full analysis of the sampling plan refer to Appendix 6 (page 283).

In addition discussions were carried out with Engineers Australia and with several Deans of Engineering of Australian Universities. The web sites of the USA and UK professional engineering bodies were also reviewed.

### 1.7 Structure of the Thesis

There are six main sections of this thesis. These sections are as follows:

**Chapter 1 -** (present chapter) contains the Introduction. This is followed by an outline of the research to be undertaken, comments on the development of Management Training for engineers, and research methods, together with a discussion on the methodology to be used.

**Chapter 2 - Literature Review** – This Chapter is divided into the following sections:

- 2.1 Introduction - Background
- 2.2 Developments in Post Graduate Engineering Management Courses
- 2.3 Summary of Postgraduate Development
- 2.4 Developments in Undergraduate Engineering Management Courses
- 2.5 Summary
Chapter 3 - Data Collection and Methodology - This methodology section outlines details of the methods to be used to gather data. It also covers the justification of the ethical considerations, and the development of the questionnaires used.

Chapter 4 - Statistical Analysis and Presentation of Data - This consists of an explanation of the data analysis methods chosen and the results of that analysis of the data obtained. The results are evaluated fully in this section and it contains a review of these results and a comparison, where applicable between the various questions. The results were then analysed for statistical significance.

Chapter 5 - Discussion of the Research Results – This chapter covers evaluation of each hypothesis, the evaluation of the research question, and the conclusions drawn for each element.

Chapter 6 - Conclusions and Recommendations - This chapter reviews implications for employers, academia and undergraduate engineers. Finally, there is a list of recommendations for future research.

1.8 Scope and Assumptions of the Thesis

The scope of this thesis is to survey Australian firms which may offer employment to engineers. This population is defined by the following segments of the ANZSIC listing (ABS, 2006).

- Consulting
- Construction
- Manufacturing
- Mining
• Public Utilities
• Transport

In addition each segment is divided into three groups based on the number of employees.

The full details are covered in Appendix 6. (page 283)

The original sample (of 1000) was chosen at random by the use of Excel random number generator. The sample was chosen to include all of the segments defined above. For example, in Mining – Small firms, 26 firms were drawn from the 463 firms listed.

The list was culled to remove those firms, which by their names were considered to be very unlikely to employ graduate engineers. About 20% of the sample was removed in this manner leaving a potential sample of 770.

1.9 Conclusions

From the above it can be seen that there is a need for a re-evaluation of the view that engineers do not need management skills to be able to carry out their engineering duties upon employment. Also there appears to be little or no research carried out into the needs of the employers of engineering graduates and their ability to fully integrate into a firm that is not totally engineering oriented.

This thesis is designed to cover, where possible, this gap in knowledge.
2.1 Introduction - Background

The large number of research and other relevant publications in this literature review is an indication of the high level of interest in the topic of management skills needed by engineers of all disciplines. Engineers need these skills to progress in their professional career as well as equipping them to be vital players in their company’s success.

Opinions, of the skills required, other than engineering excellence, have differed over time e.g. Emerson in the mid 19th century is held to have stated

“If you build a better mouse trap, the world will beat a path to your door”.

He later expanded this view of the self sufficiency of engineering excellence by stating

“If a man has good corn, or wood, or boards, or pigs to sell, or can make better chairs or knives, crucibles, or church organs, than anybody else, you will find a broad, hard-beaten road to his house, though it be in the woods.”

This quotation, cited by Cooper and Kelleher (2001), comes from an Emerson publication “Common Sense” (1855).

These statements reflect the inward looking engineer although it is worth noting that Great Britain has always, from the 19th Century industrial revolution onwards, embraced the marketing and selling of their manufactured goods, brand and place names to the world market.

In 1901, half a century after Emerson’s publication, the Tuck School of Business, associated with Dartmouth College’s, offered formal teaching on the topic. This was closely followed by Harvard University’s response of a Business/Administration Post Graduate qualification. This format of post graduate degrees quickly spread throughout the Western World and remained the ideal course for graduate engineers who were interested in further post graduate study in management.
The years from 1918 to 1983 were noted for major natural and man made disasters. These included two world wars, a world wide economic depression, many minor wars and changes to national boundaries. Changes were also frequent and revolutionary in technology and communications. The industrial world then was very different to the early days of the 20th Century. This literature search is concentrated on the post World War II to the present. It commences with comments by Flowers in 1983.

In his keynote address to the Second World Conference on Continuing Engineering Flowers (cited by Martinec (1984)) maintained that engineers needed to develop management skills through formal education and not rely completely on ‘on the job’ experiences. The time span covered in the literature research from 1983 to the present, covers the period from these watershed comments of Flowers through the electronic developments of the 80’s and 90’s and later to the 21st Century. It covers the period from when this topic, which has always been of interest to educators and employers, has become of paramount importance to the economic development of not only industrialised nations but also those aspiring to join the industrialised global village.

From early days the majority of developments in engineering management education has been in the post graduate area. Therefore the literature survey has been analysed as follows:

a) the development of post graduate courses
b) the development of graduate courses and
c) general comments concerning Professional Engineering management.

Over the period of time 1983 – 2009, as more and more engineers took on management roles it was realised that graduate engineers need to understand management principles and incorporate them into their daily duties. Much has been written over the last three decades concerning engineering business (or management) education in the post graduate area.

2.2 Developments in Post Graduate Engineering Management Courses

The two disciplines, engineering and management, at the tertiary level, have not had a close relationship. Each discipline recognises the need to interact with the other, but there is still a certain amount of reluctance by at least some engineering academics to accept that the
discipline of management is of significance to engineers. This viewpoint is illustrated by Midwinter (2000). This view however, is at odds with other authors who believe that management training for engineers is important such as Flowers (1983), Jenson (1983), Kocaoglu (1980, 1984, 1994, 2009), Wei (2004).

In addition there has also been considerable discussion on whether the best teachers for engineering management are management specialists or engineering teachers with requisite work experience and management qualifications.

2.2.1 Management versus Engineering

Jenson (1983) as cited by Martinec (1984) discussed the organisation of the management education system used at Danish Engineers Postgraduate Institute at the Technical University of Denmark. The teaching staff consisted of approximately 80% practicing (management) professionals from outside the Institute with the balance made up of academic staff. This use of ‘practical’ presenters allowed for the presentation of ‘real time’ and practical knowledge to the students. This group used the Hersey and Blanchard Model (Jenson (1983) for their program development. Martinec (1984) highlighted the need to educate engineers in a range of management skills. The Hersey and Blanchard Model considers that senior management requires mainly conceptual skills, middle management mainly human skills whilst junior management requires mainly technical skills. Naturally, as with most models, there is a reasonable degree of overlap. The technical skills under this model are normally as taught in the engineering curriculum whilst the management skills need to be developed to match the engineer’s educational background. Jenson (1983) believes that this model’s organisation is satisfactory for the education of engineers in the management (soft) skills of communication, motivation, leadership and the other behavioural skills needed to survive and prosper in the business environment.

2.2.2 Adjunct Courses

The emphasis during this period appears to be mainly focused on adjunct postgraduate courses. Metzger et al. (1982) conducted a survey of management education in French higher education in which they identified the possible nomenclature to be given to this type of education. The terms used included engineering management, engineering economics, industrial management and industrial engineering. Based on a survey
carried out in 1977, 36% of engineering graduates in France also held a higher degree in fields other than engineering. These included economics, management and law. This percentage held regardless of the age group of the engineers surveyed. However 70% of those surveyed indicated they possessed some training in management related areas.

The survey studied three basic points

1. The overall importance of an engineering management curriculum in French engineering schools.

   The results indicate that engineering management existed in nearly all institutions reviewed. The time spent on these courses varied from zero to 486 hours per annum (about 5 to 10% of the curricula). Also 29% of the institutions surveyed offered continuing education in management.

2. The content of these courses.

   The major subjects offered were accounting and management accounting together with allied costing and marketing courses.

3. The nature of the faculty concerned with these courses.

   The management training was carried out by either full or part-time lecturers drawn from a range of self-employed professionals. Their conclusion was that engineering management training as carried out in France was lacking in many areas and was not fully integrated into the existing engineering training programs.

   (Summarised from Metzger et al. 1982)

2.2.3 Engineering Management

Kocaoglu (1984) reviewed the emerging discipline of Engineering Management. His comments suggested a very rapid expansion in this field over the previous few decades. Kocaoglu suggested the reasons for this were:
“(1) At the national level, challenges to technological leadership, resulting from scarcity of raw materials, declining productivity and increased international competition, have shifted priorities towards the development of new technologies and the management of technological systems.

(2) At the industry level, the assumption that a ‘manager is a manager is a manager’ has met with strong challenges in the technical environment. The critical importance of engineering skill and knowledge is well recognised in the management of engineering systems.

(3) At the individual level, engineers who move to management positions, as a result of their technical success, have become increasingly aware that their technical skills, no matter how good, are less than adequate in dealing with the complexities of the management responsibilities thrust upon them.”

(Kocaoglu, 1984)

Both engineering and management are based on the concept of rational decision making. The decisions that need to be made and the problems faced are significantly different for each discipline. In engineering the decisions are generally well defined engineering situations whilst management (excluding Operations Management) decisions tend to be poorly defined, more general and more complex with a range of possible solutions.

As a starting point for the survey Kocaoglu (1984) developed a concept of what engineering management is, as generally it has not been quantified. The elements of an engineering management program (EMP) are as shown in Figure 2.1 below.

In this model Kocaoglu looks at the management of five areas of which Management of Technical Organisations and Management of Critical Resources would encompass those areas that are examined in this thesis.

In Kocaoglu’s survey 100 institutions which taught Engineering Management were identified, of these 86 were in the United States and 14 in other countries. This indicated a 40% growth in this field of education over the previous four years when compared to a previous study by the same author (Kocaoglu 1980) when the number of programs was 71.
This growth was primarily at the graduate level. Undergraduate programs appeared to have remained static since the 1970’s. The growth of postgraduate programs had been rapid with a fourfold increase since the 1970’s. Due to the large number of postgraduate programs available, the major discussion in this thesis is limited to undergraduate programs to identify what further developments are required.

Figure 2.1 Scope of Engineering Management

(Kocaoglu, 1984)

The post graduate programs on offer varied from Engineering Management, Engineering Administration through to Engineering Operations. Generally, these programs were located within the Faculty of Engineering. Some institutions have developed separate schools whilst others have enlarged their Industrial Engineering schools. Where other faculties provide input the program still remained under the control of the Engineering Faculty.

In the United States, of the units surveyed, 33% were considered small (less than 60 students), 18% medium (60 – 100 students) and 49% large (more than 100 students).
For other countries the figures are small 16% and large 84%, there being no students in medium sized facilities.

There were 77% of the students in the United States who, in general, were employed engineers and scientists. However, outside the United States the emphasis was on full-time students with 77% of students enrolled in full-time study.

In terms of duration, the full-time programs were of 9 to 24 months duration whilst the part-time programs typically took twice as long.

Because of the nature of these programs it was necessary to develop a strong link between the academic institution offering the program and the relevant industry in which the student would be employed. Kocaoglu (1984) suggests that this could be achieved in the following ways:

- Part-time instructors from local industry.
- Students’ involvement in relevant topics from industry.
- Industry Advisory Councils
- Some programs make arrangements with major corporations to provide projects
- Seminar speakers
- Guest lecturers

Engineers have been offered the MBA as an alternative for engineering management studies but in general they have reported that it lacks the skills they require. If the engineer is seeking a career in full time management then perhaps an MBA would be useful. However if an engineer is seeking a management role in a technology based organisation, often akin to their engineering background area, then an engineering management program holds a greater appeal (summarised from Kocaoglu (1984)).

Kocaoglu’s surveys appear to have a degree of commonality. He lists elements of Engineering Management Programs (EMP) as follows:

“- designed for engineers in transition to technical management positions

- offered with a flexible time schedule to accommodate part-time students,
- structured to provide the students with a blend of knowledge, skills and attitudes in the behavioural, mathematical, financial and project-based areas,

- addressed to the needs of middle to high level managers in technical organisations, and

- oriented towards having a “problem-solving, instead of ‘theorem-solving’ emphasis.”

Kocaoglu (1984) goes on to summarise the state of the EMPs in the middle of the 1980s and has found that EMPs were in evidence during this period. In general they addressed the needs of the engineers of the day, although the numbers of institutions and students were low by current standards. Also the emphasis (at least in the USA) was on part-time students and the further education of engineers and scientists already in employment. The emphasis outside the USA was on full-time study of engineering students who were not employed at the time of their study. However, these students did have some experience (4.3 years on average as compared to 7.3 years for the USA). From this it would appear that only students with a certain amount of experience were allowed to enrol. From the academic background of the students all were graduates. Some 84% of both groups held a bachelors degree. Overall, the need for undergraduates to be involved in management studies had been overlooked.

Aldridge (1990) comments on the subject of technology management in the following manner:

“- its fundamental importance to the technical community is not well established”

Although it was clear that from this he believed there was an increasing need for managers to take technology and change into account, he confessed that it was not clear how this could be addressed.
2.2.4 Business Schools

Business Schools moved toward addressing this problem by developing a variety of courses, generally at the post-graduate level, to meet the changing needs of technology and the rapid changes that had occurred in business organisations. However, engineering institutions had done little to respond to this changing need. They had offered limited elective courses and optional subjects within departments (e.g., Industrial Engineering), but appeared to have not grasped the concept that this topic is fundamental to undergraduate engineering courses.

Aldridge stressed the importance of definitions and quoted several sources. The definition of Engineering Management from The National Research Council (1987) as cited by Aldridge is as follows:

“Management of technology links engineering, science and management discipline to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organisation.”

He also quoted Betz (1987) as follows:

“Managing technology means to use new technology to create competitive advantages”

2.2.5 Technology – Definitions

When these definitions are examined the word ‘technology’ is not clearly defined. In order to review engineering (or technology) management there needs to be a definition of what is meant by this term. Aldridge cited the two definitions below.

Bhalla (1987)

“Technology… is products, process, tools and services…”

Smith (1986) defined it as:
“Technology is the application of knowledge, scientifically derived or otherwise, to the creation or modification of things and processes.”

However Aldridge (1990) suggested the following definition for technology:

“Technology depends on (cannot exist without) knowledge of how to apply other knowledge to create or modify useful things or processes where knowledge has been derived scientifically or otherwise.”

Using this definition Aldridge claimed that it is now possible to quantify the role of engineers in the field of engineering management. Engineering knowledge is, in general, scientifically derived. Knowledge gained otherwise can be categorised as management knowledge which is in essence non-technical. Thus it can be seen that business has a non-technical dimension that is needed to deliver goods and services to the private sector. This dimension can include such activities as are normally taught as an integral part of a Bachelor of Commerce degree or a Postgraduate Engineering Management degree. This type of knowledge will be more experience based than the scientifically rigorous engineering subjects.

Aldridge also recommended a review of decision making to allow the linking of the two disciplines (engineering and management) in a way to provide a basis for a different way of professional development.

In his keynote address to the 6th Australian Association of Engineering Education, Director (1996) reviewed both the national and the international aspects of engineering education. He commented on the world-wide pressure to review and change engineering education. This has come about for a variety of reasons, some of which have been discussed above, but the major factor that has been emphasised is the need to teach innovation to both undergraduate and post-graduate students.

2.2.6 Employees View of Graduate Qualifications – Carnegie Mellon University

A review of companies employing graduates of Carnegie Mellon University has indicated that the following attributes are considered the most important:
“Effective communication skills top everybody’s list. Next is to be broad, both technically and socially, since we are dealing with inter-national or global concerns”.

Director stressed that students need to have the ability to work in teams. The projects that engineers are expected to solve these days are very large. It is no longer the case that an engineer working by himself or herself at a desk can address these problems.

Students must have social responsibility, must understand the social implications of the things they are designing, not just for the environment but for other cultures as well.

“We are finding more and more that our companies would like our students to have some industrial experience. This means not just exposure to technical and manufacturing practice, but exposure to some business principles as well.”

(Director, (1996))

The approach of Carnegie Mellon is to consider an extended degree where the student completes a bachelor and master’s degree before they are professionally recognised. The aim of this course is to allow most of the material needed to be taught in a rational manner. The courses that they now have in place consist of a mix of engineering and the social sciences. Approximately 25% of the degree is allocated to the social sciences area and another 25% can be in specialisation electives or other areas within the university’s faculties. This point is further considered by Wei (2005).

The philosophy of this approach can be summarised as follows:

“What we are trying to teach is engineering, not necessarily engineers.”

Merkel (1995) also looked at the linking of engineering practice, graduate education and professional development. He recommended that engineers seeking additional knowledge could opt for a range of higher degrees – those based on their existing specialisation or, for those seeking to enter the ranks of managers, the MBA. This was to be a reformist degree and be taught using non-traditional methods and non-traditional subjects. This was a radical idea and suffered severe criticism from within and outside Harvard. The curriculum was to be based on
“the development of practical, directly applicable knowledge in banking, finance, commercial law, transportation and industrial organisation.”

(Merkel, (1995))

This degree was linked closely with the field of industrial engineering and with such practitioners as Frederick W. Taylor who was associated with, and lectured at, the school.

2.2.7 MBA and the Engineering Profession

The engineering profession has been deeply involved with this degree and helped pioneer the idea of an engineering first degree coupled with an MBA as a second degree. This aims to produce a well prepared engineer, who can face the rigours of both the technical side and the managerial aspects of engineering management.

The engineer of the 1990s however wanted a graduate program that was more specialised and focused on such areas as project team leadership, project management and similar fields whilst not ignoring the costing and financial aspects of these fields.

2.2.8 A Masters Degree in Engineering Management

This has led to the development of a Master’s Degree in engineering management, which in essence, allows engineers to develop management skills as applied to their normal field of expertise. The program on offer varies according to the institution and it addresses the requirements of a particular group of students and the particular core competencies of the institution.

Merkel (1995) also indicated that amongst the engineers interviewed in his survey their preference was for part-time study as it best fitted their full-time employment as professional engineers. It is evident that there is no clearly agreed upon path for engineers to require management skills.

Kocaoglu (1994) in his 5th review of the development of engineering management degree courses commented that these generally post-graduate degree courses continue to grow strongly and the growth has been from a few 40 years before to over 200 such courses in 1993.
Chelst (1998) reviewed an industry based EM Masters Program (between the Wayne State University and the Ford Motor Company) and the needs of the “working engineer”. In this review he asked the following questions,

“How can an educational experience be designed to “build the bridge” between technology and Management?”

“How do we adapt our curricula to focus on customer-driven needs (as opposed to academic characterizations) of the technical manager?”

“How can universities and employers work together to create enhanced experiential learning for the technical manager?”

Sun et al. (1999) reviewed the development of Engineering Management courses and concluded that these courses, at a Masters Degree level had grown throughout the decade, mainly at the demand of industry, and would continue as an integral part of the development of an engineering career. They also commented that admission to these courses required that the student had a degree in engineering or a similar technical area and preferably, several years of working experience.

Liyanage (2001), Gibson and Carmichael (2001) and Thilmany (2004) have all reviewed the needs and dimensions of postgraduate engineering courses. All have highlighted the need for engineers to study and absorb ‘management concepts’. The areas highlighted were - Liberal Arts, Business and Law, Social Sciences and Technology and Engineering and Physical sciences.

Gibson and Carmichael (2001) presented these principles of management concepts as a layered model (based on Midwinter’s (2000) work). Whilst it was originally designed for Electrical Engineering, Gibson and Carmichael (2001) have incorporated the above attributes with the purpose of applying the model to engineering in general. Figure 2.2, shown below, illustrates this layered model which encapsulates how they considered the above principles could be applied.
Figure 2.2 Adapted Layered Model showing unique range of disciplines in engineering and technology. (Adapted from Midwinter (2000) by Gibson and Carmichael, 2001)

The figure looks at the various aspects of engineering with management skills becoming of greater importance as the engineer moves from the technological aspects (Physical Sciences, Technology and Engineering activities) towards the more social science aspect (Social Sciences, Business and Law and Liberal Arts).

Gibson & Carmichael (2001) continue,

“Financial restraints and exploding technological complexities are affecting universities’ ability to offer universal solutions that will allow engineers and technologists to fully cover [the] breadth and depth in their undergraduate programs...”

Leading companies are working with universities to develop innovative ways to progress and develop their staff throughout their careers. The divide between working and learning is becoming increasingly blurred. The global village concept adds further challenges that will probably result in strategic alliances and networking capabilities that allow even greater degrees of customisation and just-in-time delivery. There are enormous challenges for engineering and technology schools in how they develop future profiles of their academic staff.
Nambisan and Wilemon (2003) carried out a global study of engineering graduate management programs. The major findings of this survey are shown in Table 2.1 below:

These results can be summarised as follows:

**Table 2.1 Study Summary Results (Nambisan and Wilemon, 2003)**

- For many Universities, MOT programs became increasingly popular during the 1990’s
- MOT programs often involve both business schools and engineering schools
- Business schools administer most MOT programs
- Program focus is more on “management” than technology
- MOT student undergraduate degrees are largely sponsored by engineering schools
- MOT programs serve both full-time and part-time students
- Industry is involved in many MOT programs through funding, scholarships, faculty research support, thesis support, and as members of MOT advisory councils
- Major program themes include innovation management, technology strategy, technology management, R and D management, IT, operations
- Faculty research in MOT covers a broad spectrum of interests and topics
- The reputation of MOT programs is increasing and equal or better than many traditional academic departments
- Faculties have championed most MOT programs
- MOT programs are predicted to continuously grow through increase in industry collaboration and research support, as well as in the number of faculties and students who have an interest in IT and E-business

The above types of programs are provided by both business and engineering schools. Business Schools provide either a stand alone EM degree (usually at postgraduate level) or an MBA with an engineering specialisation. These are postgraduate degrees. At the undergraduate level engineering schools also deliver some EM programs. Engineering management programs tend to be more popular as a major within an MBA program. There is some discussion as to whether an MBA specialisation is a better choice than a Master of Engineering Management (MEM) degree. There is a broad range of topics covered in the areas of degrees offered. Such topics as innovation management, technology strategy, entrepreneurship, and new product development as well as the traditional management, finance, accounting and organisational behaviour are considered relevant to this area.

### 2.3 Summary of Post Graduate Development

When considering post graduate Engineering Management developments in the period under review it is apparent that these degrees are increasing, in response to increasing demand and are also diversifying from Commerce based (MBA) to the specialised engineering based degree mentioned previously.

From the various papers reviewed the following areas of concern were highlighted,
• Financial
• Communication
• Social responsibility
• Problem solving
• Technology management
• Business principles.

The review of post graduate course development has shown that there is a need to allow engineers to study and learn business methods but this system has been developed for graduate engineers already in employment and possibly already in a management position. It does not infer that engineers should pursue a second degree immediately on graduation but wait, possibly several years, before they have the experience to appreciate the need for management skills (a prerequisite for entry to several of these courses).

2.4 Developments in Undergraduate Engineering Management Courses

Muster and Weekes (1983) discussed the perceived failures of the major Western nations to maintain their productivity gains. This comment is particularly relevant to the productivity gains achieved by Japan and some European countries. In their analysis of the situation they indicated that, in their opinion, the failure was due to the incomplete education of engineers at the undergraduate level, followed by failure of engineering management education at the postgraduate level.

They believed engineers were being trained as an elite group with little relevance to the practicality of real life. This ‘practical’ training should be imparted by the engineer’s employer (at a later stage). This situation has come about by using academically oriented engineering lecturers. In addition, they believed the educational methods used have not changed from those in the periods after the Second World War, even though problems and methods of analysis and problem solving have changed. Educators need to question the relevance of the curricula and pedagogical methods.

Metzger et al. (1982), reviewed the changes that have occurred in learning methods from the ideas of mechanism to reductionism, which served the system well until the increasing complexity of engineering and business made both of these systems redundant. Muster and
Weekes (1983) then considered the application of Action Learning which has been described as follows:

“Action learning is a means of development, intellectual, emotional or physical, that requires its subject, through responsible involvement in some real, complex and stressful problem, to achieve intended change sufficient to improve his observable behaviour henceforth in the problem field.”

Revans, 1981 as cited by Muster and Weekes (1983)

They recommended that it be incorporated into the then current curricula for both engineering and particularly, in engineering management training.

### 2.4.1 Continuous Learning Concepts

Duggan (1995) in his keynote address to the 5th AAEE Annual Convention and Conference, Auckland, New Zealand chose to address the subject of engineering management education in the context of lifelong learning.

He commented that engineering programs throughout the world were seen as facing major challenges. As the complexity of systems increases the need for more educated engineers who are capable of moving across disciplines also increases. These engineers, he said, will have the ability to operate across disciplines and be capable of using a systems approach to thinking and to problem solving.

This concept has been taken further. It has been suggested that engineering students should follow a common two year program encompassing a generalist degree. Once this is completed the student may then wish to become employed and further his/her engineering education at a later date or may wish to continue with a two year specialist degree. The specialist degree could cover such areas as:

- a specialist engineering field – mechanical, electronics, etc.,
- a non-technical area such as management, law, accounting etc.,
- a specific field of engineering such as computers, consulting, structures etc..
This second phase could be commenced immediately on completion of the first two years or left to a later date when the engineer feels the timing is appropriate. This proposal would need the involvement of industry as well as academia and the professional bodies but could represent a new way forward for engineering management education.

Michel (1995) reviewed the history of engineering education and then looked at recent developments in engineering education. The first point discussed is the development of new and diversified courses that were then being developed and offered. He commented that the current situation required consideration of a more complex regime of engineering education, in general, and diversification in particular. The two main possibilities that he suggested are:

“longer higher education oriented towards design, research and/or management on the one hand, shorter and production oriented education on the other hand”.

(Michel, (1995))

He proposed that a discussion of a possible compromise between the two options should be of high priority amongst engineering educators.

Michel also reviewed the trend for engineers to seek a specialised higher education through postgraduate work. This refers back to previous comments concerning engineers with double degrees. He suggested that such a policy would assist in the mobility of engineers, both geographically as well as inter-disciplinary.

Chapman and Martin (1995) discussed the effect of computerised business games on engineering education. The aim of this type of teaching is that the games allow the use of multi-dimensional problems. Engineers are considered to be educated away from real life and are used to solving “neatly packaged issues with definitive answers”. However, in real life, problems frequently require lateral thinking and the identification and evaluation of a range of differing solutions. The business game allows the student to become versed in the solving of multivariable situations. The debate continued into the 21\textsuperscript{st} century with many authors continuing to comment on what skills an engineer should be taught, by whom, and by what means. Ferris (2001) and Strong et al. (2004) talked about the development of undergraduate courses. Ferris discussed the revision to the undergraduate course for electrical and electronics carried out by the University of
South Australia. This revision was carried out with respect to the pedagogical form and value stream to better fit graduates for the electrical and electronics industries. In this revision the engineering management stream was completely reconstructed to offer a specific perspective that was targeted at the information technology industries.

This new stream incorporated the following subsections into the degree with each subsection being part of each year of the four year course as follows;

- Engineering Communication and Innovation - Covers the role of the engineer in society, successful communications, creativity and innovation.

- Systems Engineering Management - This stream introduces students to project management, elementary financial concepts and quality concepts.

- Systems Engineering 1 - Introduces the concepts of the engineering of complex systems.

- Systems Engineering 2 - Further develops the concepts covered in Systems Engineering 1.

Strong et al. (2004), in the United States of America, reviewed the teaching of an Enterprise Decision Making Module in an undergraduate system. The aim of this model was to involve engineering students in a multi-criteria ‘real world’ case study. The underlying concept behind this approach was based on the assumption that today’s organisation was generally an integrated business whose processes include supply chain concepts, product design and development and quality principles. These activities require employees to be closely coordinated both functionally and geographically with the students. This will often require negotiation across businesses, functions and cultures. However, most engineering schools ignore these cross-functional activities.

Using a pilot study, Strong et al. (2004), found the student’s social science knowledge did increase over the period of the study (one semester) and students exhibited an increased ability to understand the concepts and principles of the Enterprise System and materials management.
Wei (2005) posed the question of what type of engineering management education will be needed in a post-industrial world. In reviewing current education, he commented:

“Engineering education is the major exception, where students go straight from high school to an engineering school for a BSE and then he/she is declared both broad enough to be an enlightened citizen and expert enough to practice engineering, all in 4 years of education. It has always been a point of contention to achieve both breadth and depth in 4 years, and the engineering accreditation process has accepted the notion that between one-eighth and one-quarter of the engineering curriculum should be devoted to humanities and the social sciences.”

Wei reviewed the changes in both the developed and developing world in which the former is moving rapidly to become a service economy and then on to a knowledge economy, whilst the developing countries will still need traditional engineers for some time. However this time frame is shortening rapidly.

The future for engineers in the developed world will become more and more oriented towards employment in the service sector (commercial and governmental) and educational institutions will need to factor this into their offerings. Wei cites the following comment from the report from the National Academy of Engineering entitled *The Engineer of 2020: Visions of Engineering in the New Century*. In the executive summary they say:

“Engineers must adapt to new trends, and educate the next generation of engineers to arm them with the tools needed for the world as it will be, not as it is today.”

Attention is being given to the changing role of the engineer with schools incorporating ‘service’ fields such as computing, digital communication, and media with faculty makeup now at about 50-50 of full-time and part-time academic staff.

Major providers have definite plans to improve their programs by expanding their range of topics, developing closer links with local industry, and developing international academic and industry links.
Kotnour and Farr (2005) commented on the various degrees and discussed the overlap of the undergraduate and postgraduate degrees and the relationship with general management.

They commented -

“Engineers often enter the job market, not as traditional engineers but as project managers, technical sales people, and lead system engineers (especially within the defence and information management areas) involved with conceiving, defining, architecting, integrating, marketing and testing complex and multi-functional information technology centric systems (Abel (2005)). Within five years, for most this has become their primary job function. Combined with the fact that the modern engineering enterprise is now characterised by geographical dispersed and multi-cultural organisations, engineering management (EM) is more relevant than ever”.

They further commented on the history of Engineering Management and supported the Omurtag (1988) definition of that term, namely,

“Engineering management is designing, operating, and continuously improving purposeful systems of people, machines, money, time, information, and energy by integrating engineering and management knowledge, techniques, and skills to achieve desired goals in technological enterprise through concern for the environment, quality and ethics”

(Omurtag, 1988 as cited by Kotnour and Farr (2005))

Kotnour and Farr also defined what they considered to be the five different types of technical and management roles that engineers may aspire to. These five are as follows:

1 Engineering disciplines: The core engineering disciplines in which the focus is on the engineering and design process unique to a domain (e.g. civil, traditional, industrial, mechanical, electrical).

2 Discipline-specific engineering management: The engineering management discipline that focuses on the management process for a specific
engineering discipline (e.g. management of the civil engineering process, management of the industrial engineering process, etc.).

3 General engineering management: The engineering management discipline that focuses on the fundamental engineering management process across many engineering disciplines.

4 Management of Technology: The business or management discipline that focuses on managing the creation, development, and use of technology.

5 General management: The management discipline that focuses on the management of any organisation.

One of the conclusions Kotnour and Farr (2005) reached is that

“….the EM profession needs to build an integrated approach to teaching, research, technical assistance, training, and service. From this integration, the discipline will continue to grow and make significant contributions.”

Palmer (2003) comments that

“The importance of management to the long term career of the practicing professional engineer is widely acknowledged. A direct consequence of this is the need for the inclusion of management studies in undergraduate courses.”

He also comments that in 1996 it was reported in a survey conducted by the Institution of Engineers, Australia that 30% of the members surveyed were working in non-engineering roles (perhaps management) and over 40% were primarily involved in management.

Lannes (2001) expressed a view of how the career of an engineer could progress in three stages and the primary skills required at each stage. His view is illustrated in Table 2.2 below:
Table 2.2 Progression of an engineer’s career (Lannes, (2001))

<table>
<thead>
<tr>
<th>Engineering</th>
<th>Engineering Management</th>
<th>Management of Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 yrs</td>
<td>5 – 25 yrs</td>
<td>25 – 30 yrs</td>
</tr>
</tbody>
</table>

Technical Skills

<…………………………………>

Interdisciplinary Skills

<…………………………………>

Integrative Business Skills

<…………………………………>

As he rightly points out not all engineers follow this path exactly and there is a degree of overlap of the three phases. Some engineers are content to remain in phase one, others will move on to phase two and possibly on to phase three. The length of time an engineer stays in each phase will also vary widely.

Coates et al. (2004) also reviewed the field of engineering management, but from an engineering perspective, and discussed several concepts related to engineering management. They pointed out the complexity, expense and time consuming aspect of large made-to-order engineering products. These often involve various skills from a range of disciplines.

They then commented on the way engineering design has changed and discussed several methods that had been developed over the previous decade or so. These are models for the engineering design process, concurrent engineering, project management and co-ordination. They also highlighted the need for communication in all of these methods.

In 2009 Kocaoglu published a paper- *Engineering Management, Where It Was, Where Is It Now, Where Is It Going* (Kocaglu 2009) in which he revisits his past interest in Engineering Management and its development since the late 1970s. He reviews the development of the various management streams that developed within the United States and how the various names of the new streams of management were discussed
and eventually the name Engineering Management was decided on. In his conclusion he makes the following points:

“A recognisable research base and a “home” in funding agencies to support that research base must be established.

The service sector must be embraced as a key application domain for engineering and technology management.

Management of energy must be a high priority for the engineering and technology management disciplines”.

(Kocaoglu, 2009)

He concludes with the comment:

“Technology cannot solve every problem in society; but there are very few problems that can be solved without proper utilization of technology. Proper utilization requires proper management. That is what our discipline does.

Those who manage technology will be the winners in the coming generations, those who are managed by technology will be left in the footnotes of history. The challenge awaiting us is to make sure that our societies will be among the winners.”

(Kocaoglu, 2009)

Many other authors were active in this decade and include the following:

Palmer (2000) reviewed the development of management subjects in undergraduate engineering courses in Australia. He commented the one clear indication that the level of management skills of graduate engineers was not adequate, was the number of graduate engineers who enroll in postgraduate courses, in particular the MBA.

Kuhnke (2000), writing from an industrial perspective, made the following comments:

“I reiterate an often-heard demand: we must focus on the customers’ requirements. Engineering studies must not rely solely on continually perfecting our knowledge of the basics and their applications. Carefully compiled and taught marketing knowledge is the key to controlling the fantasies
of over-exuberant engineers. Properly used, knowledge of our customers’ needs and requirements will lead to satisfaction and economic success.”

As this comment is from an industrial perspective and is heavily weighted towards the needs of industry, it does highlight the need for engineers to have an understanding of the requirements of being able to communicate and understand the value of satisfying customers.

Ramos (2000) commented that

“As engineering becomes more and more involved in life sciences, courses in this area may need to be added. Engineers are increasingly taking over leadership of various industries and professions, so they need to be taught communication and management skills. …. Today’s engineer, like any modern professional, must be someone who can see the big picture”.

Inelman (2001), when reviewing the work of the first Dean of Engineering at Bogazici University Istanbul, Turkey, listed a range of ideas that the Dean researched and published during his nine years of office. These included:

“Engineering methods that apply the traditional disciplinary boundaries (ie mechanical, electrical, chemical and civil) are no longer adequate to solve the industrial expectations of today.

Engineers are required to have the ability to communicate with others, and are expected to find economical, practical, durable, innovative, aesthetic, safe and clean solutions to human needs”.

Casperson, (2002), also writing from the employers’ side, makes the comment:

“If the soft engineering issues are not taken into consideration, then one will not be able to achieve the business goals in a global company – even if one is a well-qualified engineer.”

Casperson was discussing the need of engineers to be able to work globally and respect and understand the cultures of other nations where a multi-national company may operate. He also outlined the demands on employees in such a global company. He concluded that these employees (engineers) need the following attributes.

“Creativity.

The ability to find solutions in collaboration with others.
The ability to use the necessary technical tools.

The ability to keep his/her head cool in a chaotic environment, e.g. from supplier to customer.

The ability to co-operate in teams and build up a collective feeling of responsibility for decisions.

The ability to co-operate in a multicultural environment.

Newly graduated engineers should realize that learning and improving cross-cultural competencies are necessary skills in the world today.”

(Casperson (2002))

Casperson, whilst mainly concerned with cross-cultural attributes, underscores the need for engineers to develop skills outside the traditional engineering attributes.

Short et al. (2003) reviewed the use of industrial based teaching of fourth year students. This teaching involves relying on continuously using industrial contacts to the benefit of both the student and the industrial partner. Research shows that the students believe that they have gained considerably academically, and have also acquired improved communications and management skills.

Anderson (2004) reviewed the system of international exchange students gathering together to undertake a semester course called the European Project Seminar. This subject, usually undertaken by about 50 students, typically from 12 countries, exposes the students to cross-cultural issues and the value and difficulties of international communication. These students come from a range of disciplines, including engineering, business and technology. This method has proved very effective in teaching students, who choose a project that they wish to work upon. This project does not clearly define the education level of the students but has proven to be very successful in developing engineers who are capable of working within a multicultural environment.

Jonasson et al. (2006) reviewed the problem of work place problem solving in regard to engineering education and commented:

“Practicing engineers are hired, retained and rewarded for solving problems, so engineering students should learn how to solve workplace problems”.

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They go on to comment that workplace problems are very different to the theoretical and structured problem that students are required to solve in class.

Workplace problems are ill-structured and complex because they possess conflicting goals, multiple solution methods, non-engineering success standards, non-engineering constraints, unanticipated problems, distributed knowledge, collaborative activity systems, the importance of experience, and multiple forms of presentation.

All the above suggested problems impinge on the soft management skills that have been identified in this review.

Omurtag (2009) attempted to define what engineering management is. His answer was as follows:

“It is my firm belief that engineering management is a new, broadly integrative and synthesis-focused enterprise engineering discipline. Functionally, I believe that managerial engineering is what these engineers do, that is, they do engineering in the management realm. In that sense EMGT is similar to other classical engineering disciplines that are concerned with the mechanical, electrical, civil, chemical, industrial, and other areas of technical problems in which design and synthesis are essential elements of the engineering work. EMGT professionals do engineering work in the management realm of a technological enterprise.”

Omurtag also discussed the virtues of post-graduate courses in Engineering Management (EMG) and held that these courses fit engineers better for a career in technical management. He held that these courses are better than an MBA, but that, in the long term a composite postgraduate degree may arise.

An Editorial in the ENR (2004), whilst discussing the National Academy of Engineering’s report “The Engineer of 2020” raised the following points (amongst others) regarding the needs of engineers in the construction industry:

“Employers need to provide input as curricula are designed and academia needs to listen and respond.

It may take 16 years until 2020 to figure out the proper mix of hard-core technical subjects needed for students to become proficient engineers and the soft subjects –such as leadership, public policy and business –that employers say they want engineers to have. The business world needs well-rounded
professionals who can move up the corporate ladder and be more responsive to client needs.” \( \text{(ENR (2004))} \)

Martin et al. (2005) reviewed engineering graduates’ perceptions of their suitability for employment in a South African context. Their research showed that the respondents clearly considered the following attributes were a vital part of their work related activities.

- Communications
- Interpersonal skills
- Teamwork in the workplace
- Leadership roles
- Lifelong learning

In addition, more than half of those contacted indicated that they expected to assume management (of people) roles in the future.

The responses to questions about financial and business skills were mixed and there was not a great emphasis on this area as one of concern.

Shulman et al. (2005) made comments very similar to those of Martin et al. (2005), following a review of the ABET ‘soft skills’. Ravesteijn et al. (2006) discussed and highlighted the future need for communicative engineers, concluding with the comment:

“Developing future engineers’ communicative competence is usually the weak spot in the traditional engineering curriculum.”

Goh, (2007) reviewed the report by Nicholson and Nairn (2006) on “The Manager of the 21st Century” and applied his comments to engineering management. One of Goh’s comments was

“…… there will be an increase in the need of engineering managers to have deep knowledge of their specific technical skills, but yet possess highly effective interpersonal and leadership skill, and perhaps, also possess some broad business base…….”
In an editorial in *The Australian*, Trevelyan (August 6, 2008), whilst commenting on the ‘invisibility of engineers’ made the following comments:

“In contrast to popular stereotypes, work revolves around a complex web of human relationships intertwined with mostly unwritten technical know-how. Engineers work as much by leveraging and co-ordinating the expertise of other people as they contribute themselves”.

And went on to state:

“Our research matches earlier findings showing that even novice engineers spend at least 50 percent of their time interacting with other people than in solitary technical work”.

McCrohon and Gibson (2009) reviewed the needs of undergraduates who expressed an interest in working in the construction industry. Their initial research found that there were concerns by both students and employers as to the “work readiness” of new graduates. They commented:

“Initial indications are that these students appear to be well versed and extremely capable in theoretical concepts and design and civil engineering technology but have limited perceptions of the actual work they will be involved in when they become employed in construction project work. Business skills in understanding the importance of adding value for customers through the integrated construction supply chain appear to be very underdeveloped.”

It also appears, from their study, the students surveyed recognized that some of their academic work, whilst essential in developing their problem solving, technical and intellectual abilities, has little or no direct application to activities that are part of the construction industry.

### 2.5 Summary of Undergraduate Development

The above review highlights the need for undergraduate management training. Wei (2005) believes that between 12.5% and 25% of an engineer’s four year course should be devoted to management subjects. The problem here and a gap in the literature is the lack of agreement on which management skills are required.

The review of literature regarding the ‘soft skills’ of management has shown that, whilst rated as important by many authors, in the training of undergraduate engineers these skills have been
benignly neglected or given token acceptance. There has also been a lack of research into the perceived needs of employers in Australia, both in the engineering field and general business activities, for engineers to possess such skills on graduation.

2.6 Developments in Engineering Management Courses – General

In a short article, Laver (1995) commented on the directions he felt professional employment and education would take. He presented a summary of what he considered an important future requirement of professional education as follows:

“Lifelong learning is fast becoming a cliché but is nonetheless an extremely important component of undergraduate education…….”

(Laver, (1995))

Laver commented the term ‘competency’ is also a problem in respect to professionals, although there is a collection of related facets which can provide a composite view of the requirement. All employees, in any walk of life and at any stage of their career require a mix of three different types of attributes or competencies, the balance depending on the nature of the task at hand. These are:

- Employment related
- Skill related
- Graduate attributes defined by the HEC (Higher Education Council) or similar.

In many cases these competencies need to be assessed by demonstration, rather than be taught and examined.

Laver contended that the emphasis of the engineering education needed to be changed to encompass additional aspects such as

“contextual learning, creativity, an understanding of quality and cultural awareness.”

He was also of the opinion management skills can be taught later at a time when the principles can be learnt and then applied to practical applications.
Holt et al. (1996) continued this thread in considering the future of engineering education. They argued the current engineering curriculum was based on a selective ontology that ignores specific parts of engineering knowledge. This has restricted the applications of alternate methods to teaching. They believed engineering academics consider the scientific method as satisfactory for all problems. This however does not take into account the realities that engineers will face in the workplace. Holt et al. considered there was a need to widen the material taught within mainstream engineering education. Within this concept they considered there were four underlying images of engineering applications.

These are summarised as follows:

- **Engineering as specialised problem solving activity.** - The world is where engineers make things work or work better by the systematic application of scientific (engineering) principles.

- **Engineering as physical science.** - Engineering is a field where the rigorous applications of basic scientific principles will lead to the development of knowledge.

- **Engineering as a technical business management activity.** - Engineering is tightly woven into the fabric of business and the technical and commercial aspects of market are inseparable.

- **Engineering as a design and innovative activity.** - Engineering is in a world full of potential.

Holt et al. (1996) said that each of these images of engineering define the viewpoint of each particular field of engineering. It also indicates the type of programs engineering educators should be attempting to develop to meet each of the attributes of these engineering images.

Various other authors who published during this decade commented in a similar vein. Their comments are summarised below:

Khalil (1993) stated that

“Engineering education recognises the importance of science in technological development and proceeded to foster the link between them. It also recognized the
importance of creating more rounded engineers and introduced a set of educational requirements in humanities and social sciences.”

Massey et al. (1995) looked at the approach of an Industry-University Quality Partnership. The program has multi-disciplinary, multi-institutional teams of students and faculty who work on a continuous improvement project. Topics that are covered include TQM, safety, teamwork, communications and time management. The approach has been successful and work is being undertaken to expand the concept.

Brisk (1997) looking to the future commented that engineers of the future would need to face a different environment and would need to meet this challenge:

“The culture of engineering education must change from being male-dominated and preoccupied with things technical, to become gender balanced and socially and community aware.”

Also

“Engineers will require greatly improved skills in communicating their ideas to other engineers and especially to nontechnical people, both verbally and in writing. Their education must recognise and achieve this”.

“There will be increased emphasis on engineers working in teams comprising other engineering disciplines and other professions, both technically based, and nontechnical.”

(Brisk, (1997))

Leinonen et al. (1997) discussed the requirements of industry (for mechanical engineering students) and commented that their findings showed -

“the major deficiencies in non-technical skills concern leadership, knowledge of languages, negotiation skills, project work, .......... and understanding of the functioning of a company as a whole.”

Ritter et al. (1997) evaluated the attributes of an outstanding manufacturing manager. Their survey found that the following were the major attributes identified and gave their relative ranking. Of the twelve most important identified, those skills associated with technical aspects
of manufacturing were ranked as the first three, a tertiary qualification was ranked four. The next six were:

“sound communication skills;
the ability to implement change/manage change;
the ability to develop/execute plans/budgets;
an effective leadership style
the ability to build teams and be collaborative;
the ability to motivate and inspire others;”  
(Ritter et al. (1997))

Seidel (1998) in reviewing the state of vocational education made the comment;

“Employers continually ask that graduates be better able to communicate, to relate to customers, to work in teams and to demonstrate innovation and quality improvement, and yet the same employers retain the narrow technical focus of training.”

Whilst Seidel was mainly concerned with vocational training his work highlights the apparent perplexing question of ‘what do employers really need in their employed engineers?’

A short editorial in *The Engineer* by Ramsay (1998) looked at the results or lack thereof of the Finniston enquiry which was carried out 18 years previously. Finniston (1980) commented that

“The system for training and educating engineers in the 1970s produced too many graduates whose only contact with engineering was calculating solutions to theoretical problems.”

He continued

“..the main need of industry was for practically-orientated engineers.”  
(Finniston as cited by Ramsey (1998))

Deans (1999) surveyed the needs of graduate mechanical engineers in New Zealand and in the ranking of skills of those graduates the ability to communicate effectively was ranked first with a mean score of 4.64 (on a scale of 1 to 5). He also noted that written skills were highly ranked with a mean score of 4.17. The importance of this attribute increased significantly with an increase of both experience and responsibility.
Seat and Lord (1999) commented that whilst complaints about engineers’ technical skills are rare, the complaints about softer skills (communication, interpersonal, and team skill – called performance skills by the authors) are of concern to industry employers and educators. They reviewed a training program that it was suggested may solve this problem and discussed the results of the implementation of this training program. The program has been used in both university (undergraduate) and industrial settings.

Among their results were the following:

“An observation from teaching this material is that technical people in academia and industry resist learning performance skills.”

and

“Typical students are not participating in this training out of a fundamental interest in the topic.”

Also

“Students don’t know that they need this training and show initial resistance.”

Rifkin et al. (1999) considered the attributes that define a potentially well rounded Technical Manager and developed a figure which covers the typical groups of people outside his or her reporting group with which a technical manager may be required to interact with. These may include;

- Staff Functions – HR, Marketing
- Industry Funding Arms
- Universities
- Community Groups
- Professional Societies
- Consultants
- Marketing
- Patent Counsel.

The above summary of the potential non-technical interactions of this type of manager shows professionally educated personnel require skills that are not normally taught at the undergraduate level. This is particularly true of engineers, who, unlike accountants, medical and legal practitioners can be employed in a very diverse range of occupations.
Meiksins (1998) commented:

“Engineers as well as students of the engineering profession have long been fascinated by the role of engineers in management.”

He then discussed whether engineering expertise is really a significant factor in the range of attributes that a manager may require to be able to successfully manage a technology-intensive organisation.

Many of the comments contained in Meiksins (1998) come from interviews with current managers who are of the opinion that engineers can become so involved in the technical excellence of the products they neglect the other aspects of management.

These comments mirror the experience of the researcher, based on ongoing discussions held with engineers and managers during a long industrial career.

Nguyen (1998) presents the results of a survey of academics, industry personnel and students covering their views on the essential attributes and skills required of the current modern engineer. Of the generic skills listed, the ranking of business practices varied between the selected groups. Whilst 66.2% of industry respondents rank it as important, only 27.5% of academics and 43.2% of students considered these attributes as important.

Omurtag (1998) also discussed the virtues of postgraduate courses in EMGT and held that these courses fit engineers better for a career in technical management. He held that these courses are better than an MBA, but in the long term, a composite postgraduate degree may arise.

He says

“the importance of adding value for customers through the integrated construction supply chain appear to be very underdeveloped.” (Omurtag (1998))

It also appears that students recognize much of their academic work, whilst essential in developing problem solving, technical and intellectual abilities has little direct application to work in the construction industry.
2.7 Summary

A summary of this decade indicated although more effort has been put into analysing the benefits of management education and suggesting the incorporation of these principles into both undergraduate and postgraduate courses. There appears to be no clear definition of what skills engineers will need in the coming decade and new century or of how they should be taught and when in the engineers’ career. There is a general consensus that engineers need non-technical skills (management skills) and a study of these skills should be considered part of the undergraduate curriculum. There is also agreement that additional skills can be developed later (postgraduate) when the graduate engineer has found his/her place in the workplace and has decided to pursue a strictly technical career, or a management career, or an amalgam of both.

The skills mentioned by the various researchers include,

- Communication
- Finance (perhaps at operating level)
- Human Resources, and
- Industrial Relations.

2.8 Attitudes of Undergraduate Students to Management Courses

A search of the literature has shown no longitudinal research on the attitudes to management studies of undergraduate students and how it may change over the duration of their undergraduate studies.

2.9 Faculty Reactions to Undergraduate Training and Style of Teaching

Little information has been discovered and this is covered above.

2.10 Management Skills

For the purpose of this research, the term Professional Management Skills (PMS) as described in Section 1.4 (page 25) the second definition will be used. These additional skills will be needed for engineers to successfully manage in this environment. They include human resources, financial, operations and marketing.
PMS is suggested as a term to describe the skills believed to be necessary for both undergraduates and postgraduates to possess to participate fully in the management of an organisation and be adequately prepared to successfully manage disparate groups of both professional and non-professional employees in a timely and efficient manner.

This topic has been of relevance for some decades. As noted earlier in this chapter (page 35) in 1983 comments were made by Flowers, which indicated the need for engineers to develop management skills.

Research, discussed here has identified that since at least 1983, PMS has been considered an integral part of the skills and attributes that a graduate engineer should possess. This conclusion is supported by a large body of scholarly literature including the works of Martinec (1984), Kocaoglu (1984), (1994), Aldridge et al. (1990), Director (1996), Brisk (1997), McCahon and Lavelle (1998), Jenson (2000), Carmichael and Gibson (2001), Wilkinson and Schofield (2002), Kocaoglu et al. (2003), Nambisan and Wilemon (2003), Childs and Gibson (2007, 2009).

However, to date, little research has been done on the perceptions of employers’ needs for essential or desirable skills and attributes for graduate engineers to possess and the influence this has on business performance.

The literature reviewed to date reported on the aspect of management skills for undergraduate engineers. Generally, it is mostly discipline based and covered by a small range of authors. Some authors have attempted to define these general skills without a particular reference to the term “Managerial Skills”. The authors include – Plonka et al, (1994), Chisholm (1999), Rifkin et al. (1999), Holfield and Thomas (1999), Edum and Fotwe (2000), Editorial (2004), and others.

Other authors, Liyanage (2001), Gibson and Carmichael (2001) and Thilmany (2004) have reviewed the needs and dimensions of postgraduate engineering courses and have highlighted the need for engineers to study and absorb ‘management concepts’.

Gibson and Carmichael (2001) commented that:

“Leading firms are working with universities to develop innovative ways to progress and develop their staff throughout their careers. The divide between working and learning is becoming increasingly blurred. The global dimension adds further
challenges that will probably result in strategic alliances and networking capabilities that allow even greater degrees of customisation and just-in-time delivery. There are enormous challenges for engineering and technology schools in how they develop future profiles of their academic staff.”

Patil and Codnel (2005) have found that engineers now require global competencies such as an awareness of global political and social issues, and knowledge of cross cultural and multicultural issues. They also need to understand international business, the local and international economy and the world market. These issues were also commented on by Nair and Patil (2009). Trevelyan (2008) comments on the way current engineering education is based on engineering practice which covers technical problem solving and design and this represents a misalignment between engineering education and engineering requirements in real world situations. It does not take into account the very important factor that engineers spend significant time interacting with people.

2.11 Non-Technological Professional Management Skills

In the management area of academia the art of management was generally defined in the 1955 paper by R.L. Katz published in the Harvard Business Review (HBR). His understandings of the skills of an effective administrator (manager) were listed as follows (with the current authors’ comments in parenthesis):

Technical – need sufficient technical skill to accomplish the mechanics of a particular job for which he is responsible. (These skills would presumably be part of an undergraduate degree curriculum).

Human – [have] human skills in working with others to be an effective group member and to be able to build co-operative effort within the team he/she leads; (generally not taught as an integral part of an undergraduate degree)

Conceptual – [have] sufficient conceptual skills to recognize the interrelationships of the various factors involved in his/her situation which will lead him/her to take that action which achieves the maximum good for the total organisation; (generally not taught as an integral part of an undergraduate degree.)

(Katz, (1955 p. 42))
Katz’s seminal paper was reprinted as a HBR Classic in 1974 with the additional comment that all managers, whatever their level will need some skills in all these three areas. In 1986 HBR again reprinted sections of the paper and it was revisited by Peterson and Van Fleet (2004) who expanded and modified some elements but still stayed essentially true to Katz’s original statements. In their review Peterson and Van Fleet (2004) also identified an additional seven skills listed in the literature alongside Katz’s three skills.

Thus, from this series of papers it can be postulated there are ten management skills graduate engineers need to possess. These ten skills are proposed as necessary for an engineering manager to be fully effective. They are - Technical, Analytic, Decision Making, Human, Communication, Interpersonal, Conceptual, Diagnostic, Flexible, and Administration, defined in Table 2.3 below:

**Table 2.3 A Compilation of Managerial Skills**

(Peterson and Van Fleet, (2004))

<table>
<thead>
<tr>
<th>Skill</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Ability to use methods, procedures, processes, tools, techniques, and specialised knowledge to perform specific tasks</td>
</tr>
<tr>
<td>Analytical</td>
<td>Ability to identify key variables, see how they are interrelated, and decide which ones should receive the most attention</td>
</tr>
<tr>
<td>Decision making</td>
<td>Ability to choose effective solutions from among alternatives</td>
</tr>
<tr>
<td>Human</td>
<td>Ability to work co-operatively with others, to communicate effectively, to motivate and train others, to resolve conflicts, and to be a team player</td>
</tr>
<tr>
<td>Communication</td>
<td>Ability to send and receive information, thoughts, and feelings, which create common understanding and meaning</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>Ability to develop and maintain a trusting and open relationship with superiors, subordinates and peers to facilitate the free exchange of information and provide a productive work setting</td>
</tr>
<tr>
<td>Conceptual</td>
<td>Ability to see the organisation as a whole and to solve problems from a systemic point of view</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>Ability to determine the probable cause of a problem from examining the symptoms which are observed by the manager</td>
</tr>
<tr>
<td>Flexible</td>
<td>Ability to deal with ambiguous and complex situations and rapidly changing demands</td>
</tr>
<tr>
<td>Administration</td>
<td>Ability to follow policies and procedures, process paper work in an orderly manner, and minimise expenditure within limits set by budgets</td>
</tr>
</tbody>
</table>

A major paper, by Robinson et al. (2005), surveyed design engineers in the UK on what skills they should possess to carry out their tasks competently. The authors categorised the skill sets identified into six groupings. This survey was biased towards an engineering perspective but surprisingly identified many of the softer skills of management as put forward by Katz (1955).
Peterson and Peterson (2004) researched the managerial needs of a mid-level management position within a USA government organisation. This research involved a series of surveys on management needs. In the first survey they requested 23 senior managers to comment on three aspects of management based on Katz’ (1955) listing of technical, human, and conceptual, and required them to estimate the time spent within their positions on each of these three aspects. Whilst this is a shortened list it does outline the areas that should be considered when evaluating what management skills a graduate engineer should possess.

Peterson and Peterson (2004) have developed a table (Table 2.4 below) that listed the proportion of time an engineer spends on each of these categories. They also provide an explanation of what is required for each skill. A ranking of 1 indicates the most important category with these still generally being in line with those suggested by Katz (1955), fifty years ago.

<table>
<thead>
<tr>
<th>Category</th>
<th>Range (Percent)</th>
<th>Mean (Percent)</th>
<th>Rank (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>5-50</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Human</td>
<td>20-70</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Conceptual</td>
<td>18-70</td>
<td>28</td>
<td>2</td>
</tr>
</tbody>
</table>

Interestingly, Technical skills were ranked last in this survey. The research continued with senior managers being asked to observe critical incidents, both those that were successfully resolved and those that were not successfully resolved and to identify those skill categories that were used in the incident observed.

The results were as shown below in Table 2.5.

<table>
<thead>
<tr>
<th>Category</th>
<th>Senior Manager Mean Scores</th>
<th>Successful Incidents</th>
<th>Unsuccessful Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>22%</td>
<td>12%</td>
<td>19%</td>
</tr>
<tr>
<td>Human</td>
<td>50%</td>
<td>60%</td>
<td>57%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>28%</td>
<td>28%</td>
<td>24%</td>
</tr>
</tbody>
</table>
However without access to the full details of the results it is difficult to conclude whether these are statistically significant or not.

The rankings were Human first, Conceptual second and in third place Technical. This was the same order as in the first survey. This confirms Katz’s original 1955 contention that managers need not only technical skills but also those of the ‘softer’ variety.

Peterson and Peterson (2004) continued their research and attempted to define the specific human skills needed for this position. Firstly, they researched the current literature and distilled a list of 45 differing human skills which were:

“emphasising performance, clarifying work roles, inspiring subordinates and facilitating teamwork”.

(Peterson and Peterson (2004))

As it was unlikely that the managers being surveyed could have been trained in all 45 skills the authors then needed to identify those skills that were considered the most critical and thus needed to be targeted when training potential managers. They surveyed two different populations.

The first group consisted of managers who were currently holding the targeted managerial position, (mid level managers – 96 individuals) and the second group consisted of junior managers (761 individuals) currently in the career field being considered for promotion to the targeted position.

The recipients of the survey were requested to use a seven point Likert scale to rate the importance of each skill. In addition, each respondent was asked to rate their own capability in each of the 45 skills.

The top three skills identified as essential were – “acting consistently”, “is truthful” and “builds trust”. The ranking of the top ten skills are as shown in Table 2.6 below, where 10 indicates unimportant and 1 indicates most important.

The study, although designed to assess skills for a particular position, highlights the need for managers to attain a certain set of skills to be fully successful in a managerial position.
Table 2.6 Rank Order of Ten Most Important Human Skills by Population

(Peterson and Peterson (2004)).

<table>
<thead>
<tr>
<th>Human Skills</th>
<th>Total Population</th>
<th>Mid-level Managers</th>
<th>Junior Managers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acts consistently</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Is truthful</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Builds trust</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Exhibits judgement</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Listens</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Solves problems</td>
<td>6</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Provides praise and recognition</td>
<td>7</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Inspires subordinates</td>
<td>8</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Emphasizes performance</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Delegates</td>
<td>10</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Shows enthusiasm</td>
<td>-</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Facilitates teamwork</td>
<td>-</td>
<td>10</td>
<td>-</td>
</tr>
</tbody>
</table>

- denotes the rank for this skill was lower than 10 for this sample

Of the models listed above, the one the author of this thesis believes to be most applicable to engineers is the one developed by Peterson and Van Fleet (2004) with modifications suggested by him. This listing is as above in Table 2.3. (page72).

2.12 Discussion

The literature survey identified a range of skills that has been demonstrated as important to engineers, both male and female, to successfully carry out their varied duties. It also identified that the skills needed by graduate engineers are changing and will continue to change. Unfortunately, all the authors reviewed carried out research on academic systems and very rarely considered the needs of the employers of various engineering disciplines. Whilst the need for engineers to be trained in non-engineering fields is noted, very little has been done by the academic systems as a whole, or professional bodies to address this need.

PMS education has been of concern to a group of authors who believe it is not being addressed satisfactorily. These authors range over several decades, from Flowers (1983), Martinic (1984) and Kocaoglu (1984, 1994) to Wilkinson and ‘Scofield (2002), Nambisan and Wilemon (2003), Wei (2005) and Kocaoglu (2009). All discussed the need for the engineering curricula to be reviewed and to incorporate Humanities and the Social Sciences. Wei (2005) commented on the need for engineers to be:
“…. expert enough to practice engineering, all in 4 years of education. It has always been a point of tension to achieve both breadth and depth in 4 years, and the engineering accreditation process has accepted the notion that between one-eighth and one-quarter of the engineering curriculum should be devoted to humanities and the social sciences.”

However, there have been no detailed comments on what aspects of Humanities and the Social Sciences should be included in the Engineering Curriculum.

Palmer (2003) commented as follows regarding the effects of management studies:

“The importance of management to the long term career of the practicing professional engineer is widely acknowledged. A direct consequence of this is the need for the inclusion of management studies in undergraduate courses.”

The relevance of this quotation is the specific reference to undergraduate studies, as the majority of actions undertaken so far to cover this area have been in the postgraduate area. This has seen the development from the implementation of the MBA in 1908 by Harvard Business School (Harvard Business School, 2010) through the development of Business Schools and Engineering specific Masters degrees such as Masters of Engineering Management (MEM), Masters of Technology (MOT) (e.g. Nambison and Wilemon (2003), Kotnour and Farr (2005)).

Additionally Palmer (2000) comments that in 1996 it was reported in a survey conducted by the Institution of Engineers, Australia (now Engineers Australia) that 30% of the members surveyed were working in non-engineering roles (perhaps management, marketing or other non-engineering activities) and over 40% of members surveyed were primarily involved in management.

Nambison and Wilemon (2003), and also Kotnour and Farr (2005) see the need for education in this area even after the engineer has gained experience and is ready to assume a beginning or even more senior management role. The varied topics that could be taught in Professional Management Education and what constitutes this discipline require clarification (by further research).

In the context of this review, engineering management skills are those typically taught in a Commerce faculty or a Graduate Business School: that is, the ‘softer skills’ of management.
This is not to deny the importance of skills such as Operations Management, but in the literature surveyed, it has been shown that it is the ‘softer’ management skills that have been most neglected at the undergraduate level.

Assuming it is accepted that engineers should be taught professional management concepts, the following questions need to be considered.

1. Which subjects and how many will constitute this discipline; in what part of the curriculum should they be taught and (as Wei (2005) comments) should they comprise 12.5% to 25% of the overall curriculum?

2. Where should this discipline be taught, (e.g. in the engineering faculty or in the commerce or business school faculties)?

3. Who will teach it, at what level and to what depth (undergraduate or postgraduate) will the courses be offered?

This thesis cannot fully answer these questions but, seeks to lay the foundational knowledge that will allow future researchers to fully answer these questions and to give information to engineering academics that will allow them to tailor their curricula to provide trained engineers who will satisfy the employment market place.

The aim of this thesis is to answer some of the questions listed above and to propose a list of skills considered to be required of engineers by employers to allow the graduate engineer to seamlessly integrate into an organisation and be ready to assist in the attainment of the goals and objectives of the organisation.

The common thread through all the literature reviewed is that a percentage, (as yet undefined), of graduate engineers will seek management roles as part of their career path. The literature reviewed also indicated that this role will increase in the future as the complexity of the business world increases. This view has been supported by Lannes (2001) who proposes a career path for engineers (see page 56). The career path may be Technical only, or move on to an Interdisciplinary role and then through to an Integrative role. Lannes (2001) made his comments in regard to postgraduate courses but these can be viewed more widely and indicate the career paths that all engineers may follow. This gives the engineer two possibilities; some
may wish to stay in a “hands on traditional” role, whilst others are firm in their belief that a management career (of some description) is their chosen career path.

In summary, the discipline of management, like engineering, can define what attributes or skills a manager should have. These were originally defined by Katz (1955) and subsequently elaborated by Peterson and Van Fleet (2004). From the research we can summarise a list of desirable management skills.

These skills are

- Decision Making Ability
- Human Skills
- Communication
- Conceptual
- Interpersonal
- Diagnostic
- Flexibility and
- Administration.

The question now is, are the same management skills needed by an engineering graduate at the beginning or further into his/her career.

Other skills that could have been included in the above list are

- Marketing
- Customer relations
- Product development
- Sales.

These skills were considered by the researcher to be secondary to the management skills chosen, but should be considered for inclusion if found to be important to potential employees. The major difficulty in incorporating management skills into undergraduate engineering courses is what needs to be included and what can be left out or deferred to postgraduate courses (such possible subjects as marketing, operations management and financial accounting etc.).
The engineer’s need for management knowledge has been demonstrated in a significant body of literature. However, there is a significant lack of knowledge of the needs of employers and what skills they prefer their graduate engineers to possess. The literature covers only the views of engineering employers (Kocaoglu (1984, 1994, 2009), (Robinson et al. (2005), (Kotnour and Farr (2005) and others). As shown above, not all graduate engineers are employed for their ‘pure’ engineering skills. Often they are, for example employed in marketing.

2.13 Current Professional Status

Discussions were held with the Executive Officer of Australian Council of Engineering Deans (ACED), and the staff of Engineers Australia. The websites of Engineers Australia, The Royal Academy of Engineers, The Council of Engineers UK and ABET of the USA were reviewed. Their standards relating to the accreditation of the various grades of engineers were then compared.

2.13.1 Australian Council of Engineering Deans

A report “Engineers for the Future – addressing the supply and quality of Australian engineering graduates for the 21st century” (King 2008) was reviewed. This report was undertaken by the Australian Council of Engineering Deans with the support of a range of other groups. A booklet was also published containing a Summary and Recommendations.

Among the principal issues identified in the Executive Summary (page iii) was the comment:

“concerns the balance of subjects within the current engineering curricula are not adequately matched to graduates’ and industry’s current and future needs:”

The following comments were also made,

Recommendation 5 was:

“Engineering educators and industry practitioners must engage more intensively to strengthen the authenticity of engineering students’ education.”
Chapter 5 Employer demand for engineering graduates - the comment is made that

“…statistical work based on ABS classifications may exaggerate the apparent loss of many graduate engineers to ‘management’,…”

In Chapter 7 “Developments in undergraduate engineering education”, under Section 7.2, the following comment is made.

“The most common general criticism of graduates by members of the business community, in engineering and other disciplines, is that they have poor communications skills, particular in business-specific writing.”

Further, in Section 7.6 “Management courses and interpersonal skills development” a comment on the use of Danny Sampson’s text “Management for Engineers” is that those faculties that use it in their undergraduate courses should have provided their graduate engineers “with foundation level coverage of contextual topics (such as macroeconomics)”. However this comment should be viewed in the light of the ability of the lecturer to provide the relevant managerial focus.

A review of Sampson book (3rd edition) indicates it was last published in 2001. The publisher’s description (Samson, 2001) comments,

“Management for Engineers is the classic Australian text that provides everything an engineering student needs to know about management. Appropriate for students studying all areas of engineering, this new edition has been significantly re-written and includes the latest research and debates on organisations, strategies and marketing.

Courses: Undergraduate subjects in management for engineers, taught either within engineering departments or service taught from management/business departments.”

The publishing date of 2001 indicates the information enclosed within may be out of date, particularly those sections referring to OH & S, Human Resources (relating to employment conditions and industrial aspects) and Quality Management. The range of contributing authors is impressive but only four (4) have engineering qualifications.
There are 16 chapters and for a 13 week semester this amount of material will be covered only skimpily. Eliminating several chapters is also unsatisfactory as the choice of which to eliminate could be handled rather carelessly.

This text is in use at the present time and in the authors view, it should be either rewritten or discarded. There are other texts that could serve equally well or better in the teaching of engineers the management skills they may need.

The report also discusses the relevance of inter-discipline activities and the use of lecturers from the business faculties.

2.13.2 Discussions with Engineers Australia

EA staff outlined the competency standard required of a Professional Engineer. This current standard is attached in Appendix 4 (page 270). General discussion on management skills elicited the comment that EA set general guidelines only. It is then up to the relevant University Faculty to translate these guidelines into specific subjects and justify them to the accrediting body.

The competency standard mentions management in general terms but does not specifically mention any of the skills (with the exception of communication) outlined above. Below is an example of the areas where management is mentioned (refer to Competency Standards in Appendix 4 (page 270).

2.4. Application of systematic approaches to the conduct and management of engineering projects.

a) Contributes to and/or manages complex engineering project activity, as a member and/or as leader of an engineering team.

c) Accommodates relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management.
d) Proficiently applies basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard.

3.2. Effective oral and written communication in professional and lay domains.

a) Is proficient in listening, speaking, reading and writing English.

3.4. Professional use and management of information.

2.13.3 ABET (formerly the Accreditation Board for Engineering and Technology)

ABET is the accreditation body for Universities in the USA and in the Criteria for Accreditation for Engineering Programs for 2011-2012 and in the General Criteria for Baccalaureate Level Programs, Criteria 3 Student Outcomes, they state that engineers should have (amongst others) the following skills.

“(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 multidisciplinary teams.

(g) an ability to communicate effectively.

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context.”

2.13.4 The Royal Academy of Engineering

In the publication “Educating Engineers for the 21st Century” (2006) in Appendix 2 Executive Summary of the Henley Report for The Royal Academy of Engineering, the following comment is made

“Newly recruited engineering graduates are used in a wide range of roles. Whilst research and development, design and production/manufacturing are the
most prevalent, engineering graduates are found across the product lifecycle and throughout the value chain. As a result many graduate engineers find themselves in roles which do not necessarily involve hands-on specialist engineering….. Technical skills must be supported by enabling skills that allow the engineer to operate efficiently in a commercial working environment; communication skills: team-working skills; business awareness of the commercial implications of engineering decision.”

2.13.5 Engineering Council (UK)

The Engineering Council (UK) is the accrediting body of the United Kingdom and their publication – UK Standards for Professional Engineering Competence, June 2011 lists three possible engineering standards. These are – Engineering Technician Standards, the Incorporated Engineering Standard and the Chartered Engineer Standard. For this comparison the Chartered Engineer Standard and the Incorporated Engineering Standard were chosen. The Engineering Technician Standard in general applies to Technical College trained engineers and, whilst some aspects of this thesis may also apply, this is outside the scope of this research.

In the Chartered Engineer Standard (2011) a Chartered Engineer (CE) is partially described as:

“They might develop and apply new technologies, promote advanced designs and design methods, introduce new and more efficient production techniques, marketing and construction concepts, or pioneer new engineering services. Chartered Engineers are variously engaged in technical and commercial leadership and possess effective interpersonal skills.”

By comparison an Incorporated Engineer has the following general description.

“Incorporated Engineers maintain and manage applications of current and developing technology, and may undertake engineering design, development, manufacture, construction, and operation. Incorporated Engineers are variously engaged in technical and commercial management and possess effective interpersonal skills”.
In Section C2 of the Chartered Engineer Standard (2011) it calls for a CE to

“Plan, budget, organise, direct and control tasks, people and resources.”

By comparison, for an Incorporated Engineer this section calls for them to

“Manage the planning, budgeting and organisation of tasks, people and resources.”

2.13.6 Summary

A review of the professional bodies in Australia, the UK and the USA showed several variations when the relevant aspects of management skills are considered. The USA and Australian bodies are in general agreement, with management skills mentioned but only in a relatively minor way. The two UK organisations are more definite in the need for the various grades of Professional Engineers to have a prescribed set of management skills. The need for, and the extent of these skills increases with the seniority of the Professional grades.

2.14 Research Development

The research described in this thesis, was designed to fill the gap in the knowledge of employers’ requirements by testing the proposition that a graduate engineer needs to possess management skills listed in Table 2.3 (page 72). These skills enable him/her to carry out activities that add value to their employer organisation. Based on the review in this chapter, a questionnaire was designed to determine, within the Australian context, the viewpoint of the employers of engineers (of all disciplines) as to whether engineers require the listed ‘softer’ management skills upon graduation, as this thesis maintains.

It was proposed this research would blend the work of Robinson et al (2005) and Katz (1955) with later authors, Peterson and Van Fleet (2004). The work of Katz (1955 etc), and others is included because it allows for the review of management skills from the ‘commerce’ side of an organisation.

Peterson and Van Fleet (2004) developed a list of recommended skills together with an explanation of what is required of each skill. Their definitions of these skills were used to
develop a list of suggested attributes which all graduate engineers should possess. The skills which are listed as technical have not been included here because these skills normally form part of the engineering curriculum. This list of skills required, together with their ‘definition’ is given below and discussed more thoroughly. Comments by the author are added in italics.

**Decision Making Ability** - To be able to assess and decide between competing solutions to a particular problem.

*This skill forms part of the procedures used in technical decisions. It includes Project Management and Quality Management (where available, and taken as part of the undergraduate degree) but not necessarily in relation to the decisions that a manager needs to make.*

**Human Skills** - To be able to work with, communicate, negotiate and relate to others both within the organisation and outside the organisation.

*Also be able to instruct others, work in groups and with individuals at various levels of management, and resolve conflicts.*

**Communication** - Be able to send and receive information, thoughts and feelings, which create common understanding and meaning.

*This is considered to be the most important skill of a manager.*

**Interpersonal** - Ability to develop and maintain a trusting and open relationship with superiors, subordinates, peers and external personnel to facilitate the free exchange of information and provide a productive work setting.

**Conceptual** - Ability to see the organisation as a whole and to solve problems from a systematic point of view.

**Diagnostic** - Ability to determine the probable cause(s) of a problem from examining the symptoms which are observed by the manager.
**Flexible** - Ability to deal with ambiguous and complex situations and rapidly changing demands.

**Administration** - Ability to follow policies and procedures, process paperwork in an orderly manner and manage and minimise costs within the limits set by budgets.

The above list of attributes was used as the basis of the questionnaire which was distributed mid 2010 to a range of Australian organisations. In addition, a question was included on the need for both Financial and Human Resource skills. The results are a key component of the conclusions and recommendation of this thesis. The respondents were questioned as to whether they feel these skills should be taught as part of a University engineering curriculum or as part of normal ‘on the job’ training by the employing entity.

### 2.15 Conclusion

The review of the development of engineering management education and in particular the understanding of engineering management skills has shown that this field is still an area of concern to engineering educators. One of the concerns is the different approaches to the teaching of engineering and management. The question needs to be asked, is it possible to blend a hard fact-driven education, such as engineering, with a discipline that seeks solutions based on anecdotes, case studies and similar methods?

All authors reviewed identified problems with engineering management education. However, they varied in their opinions of which topics should be in engineering management education and what constitutes this discipline. This requires clarification, as well as where this discipline will be taught, who will teach it and at what level the courses will be offered. Underlying this dilemma are the questions:

How can engineers be trained to satisfy tomorrow’s requirements?

Will these skills be taught as a separate part of the engineering curricula? Will they be incorporated into the existing curricula in a way that allows the training engineer to perceive how management skills help and also reinforce their problem solving and interaction skills?

What skills will these engineers need?
These skills need to be identified and, based on the review above, the author has defined a range of suggested skills. These were evaluated by survey and face to face interviews. The results of these research activities are reported in Chapters 4 and 5 of this thesis.

What type of academics will be needed?
Possibly, academics external to the Engineering Faculty could carry out these activities. If Engineering Faculty academics are used they will need to consider how these skills can be incorporated into their engineering subjects.

Gibson and Carmichael (2001) believe that engineers of the future will receive just-in-time (JIT) management education. This requires the delivery of education in exactly the right amount and quality at exactly the right time and place. This may require shorter modular courses often delivered in the workplace with the education specifically tailored to suit the general needs of the employing organisation. This could also be allied with international delivery of this type of product where organisations may require similar programs taught at geographically diverse locations. These programs may also incorporate international teaching institutions.

This system has been successfully applied at many institutions where several major industrial and service organisations have had specially developed courses taught both at the campus and at the organisations training facilities. These courses allow entry into graduate certificates and diplomas and articulation into more formal Masters Degrees (for example see Chelst (1998)). The University of Wollongong (The Sydney Business School) has presented such courses at the premises of a major steel corporation (Bluescope) at various locations in Australia and Malaysia.

These examples of further education by the co-operation of tertiary institutions and employers may well be the future of Engineering Management Education but further research is required to form a definitive opinion. From a research point of view the gaps that have been identified in this review are diverse and can be summarised as follows;

What skills of those proposed are considered desirable by the full range of potential employers of engineers? Are there differences in needs between various types of organisations (for example manufacturing, mining and consulting) and between differing sized organisations (small, medium and large)?
What needs to be accomplished to ensure that future newly graduated engineers are “work ready” in the fullest sense when they take up employment?

What constitutes engineering management education? What topics (subject areas) are essential for an engineer to know and understand? What other topics are desirable?

The following questions, which were not included in the questionnaire, are also very important and should be the subject of further research. Comments, where applicable are shown in italics.

At which level (undergraduate, postgraduate) should these topics be taught?

*The inference from the responses is that they should be taught at an undergraduate level.*

Should there be a designated list of topics for the undergraduate with a follow-up and more detailed analysis later in a postgraduate course?

What should be the split be between academic training and “on-the-job” training?

Who should control the delivery and who will be the deliverer? What will be the relationship between full-time academics and part-time practitioners? What skills will the deliverers need?

What will be the role of accrediting professional bodies (not yet reviewed or discussed)? Will professional bodies need to review their accreditation policy as applied to current university courses? Will they need to restructure their current organisations?

The accrediting body needs to review its standards in this changing post industrial world and how it accredits institutions. It may need to be more prescriptive in its standards and during accreditation to ensure that the subjects listed do, in fact, allow the student to meet the desired outcomes listed in the standards. The accrediting body should also ensure, by regular auditing that the approved courses maintain the emphasis on the teaching of management skills. The current situation is that a large body of authors feel there is a need for Professional Management Education but this is not yet clearly articulated. The major gap in the literature is that the
opinions of the employers has not been quantified, as most research has been by academic based engineers and little has been produced on the practical employment needs.

The viewpoints of potential employers of engineers in Australia have not been defined and until various management skills are identified, desirable or essential, it is difficult to expect engineering academics to consider reviewing the engineering curricula to include Professional Management Skills as either part of the undergraduate or post-graduate course work. The needs of the various engineering disciplines also should be identified in order to find a common set of skills or whether separate sets of skills are needed.

This research aims to rectify these gaps and provide information concerning the needs of employers and the type of skills they believe are needed from future graduates.
CHAPTER 3 DATA COLLECTION AND METHODOLOGY

3.1 Introduction

In the previous chapter a review of the relevant literature was presented. Within that review it has been shown there is a lack of data concerning what industry/commerce needs for well rounded engineering graduates with particular skills in the professional management area. Also there is a lack of data on the needs or perceived needs of employers concerning these skills and the type and the degree to which each nominated skill is needed. A review of management skills was also presented and a suggested list of management skills needed was developed based on this review. The opinion of employers was sought on which skills are required.

The literature reviewed covered a range of several decades and the consistent theme was that only a small percentage of engineering academics have continually advocated the need to educate undergraduate engineers in professional management skills. Current literature has highlighted the fact that there has been little change in this respect.

The area of research undertaken here was identified by the researcher from personal observations made during an industrial career spanning four decades in the manufacturing, product development and installations spheres. It has been my experience that graduate engineers do not always commence their careers in engineering per se, but often start in peripheral areas, such as marketing (of technical products for example) or are promoted to non-engineering or managerial positions reasonably quickly after graduation (within one to five years). In this “new” career, tasks such as budget setting, marketing analysis and cost control of a section or department are quite new to them. Often these engineers will turn to further education such as an MBA qualification or similar, to cover the gap in their managerial skills.

The first steps in this research project were to quantify the problem and to propose that there is a need to evaluate this potential problem.

This chapter will consider the methodology to be used to gather the data required and will include a description of that methodology, the justification, and the development of the method for gathering the data needed.
3.2 Methodology

The research was divided into four different segments to allow a cross sectional review of the need for Professional Management Skills to be evaluated. These segments are:

1. A series of discussions will be conducted with several Deans of Australian University Engineering Faculties (see pages 79 and 108) for their views on the subject of PMS.

2. A review of Engineering Australia’s stance regarding their criteria for the accreditation of Engineering faculties and graduate engineers will be carried out. The criteria for accreditation of graduate engineering courses will also be reviewed for the Engineering Council (UK) and ABET (USA).

3. A short pilot survey will be conducted to review the questionnaire and to evaluate the responses.

4. Following the literature study and its recommendations a questionnaire will be submitted to a range of potential employers of engineers in the Australian industrial scene. This will be carried out using a random selection process from a list of firms as indicated in Appendix 6 (page 283).

This research project will fall under the classification of basic or fundamental research. Basic research is

“where knowledge [is] generated to understand a phenomenon of interest to the researcher”. (Sekaran and Bougie, (2009)).

The method to be used is categorised as the hypothetico-deductive method and is carried out in seven steps, these being:

1. Identify a broad problem area
2. Define the problem statement
3. Develop hypothesis
4. Determine measures
5. Data collection
6. Data analysis
7. Interpretation of data

(Sekaran and Bougie, (2009))
Using the definitions and explanations included in Sekaran and Bougie (2009) the following table has been developed to encapsulate the various elements of the research project. The table refers primarily to the questionnaires that will be posted or hand delivered. Where there is a difference for the face to face interviews these comments are shown in italics.

This summation will relate to all four points mentioned in Chapter 3.2 (page 91). The first three points will be carried out by face to face interview or web search whilst point four will be by mailed out questionnaire.

The research design, as modified from Sekaran and Bougie (2009) is shown below and outlines how the research program will be carried out.
Table 3.1  Summary of the Research Design (After Sekaran and Bougie (2009))

<table>
<thead>
<tr>
<th>Study Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Research</td>
<td>Hypothetico-deductive</td>
</tr>
<tr>
<td>Research Design</td>
<td>Hypothesis testing</td>
</tr>
<tr>
<td>Type of investigation</td>
<td>Non-causal</td>
</tr>
<tr>
<td>Extent of researcher interference</td>
<td>Minimal</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>Study setting</td>
<td>Field study</td>
</tr>
<tr>
<td></td>
<td>Face to face interview</td>
</tr>
<tr>
<td>Unit of analysis</td>
<td>Organisational level</td>
</tr>
<tr>
<td>Sampling design</td>
<td>Random sampling based on the ABS ANZSIC listing, segments chosen to represent employers of engineers Selected respondents</td>
</tr>
<tr>
<td>Time horizon</td>
<td>Cross-sectional study, one contact only</td>
</tr>
<tr>
<td>Data collection method</td>
<td>Mailed out questionnaire</td>
</tr>
<tr>
<td></td>
<td>Interview – written notes</td>
</tr>
<tr>
<td>Measurement of Variables</td>
<td>Scale and ordinal variables (yes/no answers and Likert Scale)</td>
</tr>
<tr>
<td></td>
<td>Analysis of responses</td>
</tr>
</tbody>
</table>
3.3 Research Hypotheses

Research of academic literature covering the past four decades has shown the following:

Engineering management education is a relevant topic that is discussed at length in the literature.

Little has been done on the aspects of what constitutes PMS and what ‘managerial skills’ should be taught.

Below are listed the research hypothesis and the sub-hypothesis that guided the progress of this research project.

Research Hypotheses

1. That the current methods of teaching and the curricula content of undergraduate engineering education does not fully meet the needs of business (employers).

2. That engineering graduates, as currently educated, do not have the necessary management skills to assist business in achieving their organisational goals and objectives.

Sub-Hypotheses

1. That the current University curriculum for engineering undergraduate students does not prepare them for rapid integration into the engineering and commercial workforce.

2. That the skills and attributes required, of engineering graduates, by industry and commerce have not been fully identified.

3. That there are perceived negative reactions and poor motivation from undergraduate engineering students to business/management subjects.

4. That students have difficulties in accepting the relevance of engineering management education.
5. That the Australian Professional Engineering bodies recognise management studies are important, but they do not enforce that management attributes are addressed in the various accredited engineering courses within Australia.

6. That management concepts need be introduced into the undergraduate engineering curriculum for engineering students.

7. That communication subjects should be taught to undergraduate engineering students as part of their engineering curriculum.

The research project has been designed to test whether the research hypotheses and sub-hypotheses are supported and if the current training given to undergraduate engineers is satisfactory for the needs of employers of graduate engineers.

3.4 Sampling Considerations

From the available databases it was decided to use the Australian Bureau of Statistics web site and to draw the required number of respondents from the Australian and New Zealand Standard Industrial Classification 2006. ANZSIC is broken into 19 Divisions by application. The divisions are then subdivided into various subsections by particular activities within the industrial division.

The Divisions (six in total) and subsections chosen are listed in Appendix 5 (page 280). The total number of firms listed in each of the divisions was 18095 (refer to Sampling Schedule in Appendix 6 (page 283) for a break down of the number of firms in each Division and Subsection).

The overall listing of firms in each of the selected classifications was prepared and confirmed. Based on these discussions a sampling plan was developed. From this discussion, the required sample size was found to be 770 for a confidence level of ninety five percent (95%).
3.5 Measurement of Variables

The variables that are to be examined in this study are delineated by the individual questions in the questionnaire. Questions 1 to 8, 12, 13, 19, 20 and 21 require a Yes/No answer or for those unable to commit to a firm answer a five point Likert Scale is also included to allow a variation in the answer given. Question 20 also has a seven point Likert Scale included to allow a comment for those who chose “No” or “To some degree”. Questions 9 and 10 cover a series of attributes and a seven point Likert Scale for each attribute.

Question 11 requires a summary of the disciplines employed whilst Questions 15, 16, 18, 22 and 23 require a Yes/No answer only. Question 17 requires a Yes or modified No answer.

All answers are ordinal and will require only summation and collating to develop the raw data. This method follows that of Sekaran and Bougie (2009) who describe an ordinal scale as follows,

“An ordinal scale not only categorises the variables in such a way as to denote differences among the various categories, it also ranks-orders the categories in some meaningful way.”

(Sekaran and Bougie (2009))

3.6 Questionnaire Development

The questionnaire commenced with a preamble outlining the concept of the need for graduate engineers to possess professional skills to allow them to “fit” in with the organisation and to be productive from the commencement of their employment. This is based on the perceived need of any new employee to be productive as soon as possible.

The eight attributes are based on work by Peterson and Van Fleet (2004) and Robinson et al. (2005). The included definitions of the Management skills mentioned above (Peterson and Van Fleet (2004)) allow those completing the questionnaire to be fully conversant with the terms used in the questionnaire.

Another task which was covered within this survey was an attempt to determine if there are differing views of the required PMS for different disciplines. For example, would a mechanical
engineer, working for a manufacturing organisation (with marketing and technical duties) require a different skill set to a civil engineer working within a construction company?
The final format of the questionnaire (see Appendix 3 (page 259)) was a result of discussions with academic advisors, and feedback from the pilot survey. The questions were grouped together in order to obtain data that could be directly compared.

Questions 1 – 10 asked the respondents’ opinion on the eight attributes outlined above. Questions 1 – 8 asked for the personal opinion of the respondents to these attributes. Questions 9 and 10 each contained 8 sub-questions. Question 9 sought the opinion on the need for these attributes for the firm employing the respondents and Question 10 sought a response on behalf of the industry.

Question 11 was aimed at identifying how many engineers in total and of each discipline were employed by the respondents.

Questions 12 - 13 sought the views on the level of skills of engineers currently employed by the company. If the respondents believed some skills are missing the next question sought opinions on how graduate engineers could be taught these “missing skills”. Question 13 asked if the missing skills could be taught ‘on the job’.

Question 14 requested written comments on the skills that were deemed missing and which of these skills should be considered as part of the formal training of the undergraduate engineer.

Questions 15 and 16 looked for the respondents’ opinions on how engineering would change over the next five (5) years (Q15) and later (10 plus) years (Q16). These responses will be compared to results of Questions 1 – 10 to ascertain if the respondents see a need for management skills increasing with time.

Questions 17 to 23 were aimed at obtaining information about the various aspects of how engineers can be embedded into an organisation, considering the type of activities engineers can be expected to carry out.

Question 17 sought information on how quickly a graduate engineer may be required to take up (unspecified) managerial roles. Unfortunately the survey could not differentiate between part and full time graduates.
Question 18 looked at the need for graduate engineers to possess an (unspecified) degree of knowledge of the workings of the financial system and have some (unspecified) knowledge of Human Resource management.

Questions 19 and 20 sought the view of the respondents on the suitability of the newly employed graduate engineer to be incorporated into the organisation and contributing to the organisation’s goals immediately or very soon after employment.

Question 21 looks at the perceived view that undergraduate engineers profess a dislike for management subjects and believe that management will not be a part of their career.

Questions 22 and 23 sought the respondents’ views on whether employers want to take a greater role in the curriculum setting and also the training (by practical means) by the use of in plant projects, case studies etc..

Where possible the responses of different industries to the same question were analysed to see if the opinions varied according to different sized organisations and also a comparison was made to see if there was a difference between industrial divisions.

All questions had the option of commenting (both requested and volunteered). These were analysed to discover if there was a common thread.

3.7 Ethical Considerations

The University of Wollongong’s policy on ethical behaviour applied to this research. Accordingly, a proposal concerning the research and its potential effect on the participants was submitted to the Ethics committee on 14 December 2009 and was approved under reference number HE 09/397 on the 4 February 2010. After 12 months an application was submitted to extend the approval for another 12 months and was approved on the 4 February 2011 under the same reference number.

3.8 Face to Face Discussions

These discussions were held with several Deans of Engineering (pages 79 and 108) as well as with the staff of Engineers Australia (page 109) who were involved in setting the parameters of Competency Standards for Professional Engineers and in the bodies that accredit faculty’s curricula.
3.9 **Pilot Study**

A small pilot study comprising four (4) respondents was carried out to assess the suitability of the questionnaire and to gauge the reactions of the respondents to the aims of the research and their views on both of these aspects. The respondents were chosen for their knowledge of the employment and utilization of engineers in heavy industry as well as a theoretical knowledge of the requirements for accreditation.

3.10 **Conclusion**

The research project has been outlined and will seek to clarify the needs and wants of employers of graduate engineers. This project consists of several parts, the main one being the development of a questionnaire. This will be sent to a representative sample of a chosen group of potential employers of graduate engineers. This questionnaire will be augmented by a series of face to face discussions with Deans of Engineering as well as staff of Engineers Australia and a review of web sites for Engineers Australia, ABETS, The Royal Academy of Engineering and The Engineering Council UK.
CHAPTER 4 STATISTICAL ANALYSIS AND PRESENTATION OF DATA

4.1 Introduction – Statistical Analysis

The data collected from the questionnaire was collated and then summarised. The response rate was low with only 60 completed forms being returned. Seventy one questionnaires were returned as undeliverable. Unsuccessful attempts were made to track these organisations through the internet and telephone books. The response rate was 8.6% if the 71 undelivered are excluded or 7.8% if the total number of mailed questionnaires is included. The data was collated by question and by size of the responding organisation. Due to the relatively small number of respondents the responses were then summarised for each industry segment e.g. Manufacturing, and the response treated as one segment for analysis. In the segments which received the most responses further statistical analysis was then carried out.

The basic data is listed by question in Appendix 1 (page 221). To aid in the analysis the data in Appendix 1 was rearranged as shown in Appendix 2 (page 243) and used in that form in all statistical analysis. By rearranging some of the data it was transformed into a de facto seven point Likert scale. Further discussion on the effects of transforming the data will be covered in Sections 5.1.1 and 5.1.2 (pages 166 and 167).

4.2 Data Analysis Methods and Evaluations Chosen

Because data obtained from the survey questionnaire is at the ordinal level, neither means nor standard deviations were calculated. Chi squared tests were used where possible to test whether observed patterns within the responses to a question were significantly different from the null hypothesis of random allocation of responses among the categories for that question. In each case, statistical significance at the 5% significance level was considered as sufficient evidence for rejecting the null hypothesis, though, in fact, most results were much more highly significant. Chi squared tests on contingency tables were used to test for significant differences in responses from different industry sectors and from organisations of different sizes. Where the small number of responses to a question allowed only a 2x2 table to be tested, Fisher’s Exact Test was used.
4.3 Hypothesis Testings

Hypothesis testing can be carried out to determine the probability that the observed responses will be obtained if a stated null hypothesis is true. It is normally carried out using the following four (4) steps:

1. The null hypothesis $H_0$ (which is commonly framed as that the recorded observations are the result of pure chance) and the alternate hypothesis $H_1$ (normally the observed results show a real effect when it is combined with a component of chance variation).

2. Identify the statistics that will be used to assess the truth of the null hypothesis.

3. Calculate the $p$-values. These calculated values are the probability that a test statistic is at least as extreme as the one observed would be obtained, assuming the null hypothesis was true. The smaller the $p$-value the stronger the evidence against the null hypothesis.

4. Compare the $p$-values to an acceptable significance value $\alpha$. If $p \leq \alpha$ then the observed value is a statistically significant, the null hypothesis is rejected and the alternative hypothesis is accepted.

Modified from Weisstein (2010)

**Chi Squared Test**

A Chi Squared test is a non-parametric statistical hypothesis test in which the sampling distribution of the test statistics is a chi square distribution when the null hypothesis is true, or asymptotically true, meaning that the sampling distribution (if the null hypothesis is true) can be made to approximate a chi square distribution as closely as desired by making sample size large enough.

**Fisher’s Exact test** is a significance test used in the analysis of contingency tables where sample sizes are small. It is one of a class of exact tests, so called because the significance of the deviation from a null hypothesis can be calculated exactly, rather than relying on an approximation that becomes exact as the sample size grows to infinity, as with many statistical
tests. Fisher’s Exact test was used when required and is applied to various responses as shown in Appendix 2 (page 243).

According to Keller and Warrack (2003), in hypothesis testing there are two possible errors. These can occur when a true hypothesis is rejected (Type 1 error) and when a false null hypothesis is not rejected (Type 2 error).

The initial statistical analysis was carried out on all questions using a Chi Squared Test. This analysis is shown in Appendix 2 (page 243). The full results are summarised in Table A2.4 (page 251). The analysis showed 3 of the 37 overall responses were considered not significant at the 5% level. These questions were Questions 5, 21 and 23. Question 5 (below) had a Chi Squared value of 0.21387.

Question 5 - Conceptual

“Ability to see the organisation as a whole and to solve (organisational) problems from a systematic point of view.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree”

This question was solely based around management concepts and may have made it difficult for the respondents to provide a firm Yes/No answer. The results were “Yes” 33.9%, “No” 23.7% and “To some degree” 42.4%. Adding the “Yes” and “To some degree” totals gives a response of 76.3% which indicates the respondents feel their engineers do have some understanding of the skill mentioned. In Questions 9 and 10 the respondents indicated this skill was desirably.

Questions 21 and 23 had Chi Squared values of 0.13050 and 0.10247 respectively. Question 23 (requiring a “Yes” or “No” answer only) was retested using Binomial methods and was still not statistically significant. The results for both these questions are covered fully in Chapter 5 Section 5.8.5 (page 178).

4.4 Summary

The ordinal data gathered during the survey was statistically evaluated as described above. The results have been presented in both numerical as well as graphical form in this chapter. Where
possible, comparisons between each segment by types of organisation were carried out as well as comparisons between differing sized organisations within a segment. Results of these comparisons are also shown in this chapter.

4.5 Results of the Research Project

4.5.1 Introduction

The results of the pilot study, survey, the review of the Standards for Professional Engineer by The Royal Academy on Engineers, The Council of Engineers, UK, ABET, and EA and of discussions with individuals are presented in this chapter. For statistical analysis, in some cases, the questionnaire results were reordered from forms as listed in Appendix 1 (page 221) to form ordinal scales. The reordered data was used in the presentation of the results below and in the Discussion (Chapter 5 page 166). The results of the pilot study (Chapter 4.6.1 page 106) discussions with individuals (Chapter 4.6.2 page 108), Engineers Australia (Chapter 4.6.3 page 109) and review of overseas professional body’s web sites (Chapter 4.7 page 109) are dealt with first. Then the responses to each question of the survey and the analysis of the resulting data are then discussed in Chapter 4.8 (page 110).

In the questionnaire the responses fell into three categories. The first group required a “Yes” “No” answer only. The second group of questions required a “Yes” “No” answer or if this was not possible and the respondent felt the answer was between these two values then they could mark a 5 point Likert scale headed “To some degree”. The final group of questions sought to elicitate how important particular skills are to both individual organisations and the industry or service sectors they represent. These questions were scored on a 7 point Likert scale.

The sixteen sub-questions of Questions 9 and 10 required a response on a 7-point Likert scale and thus provide data on an ordinal scale. These responses were statistically analysed, as shown in Chapter 5 (page 166), to detect patterns differing significantly from a random allocation of scores among the seven categories of the Likert scale. The other major group of questions sought to determine whether newly graduated engineers possess the skills included in the second group of questions and, besides a “Yes” or “No” response, allows a response of “To some degree” using a 5-point Likert scale of 1 to 5. Initially, it was planned to convert the responses to a 7-point Likert scale with
“No” being scored as 0 and “Yes” being scored as 6. However, the patterns of responses within the “To some degree” category confused significance testing of some trends in the responses. Therefore after discussions with statisticians, “To some degree” was treated as a single category for initial significance testing of responses to the questions concerned. The “No”, “To some degree” and “Yes” then formed a 3-point ordinal scale. Additional information obtained from the patterns of responses within the “To some degree” category is also discussed, especially in Chapter 5 (page 166).

As is shown in Chapter 4.8.12, 13, (pages 130-138), statistical analysis of responses to Questions 9 and 10 provides significant evidence that the literature survey and other sources used in the design of the questionnaire correctly identified significant skills considered by the respondents, to be important to both the respondent’s organisation and the industry or service sector of which they belong. Similarly, statistical analysis of responses to those questions asking whether newly graduated engineers possess those required skills, provided significant evidence that employers are not completely satisfied with the degree to which newly graduated engineers possess those required skills. This confirms the gaps in the current training of engineers suggested in the earlier chapters of this thesis.

A full discussion of the conclusions and recommendations resulting from the statistical analysis is given in Chapter 5 (page 166).

The majority of responses to Question 9 and Question 10 were at the high end of the Likert scale indicating that the literature survey and other sources used in the design of the questionnaire had correctly identified skills that organisations consider important for an engineering graduate to possess.

All results are highly statistically significant except for Question 5. Further analysis showed the responses in the combined "To some degree" and "Yes" categories are very significantly higher than those in the "No" category (p=0.0003). That is, there is a very significant preference of the respondents for a "To some degree" response or a "Yes" response rather than a "No" response. This indicates that the responding employers do believe that Conceptual skills are present in their employed engineers on graduation, though this belief is not as strong as it is for some of the other skills mentioned in this section of the Questionnaire, namely, Diagnostic (Question 6) and Administrative (Question 8). In Questions 1, 2, 4 and 7, there are significantly more responses in the "To some degree" category than in either the "No" or "Yes" categories. This indicates
that while employers believe their newly graduated employed engineers have these skills to some degree, they are not completely satisfied with the levels of those skills. The additional calculations are attached to Question 5.

The Questions 9 and 10 were designed to check the importance of the attributes across the respondent’s firm and industry to ascertain if there was any variation in their importance between firm and industry levels. Tables 4.1 and 4.2 show the importance level of each skill is similar at firm and industry level.

**Table 4.1 Question 9: Skills importance to the individual organisation**

<table>
<thead>
<tr>
<th>Skill</th>
<th>Mode</th>
<th>Responses of more than 4 on 1 to 7 scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>5</td>
<td>66.1%</td>
</tr>
<tr>
<td>Communication</td>
<td>7</td>
<td>98.3%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>5</td>
<td>91.5%</td>
</tr>
<tr>
<td>Decision Making</td>
<td>6</td>
<td>94.9%</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>7</td>
<td>96.6%</td>
</tr>
<tr>
<td>Flexible</td>
<td>7</td>
<td>88.1%</td>
</tr>
<tr>
<td>Human Skills</td>
<td>6</td>
<td>91.5%</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>5.5*</td>
<td>93.1%</td>
</tr>
</tbody>
</table>

(*5 and 6 had equal frequencies)
Table 4.2 Question 10: Skills importance to the applicable industry

<table>
<thead>
<tr>
<th>Skill</th>
<th>Mode</th>
<th>Responses of more than 4 on 1 to 7 scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>5</td>
<td>69.0%</td>
</tr>
<tr>
<td>Communication</td>
<td>7</td>
<td>98.3%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>5</td>
<td>94.8%</td>
</tr>
<tr>
<td>Decision Making</td>
<td>7</td>
<td>94.8%</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>6</td>
<td>94.9%</td>
</tr>
<tr>
<td>Flexible</td>
<td>6</td>
<td>88.0%</td>
</tr>
<tr>
<td>Human Skills</td>
<td>6</td>
<td>93.0%</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>6</td>
<td>91.4%</td>
</tr>
</tbody>
</table>

All responses had modes greater than the mid-range value of 4 and all skills, except Administration, had more than 88% of responses greater than 4. The modes tended to be a little higher for Question 9 than Question 10 which indicates that although respondents considered all skills except Administration to be very important, for both their own organisation and their manufacturing or service sector, they were a little less sure of their importance to their industry or service sector than they were of the importance to their individual organisations. The results for Questions 9 and 10 were also analysed using the Mann Whitney U test using pair wise comparisons to ascertain if the responses to these questions were significantly different and whether these skills could be ranked in importance. These results are discussed more fully in Chapter 5 (page166).

4.6 Results - Discussions

4.6.1 Pilot Study

The pilot study was carried out using four (4) individuals located within the Wollongong area. All had engineering and management experience and three (3) of these had experience in employing engineers over a significant period of time.

The four were:
John Flanagan, Fellow of the University of Wollongong. John was employed by BHP for 35 years in process improvement, process automation, logistics and quality management. He also taught for 17 years at the University of Wollongong where he developed new courses in logistics and operations management, quality management and engineering management.

Umar Ali Asslam, Consulting engineer, Bachelor of Engineering Degree in Electronics and Communication Engineering, Master Business Administration Advanced with Distinction major in Engineering Management and a Master of International Business. Asslam began his career in the midst of the Dubai construction boom working for a manufacturing conglomerate and dealing with a range of construction sector clients spread across the Middle East and Asia. Asslam currently works with Sydney Business School as Special Projects Officer. He focuses on market research, course work research, quality assurance and marketing communication.

Dr. Lee Styger MSc PhD CEng CSci CEnv FIED FIMMM FICME REngDes SMSME MIEAust Lecturer Sydney Business School, University of Wollongong. Lee has over 25 years experience in business reconfiguration, new product development, international research and advanced manufacturing technology.

Gary Dewhurst, Retired Engineer, with 48 years experience in engineering activities. General Manager Alminco Pty Ltd. Currently Operations Manager at Alminco (short term contract). Was General Manager for 5 years.

The views expressed by this pilot group in their completed questionnaires and in face to face discussions generally agreed with those which were subsequently expressed in the full scale questionnaire.

Discussions on the question on the difficulty of finding suitably skilled engineers, led to its removal from the final questionnaire.

Overall the responses indicated that the questionnaire was suitable and would generate the information sought.
4.6.2 Face to Face Personal Discussions

Discussions were held with Professor Chris Cook, the current Dean of Engineering at the University of Wollongong and with Professor Robin King, Emeritus Professor at the University of South Australia, an Adjunct Professor at the University of Technology Sydney and Executive Officer of the Australian Council of Engineering Deans (ACED). Comments by the former Dean of Engineering UOW Professor Brendan Parker are included.

The purpose of these meetings was to discuss the setting of curricula and the methods by which information is gathered from employers of graduate engineers and to find out how these representatives of advisory committees are chosen.

A meeting with Professor Chris Cook was held during May 2010 and the following points were made:

The deans meet regularly to discuss various matters pertaining to the various Schools and to decide on the general format of engineering courses, in conjunction with Engineers Australia.

Engineers Australia accredits engineering courses. These courses are accredited to monitor the acceptance of graduate engineers into the various grades of the professional body.

Professor Cook advised the author to contact Professor Robin King, Executive Officer of the ACED to discuss the thoughts of other Engineering Deans. Notes on the discussions can be found on pages 79 and 109.

The University of Wollongong also uses Faculty Advisory Committees to check with employers as to the attributes they require in their graduate engineers.

Comments made to the author by Professor Parker (former Dean of Engineering, UOW) during early discussions in 2008 are summarised as follows:

Employers are no longer willing to train engineers in the various aspects of their position, including dealing with other engineers and customers, but expect
them to begin earning income for the company from the moment that they sit down at their desk on day one.

Discussions were held with Professor King (2010) on several occasions (pages 79 and 109). For information on EA matters the author was advised to contact Alan Bradley (Professor Emeritus and Associate Director of Engineers Australia) who was basically responsible for the development of competency standards for Professional Engineer. Professor Bradley subsequently retired and was replaced by Professor Peter Hoffman.

Professor King supplied a copy of “Engineers for the Future – addressing the supply and quality of Australian engineering graduates for the 21st century” (King 2008) together with a booklet containing a Summary and Recommendations.

4.6.3 Discussions with Engineers Australia

Phone discussions were held with Professor Bradley (2010) who outlined the competency standards required of a Professional Engineer. Engineers Australia was, at the time, finalising a revision of these requirements and Professor Bradley provided a draft of the new guidelines. Subsequently they were finalised and a copy is attached in Appendix 4 page 270.

General discussion on management skills elicited the comment that EA set general guidelines and then it was up to the relevant University Faculty to translate these into specific subjects and then justify these subjects to the accrediting body.

The competency standard mentions management in general terms but does not specifically mention any of the skills (with the exception of communication) outlined above. The Competency Standards are included in Appendix 4 (page 270).

4.7 Review of the Web sites of Other Professional Bodies

Other professional engineering bodies’ web sites were reviewed and comments and accreditation details which were applicable to graduate engineers are covered in Chapter 2 Section 2.13 (page 79) and Chapter 5 Section 5.4 (page 168).
4.8 Results of the Questionnaire

The results of each question in the questionnaire are listed below. The questions have been grouped together when they provide data on specific areas. Where they are stand alone responses they will be dealt with individually. The wording of each question will preface the data generated for that question.

A list of comments made by the respondents is attached to the relevant question. Each comment has a reference that allows the identification of the industry segment as well as the organisation size. The key to this reference is shown in Appendix 6 (page 283). For comments on the analysis of data refer to Chapter 4.2 and 4.3 (pages 100 and 101).

The data for each question, where applicable, can be presented in three ways.

- As summated ordinal data
- As a graph showing the results of all responses
- As a graph (for those questions which required a “To some degree” answer) showing the results as a “Yes”, “No” and a totalled “To some degree”.

4.8.1 Question 1 - Decision Making Ability

Examples of statistical calculations are attached to relevant questions.

In all statistical presentations NR* means “No Response”. This abbreviation will be maintained throughout Chapter 4.
Question 1 – Decision Making Ability

To be able to assess and decide between competing solutions to a particular problem.

No  To some degree  Yes  No  To some degree  Yes

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5</td>
<td>3.4</td>
<td>15.3</td>
<td>18.6</td>
<td>6.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Figure 4.1  Results of Question 1

In summary, 57.6% responded “Yes”, 54.3% had a response of 4 or more, whilst 91.5% responded “Yes” or “To some degree”.

111
4.8.2 Question 2 (a) Human Skills

a) To be able to work with, communicate, negotiate and relate to others both within the organisation as well as outside the organisation.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Percentage**

- No: 8.5
- To some degree: 8.5, 28.8, 8.5, 0.0, 45.8
- Yes: 8.5, 45.7, 45.8

![Figure 4.2 Results of Question 2(a)](image)

In summary, 45.8% responded “Yes”, 54.3% had a response of 4 or more, whilst 91.5% responded “Yes” or “To some degree”.

112
Question 2 (b)

Also be able to teach others, work in groups and with individuals at various levels of management. Resolve conflicts.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree. Please comment on the individual elements of the question if you wish to.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
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<td>1</td>
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<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Percentage**

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Yes %</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5</td>
<td>6.8</td>
</tr>
<tr>
<td>15.3</td>
<td>23.7</td>
</tr>
<tr>
<td>10.2</td>
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<tr>
<td>35.6</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.3 Results of Question 2(b)**

In summary, 35.6% responded “Yes”, 45.8% had a response of 4 or more, whilst 91.5% responded “Yes” or “To some degree”.

113
4.8.3 Question 3 - Communication

Be able to send and receive information, thoughts and feelings, which create common understanding and meaning.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
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<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Percentage 8.5 3.4 11.9 28.8 11.9 0.0 35.6

Figure 4.4 Results of Question 3

In summary, 35.6% responded “Yes”, 47.5% had a response of 4 or more, whilst 91.5% responded “Yes” or “To some degree”.

114
4.8.4 Question 4 - Interpersonal

Ability to develop and maintain a trusting and open relationship with superiors, subordinates, peers and external personnel to facilitate the free exchange of information and provide a productive work setting.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
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<td>4</td>
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</tr>
<tr>
<td>Percentage</td>
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<td>0.0</td>
<td>5.0</td>
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</table>

<table>
<thead>
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<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.5</td>
<td>52.5</td>
<td>39.0</td>
</tr>
</tbody>
</table>

In summary, 39.0% responded “Yes”, 71.2% had a response of 4 or more, whilst 91.5% responded “Yes” or “To some degree”.

Figure 4.5 Results of Question 4
4.8.5 Question 5 - Conceptual

Ability to see the organisation as a whole and to solve (organisational) problems from a systematic point of view.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>23.7</td>
<td>1.7</td>
<td>18.6</td>
</tr>
</tbody>
</table>

In summary, 33.6% responded “Yes”, 39.0% had a response of 4 or more, whilst 76.3% responded “Yes” or “To some degree”.

Figure 4.6 Results of Question 5
<table>
<thead>
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<th>To some degree</th>
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<td></td>
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<tr>
<td>21 - 99</td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>100 +</td>
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<td></td>
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<tr>
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<td>3</td>
<td></td>
<td>1</td>
<td>8</td>
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<tr>
<td>21 - 99</td>
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<td>3</td>
<td>1</td>
<td></td>
<td>8</td>
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<td>4</td>
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<td>% of responses</td>
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<td>1.7</td>
<td>18.6</td>
<td>16.9</td>
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**Question 5**

<table>
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<tr>
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<td>16.9</td>
<td>3.4</td>
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</table>

Chi Squared Tests

<table>
<thead>
<tr>
<th>Obs</th>
<th>Exp</th>
<th>Obs-Exp</th>
<th>((o-e)^2/n)</th>
<th>Chi Squared =</th>
<th>Degrees of freedom =</th>
<th>P(Chi Squared) =</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
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<td>1.446328</td>
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<tr>
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<td>0.333</td>
<td>0.00565</td>
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<td></td>
</tr>
</tbody>
</table>

H₀: In the population, responses are equally allocated among the three categories. Not rejected, P(Chi Squared) = 0.214.

The observed responses do not differ significantly from an equal spread among the three categories.

<table>
<thead>
<tr>
<th>Observed</th>
<th>Expected</th>
<th>o-e</th>
<th>((o-e)^2/e)</th>
<th>Chi Sq =</th>
<th>d.f =</th>
<th>p(Chi Sq) =</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5.571</td>
<td>3.682809</td>
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<td>6</td>
<td>8.4043E-07</td>
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<td>6.547215496</td>
<td>6.4043E-07</td>
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</tr>
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<td>0.292978</td>
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</tr>
</tbody>
</table>

H₀: In the population, responses are equally allocated among the seven categories. Rejected, P(Chi Squared) = 8.40x10⁻⁷.

This result indicates that "To some extent" should be treated as a single category as above.
Question 5

<table>
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<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</tr>
</thead>
<tbody>
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<td>Observed</td>
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<td>11</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Expected</td>
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<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
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</tr>
<tr>
<td>o-e</td>
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<td>6.000</td>
<td>5.000</td>
<td>-3.000</td>
<td>-4.000</td>
<td></td>
</tr>
<tr>
<td>(o-e)^2/e</td>
<td>3.20000</td>
<td>7.20000</td>
<td>5.00000</td>
<td>1.80000</td>
<td>3.20000</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Chi Sq} = 20.40000  \quad \text{d.f} = 4  \quad \text{P(Chi Sq)} = 0.00041631 \quad \text{Significant}
\]

\(H_0\): In the population, responses are equally allocated among the five ranks. Rejected, \(p(\text{Chi Squared}) = 0.0004\).

There is significant clustering of responses into ranks 2 and 3.

Chi Squared Tests

<table>
<thead>
<tr>
<th>Obs</th>
<th>Exp</th>
<th>Obs-Exp</th>
<th>(o-e)^2/n</th>
<th>Chi Squared =</th>
<th>Degrees of freedom =</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>14</td>
<td>29.500</td>
<td>-15.500</td>
<td>8.144068</td>
<td>2</td>
</tr>
<tr>
<td>Some/Yes</td>
<td>45</td>
<td>29.500</td>
<td>15.500</td>
<td>8.144068</td>
<td>0.00029</td>
</tr>
</tbody>
</table>

\(H_0\): In the population, responses are equally allocated among the five ranks.

Rejected, \(p(\text{Chi Squared}) = 0.0003\).

There are significantly more responses in the "To some degree" or "Yes" categories than would be expected by chance.
4.8.6  Question 6 - Diagnostic

Ability to determine the probable cause(s) of a problem from examining the relevant data and observations by the manager.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentage: 0.0  6.8  3.0  18.6  11.9  1.7  57.6

In summary, 57.6% responded “Yes”, 71.2% had a response of 4 or more, whilst 100% responded “Yes” or “To some degree”.

Raw data and an example (for Question 6) of the statistical analysis follows:
Table 4.4 Statistical Analysis of Question 6

<table>
<thead>
<tr>
<th>Question 6</th>
<th>Yes</th>
<th>No</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>No Response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>21 - 99</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>100 +</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Consulting</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>21 - 99</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>100 +</td>
<td>2</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>100 +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>21 - 99</td>
<td>8</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>100 +</td>
<td>5</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
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<tr>
<td>PS &amp; U</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
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<td></td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>100 +</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
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<td></td>
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<tr>
<td>To 20</td>
<td>1</td>
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<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
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<td></td>
<td>4</td>
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<tr>
<td>100 +</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Column Totals</td>
<td>34</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>% of responses</td>
<td>57.6</td>
<td>0.0</td>
<td>6.8</td>
<td>3.4</td>
<td>18.6</td>
<td>11.9</td>
<td>1.7</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Total responses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59</td>
</tr>
</tbody>
</table>
### Question 6

<table>
<thead>
<tr>
<th>Percent</th>
<th>0.0</th>
<th>6.8</th>
<th>3.4</th>
<th>18.6</th>
<th>11.9</th>
<th>1.7</th>
<th>57.6</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>1</td>
<td>34</td>
<td>59</td>
</tr>
</tbody>
</table>

Chi Squared Tests

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Exp</th>
<th>Obs-Exp</th>
<th>(o-e)^2/n</th>
<th>Chi Squared =</th>
<th>Degrees of freedom =</th>
<th>n =</th>
<th>P(Chi Squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>0</td>
<td>19.667</td>
<td>-19.667</td>
<td>19.66667</td>
<td>31.55932</td>
<td>2</td>
<td>59</td>
<td>0.00000</td>
</tr>
<tr>
<td>Some</td>
<td>25</td>
<td>19.667</td>
<td>5.333</td>
<td>1.446328</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>34</td>
<td>19.667</td>
<td>14.333</td>
<td>10.44633</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H₀: In the population, responses are equally allocated among the three categories. Rejected, P(Chi Squared) < 0.00001.

The 57.6% "Yes" response coupled with a zero "No" response is very statistically significant.

<table>
<thead>
<tr>
<th>Observed</th>
<th>57.6</th>
<th>10.0</th>
<th>18.6</th>
<th>11.9</th>
<th>1.7</th>
<th>6.8</th>
<th>100.0</th>
<th>59</th>
</tr>
</thead>
<tbody>
<tr>
<td>d.f</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H₀: In the population, responses are equally allocated among the seven categories. Rejected, P(Chi Squared) = 1.70x10^-9.

This result indicates that "To some degree" should be treated as a single category.
## Question 6

```
--------------------------- To some degree ---------------------

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Expected</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td></td>
</tr>
<tr>
<td>o-e</td>
<td>-1.000</td>
<td>-3.000</td>
<td>6.000</td>
<td>2.000</td>
<td>-4.000</td>
<td></td>
</tr>
<tr>
<td>(o-e)^2/e</td>
<td>0.20000</td>
<td>1.80000</td>
<td>7.20000</td>
<td>0.80000</td>
<td>3.20000</td>
<td></td>
</tr>
</tbody>
</table>
```

Chi Sq = 13.20000  d.f = 4  
P(Chi Sq) = 0.0103388  Significant

$H_0$: In the population, responses are equally allocated among the five ranks. Rejected, P(Chi Squared) = 0.0103.

There is significant clustering of responses into ranks 3 and 4.
4.8.7 Question 7 - Flexible

Ability to deal with ambiguous and complex situations and rapidly changing demands.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>11.9</td>
<td>5.1</td>
<td>20.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>11.9</td>
<td>54.2</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Figure 4.8 Results of Question 7

In summary, 33.9% responded “Yes”, 49.2% had a response of 4 or more, whilst 88.1% responded “Yes” or “To some degree”.

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4.8.8 Question 8 - Administration

Ability to follow policies and procedures, process paper work in an orderly manner and manage expenditures within the limits set by budgets.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Percentage

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.8</td>
<td>5.1</td>
</tr>
<tr>
<td>2</td>
<td>5.1</td>
<td>15.3</td>
</tr>
<tr>
<td>3</td>
<td>10.2</td>
<td>1.7</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>55.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.8</td>
<td>37.3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>55.9</td>
</tr>
</tbody>
</table>

Figure 4.9 Results of Question 8

In summary, 55.9% responded “Yes”, 67.8% had a response of 4 or more, whilst 93.2% responded “Yes” or “To some degree”.

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4.8.9 Additional Statistical Analysis of Responses to Questions 1 – 8

Additional comparisons of the responses to Questions 1 – 8 were carried out to ascertain if there were significant differences between the two major groups - Consulting (20%) and Manufacturing (41.7%). The results of these tests indicate there are no significant differences between the responses from the two sectors.

As Manufacturing and Consulting made up the bulk of the responses with the number of responses from the other sectors being small, there is no significant evidence of any difference in responses from organisations from different sectors of the economy.

The responses between small or medium sized companies (up to 99 employees) and the large organisations (100 or more employees) were statistically analysed and again the results showed no significant differences between the two groups. Samples of the calculations follow, whilst the full results are in Appendix 1 (page 221) where the calculations are to be found with each question.

4.8.10 Comments from the Respondents on Questions 1 - 8

A few comments were written in by respondents. These are as follows:

Question 1 Decision Making Ability

They need to not (only) understand the technical implications and assessments but also the contractual and administration flow as well.  

Question 2 (b) Human Skills

How do I separate their personal characteristics and behaviour from what they have generically acquired as skills through training?  

This seems more to vary with an individual personality rather than their training when at graduate level.

Not in all engineers and not great in those who have some skills.
These skills are definitely present in some engineers we have employed, but not all. A lot of this relates to self confidence. (DM)

Conflict resolution is acquired with experience. Do you think you can teach it? (DM)

You’ve asked me to respond to seemingly unrelated aspects. Able to teach others? No. Work in groups? Yes. Resolve conflicts? No. (BS)

Question 3 Communication

New graduates are often hopeless. They get better as they learn to write English. (BS)
4.8.11  Summary of the Responses to Questions 1 - 8

Below is a summary of the results for Questions 1 – 8. These responses are also shown in graphical form in Figure 4.10 below.

Table 4.5  Comparison of Desirability of Management Skills as shown in Questions 1 – 8

<table>
<thead>
<tr>
<th>Question</th>
<th>Skill</th>
<th>Yes</th>
<th>To some degree</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Decision Making</td>
<td>47.5</td>
<td>44.0</td>
<td>8.5</td>
</tr>
<tr>
<td>2.</td>
<td>Human Skills</td>
<td>45.8</td>
<td>45.7</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>(a)</td>
<td>35.6</td>
<td>55.9</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>35.6</td>
<td>55.9</td>
<td>8.5</td>
</tr>
<tr>
<td>3.</td>
<td>Communication</td>
<td>35.6</td>
<td>55.9</td>
<td>8.5</td>
</tr>
<tr>
<td>4.</td>
<td>Interpersonal</td>
<td>39.0</td>
<td>52.5</td>
<td>8.5</td>
</tr>
<tr>
<td>5.</td>
<td>Conceptual</td>
<td>33.9</td>
<td>42.4</td>
<td>23.7</td>
</tr>
<tr>
<td>6.</td>
<td>Diagnostic</td>
<td>57.6</td>
<td>42.4</td>
<td>0</td>
</tr>
<tr>
<td>7.</td>
<td>Flexible</td>
<td>33.9</td>
<td>54.2</td>
<td>11.9</td>
</tr>
<tr>
<td>8.</td>
<td>Administration</td>
<td>55.9</td>
<td>37.3</td>
<td>6.8</td>
</tr>
</tbody>
</table>

It should be noted that other management skills, such as marketing, OH&S, Quality Management and Customer Relations (and possibly others) were not addressed in this research program. However some of these skills were commented upon by respondents within the comments sections of the questionnaire.
Figure 4.10 Graphical results (percentages) from Questions 1 – 8 for “Yes” and “To some degree”
(As the responses to the “No” option were minimal these have not been included)
4.8.12 Questions 9 and 10

Please indicate the importance each of these attributes has to your industry by circling the appropriate number, with one (1) being least important and seven (7) being most important. If you have no viewpoint or consider the skills as irrelevant to your industry please circle 1 (one).

The responses sought for these two questions were to be presented as a Likert seven (7) point scale. Question 9 sought the responses from the viewpoint of the respondents firm and Question 10 sought similar views but from an industry perspective. On the seven point Likert scale 1 was a very negative response whilst 7 was a very strong positive response. The results are as tabulated below in Table 4.6 and Table 4.7

**Question 9**

<table>
<thead>
<tr>
<th>Likert scale value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
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<tbody>
<tr>
<td>Decision Making</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.1</td>
<td>28.8</td>
<td>33.9</td>
<td>32.2</td>
</tr>
<tr>
<td>Human Skills</td>
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<td>0</td>
<td>1.7</td>
<td>6.8</td>
<td>28.8</td>
<td>40.7</td>
<td>22.0</td>
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<td>0</td>
<td>0</td>
<td>1.7</td>
<td>11.9</td>
<td>37.3</td>
<td>49.2</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>5.2</td>
<td>32.8</td>
<td>32.8</td>
<td>27.6</td>
</tr>
<tr>
<td>Conceptual</td>
<td>0</td>
<td>1.7</td>
<td>0</td>
<td>6.8</td>
<td>35.6</td>
<td>30.5</td>
<td>25.4</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>3.4</td>
<td>28.8</td>
<td>32.2</td>
<td>35.6</td>
</tr>
<tr>
<td>Flexible</td>
<td>1.7</td>
<td>0</td>
<td>3.3</td>
<td>6.7</td>
<td>26.7</td>
<td>28.3</td>
<td>33.3</td>
</tr>
<tr>
<td>Administration</td>
<td>0</td>
<td>0</td>
<td>8.5</td>
<td>25.4</td>
<td>35.6</td>
<td>20.3</td>
<td>10.2</td>
</tr>
</tbody>
</table>
The graphs for all the attributes in Question 9 follow:

**Question 9**

**Decision Making**

**Human Skills**

**Communication**

**Interpersonal**
Figure 4.11  Graphical results for Question 9
Question 10

Please indicate the importance each of these attributes has to your firm by circling the appropriate number, with one (1) being least important and seven (7) being most important? If you have no viewpoint or consider the skills as irrelevant to your firm please circle 1 (one).

<table>
<thead>
<tr>
<th>Likert scale value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Making</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
<td>19.0</td>
<td>32.8</td>
<td>43.1</td>
</tr>
<tr>
<td>Human Skills</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7.0</td>
<td>33.3</td>
<td>36.8</td>
<td>22.8</td>
</tr>
<tr>
<td>Communication</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>10.3</td>
<td>27.6</td>
<td>60.3</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>0</td>
<td>0</td>
<td>3.4</td>
<td>5.2</td>
<td>32.8</td>
<td>34.5</td>
<td>24.1</td>
</tr>
<tr>
<td>Conceptual</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
<td>32.8</td>
<td>31.0</td>
<td>31.0</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>3.4</td>
<td>20.7</td>
<td>39.7</td>
<td>34.5</td>
</tr>
<tr>
<td>Flexible</td>
<td>1.7</td>
<td>0</td>
<td>3.4</td>
<td>8.6</td>
<td>19.0</td>
<td>36.2</td>
<td>31.0</td>
</tr>
<tr>
<td>Administration</td>
<td>0</td>
<td>1.7</td>
<td>3.4</td>
<td>25.9</td>
<td>29.3</td>
<td>24.1</td>
<td>15.5</td>
</tr>
</tbody>
</table>
The graphs for all the attributes in Question 10 follow:

**Question 10**

**Decision Making**

**Human Skills**

**Communication**

**Interpersonal**
An example of the statistical analysis used for both Questions 9 and 10 is shown below. This analysis is the same for all parts of Questions 9 and 10.
<table>
<thead>
<tr>
<th>Question 10</th>
<th>Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Mining</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>Consulting</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>Construction</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>PS and U</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>Transport</td>
<td>To 20</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
</tr>
<tr>
<td>Question 10</td>
<td>Administration</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Percent of responses</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observed No. of responses</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>15</td>
<td>17</td>
<td>14</td>
<td>6</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(0-e)^2/e</td>
<td>7.857</td>
<td>5.984</td>
<td>4.366</td>
<td>6.494</td>
<td>10.639</td>
<td>4.803</td>
<td>0.439</td>
<td>40.582</td>
</tr>
</tbody>
</table>

Chi Squared = 40.582
Deg of freedom = 6
P(Chi Squared) = 3.5E-07

H0: (Population ranked responses 1 to 7 equally) was rejected

The respondents rank Administrative skills as being unimportant to highly important with scores ranging from 2 to 7 on the Likert scale. The mode was 5 which had 29.3% of the responses whilst 4 had 25.9% and 6 had 24.1%. This is very significantly different from an equal spread over all seven scores; p(Chi Squared) = 3.50x10^-7.
4.8.13 Comments on the Spread of Data for each Management Skill

The responses for both Questions 9 and 10 were found to be statistically significant. Full comments and calculations of the mode and spread of the data are listed in Appendix 2 (page 243).

One interesting point about the results from all questionnaire responses was that there were few responses in the lower values of the Likert scale. In Question 9, 83.7% of responses were 4 or above and in Question 10, 75% of responses were 4 or above. This would indicate all these aspects of management were considered important to both the individual organisation and to the sector of which it forms a part.

The possibility that the data exhibited non random selection or end-piling was considered but as discussed in Chapter 5.1.1 page 167. This possibility was dismissed.

For Question 9 and Question 10 the ranges of Likert scale values and the modes are as shown in Table 4.6 and Table 4.7 above (pages 130 and 133).

The tables show that in general the mode is towards the high end of the Likert scale, the positive end, and shows that the majority of the respondents agree it is important for both their own organisation and their industry or service sector that newly graduated engineers possess the listed management skills.

Further analysis was carried out to ascertain whether this was a statistically significant difference in responses from the two major groups of respondents – Consulting and Manufacturing. There was found to be no significant difference between the two types of organisations, which is very interesting as one segment is composed of service organisations whilst the other is composed of manufacturing organisations.

Analysis was then carried out to compare the responses from different sized organisations and no significant differences were found. Thus conclusions from the survey responses can be applied to organisations of all sizes.
Summary of Question 9 Responses

The respondents ranked **Decision Making** skills as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 6 which had 33.9% of the responses whilst 7 had 32.2% and 5 had 28.8%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 1.99 \times 10^{-12} \).

The respondents ranked **Human Skills** as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 6 which had 40.7% of the responses whilst 5 had 28.8% and 7 had 22.0%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 3.11 \times 10^{-12} \).

The respondents ranked **Communication** skills as being from moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 7 which had 49.2% of the responses whilst 6 had 37.3% and 5 had 11.9%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 3.44 \times 10^{-20} \).

The respondents ranked **Interpersonal** skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 5 and 6 which each having 32.8% of the responses whilst 7 had 27.6%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 2.52 \times 10^{-11} \).

The respondents ranked **Conceptual** skills as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 5 which had 35.6% of the responses whilst 6 had 30.5% and 7 had 25.4%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 3.60 \times 10^{11} \).

The respondents ranked **Diagnostic** skills as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 7 which had 35.6% of the responses whilst 6 had 32.2% and 5 had 28.8%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 2.65 \times 10^{-13} \).
The respondents ranked **Flexible** skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 7 which had 33.9% of the responses whilst 6 had 28.8% and 5 had 25.4%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 8.84 \times 10^{-10} \).

The respondents ranked **Administration** skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 5 which had 35.6% of the responses whilst 4 had 25.4% and 6 had 20.3%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 6.33 \times 10^{-8} \).

**Summary of Responses to Question 10**

The respondents ranked **Decision Making** skills as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 7 which had 43.1% of the responses whilst 6 had 32.8% and 5 had 19.0%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 1.72 \times 10^{-14} \).

The respondents ranked **Human Skills** as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 6 which had 36.8% of the responses whilst 5 had 33.3% and 7 had 22.8%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 6.25 \times 10^{-12} \).

The respondents ranked **Communication** skills as being from moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 7 which had 60.3% of the responses whilst 6 had 27.6% and 5 had 10.3%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 1.31 \times 10^{-24} \).

The respondents ranked **Interpersonal** skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 6 which had 34.5% of the responses whilst 5 had 32.8% and 7 had 24.1%. This is very significantly different from an equal spread over all seven scores; \( p(\text{Chi Squared}) = 6.96 \times 10^{-11} \).
The respondents ranked **Conceptual** skills as being moderately important to highly important with scores ranging from 4 to 7 on the Likert scale with the mode being 5 which had 32.8% of the responses whilst 6 had 31.0% and 7 had 31.0%. This is very significantly different from an equal spread over all seven scores; $p(\text{Chi Squared}) = 4.60 \times 10^{-12}$.

The respondents ranked **Diagnostic** skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale with the mode being 6 which had 39.7% of the responses whilst 7 had 34.5% and 5 had 20.7%. This is very significantly different from an equal spread over all seven scores; $p(\text{Chi Squared}) = 1.51 \times 10^{-13}$.

The respondents ranked **Flexible** skills as being quite unimportant to highly important with scores ranging from 1 to 7 on the Likert scale with the mode being 6 which had 36.2% of the responses whilst 7 had 31.0% and 5 had 19.0%. This is very significantly different from an equal spread over all seven scores; $p(\text{Chi Squared}) = 1.44 \times 10^{-9}$.

The respondents rank **Administration (financial)** skills as being unimportant to highly important with scores ranging from 2 to 7 on the Likert scale with the mode being 5 which had 29.3% of the responses whilst 4 had 25.9% and 6 had 24.1%. This is very significantly different from an equal spread over all seven scores; $p(\text{Chi Squared}) = 3.50 \times 10^{-7}$.

Table 4.9 below presents a comparison of modes and ranges of the results for Questions 9 and 10. As can be seen it shows clearly all attributes are considered important with modes generally in the 5, 6 and 7 range.
<table>
<thead>
<tr>
<th></th>
<th>Question 9</th>
<th></th>
<th>Question 10</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mode</td>
<td>Mode Percent</td>
<td>Range</td>
<td>Mode</td>
</tr>
<tr>
<td>Decision making</td>
<td>4 – 7</td>
<td>6</td>
<td>33.9</td>
<td>4 – 7</td>
<td>7</td>
</tr>
<tr>
<td>Human Skills</td>
<td>3 – 7</td>
<td>6</td>
<td>40.7</td>
<td>4 – 7</td>
<td>6</td>
</tr>
<tr>
<td>Communication</td>
<td>4 – 7</td>
<td>7</td>
<td>49.2</td>
<td>4 – 7</td>
<td>7</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>3 – 7</td>
<td>between 5 and 6</td>
<td>32.8 (both)</td>
<td>3 – 7</td>
<td>6</td>
</tr>
<tr>
<td>Conceptual</td>
<td>4 – 7</td>
<td>5</td>
<td>35.6</td>
<td>4 – 7</td>
<td>5</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>4 – 7</td>
<td>7</td>
<td>35.6</td>
<td>3 – 7</td>
<td>6</td>
</tr>
<tr>
<td>Flexible</td>
<td>3 – 7</td>
<td>7</td>
<td>33.3</td>
<td>1 – 7</td>
<td>6</td>
</tr>
<tr>
<td>Administration</td>
<td>3 – 7</td>
<td>5</td>
<td>35.6</td>
<td>2 – 7</td>
<td>5</td>
</tr>
</tbody>
</table>
4.8.14 Question 11

This question sought the range of engineering disciplines, together with the number of engineers employed within each discipline. A total of 829 engineers were employed by the respondents and their distribution among the disciplines is shown in the Table 4.10 below.

As can be seen there was a wide spread of disciplines although a large percentage of the engineers were not fully identified. Further research is needed to clarify the 43.3% not classified to assess whether the results of the survey are discipline oriented or general across all disciplines. However, responses do cover the major disciplines included in an Engineering Faculty. Those disciplines covered by an Informatics Faculty were not included as the survey was limited to the traditional engineering disciplines.

Table 4.10 Engineers Employed by Discipline

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number Employed</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>198</td>
<td>23.6</td>
</tr>
<tr>
<td>Mining</td>
<td>33</td>
<td>4.0</td>
</tr>
<tr>
<td>Civil</td>
<td>198</td>
<td>23.6</td>
</tr>
<tr>
<td>Materials</td>
<td>16</td>
<td>1.9</td>
</tr>
<tr>
<td>Mechatronics</td>
<td>25</td>
<td>3.0</td>
</tr>
<tr>
<td>*Others</td>
<td>359</td>
<td>43.3</td>
</tr>
</tbody>
</table>

*This table of engineering disciplines was restricted to the traditional engineering disciplines in the belief that the vast number of engineering positions would be covered. Any further research should include the other disciplines such as electrical, computer, materials, environmental etc..
4.8.15 Question 12

Are you satisfied with the skills of the engineers you employ? Please mark the relevant box. If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No</strong></td>
<td>10.7</td>
<td>0</td>
<td>3.6</td>
<td>16.1</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>To some degree</strong></td>
<td>10.7</td>
<td>41.1</td>
<td>48.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Yes</strong></td>
<td>10.7</td>
<td>3.6</td>
<td>16.1</td>
<td>3.6</td>
<td>48.2</td>
</tr>
</tbody>
</table>

Figure 4.13 Results of Question 12

In summary, 48.2% responded “Yes”, 69.7% had a response of 4 or more, whilst 89.3% responded “Yes” or “To some degree”.

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Comments from the Questionnaire – Question 12

Conceptual, human skills, decision making rank 5 (FL)

Ethics, emotional quotient (FM)

Electronics (DL)

Getting on with paperwork and speaking good and understandable English. (DM)

Young engineers are well educated and more multi-cultural but lack practical knowledge of how things work. (DM)

Lack of interpersonal (skills) as well as practical engineering skills. Some even lack any passion for their chosen field. (DM)

Soft skills/people skills/interpersonal skills (DM)

1. Knowledge of specific codes in which engineers work. 2. The ability to ascertain capacity by quick reference. 3. Clients are paying for code investigation instead of design. (DS)

1 True understanding of the engineering concepts. 2. Lack in knowledge of Australian Standards. 3. Practical solutions to design. 4. Assessment of installations. (BM)

Interpersonal and communication skills (BM)

Based on the results there appears to some disquiet among employers with the skills present in newly graduated engineers. The level of satisfaction at 48.2% does not assure employers their newly employed engineers do have a reasonable grasp of the professional skills needed. There is a level of dissatisfaction with the preparedness of newly graduated engineers among the employers of these engineers.
4.8.16 Question 13.

Can these skills be learnt on the job? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Percent</td>
<td>3.7</td>
<td>0.0</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>22.2</td>
</tr>
<tr>
<td></td>
<td>16.7</td>
<td>3.7</td>
<td>48.1</td>
</tr>
</tbody>
</table>

In summary, 48.1% responded “Yes”, 68.5% had a response of 4 or more, whilst 96.3% responded “Yes” or “To some degree.”
Comments from the Questionnaire – Question 13

Note; whilst they can be learned on the job, it is important that they have training at the University level so that they don’t start off work with no useful knowledge.  

(BM)

4.8.17 Question 14

If you answered “No” to Question 13 what skills do you feel need to be provided with formal training? Please list in order of importance.

Comments from the Questionnaire – Question 14

Universities need to impart some writing skills in new graduates. Spelling, grammar, proper sentence formation NOT SMS language.  

(BS)

Those mentioned in Q12. It’s all about people!  

(BS)

Human skills, Communication, Management/interpersonal  

(BM)

Some are internal personal skills that some people will have and others will never possess.  

(BM)

As per Q12.  

(DS)

English, English, English. The rest is nowhere near as important  

(DM)

These skills can be developed and improved while on the job but all our engineers that we employ here already possess these skills.  

(DM)

Although I did not tick No. 1 I think it is imperative that their tertiary education pick up on these themes.  

(DM)

Engineering’s role in the broader business process  

(DM)

Leadership and management (at a conceptual level)  

(DM)
Whilst a significant number (48.1%) consider that ‘on the job training’ is possible there were a large number of comments written in (in response to Question 14) that indicate that there is still a need to include some management skills in undergraduate training.

4.8.18 Questions 15 and 16 - Comments

Questions 15 and 16 sought the views of the respondents on the future needs of graduate engineers using a five (5) and ten (10) year time frame. Responses to both Questions were found to be statistically significant. The responses are shown below:

4.8.19 Question 15

a) Do you feel the skills and attributes required of an engineer will change in the short term future (within the time frame of up to 5 years)? For example – sustainability issues. If your answer is “Yes” please comment on the way you see engineering attributes changing.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>64.9</td>
<td>35.1</td>
</tr>
</tbody>
</table>

Figure 4.15  Results of Question 15
This question required either a “Yes” or “No” answer. A significant percentage responded with a “Yes” answer of 64.9% indicating they felt that the skills and attributes an engineer will need will change over the next 5 years.

Comments from the Questionnaire – Questions 15

Environment, sustainability, technology, stakeholder management  

(FM)

Social and sustainability issues will determine the way and form of the engineering attributes.  

(FM)

Human resource issues need to be increasingly managed. An integrated approach to conciliation, health, safety, enviro issues has increasing emphasis.  

(FS)

Will need more flexibility in learning computer skills, presentation skills, customer svc (service?), customer management, organisation wide perspectives, and especially an understanding of finance as well as env, OHS QA.  

(FM)

More customer focused, more effectual communication and interpersonal skills  

(DL)

Innovation and sustainability will become increasingly important. In our industry energy conservation will be particularly important.  

(DL)

Heavy emphasis on electronic applications requires far higher learning by engineering team.  

(DL)

Technology changes and social  

(DL)

Technology change and compatibility, technological advancement, environmental change.  

(DL)

Yes, but it depends on the industry. For construction/civil/mining/environmental and safety concerns will assume importance. For manufacturing – technology and dealing with overseas companies/subsidiaries (in particular China) will be essential.  

(DL)
The nature of globalisation and corporate consolidation result in design in one country, drawing in second country, project mgmt in a third etc. i.e. no longer Australian stds, Aust design etc. (DM)

Safety, people/process interaction (automation), environment are key design criteria now. (DM)

Management and people skills –HR oriented (DM)

Chemicals, machinery, usages and availability have changed radically in the past 5 years. (DM)

Engineers are becoming more and more expected to know a bit of everything i.e. generalists. This may be due to the rise in project management requirements rather than specific technical skills that would be used in manufacturing/development etc. (DM)

Management, personal evaluations, financial, other business skills are sorely needed. (DM)

Just engineering does not give them all the skills they need to function in a business environment. (DM)

Depends on the size of the company and number of employees. Anal types are quickly exposed in smaller companies (no where to hide!). (DM)

Management of resources, environment and longevity requirements are becoming a larger part of requirements, i.e. design life 100 yrs, reduced carbon emission for that life span. (DL)

Awareness of expanding regulation after taking time away from the engineering function OH&S –administration (DS)

More detailed management will be required (CS)

Regulations, standards and technology is constantly changing and must be kept up with. (BM)
Professionals are tools to achieve business success and as business changes so the skills of professionals must change. (BM)

Client/customer needs (BM)

Regulations, WH and S operations, technical requirements (BS)

The world is changing and basics of computer control is changing. (BS)

The industry is constantly changing, the areas that engineers now get exposed to include safety management, environmental engineering, and community consultation. In particular expatriate positions have a far broader exposure than ever before. (BS)

Zero harm focus with emphasis on $. (AL)
4.8.20 Question 16

Do you feel the skills and attributes required of an engineer will change in the long term (beyond 5 years)? For example – sustainability or environmental issues. If your answer is “Yes” comment on the way you see engineering attributes changing.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>84.2</td>
<td>15.8</td>
</tr>
</tbody>
</table>

![Figure 4.16 Results of Question 16](image)

The responses to this question were found to be statistically significant. A significant response (Yes - 84.2%) indicated that there will need to be a greater change in engineering attributes within the next ten (10) years to meet the projected engineering skills required for that era.

**Comments from the Questionnaire Question 16**

Culture and demographical issues will determine the change of engineering attributes. (FM)

Engineering solutions will have to be examined more closely from the cultural and global perspectives. (FM)

Environment issues (FM)
Possibly that increasing engineering specialty degrees will be required (e.g. waste recovery engineering)  

Sustainability – understanding of TCO

Required to not only have essential engineering skills but also have added skills – financial, management, interpersonal etc.

Evolution of new processes and materials in manufacturing.

Electronic and other developments will cause major employment training issues for the future.

More of above. However design and manufacturing may be absent from Australia completely unless geopolitical/environment/economic factors reverse current trends.

Through education and trends as you have highlighted

Need to be well rounded/flexible to survive in the new world skills.

Engineers will be as important as the scientists and environmentalists to put in place the functional aspects of sustainability.

As above unless Australia stops becoming nothing more than a coal/iron ore mine.

More multi disciplined i.e. both electrical and mechanical amalgamated to facilitate automation.

Information technology is changing, design and drafting roles will become increasingly specialised and departmentalised. Engineers will be working in large global organisations.

The overall spectrum of both sustainability and environment is in an evolution and education stage that will continue long into the future.
Regret that the trend will dilute engineering focus due to the (peripheral) workload

Environmental, safety in design and engagement with communities on major construction projects.

Diversity of tasks in a sustainable world.

Environmental, ethics of new technology

As above also to keep pace with industry advances.

More admin/people/financial management

Computer skills, environmental awareness.

Technology and ecology are evolving. It will become necessary to use alternative resources when existing resources are becoming extinguished. Water supply, energy, building construction.

Good example – sustainability and environmental issues particularly.

Hopefully we are in “interesting times”, perhaps there will be many changes, largely dealing with “difficult” sites as we have already colonised the best bits.

We are already seeing it with the exposure to corporate governance issues

Increased reliance on technology
4.8.21 Question 17

Do you believe a newly graduated engineer could be required to assume junior management roles within six months of joining your firm? Please circle your answer.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>12 Months</th>
<th>Later</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage</strong></td>
<td>19.6</td>
<td>28.6</td>
<td>17.9</td>
<td>33.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Other Times</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage</strong></td>
<td>19.6</td>
<td>28.6</td>
<td>51.8</td>
</tr>
</tbody>
</table>

In summary, 19.6% responded “Yes”, 28.6% responded “No” whilst 51.8% indicated that management duties may come at some time after 12 months. A total of 80.4% respondents indicated that engineers may be required to assume management roles during their careers.
Comments from the Questionnaire – Question 17

By filling in their own time sheet and then becoming responsible for the productivity of others in their team. It is a continuing process. (BS)

Perhaps five years (BM)

(Within 12 months) if they have the correct people skills (BM)

The survey responses show some graduate engineers can expect to be offered Junior Management roles within 6 months of joining a firm whilst more than half can expect to be offered management roles after 12 months whilst over 80% will be expected to assume a managerial role at some time during their career. These results again highlighted the need for graduate engineers to possess managerial skills on graduation. If these results can be taken as typical then management becomes an important and valuable skill for an engineer.
Question 18 is considered next as it also seeks information regarding Management Skills.

In your opinion do you believe a newly graduated and employed engineer should have a basic understanding of financial and human resource aspects of management so they can successfully fill their position? Please tick your answer.

<table>
<thead>
<tr>
<th>Financial</th>
<th>Human Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Percentage</td>
<td>89.5 10.5</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Percentage</td>
<td>84.2 15.8</td>
</tr>
</tbody>
</table>

![Bar chart showing results of Question 18](chart.png)

**Figure 4.18** Results of Question 18
Comments from the Questionnaire – Question 18

If you are going to ask people to spend their money on your design, you should have some idea of where the money comes from. Hiring is easy. Firing is very difficult (for me anyway).

(35)

4.8.23 Question 19

Is it your opinion that engineers as currently trained to bachelor level are ready to fully participate in and contribute to the successful running of your organisation? The responses were found to be statistically significant.

<table>
<thead>
<tr>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>26.3</td>
<td>5.3</td>
<td>15.8</td>
</tr>
<tr>
<td>19.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In summary, 19.3% responded “Yes”, 35.1% had a response of 4 or more, whilst 73.7% responded “Yes” or “To some degree”.

158
Comments from the Questionnaire – Question 19

In the Roles we give them recognising they are graduates. (DM)

To do what they are told for a few years until they acquire sufficient experience to be given more autonomy. (BS)

4.8.24 Question 20

Do you believe graduate engineers, as currently trained, have all the necessary skills to integrate fully into your organisation.

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.0</td>
<td>3.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

In summary, 29.8% responded “Yes”, 45.6% had a response of 4 or more, whilst 86.0% responded “Yes” or “To some degree”.

Figure 4.20 Results of Question 20

In summary, 29.8% responded “Yes”, 45.6% had a response of 4 or more, whilst 86.0% responded “Yes” or “To some degree”.

159
Comments from the Questionnaire – Question 20

They need to learn to write in English that can be read and understood by non-technical people. Grammar, spelling and punctuation. Proper sentence formation. They need to be able to write an informative report. (BS)

Legal Skills (written in and given a 7) (BS)

English (written in and given an 8) (DS)

The question also included the following comment:

If your answer was “No” or “To some degree”, what skills do you believe are required to become fully effective? Indicate, in order of importance, those skills you consider important with 1 being very important and 7 being of little importance. Mark all skills you believe are important.

Below are the results of the 79 respondents, replies.

<table>
<thead>
<tr>
<th>Skill</th>
<th>Number of Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision making</td>
<td>Zero</td>
</tr>
<tr>
<td>Human Skills</td>
<td>7</td>
</tr>
<tr>
<td>Communication</td>
<td>14</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>13</td>
</tr>
<tr>
<td>Conceptual</td>
<td>10</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>11</td>
</tr>
<tr>
<td>Flexible</td>
<td>11</td>
</tr>
<tr>
<td>Administration (financial)</td>
<td>13</td>
</tr>
</tbody>
</table>

An additional comment was noted in this section.

Surely these are inherent skills not learnt as such. (DM)
4.8.25 Question 21

Do junior or newly graduated engineers profess a disinterest in management activities?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>45.5</td>
<td>1.8</td>
<td>5.</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>3.6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>23.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In summary 23.6% responded “Yes”, 27.2% had a response of 4 or more, and 54.5% responded “Yes” or “To some degree”.

Figure 4.21 Results of Question 21
Comments from the Questionnaire – Question 21

Usually keen to be managers from day 1 (EM)

No comment (DM)

Young engineers want to exercise their newly acquired skills to build something large of which they can be proud. (written communication?) (BS)

4.8.26 Question 22

Do you think employers should have a direct role in developing and teaching curricula?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>82.5</td>
<td>17.5</td>
</tr>
</tbody>
</table>

![Bar chart showing results of Question 22]

Figure 4.22 Results of Question 22

The respondents were very positive that employers should have direct input to the development of engineering curricula with 82.5% recording a “Yes” response.

Employers have a voice and are indicating that they want to be heard. How this can be accommodated is a topic for further research.
Comments from the Questionnaire – Question 22

But utilise prac placements and vacation placements  

Universities need to produce technically competent engineers who are capable of choosing their own path in their profession. Allowing employers a direct role in engineering curricula will see engineers being trained as technicians rather than innovative professionals.  

To some degree  

YES!  

Should be willing to express views which can contribute to the development of good and relevant curricula.  

Yes, to the extent of being consulted on a variety of things to include in the curriculum. This type of survey is an excellent start.
4.8.27 Question 23

Would you be prepared to partner with an Engineering Faculty in allowing students to undertake assessed tasks in the workplace that are directly aimed at developing realistic and practical management skills?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>61</td>
<td>38.9</td>
</tr>
</tbody>
</table>

![Bar chart showing percentage of responses to Question 23]

**Figure 4.23 Results of Question 23**

**Comments from the Questionnaire – Question 23**

- Yes, we do with Deakin University (EL)
- Based in Villawood NSW and process is repetitive and no suitable tasks. (DM)
- Because we are a small organisation we would not meet our inspirational needs to the students benefit. (DS)
- Note: However our organisation is small and we could best help by having students learn at our works. (BM)
We quite often have university students on work experience. They take up a lot of time and staffing resources. (BS)

If time available (BS)

However, I am a “one man band” working in remedial waterproofing and building rectification. I guess all they would see is the result of poor work practices. (BS)

This may be difficult given our mine sites are overseas, but I believe this aspect of undergraduate development needs to be seriously looked at. (AL)

The response to employers being involved with students on a partnering system of some description with an engineering faculty was supported by 61.1%. Several comments were positive but the size of the organisation (small) or its geographical location suggested that it would be impractical for some firms.

A discussion on the implications of these results is presented in Chapter 5.
CHAPTER 5  DISCUSSION OF RESEARCH RESULTS

5.1 Introduction - Statistical Comments

The results of the questionnaire have been subject to statistical analysis and except where noted, responses to all questions are significantly different from random. The data was also statistically tested for any significant difference in responses of Consulting and Manufacturing organisations (the largest two segments). It was also tested for any significant difference in the responses of various sized organisations. The only significant difference detected was for Question 12 where responses from Small companies were compared to the combined responses from Medium and Large sized companies. Question 12 sought the views of respondents on whether they were satisfied with employed engineers. The smaller companies indicated a significant “No” answer. This may be caused by the small number of employed engineers who could be expected to shoulder a significantly different range of roles than those of an engineer employed in larger organisations where their initial starting roles would be more traditional.

5.1.1 Comments on the structure of questions allowing a “To some degree” response.

In the questionnaire sent to employers, Questions 1 to 8, 12, 13 and 19 to 21 did not use a standard Likert scale, though for purposes of presentation and analysis the responses were converted to a Likert scale. Respondents were asked whether particular skills are present in newly graduated engineers and whether they are satisfied with particular characteristics of those engineers. The order in which possible responses were presented to the respondents was “Yes”, “No” and “To some degree” with the latter category being scored on a 5-point Likert scale. This is similar to the two-stage selection process discussed by Albaum (1996) in which respondents are asked first to indicate whether they agreed or disagreed with a given statement and then are asked to indicate their degree of agreement on a Likert scale. In the questionnaire discussed in this thesis Questions 1 to 8, 12, 13 and 19 to 21 were structured to encourage a clear “Yes” or “No” response. Those unable to commit to this “Yes” or “No” then had the opportunity to choose the degree to which they agreed using a Likert scale. Albaum (1996) found that the two-stage selection process provided a more accurate assessment of the opinions of respondents than the standard Likert Scale.
5.1.2 Possible Bias in Responses Through Choice of Extreme Values

In two frequently cited studies Greenleaf (1992a, 1992b) considered the possibility of bias in the responses to a questionnaire using Likert scales due to some respondents being either “Yea sayers” who consistently choose the extreme positive end of the Likert scale or “Nay sayers” who consistently choose the extreme negative end of the scale. This phenomenon is also called “end-piling”. Greenleaf held that there is evidence of end-piling if the mean response over a series of items is very close to one extreme end of the Likert scale and the standard deviation of the responses is small. The calculation of means, standard deviations and other parameters for ordinal data of the type under discussion entails assumptions that are not valid. For testing for end-piling in ordinal data from responses to individual questions the mode is a better measure of location than the mean. When estimating dispersion of ordinal data neither standard deviation nor range (as the difference between highest and lowest scores) can be validly calculated. Thus it is better to study the histogram of responses to see whether or not the responses are tightly clustered about a particular value. Thus we can consider that there is evidence of end-piling if the modes of responses are all, or mostly at an extreme end of the Likert scale and responses are tightly clustered at that end of the scale. An examination of responses to all parts of Questions 9 and 10 (page 167) shows little evidence of end-piling. Also, the “To some degree” responses to the questions discussed in Section 5.1.1 above tended to be clustered around the mid value of the Likert scale. Overall then, we can conclude that there is little evidence of end-piling in the responses to the questionnaire. Additional comments provided by the respondents strengthen the view that the responses accurately reflect their views and thus form a sound basis for the discussion to follow in the remainder of this chapter.

Structure of this Chapter

The data gathered and presented in Chapter 4 (page 100) will be discussed in the following sub-sections. The results of the questionnaire will not be discussed question by question but by sub-groups 5.5 to 5.8.

5.2 Personal Discussions with Professors Cook, King, and Parker.
5.3 Discussions with Engineers Australia
5.4 Overseas Professional Bodies.
5.5 Evaluation of Professional Management Skills (by Questionnaire)
5.6 Employer Satisfaction
5.2 Personal Discussions - Professors Cook, King and Parker

Management skills are not considered a high priority and as such are not adequately covered within the hierarchy of engineering curricula. However one comment made in general discussions with engineering academics was that they need more engineering subjects not less (as would happen if management subjects were to be included and therefore displace some engineering subjects). A possible solution to this dilemma could involve the blending of management skills into current engineering subjects, by way of case studies, which highlight the interaction of engineering techniques and their resulting application in real world situations.

5.3 Discussions with Engineers Australia

EA is an organisation dedicated to the needs and the future of all engineering graduates. It does not consider management skills as an important part of a graduate engineer’s skill set but admits there is a need for engineers to be given more than a token course in Management Skills. Therefore there is a need for their current attitude to change and to consider reviewing their current Competency Standards (see Appendix 4 page 270). They need to consider incorporating a competency that includes training in the skills of finance, communication, customer approach, marketing and in general dealing with and being a part of the general industrial/commercial world. This would bring it more into line with overseas professional bodies, particularly the UK bodies.

5.4 Overseas Professional Bodies

From the information presented in Section 5.4 (page 168) it is clear international professional bodies believe graduate engineers need some degree of management skills to be able to attain the various professional qualifications and to be able to fully develop their potential if they wish to follow a management career path. The Engineering Council, UK, is very definite in this area. ABET is similar to EA in that they state general competencies rather than the specifics mentioned by the Engineering Council UK.
5.5 Evaluation of Professional Management Skills (by Questionnaire)

The questions that directly related to management skills as outlined by Peterson and Van Fleet (2004) are Questions 1 to 8, 9, 10 and 18.

Questions 1 to 8 seek the views of the individual respondents on whether newly graduated engineers possess particular skills. Questions 9 and 10 requested the views of respondents on the importance of those skills from the point of view of the respondent’s organisation and its Industry sector, respectively. Question 18 asked whether newly graduated engineers should have a basic understanding of the additional skill of Finance and Human Resources.

Responses to all the above questions were significantly different from random with the exception of Question 5 (Conceptual). However, subsequent analysis showed the combined responses to “Yes” and “To some degree” were significantly higher than the “No” responses. This indicates the responding employers do believe that Conceptual skills are present in their employees, on graduation, but not as strongly as other skills mentioned.

Of the permitted responses to Questions 1 to 8, namely, “Yes”, “No” and “To some degree”, few respondents chose “No”. Of the eight (8) management skills listed, those of Question 1 – Decision Making, Question 2 – Human Skills, Question 6 – Diagnostic and Question 8 – Administration, received “Yes” responses at close to or above 50%, indicating the respondents believed the graduate engineers had a reasonable degree of these skills. A summary of the results for Questions 1 to 8 is shown in Table 4.5 (page 115) and is shown in graphical form in Figure 4.10 (page 129).

Reviewing the first eight questions the “Yes” responses varied between 33.9% and 57.6% whilst the “No” responses varied between 0.0% and 23.7%. This indicates there is a decided view that newly graduated engineers do have some basic knowledge on the management skills listed.

Question 18 asked whether newly graduated engineers should have a basic knowledge of Financial and Human Resources aspects of management, with only a “Yes” or “No” response permitted for each of these skills. For the Financial aspect the “Yes” response was 89.5% and for the Human Resources aspect the “Yes” response was 84.2%. These responses show very definite indications that Finance and Human skills are of great importance to employers and that they strongly believe these skills should be part of an engineering curriculum for undergraduate engineers.
For Questions 1 to 8 those skills receiving the highest proportions of “Yes” responses were Diagnostic (57.6%), Administration (55.9%), Decision Making (47.5%) and Human Skills (45.8%). Those receiving the lowest proportions of “Yes” responses were Flexible and Conceptual (both 33.9%), Communication (35.6%), and Interpersonal (39.0%).

Questions 9 and 10 (which were based on an ordinal scale ranging from 1 to 7) sought to rank the skills in level of importance to the organisation and industry/service sector respectively. The responses to the two questions were very similar and were all clustered towards the higher end of the scale. Analysis revealed, with the exception of Conceptual, Administration and Interpersonal skills, all skills had a mode of 6 or 7. Conceptual and Administration had modes of 5 for both questions with Interpersonal having a mode of between 5 and 6 for Question 9 and a mode of 6 for Question 10.

Statistical analysis showed the responses to Questions 9 were not significantly different from responses to the corresponding sections of Question 10. As shown in Table 4.9 (page 142) the values of the modes accounted for between 32.8% and 49.2% of responses to Question 9 and between 29.3% and 60.3% to Question 10. Responses of 1 on the seven point Likert scale for Question 9 varied from 0.0% to 1.7%. Responses of 1 for Question 10 also varied from 0.0% to 1.7%. The analysis showed that Communication was the most important skill and was significantly different to the other 7 skills whilst Administration was the least important and also significantly different to the other skills. The remaining skills were not significantly different to each other.

In Questions 9 and 10 the modes for Communication were both 7 and comprised 49.2% and 60.3% of responses respectively. For Human Skills, the modes were both 6 and comprised 40.7% and 36.8% of responses respectively. These responses to the questionnaire thus indicate that respondents consider Communications and Human Skills to be very important for both their own organisation and the industry or service sector of which it forms a part.

The second part of Question 18 asks whether newly graduated engineers should have a basic knowledge of Human Resources (with only a “Yes” or “No” response permitted). The “Yes” option received 84.2% of the responses. Thus respondents not only stressed the importance of Human Skills for their organisation and its industry/service sector but agreed engineers should have a basic knowledge of Human Resources on graduation. These responses can be compared to the responses of Question 2 which asks whether recently graduated engineers do have Human Skills. While only 8.5% of respondents chose “No”, the remainder were almost equally split between “To some degree” (45.85%) and “Yes” (45.75%). This disproves the anecdotal view
that recently graduated engineers have no Human Skills but also identifies a need for further development of undergraduate training in these skills.

Overall, there appears to be a distinct need for Communication and Human Resources skills to be taught at a more advanced level in engineering undergraduate courses. This is reinforced by written comments from the questionnaire.

The first part of Question 18 asks whether engineers should have a basic knowledge of financial aspects of management on graduation. Only a “Yes” or “No” response was permitted with 89.5% of respondents choosing “Yes”. This confirms the need to include Financial Management as part of undergraduate training for engineers.

Whilst Questions 1 to 8 sought responses on the skills present in graduate engineers, Questions 9, 10 and 18 sought responses on whether particular skills should be possessed by graduate engineers. Responses to the two different requests can be seen as expressing the overall view that newly graduated engineers do not possess adequate knowledge of management skills to fully satisfy the needs of employing organisations.

It is unwise to directly compare values from questions using different measurement scales. However, it can be seen that basically all responses are telling the same story. That is, the management skills listed above are seen as important to employers of graduate engineers.

5.5.1 Comments by Respondents on Questions 1 – 8, 9, 10 and 18

There were few comments for these questions but the few that were written are listed in Chapter 4 (pages 126 and 158). These comments can be summarised as:

- a lack of human skills,
- poor understanding of administration flow and
- a poor grasp of English (both written and verbal).

These comments reinforce the concerns regarding management skills shown in the responses and also highlight the problem of Communication (both written and spoken English), which was a recurring theme throughout the responses, particularly in the written comments.
5.5.2 Summary

The responses to Questions 1 to 8 show that newly graduated engineers do possess some level of skill in the eight management skills and responses to Questions 9, 10 and 18 clearly show there is a desire amongst employers that newly graduated engineers have a higher level of these skills, especially in Communication and Human Resources.

However, the main area of concern appears to be the engineers’ lack of ability to be fluent in both written and verbal communication. This is a skill that is commented upon throughout the responses to the research questionnaire.

5.5.3 Conclusion

Responses to Questions 1 to 8, 9, 10 and 18 show clearly that the eight skills as described by Peterson and Van fleet (2004), together with Financial skills, are considered by employers as required in their engineering staff. However, they consider these skills are not developed to the required degree in newly graduated engineers. The major skills they believe engineers lack are:

- Finance
- Communication (written and spoken English)
- Human Resources.

The other attributes discussed, namely, Diagnostic, Administration, Decision Making, Interpersonal, Conceptual and Flexible are also important and need to be considered along with the above three. Engineering academics need to carefully consider the requirements of the employment marketplace. Whilst Universities should not be considered a source of groomed employment-ready engineers, they should consider incorporating the needs of the eventual employer of the engineers they educate within their engineering curricula in the form of case studies, plant visits, work experience and engineering subjects that use “real life” situations that demonstrate the complexities of engineering tasks. The comments regarding poor knowledge of management skills among recently employed engineers, is a strong indictment of the quality of educational processes in general and, in particular, of engineers educated by Australian Universities.
5.6 Employer Satisfaction – Questions 12, 13 and 14

The purpose of Question 12 was to seek responses from employers on their satisfaction with the skills of the newly graduated engineers they employ. The responses to the question gave a “Yes” result of 48.2% with 41.1% satisfied “To some degree”. Question 13 asked whether the skills lacking could be taught “on the job” with 48.1% indicating “Yes” and 48.2% indicating “To some degree”. Referring to the responses graphed in Figure 4.14 (page 146) which shows the full range of responses, the “To some degree” showed the responses for values 3 and 4 were 22.2% and 16.7% respectively. This indecision may be caused by respondents not being sure all management skills could be taught on the job. This problem needs to be resolved by future research.

Question 14 asked whether the required skills could be learnt “on the job” and, if a “No” answer was given, they were asked for a list, in order of importance, which skills were needed to be provided by formal training.

Whilst the responses indicate a general satisfaction with the skills of current engineers the comments attached indicated a slightly differing viewpoint. The comments can be divided into those covering engineering skills and those covering management skills. The following comments are those which cover management skills. Comments covering engineering skills are outside the scope of this research. Comments applying to management skills fall into the following categories:

- Communication – Both written and verbal English. This is a recurring theme throughout the comments listed in the survey.
- Ethics
- Paperwork (Administration)
- People skills (Human Resources)
- Interpersonal Skills
- Soft Skills (generally management skills)

The range covers most of the management skills mentioned above, but the recurring theme is that graduate engineers have a poor grasp of both written and spoken English.

This may be due to the increasing number of foreign students graduating from our Universities or it may be pointing towards a problem within our curricula which does not value the skills of writing clear logical reports and does not teach students how to make technical and concise
presentations to fellow students and outsiders. Perhaps these presentations should be assessed by suitably qualified academics from outside the Engineering Faculties.

Questions 13 and 14 investigated the possibility of the above skills being taught “on the job”. Most respondents indicated this could be done (but it would be difficult to teach English in an “on the job” situation). However some comments indicated the Universities should have a role in preparing their students in some basic English skills.

One comment highlighted the problems that employers face. A part of that comment follows.

    Spelling, grammar, proper sentence formation NOT SMS language (BS)

The comment can be accessed in full in Section 4.8.17 (page 147)

The essence of the comments was that the University needs to instil in potential graduates a basic understanding of all skills mentioned above with the employer building on these skills.

Again there is a distinct pointing towards a deficiency within our curricula with regard to the soft management skills.

5.6.1 Summary

The research sought to identify whether the skills currently taught to Australian undergraduate engineers are the skills employers’ value. It did not seek to identify what other skills, if any, employers desire in their newly employed graduates.

The research has shown there are skills that are required by industry and commerce which have not been taken into account or identified in the current engineering curricula. Whilst the respondents indicated some or most of these skills could be taught on the job, they believed Universities need to educate engineers to a level which will allow the employing company to build on these skills with in-house (or ex-house) training.

Further research in this area is recommended as is a review by academic staff of this area of concern.
5.7 Engineers’ Contributions to Organisational Management – Questions 17, 19 and 20

The research questionnaire sought the views of respondents on the contribution that newly graduated engineers could make to the performance of the organisation. Questions 17, 19 and 20 covered this area.

Question 17 sought views on the possible time scale for the promotion of engineers to a management role (albeit at a junior level). The responses permitted were “Yes (within six months)”, “No (not within six months)”, “12 months” or “Later”. For statistical analysis these responses were reordered to “Yes”, “No”, and “Later”, (this value was the sum of the 12 months and Later responses).

The results shows approximately 20% of employers indicated that graduate engineers could be expected to assume management roles within 6 months and a further 17.9% within 12 months. In total 37.5% of engineers could be in a management role within their first year of employment and an additional 33.9% may assume management roles at some time in their career.

Thus there is strong evidence a significant proportion of graduate engineers will move into a management position (either senior or junior) at some time during their career. Therefore training in management concepts is better begun in the undergraduate studies.

In Question 19 respondents were asked to comment on whether engineers, trained to bachelor level, are ready to fully participate in and contribute to the successful running of the organisation. This question seeks information about the level of valuable input a newly graduate engineer could apply to current and near future projects. The permitted responses were “Yes”, “No”, and “To some degree”.

The responses have a higher than usual “No” value at 26.3%, with the “Yes” value being 19.3%, coupled with “To some degree” at 54.4%. This indicates there is some concern graduate engineers are not fully ready, on employment, to fully contribute to the successful running of an organisation. This supports the comment made by Professor Brendon Parker (page 108).

The “No” responses, 26.3%, whilst not a majority, are still troubling in that more than a quarter of employers are dissatisfied with the relevant skills of graduate engineers. The large result for “To Some Degree” is also of concern. This response was centred around the mid-scale 3 value which indicates that respondents were in general reluctant to range their degree of satisfaction within the “To some degree” category.
Question 20 sought views on the ability of a newly employed engineer to have the necessary skills to be able to integrate into the organisation, that is, whether he or she would fit into the culture of an organisation. The responses, as listed in Figure 4.20 (page 159), showed that 29.8% indicated engineers, as currently trained, have the ability to integrate into an organisation whilst 14.0% feel they did not have this ability. The “To some degree” results are centred around the mid-scale value of 3 which would indicate some difficulty in differentiating within the “To some degree” category.

5.7.1 Comments on Questions 17, 19, and 20 by Respondents

The comments that were written for the three questions again voiced some concern regarding the lack of specific management skills. The full listing of all comments can be found at Chapter 4.8.21 (page 155) and Chapter 4.8.24 (page 159).

The respondents again highlighted the lack of English skills as well as noting the graduate engineer requires mentoring in the various aspects of a paid position. They are given tasks commensurate with their experience level in their field whilst they “learn the ropes”.

5.7.2 Summary

The responses to these three questions indicate, whilst there are some satisfied employers, there is still some concern about the readiness of graduate engineers to participate fully in the organisation from an early stage of their employment.

Organisations need graduates who can commence useful work from an early stage. Also, the graduates need the ability to integrate into and have an understanding of the goals, objectives and directions of the organisation from an early stage of employment. Knowledge of the management skills mentioned above would be of great assistance in allowing the graduate engineer to integrate quickly into the employing organisation. Again, the skills of Communication are highlighted.
5.8 General Information – Questions 11, 15, 16, 21, 22 and 23.

This section reports on the remaining six (6) questions, which cover general information additional to the main research. Question 11 explores the range of engineering disciplines which are employed by the respondents. Questions 15 and 16 seek comments on the possible changes of skills required of engineers over the next 5 years and beyond. Questions 21, 22 and 23 seek comments on the participation of employers within the training regime of engineering undergraduates.

5.8.1 Disciplines Covered

Question 11 requested the number of engineers employed by discipline. The range of disciplines employed was as listed in Table 4.10 (page 143).

This range covers the main disciplines but the figure for “Others” at 43.3% is disappointing and requires further clarification.

5.8.2 The Future – Questions 15 and 16.

Question 15 sought comments regarding the future path of engineering. Respondents were asked to comment if they felt the skills and attributes of engineers would change over the next five (5) years. The result was a 64.9% “Yes” response and a 35.1% “No” response.

Question 16 sought comments for the future beyond the next five (5) years with the result being 84.2% “Yes” and a 15.8% “No” response.

The balance of answers to both these questions was in the form of comments and these are reproduced in full in Chapter 4 pages 149 and 152. The comments covered both engineering and managerial skills. The engineering comments are not presented as they are outside the scope of this research project.

5.8.3 Respondents’ Comments on Questions 15 and 16

The major comments regarding the skills mentioned above were made for the time period up to five (5) years and covered a variety of Management Skills which included

Comments were also made concerning other areas that needed to be considered as being important in the training of engineers. These included – sustainability, the environment, social, technology changes, innovation, international engineering, cultural issues, multi-discipline engineers, and ethics.

The general tenor of the comments was that management skills will be in greater demand over the next 5 years with Communication, Human Skills, and Business Skills being the major areas of concern.

For Question 16 the changes suggested as important were similar to the above with the additional factors – cultural, global, the evolution of new processes and materials, multi-disciplined, and corporate governance.

5.8.4 Summary

The responses to both Questions 15 and 16 indicated the respondents are of the opinion the management skills required of engineers will increase over the next 5 years and beyond. Some respondents indicated this will be an ongoing trend. The skills highlighted were, Communication (including customer interaction), Human Resources and general Business Skills. These statements reinforce the above comments made about the need for undergraduates to have additional management skills included in their engineering curricula.

5.8.5 General Questions – Questions 21, 22 and 23.

The Chi Squared Test returned a value of 0.13050 and was not statistically significant at the 5% level. Question 21 looked at the attitude of engineering graduates to management activities. Anecdotal evidence from discussions with students and academics indicated it was generally considered undergraduate engineering students dislike management subjects and often comment on the waste of time spent on these activities. The question sought to ascertain if this attitude persisted into employment or is an inaccurate assumption. The responses indicated that 45.5% of employers believe engineering graduates do not express a disinterest in management activities. A total of
23.6% believe newly graduated engineers show a disinterest in management activities whilst 30.9% indicated disinterest to some degree.

Expressed positively, the above results show that 45.5% of employers believe that junior engineers have a definite interest in management whilst a further 30.9% believe they have some degree of interest; that is, more than three quarters of employers reject the idea that junior engineers have no interest in management. This result is surprising in view of strong anecdotal evidence that junior engineers during their University studies have no interest in management. This highlights the need for further research to determine the level of interest in management and whether their attitudes change over the period of their University studies and onto, perhaps their first 1 – 3 years in employment.

Questions 22 and 23 looked at the possible involvement of employers within the University system. Question 22 asked should employers have a direct role in the developing and teaching of the engineering curricula. The result was a very positive value of 82.5% in favour. However there was one negative comment that needs to also be considered, namely:

“Universities need to produce technically competent engineers who are capable of choosing their own path in their profession. Allowing employers a direct role in engineering curricula will see engineers being trained as technicians rather than innovative professionals.”

(BS)

This can be countered balanced by another comment from an enthusiastic respondent.

“YES!”

(BM)

It appears employers do want to have a say in the material that engineers are to be taught. Again this response will require additional research to ascertain fully how and to what extent employers should have an input into the development and teaching of undergraduate engineers. Their input could be a very valuable resource in their training.

Question 23 returned a value of 0.10247 for the Chi Squared Test and was not statistically significant at the 5% level. The question looked at the possibility of undergraduate engineers being invited to take part in assessed tasks within the engineering employing community. The response was positive with 61.1% of
respondents marking “Yes”. Comments indicated this does occur now but serious concerns were raised in terms of location and size. Some mining sites and processing plants are located in difficult to access areas in Australia. Some organisations have a very small number of employees and would find it difficult to supervise an undergraduate engineer. These factors will have to be addressed. The tasks would be controlled by the Engineering Faculty and the outcome assessed by that same body. This aspect requires further analysis and research to ensure feasibility and applicability.

5.8.6 Summary

The attitude of undergraduate and newly graduated engineers towards the need for management skills is uncertain. The responses from the respondents were not statistically significant at the 5% level. This area requires further research, as the young engineers’ attitude to management skills may change during training or shortly after graduation.

The responses to Questions 22 and 23 showed employers believe they can assist in the training of undergraduate engineers by direct involvement in curricula development. In addition they have very positive attitudes as to being involved in the practical training of undergraduate engineers by either plant projects or providing targeted “on site” training programs.
CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 The Research Hypotheses

With regard to the Research Hypotheses 1 and 2, results from the responses to Questions 1 to 8, 9 and 10 have shown conclusively engineers, as currently educated do not have all the necessary non-engineering skills industry requires. Responses to the two parts of Question 18 also strongly indicate that newly graduated engineers should possess Financial and Human Resource skills. The lack of these skills hinders the integration and utilisation of the engineer and therefore limits his/her progress in the company.

Thus the research hypotheses have been tested and confirmed.

The first two sub-hypotheses are

1. That the current University curriculum for undergraduate engineering students does not prepare them for rapid integration into the engineering and commercial workforce.

2. That the skills and attributes, required of engineering graduates, by industry and commerce has not been fully identified.

Sub-hypothesis 1 is confirmed by Question 19 which asked whether engineers, as currently trained to bachelor level, are ready to fully participate in and contribute to the successful running of the respondent’s organisation, and where 26.3% said “No”, 19.3% said “Yes” and 54.4% said “To some degree”. This shows approximately 80% of respondents have reservations concerning this particular ability. Sub-hypothesis 2 is supported by the responses to Questions 1 to 8, 9, 10 and 18 (which asked about the importance of various management skills and the extent to which new engineering graduates possess them) together with a wide range of comments.

The next two sub-hypotheses are

3. That there are perceived negative reactions and poor motivation from undergraduate engineering students to business/management subjects.

4. That students have difficulty in accepting the relevance of engineering management education.
Sub-hypotheses 3 and 4 were tested by Question 21 of the questionnaire administered to employers which asked if junior engineers or newly graduated engineers profess a disinterest in management activities. For statistical analysis the responses were classified as “Yes”, “No” and “To some degree”. This has given an inconclusive result in that a Chi-Squared test showed the responses received were not significantly different from a random allocation of responses among the three categories (p=0.13). It appears employers are not in agreement on this question. Whilst the sub-hypotheses are not rejected, neither are they supported. The evidence tends to reject the sub-hypotheses rather than support them. Of responses to Question 21, as shown in Figure 4.21, on page 161, 76.4% are either “No” or “To some degree” with 88% of the “To some degree” responses at either the mid-value of the Likert scale or at the “No” end of the scale. The lack of statistical significance of responses to Question 21 is partly due to the low response rate to that question with only 55 responses being received. Had there been 110 responses divided in the same proportions then the null hypothesis of random allocation would have been rejected (p<0.025). The “To some degree” and “Yes” responses to Question 21 may be the result of changing attitudes of engineers after employment or during the later stages of their degree. More research into this area is required to test this proposal and to ascertain whether the body of engineering undergraduates is fragmented into groups of undergraduates who see their future in management and those who wish to have careers of engineering only.

The next sub-hypothesis is:

5. That the Australian Professional Engineering bodies recognise management studies as important, but they do not enforce that management attributes are addressed in the various accredited engineering courses within Australia.

Sub-hypothesis 5 is supported, with EA personnel commenting that Universities decide the level and content of management studies for undergraduates. The document showing the competencies for Professional Engineers (Appendix 4 page 270) includes very little on management skills and does not clearly state the expectation of those skills that it does mention.

The final two sub-hypotheses are:

6. That management concepts need to be introduced into the engineering curriculum for engineering students.
7. That communication subjects should be taught to undergraduate engineering students as part of their engineering curriculum.

Sub-hypotheses 6 and 7 are strongly supported by responses to Questions 1 to 8, 9, 10, and 18. The responses to Questions 9 and 10 showed the respondents felt all the listed management skills were of importance to their organisation as well as to their industry overall. In addition the overriding view throughout the responses to the questionnaire was the need to graduate literate engineers. This opinion was confirmed by the comments made.

The research has shown there has been a lack of knowledge concerning the needs of employers of engineers. This is shown by the responses and comments to Questions 9, and 10, and also 20 which asked respondents to rank in order of importance those management skills they consider lacking in newly graduated engineers. The employer groups include engineering companies, industrial companies, consulting groups, Government instrumentalities and local government. Most of the literature in this area has studied engineering organisations which employ engineers and are managed by engineers. The needs and wants of other employers of engineers appear to have been overlooked. This research has attempted to partially cover this gap in the literature.

6.2 Evaluation of Professional Management Skills Required

Discussions with Deans of Australian Engineering Faculties and with Engineers Australia, together with a study of the requirements of professional accreditation bodies for engineers in the UK and the USA, have identified areas where university training of engineers in Australia could be improved. The major areas of improvement are in the teaching of management skills. The UK professional bodies emphasise accredited professional engineers need to understand the various concepts of management and as the seniority of the accreditation increases so does the requirement to understand detailed management concepts. The Deans understand this but appear reluctant to commit fully to the concept. EA follows the USA (ABET) model and does not consider management skills to be of great importance whereas the UK model puts a strong emphasis on these skills.

Overall, the survey instrument, the literature research and face to face discussions have shown the following:

There is a definite need, as expressed by the surveyed employers, for graduate engineers to possess specific management skills.
The management skills being taught at present by the various Institutions are not adequate as the responses to the survey indicated graduate engineers possess the defined skills only to a minor degree.

The management skills most in demand are:-

**Communication** – particularly written and spoken English

**Finance** – this was referred to in only one question (Question 18) but the response was very significant with 89.5% of respondents supporting the need for this skill.

**Human Resources** – this was referred to in several questions (Questions 4, 9, 10 [Interpersonal]) as well as specifically in Question 18 where 84.2% of respondents supported the need for this skill.

Communication skills and Human Resources skills as defined by Peterson and Van Fleet (2004) and while Finance remains undefined.

The other management skills, including **Decision Making, Conceptual, Interpersonal, Diagnostic, Flexibility and Administration** are considered important, confirming the findings of Peterson and Van Fleet (2004).

The responses also show the majority of respondents are of the belief that the need for management skills in graduate engineers will only increase over the next five years and beyond.

The relative importance of each skill can be argued but the list of skills above (plus Finance) forms an excellent platform from which to review current engineering curricula and incorporate management skills.

Because of a low response rate the research could not differentiate between disciplines as to which skill was considered most important. It was not possible to ascertain if there were significant differences in the managerial needs of individual disciplines.

All the above skills are considered by employers to be important for both their own organisations and for the business sectors they represent. Administration skills were considered significantly less important than the others with Communication skills
considered significantly more important. Lack of Communication skills stands out as the factor that causes the most angst amongst employers. The teaching of this skill needs to be reviewed by each Faculty to ascertain whether graduates do possess the communication skills, written and verbal, needed in today’s business environment. In both engineering companies and industrial/commercial organisations engineering graduates will not only be called upon for engineering duties but will also be required to communicate and work with other disciplines. They will also need to communicate clearly within and outside the organisation, with each other, with customers and with the community. They must be able to clearly articulate their vision and solutions to the problems that present themselves for resolution.

Management subjects (such as Communication) will need to be developed as either a standalone subject or as an integral part of an engineering subject. They could possibly be taught and assessed (wholly or partly) by academics from other Faculties. It is also possible for the engineering curricula to include external subjects (on management skills) from other faculties, such as Commerce.

Questions 9 and 10 of the questionnaire asked employers to assign the level of importance to their own organisation and its business sector, respectively, of each of the following eight skills: Administration, Conceptual, Human Skills, Flexible, Interpersonal, Decision Making, Diagnostic and Communication. As discussed in Chapter 4, (page138) all of those skills were considered important with scores having a median of 6 or 7 on a 7 point Likert scale. There were no significant differences in scores between the organisation level and the sector level. However, Administration was ranked significantly lower in importance than the other seven skills with Communication being ranked significantly higher. The remaining six skills were ranked between Administration and Communication with no significant differences in the ranking.

Skills not surveyed that could also be considered are: Sustainability, OH&S, Marketing, Operations Management, Environmental Management, etc..

6.3 Employer Satisfaction

Assuming the employers of engineers are the customers of the institutions who are training the graduating engineers then they are not fully satisfied customers. Only 48.2% of the employers were happy with the skills of the engineers they employed (Question 12). A similar number
(48.1% - Question 13) believed these skills could be taught to the employed engineers whilst they are employed. The statements made by the employers highlighted the lack of communication and human skills together with a lack of practical knowledge.

Overall, the skills considered the most lacking and greatly needed are

- Communications (grammatically correct English, both written and spoken)
- People skills (Human Resources, Interpersonal Skills)
- Soft skills (generally management skills) – an appreciation of the following - equity, diversity, project management, motivation, leadership
- Financial skills

Whilst the respondents believe some or all the skills can be taught on the job, they believe the training institution should at a minimum, provide a basic understanding of these skills to the undergraduate engineer.

6.4 **Engineers’ Contribution to Organisational Management**

Some concern was expressed by respondents as to the ability of newly graduated engineers to partake fully in the operation of the organisation from an early stage.

Knowledge of management skills will assist in integrating the engineer into the organisation early in his/her career. Knowledge of communication and human skills would be of great assistance in allowing the graduate engineer to integrate quickly into the employing organisation.

6.5 **Students Attitude to Management**

Respondents were divided on this topic but did not support the claim newly graduated engineers are not interested in management. When asked if they agreed with the claim a significant percentage (45.5%) responded with “No” and only 23.6% “Yes”. Of the 30.9% “To some degree” responses, the majority are at the mid-scale value of 3 and most of the remainder are at the “No” end of the scale, 1 or 2.
This result could indicate a variation between engineers who wish to pursue an “engineering only” career and those who have an interest in management and engineering. This difference could reflect the individual interest of the fledgling engineer. This attitude towards management studies amongst engineers requires further research to plot the level of interest and attitudes over the period of their University studies and then, perhaps their first 1 to 3 years in employment. It may also be discipline based and this also needs to be considered.

6.6 The Future

The responses to both Questions 15 and 16 indicated the respondents are of the opinion that the management skills required of engineers will increase over the next 5 years and beyond. Some respondents indicated this will be an ongoing trend. The skills highlighted were, Communication (including customer interaction), Human Resources and general Business Skills. This reinforces the above comments made about the need for undergraduates to have additional management skills included in their engineering curricula.

6.7 Co-operation between Universities and Employers

Employers are very interested in co-operating with universities on discussing curricula and in assisting the teaching of students either as guest lecturers or having students work with them on meaningful projects during the university semesters. The responses to both the relevant questions (Questions 22 and 23) were positive with 82.5% indicating a desire to have an influence on the setting of curricula and 61.1% willing to participate in sharing the teaching of practical skills.

This response will require additional research to fully ascertain how and to what extent employers should have an input into the development and teaching of undergraduate engineers. Their input could be a very valuable resource in the training of these engineers. However the comment listed in Chapter 4.8.26 (page 162) regarding one respondent’s view (a warning against simply training technicians) should be considered.

6.8 Limitations of the Research

The research survey was designed to encompass the full range of potential employers of engineers. However the responses from four sectors (Construction, Mining, Public Services and Utilities and Transport) were limited. Both Consulting and Manufacturing gave reasonable rates of responses, namely 33.9% and 42.4% respectively. Overall the response rate was low at
7.8%. It was intended to cross reference the skills to discipline but with this response rate it was only possible to compare Consulting and Manufacturing. Also it was intended to cross reference between the three differing sizes of organisations and between the various groupings. This was only possible for the two Industry segments – Consulting and Manufacturing.

This gives rise to two problems:

With the above four segments responding poorly to the general survey, as distributed, the research method may need altering to an individual segment survey (e.g. Mining - which represented 962 firms out of a total 18115). In addition the random sampling method did not select many of the larger mining companies. The other possibilities are that the poorly responding segments see no relevance in management skills, are not willing to be surveyed, or they are quite content with the status quo.

This low response rate from the four segments indicate there is need for further research in this area. Whilst support for the management skills mentioned above was very strong, we need to ascertain what skills are important to each segment and discipline.

The list of management skills was adapted from the paper by Peterson and Van Fleet (2004) with Finance added. Other potential skills such as Marketing, Quality Management, OH&S, were not included as this survey concentrated on the “soft” management skills. This is an area that requires further consideration. The skills defined as Management skills were considered. Those defined as Engineering skills were not considered.

6.9 Contributions to Knowledge from this Research

The poor response rate to the questionnaire (8.6%) means that the results cannot be considered a random sample from employers but nevertheless responses were received from 59 organisations of various sizes representing six different sectors of business and industry. Statistical analysis established that the responses are significantly different from random and thus provide a valuable insight into the perceptions and requirements of a large number of employers representing a range of different sectors of the economy. For the two largest groups of respondents, representing the Mining and Consulting sectors, it was also possible to test for significant differences in the perceptions and requirements of organisations of different sizes within a sector.
The major elements that have been discovered by this research are

- A list of management skills have been suggested and confirmed as desirable for undergraduate engineers to possess. These are Communication, Decision Making, Human Skills, Conceptual, Interpersonal, Diagnostic, Flexibility, Administration and Finance (see Questions 1 to 8, 9, 10 and 18), with Administration ranking lowest in relative importance to employers and Communication ranking highest.

- Other desirable skills have been suggested by the respondents. Those mentioned in the written comments are entrepreneurship, sustainability, equity, diversity, motivation, ethics, leadership and legal.

- Employers of graduate engineers are not fully satisfied with the management skills of newly graduated engineers. As well as the major skills listed above they believe the following skills are also desirable - Entrepreneurship Sustainability, Equity, Ethics, Diversity, Motivation, Leadership and Legal.

- The management skills required in newly graduated engineers have not been fully understood by the various tertiary institutions and Engineers Australia.

- The management skills being taught at present by most Institutions are not adequate. The responses to the survey indicated graduate engineers possess the defined skills only to a minor degree.

- This work has produced evidence to confirm Wei’s (2005) suggestion that one quarter of the undergraduate curriculum should be devoted to management studies. If this is accepted then it will require not only a drastic rethink of the curricula of undergraduate engineering courses but also the subjects taught and the way they are taught. A semester or two of studying a management book, such as Management for Engineers (ed Danny Samson (2001)) will no longer suffice.

- The accreditation by EA for both Professional Engineers and Engineering Faculties do not adequately address these requirements. The Royal Academy of Engineering and The Engineering Council UK serve as a better model to follow.
This lack of Managerial skills inhibits the rapid integration of graduate engineers into the corporate structure of an organisation.

Anecdotal comments regarding the lack of English skills, particularly in new graduates have been confirmed, mainly by respondents’ written comments.

Anecdotal comments regarding the lack of interest by undergraduate engineers in Management studies and a future in Management careers was not confirmed nor confirmed with the responses to Question 21 not being statistically significant.

Anecdotal comments regarding the lack of people skills in engineers in general was confirmed with Question 2a showing 45.8% of respondents disagreeing with those comments and a further 30.9% agreeing to some extent.

Responses to the questions in the questionnaire were examined for bias and “end piling” and were found to be not affected by these problems. The use of three different methods of response to the questions needs to be considered and in future research consideration should be given to the use of a Yes/No and Likert Scale response only.

Overall the response was poor. Possible methods to overcome this deficiency in the response rate are suggested below.

Use the EA date bases of the various grades of Engineer to survey the attitude of current engineers to the teaching of Management

The Australian Council of Deans be responsible for the overall control of the survey with other Universities Faculties of Engineering to carry out a co-ordinated survey with each participating University being responsible for their relevant geographical area.

Survey the population of engineering employers by size (of employees) or by individual industrial segment as listed in the relevant ABS date base.

Rather than a mailed out questionnaire, use face to face interviews with the relevant sample.
6.10 Recommendations

Recommendations are as follows:

1. The critical skill – Communications should be introduced into engineering curricula as soon as possible. This will ensure graduating engineers are capable of communicating effectively to employers, customers, other professionals, office staff and process workers. This could be developed (and taught) by another Faculty. This needs to be addressed at a very early stage and integrated into “basic” technical and scientific subjects.

2. Based on the results of the survey and discussions carried out; there should be a review of engineering curricula with up to 25% management content included. The preferable system would be to integrate the management attributes identified above into the technical/scientific/engineering content. This will allow graduate engineers to participate fully in the progress of their organisations and to learn the process of solving “real life problems”.

3. There should be discussions with the relevant employers of engineers (including engineering, industrial, consulting, government and commercial organisations) as to which skills they believe engineering graduates should possess (on graduation) so as to be able to be a valuable and contributing member of staff from an early point in their career.

4. Engineering Faculties should discuss with various other faculties the incorporation of the necessary skills into the engineering curriculum in such a way as to be seen as part of the engineering learning process. This could involve the development of new teaching methods such as the Society of Automotive Engineers (SAE) project that is being used within a worldwide range of universities. The SAE Collegiate Design Series (2011) in its general comments under “What is FSAE”, states

“Formula SAE promotes careers and excellence in engineering as it encompasses all aspects of the automotive industry including research, design, manufacturing, testing, developing, marketing, management and finances. Formula SAE takes students out of the classroom and allows them to apply textbook theories to real work experiences”.

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This holistic approach to Engineering Education is much more than just scientific/technical training and should be considered a template for the development of similar processes to demonstrate how engineering and management are intertwined and how management is an important part of the complete engineer.

This SAE process is voluntary and encourages undergraduate engineers to innovate and develop unique solutions to engineering as well as management, finance and marketing problems needed to fund and run a project set against a range of criteria and a definite time line.

5 Other skills, such as marketing, sales, motivation, and management costing be reviewed and potentially added to the list of skills already identified. These topics could be introduced into the curricula as specifically targeted case studies. Not all engineers enter the work force as practicing engineers. Many commence their careers in allied fields such as Technical Representatives marketing technical products.

6 Consideration should be given to a course structure that allocates three years to typical engineering subjects with the fourth year being dedicated to specialised subjects, such as management skills, research projects or other similar interests. This year could also be dedicated to a series of case studies along the lines of the FSAE project mentioned in Point 2. This however, will increase the need for a more efficient method of teaching both technical and non-technical subjects.

7. Engineers Australia should revise their Competency requirements to clearly state management skills (as discussed above) are necessary and define the level to which a graduate engineer should possess each skill. EA should use the criteria of the Royal Academy of Engineering and The Engineering Council UK as guides to their own accreditation criteria to ensure all accredited University courses include the desired management skills, and are taught at an appropriate level by suitably qualified teachers.

8. As a proportion of graduate engineers are employed in Industry, in addition to the above management skills, further research is recommended to determine
whether and how operations management and other similar skills should be integrated into undergraduate engineering courses.

9. Innovation and entrepreneurship are very important areas of current concern which have been identified by respondents (pages 232, 241). Innovation and the management of innovation need to be fostered and researched. Other management skills such as the “scientific” fields of Operations Management, Operations Research together with management skills such as Finance, Marketing and Customer Relationships also need to be considered and researched.

6.11 Recommendations for Future Research

The following additional research is recommended.

1 Due to the low response rates from the segments other than Manufacturing and Consulting, this survey should be repeated for all segments with all segments being encouraged to participate more fully. This will confirm the findings of this survey and also allow identification of any variations between segments.

2 Future research in the area of curriculum development relating to the field of undergraduate management training be carried out as a joint venture between the engineering faculty and a business school and/or Faculty of Commerce with, perhaps, advice from an industry and service advisor board. Whilst this thesis is based on the education of undergraduates the involvement of a business school and/or a business school within the Faculty of Commerce will bring together all the relevant knowledge pertaining to the teaching of relevant management subjects.

3 Further research be carried out to confirm the ranking of the skills identified. These, at least, should be incorporated into the engineering curricula using the importance ranking to indicate the weighting when calculating lecture time. In addition, the method of teaching should include case studies that incorporate the management skills mentioned above so the student is presented with a holistic view of a “real life” situation and gains a perspective on how engineering relates to, and is integral in the solving of real life problems.
4. Industry and commerce should be further researched to ascertain if the management skills identified are discipline based or if there is a core group of skills all graduate engineers should possess.

5. The research listed above should be carried out to fully define the managerial subjects that are required by employers of graduate engineers. This may be important in defining whether the skills will be generic or discipline specific and whether these are organisational size specific.

6. Longitudinal research be carried out from the first year of undergraduate studies through to at least the second or third year of employment to track the possible changing attitudes of an engineer “in training” to the concepts and needs of management studies.

6.12 Conclusion

This research has uncovered a significant amount of knowledge concerning the needs of employers with regard to management skills. However this is the beginning of the development of knowledge in this particular area. A comment from the questionnaires highlighted the point that surveys like this are only the beginning and further research in this area should be undertaken. The respondents have shown they have a voice and it needs to be heard. They are the customers of the Universities and Professional bodies. They need well educated engineers who can take their place in society and employment and contribute to both from an early stage in their careers. They believe current engineers will require additional education, preferably at Universities, in management skills (and the others) mentioned above. Also ‘on the job’ training may be required to develop a fully rounded engineer capable of meeting tomorrow’s challenges.

A wide cross-section of employers of engineers has confirmed there is a definite need for graduate engineers to possess specific management skills. Those considered most important are Communication, Finance Skills and Human Resource Management. Other attributes mentioned in the responses were Entrepreneurship, Ethics, Sustainability, and Leadership. It also shows the Management Skills being taught at present by the various institutions are not adequately equipping graduate engineers to undertake their duties successfully in many engineering and industrial/commercial enterprises. They may possess some of the defined skills, but not to an acceptable level.
The management skill set for each engineering discipline is unknown and needs to be assessed by use of similar instruments to this research. This could be individual, targeted either by discipline, ABS segment or by company size. All aspects require further research.

Evaluation of the accrediting criteria for Professional Engineers was reviewed with the criteria for Engineers Australia (EA) and the USA (ABET) being similar. They did not include management skills to the level expected by the Australian respondents. The criteria for UK Professional accreditation was more descriptive in defining the duties of the various grades of Professional Engineers. EA should review their criteria taking into account that of the UK bodies.

Over the next 5 – 10 years with society and technology changing, the engineering and management skills required of engineers will also change. The skills that will be needed require identifying. Responses to Questions 15 and 16 of the survey provide a very good starting point. To facilitate this development of the “new age” engineer a list of management skills which will assist in the development of suitable engineering curricula for undergraduate engineers has been suggested.

The research has shown the list of management skills as listed in the survey is needed. These are not fully present in the current newly graduated engineer to a level employers consider satisfactory. The skills considered most important are Communication, Finance, and Human Resources.

The attempts to add managerial skills as adjuncts to the curricula have not worked and a new approach that is gaining acceptance is to teach management as an integral part of each engineering subject. This approach however will need to be modified to incorporate the skills identified in this research.
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APPENDIX 1

STATISTICAL RESULTS FOR THE SURVEY QUESTIONS

This appendix contains the summary of results as obtained directly from the survey. The questions asked are listed and the various results shown in mathematical form only, together with the comments which were included in the questionnaire responses. These results form the basis of the reordered results listed in Appendix 2 (page 243). Results are also shown in Chapter 4 (page 100) in the main body of the thesis and discussed in Chapter 5 (page 166). They are shown in both mathematical and graphical form.
STATISTICAL RESULTS FOR THE SURVEY QUESTIONS

Where results have been aggregated this is noted. The various statistical methods used are as listed in Chapter 4 (page 100) in the main body of the thesis.

Results are by question as listed in the questionnaire. Where several questions have been compared this is noted

**Question 1 - Decision Making Ability**

To be able to assess and decide between competing solutions to a particular problem.

This skill will have been taught in relation to their technical skills but not necessarily in relation to the decision that a manager needs to make.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.5</td>
<td>8.5</td>
<td>3.4 15.3 18.6 6.8 0.0</td>
</tr>
</tbody>
</table>

Comment:

They need to not (only) understand the technical implications and assessments but also the contractual and administrative flow as well. (DM)

**Question 2 - Human Skills**

a) To be able to work with, communicate, negotiate and relate to others both within the organisation as well as outside the organisation.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.
b). Also be able to teach others, work in groups and with individuals at various levels of management. Resolve conflicts.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree. Please comment on the individual elements of the question if you wish.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1   2   3   4   5</td>
</tr>
</tbody>
</table>

Percentage
45.8 8.5 0.0 8.5 28.8 8.5 0.0

Comments: No written comments

How do I separate their personal characteristics and behaviour from what they have generically acquired as skills through training? (DM)

This seems more to vary with an individual personality rather than their training when at graduate level. (DM)

Not in all engineers and not great in those who have some skills (DM)

These skills are definitely present in some engineers we have employed, but not all. A lot of this relates to self confidence. (DM)

Conflict resolution is acquired with experience. Do you think you can teach it? (DM)

You’ve asked me to respond to seemingly unrelated aspects. Able to teach others? No. Work in groups? Yes. Resolve conflicts? No. (BS)
**Question 3 - Communication**

Be able to send and receive information, thoughts and feelings, which create common understanding and meaning.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
</tr>
</tbody>
</table>

Percentage: 35.6% 8.5% 3.4% 11.9% 28.8% 11.9% 0.0%

Comment: New graduates are often hopeless. They get better as they learn to write English. (BS)

**Question 4 - Interpersonal**

Ability to develop and maintain a trusting and open relationship with superiors, subordinates, peers and external personnel to facilitate the free exchange of information and provide a productive work setting.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
</tr>
</tbody>
</table>

Percentage: 39.0% 8.5% 0.0% 5.1% 15.3% 30.5% 1.7%

Comment: No written comments
**Question 5 - Conceptual**

Ability to see the organisation as a whole and to solve (organisational) problems from a systematic point of view.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

Percentage 33.9 23.7 1.7 18.6 16.9 3.4 1.7

Comments: No written comments

**Question 6 - Diagnostic**

Ability to determine the probable cause(s) of a problem from examining the relevant data and observations by the manager.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

Percentage 57.6 0.0 6.8 3.4 18.6 11.9 1.7

Comments: No written comments

**Question 7 - Flexible**

Ability to deal with ambiguous and complex situations and rapidly changing demands.
In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
</tr>
</tbody>
</table>

Percentage 33.9 11.9 5.1 20.3 15.3 0.0

Comments: No written comments

Question 8 - Administration

Ability to follow policies and procedures, process paper work in an orderly manner and manage expenditures within the limits set by budgets.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
</tr>
</tbody>
</table>

Percentage 55.9 6.8 5.1 5.1 15.3 10.2 1.7

Comments: No written comments

Question 9

Please indicate the importance each of these attributes has to your industry by circling the appropriate number, with one (1) being least important and seven (7) being most important. If you have no viewpoint or consider the skills as irrelevant to your industry please circle 1 (one).

**Decision Making**

<table>
<thead>
<tr>
<th>Decision Making</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>

Percentage 0.0 0.0 0.0 5.1 28.8 33.9 32.2
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<td></td>
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<td>40.7</td>
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<td></td>
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</tr>
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<td>0.0</td>
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<td>11.9</td>
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<td></td>
</tr>
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<td>32.8</td>
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<td>3.4</td>
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</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.0</td>
<td>3.4</td>
<td>6.8</td>
<td>25.4</td>
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<tr>
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<td></td>
<td></td>
</tr>
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<td>Percentage</td>
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<td>25.4</td>
<td>35.6</td>
<td>20.3</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Comments: No written in comments

**Question 10**

Please indicate the importance each of these attributes has to your firm by circling the appropriate number, with one (1) being least important and seven (7) being most important. If you have no viewpoint or consider the skills as irrelevant to your firm please circle 1 (one)
<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
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<th>5</th>
<th>6</th>
<th>7</th>
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<td>32.8</td>
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<td>3.3</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
<td>32.8</td>
<td>33.1</td>
<td>3.3</td>
</tr>
<tr>
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<td>22.8</td>
<td>33.3</td>
<td>36.8</td>
<td>22.8</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
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<td>0</td>
<td>0</td>
<td>7.0</td>
<td>33.3</td>
<td>36.8</td>
<td>22.8</td>
</tr>
<tr>
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<td>10.3</td>
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<td>1.7</td>
<td>10.3</td>
<td>27.6</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
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<td>0</td>
<td>0</td>
<td>1.7</td>
<td>10.3</td>
<td>27.6</td>
<td>60.3</td>
</tr>
<tr>
<td><strong>Interpersonal</strong></td>
<td>2.8</td>
<td>32.8</td>
<td>34.5</td>
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<td>2.8</td>
<td>32.8</td>
<td>34.5</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
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<td>0</td>
<td>0</td>
<td>3.4</td>
<td>32.8</td>
<td>34.5</td>
<td>24.1</td>
</tr>
<tr>
<td><strong>Conceptual</strong></td>
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<td>8.6</td>
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<td>34.5</td>
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<td>3.4</td>
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<td>39.7</td>
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<tr>
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<td>8.6</td>
<td>19.0</td>
<td>36.2</td>
<td>31.0</td>
</tr>
<tr>
<td><strong>Flexible</strong></td>
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<td>29.3</td>
<td>24.1</td>
<td>3.4</td>
<td>25.9</td>
<td>29.3</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
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<td>3.4</td>
<td>8.6</td>
<td>19.0</td>
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<td>31.0</td>
</tr>
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<td>29.3</td>
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<tr>
<td><strong>Percentage</strong></td>
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<td>5.2</td>
<td>32.8</td>
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<td>3.3</td>
</tr>
<tr>
<td><strong>Comments:</strong></td>
<td>No written comments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Question 11**

Nominate from which discipline your engineers originated. Indicate the approximate numbers in the area allocated. If you employ zero engineers in any of the disciplines please enter zero.

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>198</td>
</tr>
<tr>
<td>Mining</td>
<td>33</td>
</tr>
<tr>
<td>Civil</td>
<td>198</td>
</tr>
<tr>
<td>Materials</td>
<td>16</td>
</tr>
<tr>
<td>Mechatronics</td>
<td>25</td>
</tr>
<tr>
<td>Others</td>
<td>359</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>829</strong></td>
</tr>
</tbody>
</table>

**Question 12**

Are you satisfied with the skills of the engineers you employ? Please mark the relevant box. If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1   2  3  4  5</td>
</tr>
<tr>
<td>Percentage</td>
<td>48.2</td>
<td>10.7</td>
<td>0.0 3.6 16.1 17.9 3.6</td>
</tr>
</tbody>
</table>

Comments:

- Conceptual, human skills, decision making - rank 5 (FL)
- Ethics, emotional quotient (FM)
- Electronics (DL)
- Getting on with paperwork and speaking good and understandable English. (DM)
Young engineers are well educated and more multi-cultural but lack practical
knowledge of how things work. (DM)

Lack of interpersonal (skills) as well as practical engineering skills. Some even lack any
passion for their chosen field. (DM)

Soft skills/people skills/interpersonal skills (DM)

1. Knowledge of specific codes in which engineers work. 2. The ability to ascertain
capacity by quick reference. 3. Clients are paying for code investigation instead of
design. (DS)

1. True understanding of the engineering concepts. 2. Lack in knowledge of Australian
Standards. 3. Practical solutions to design. 4. Assessment of installations. (BM)

Interpersonal and communication skills (BM)

**Question 13**

Can these skills be learnt on the job? If your answer is “To some degree” indicate the degree by
marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Percentage 48.1 3.7 0.0 5.6 22.2 16.7 3.7

Comments:

Note; whilst they can be learned on the job, it is important that they have training at the
University level so that they don’t start off work with no useful knowledge. (BM)

**Question 14**

If you answered “No” to Question 13 what skills do you feel need to be provided with formal
training? Please list in order of importance.
Comments:

Universities need to impart some writing skills in new graduates. Spelling, grammar, proper sentence formation NOT SMS language.  (BS)

Those mentioned in Q12. It’s all about people!  (BS)

Human skills, Communication, Management/interpersonal  (BM)

Some are internal personal skills that some people will have and others will never possess.  (BM)

As per Q12.  (DS)

English, English, English. The rest is nowhere near as important.  (DM)

These skills can be developed and improved while on the job but all our engineers that we employ here already possess these skills.  (DM)

Although I did not tick No. 1 I think it is imperative that their tertiary education pick up on these themes.  (DM)

Engineering’s role in the broader business process.  (DM)

Leadership and management (at a conceptual level).  (DM)

Question 15

a) Do you feel the skills and attributes required of an engineer will change in the short term future (within the time frame of up to 5 years)? For example – sustainability issues. If your answer is “Yes” please comment on the way you see engineering attributes changing.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>64.9</td>
<td>35.1</td>
</tr>
</tbody>
</table>
Comments:

Environment, sustainability, technology, stakeholder management (FM)

Social and sustainability issues will determine the way and form of the engineering attributes. (FM)

Human resource issues need to be increasingly managed. An integrated approach to conciliation, health, safety, enviro issues has increasing emphasis. (FS)

Will need more flexibility in learning computer skills, presentation skills, customer svc (service?), customer management, organisation wide perspectives, and esp(ecially) an understanding of finance as well as env, OHS QA. (EM)

More customer focused, more effectual communication and interpersonal skills (DL)

Innovation and sustainability will become increasingly important. In our industry energy conservation will be particularly important. (DL)

Heavy emphasis on electronic applications requires far higher learning by engineering team. (DL)

Technology changes and social (DL)
Technology change and compatibility, technological advancement, environmental change. (DL)

Yes, but it depends on the industry. For construction/civil/mining/environmental and safety concerns will assume importance. For manufacturing – technology and dealing with overseas companies/subsidiaries (in particular in China) will be essential. (DL)

The nature of globalisation and corporate consolidation result in design in one country, drawing in second country, project mgt in a third etc. i.e. no longer Australian stds, Aust design etc. (DM)

Safety, people/process interaction (automation), environment are key design criteria now. (DM)
Management and people skills –HR oriented  
(DM)

Chemicals, machinery, usages and availability have changed radically in the past 5 years.  
(DM)

Engineers are becoming more and more expected to know a bit of everything i.e. generalists. This may be due to the rise in project management requirements rather than specific technical skills that would be used in manufacturing/development etc. (DM)

Management, personal evaluations, financial, other business skills are sorely needed. Just engineering does not give them all the skills they need to function in a business environment. (DM)

Depends on the size of the company and number employees. Anal types are quickly exposed in smaller companies (no where to hide!). (DM)

Management of resources, environment and longevity requirements are becoming a larger part of requirements, i.e. design life 100 yrs, reduced carbon emission for that life span (DS)

Awareness of expanding regulation after taking time away from the engineering function OH & S –administration (DS)

More detailed management will be required (CS)

Regulations, standards and technology is constantly changing and must be kept up with. (BM)

Professionals are tools to achieve business success and as business changes so the skills of professionals must change. (BM)

Client/customer needs (BM)

Regulations, WH & S operations, technical requirements (BS)

The world is changing and basics of computer control are changing. (BS)
The industry is constantly changing, the areas that engineers now get exposed to include safety management, environmental engineering, and community consultation. In particular expatriate positions have a far broader exposure than ever before. (AL)

Zero harm focus with emphasis on $. (AL)

**Question 16**

Do you feel the skills and attributes required of an engineer will change in the long term (beyond 5 years)? For example – sustainability or environmental issues. If your answer is “Yes” comment on the way you see engineering attributes changing.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>84.2</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Comment:

- Culture and demographical issues will determine the change of engineering attributes. (FM)
- Engineering solutions will have to be examined more closely from the cultural and global perspectives. (FM)
- Environment issues (FM)
- Possibly that increasing engineering specialty degrees will be required (e.g. waste recovery engineering) (FS)
- Sustainability – understanding of TCO (EM)
- Required to not only have essential engineering skills but also have added skills – financial, management, interpersonal etc. (DL)
- Evolution of new processes and materials in manufacturing. (DL)
Electronic and other developments will cause major employment training issues for the future. (DL)

More of above. However design and manufacturing may be absent from Australia completely unless geopolitical/environment/economic factors reverse current trends. (DL)

Through education and trends as you have highlighted (DM)

Need to be well rounded/flexible to survive in the new world skills. (DM)

Engineers will be as important as the scientists and environmentalists to put in place the functional aspects of sustainability. (DM)

As above unless Australia stops becoming nothing more than a coal/iron ore mine. (DM)

More multi disciplined i.e. both electrical and mechanical amalgamated to facilitate automation. (DM)

Information technology is changing, design and drafting roles will become increasingly specialised and departmentalised. Engineers will be working in large global organisations. (DM)

The overall spectrum of both sustainability and environment is in an evolution and education stage that will continue long into the future. (DS)

Regret that the trend will dilute engineering focus due to the (peripheral) workload. (DS)

Environmental, safety in design and engagement with communities on major construction projects. (BL)

Diversity of tasks in a sustainable world. (BM)

Environmental, ethics of new technology (BM)

As above also to keep pace with industry advances. (BM)
More admin/people/financial management  (BS)

Technology and ecology are evolving. It will become necessary to use alternative resources when existing resources are becoming extinguished. Water supply, energy, building construction.  (BS)

Good example – sustainability and environmental issues particularly.  (BS)

Hopefully we are in “interesting times”, perhaps there will be many changes, largely dealing with “difficult” sites as we have already colonised the best bits.  (BS)

We are already seeing it with the exposure to corporate governance issues  (AL)

Increased reliance on technology  (AM)

In the questionnaire this section was prefaced with the following comment:

The following section covers the perceived effect that engineer’s management skills (or lack of them) can affect the financial and economic well being of an organisation. If you believe management skills of current engineers are satisfactory then do not complete this section. However any views you do have in this area would be gratefully appreciated.

The following comments were noted:

Human Resources skills units should be incorporated with routine management training.  (FS)

1. They need better English.  2. They need to understand we haven’t got all the time and money to create a better answer commercially. We have to do something now, even some things can be done better over time.  (DM)

Both my chemical engineers were trained at a university overseas – 7 yr course  (DM)

Most graduates lack commercial savvy and need more work experience in various size companies during learning phase.  (DM)
Young engineers need to understand that they will need to acquire management skills to progress in seniority. Many will fail to acquire these skills and will not progress in seniority. (BS)

**Question 17**

Do you believe a newly graduated engineer could be required to assume junior management roles within six months of joining your firm? Please circle your answer.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Within 12 months</th>
<th>Later</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.6</td>
<td>28.6</td>
<td>17.9</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Comments:

By filling their own time sheet and then becoming responsible for the productivity of others in their team. It is a continuing process. (BS)

Perhaps five years (BM)

(Within 12 months) if they have the correct people skills (BM)

**Question 18**

In your opinion do you believe a newly graduated and employed engineer should have a basic understanding of financial and human resource aspects of management so they can successfully fill their position? Please tick your answer.

<table>
<thead>
<tr>
<th>Financial</th>
<th>Human Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
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<tr>
<td>89.5</td>
<td>10.5</td>
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<tr>
<td>84.0</td>
<td>15.8</td>
</tr>
</tbody>
</table>
Comments:

If you are going to ask people to spend their money on your design, you should have some idea of where the money comes from. Hiring is easy. Firing is very difficult (for me anyway). (BS)

Not immediately (BS)

(No) Within 12 months (BS)

(Yes) To what extent depends on the industry. (DL)

Question 19

Is it your opinion that engineers, as currently trained to bachelor level, are ready to fully participate in and contribute to the successful running of your organisation?

If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19.3</td>
<td>26.30</td>
<td>5.30 15.8 17.5 14.0 1.8</td>
</tr>
</tbody>
</table>

Comments:

In the Roles we give them recognising they are graduates. (DM)

To do what they are told for a few years until they acquire sufficient experience to be given more autonomy. (BS)

Question 20

Do you believe that graduate engineers, as currently trained, have all the necessary skills to integrate into your organisation?
If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Percentage 29.8 14.0 3.5 8.8 28.1 14.0 1.8

Comments:

They need to learn to write in English that can be read and understood by non-technical people. Grammar, spelling and punctuation. Proper sentence formation. They need to be able to write an informative report.

(BS)

English (written in and given an 8) (DM)
Legal Skills (written in and given a 7) (BS)

If your answer is “No” or “To some degree”, what skills do you believe are required to become fully effective? Indicate, in order of importance, those skills you consider important with 1 being very important and 7 being of little importance. Mark all skills you believe are important.

Of the 79 responses recorded the following were the results

- Decision making: Zero
- Human Skills: 7
- Communication: 14
- Interpersonal: 13
- Conceptual: 10
- Diagnostic: 11
- Flexible: 11
- Administration (financial): 13

Comment:

DC and F – surely these are inherent skills not learnt as such (BS)
Question 21

In your experience do junior engineers or newly graduated engineers profess a disinterest in management activities?

If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
</tr>
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<tbody>
<tr>
<td>23.6</td>
<td>45.5</td>
<td>1.8 5.5 20.0 3.6 0.0</td>
</tr>
</tbody>
</table>

Comments:

Usually keen to be managers from day 1 (EM)

No comment (DM)

Young engineers want to exercise their newly acquired skills to build something large of which they can be proud. (written communication?) (BS)

Question 22

Do you think employers should have a direct role in developing and teaching curricula?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td>82.5</td>
<td>17.5</td>
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</table>

Comments:

But utilise prac placements and vacation placements (AL)

Universities need to produce technically competent engineers who are capable of choosing their own path in their profession. Allowing employers a direct role in
engineering curricula will see engineers being trained as technicians rather than innovative professionals. (BS)

To some degree (BS)

YES! (BM)

Should be willing to express views which can contribute to the development of good and relevant curricula. (DS)

Yes, to the extent of being consulted on the variety of things to include in curriculum. This type of survey is an excellent start. (FL)

**Question 23**

Would you be prepared to partner with an Engineering Faculty in allowing students to undertake assessed tasks in the workplace that are directly aimed at developing realistic and practical management skills?

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Percentage</td>
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</table>

Comments:

Yes, we do with Deakin University (EL)

Based in Villawood NSW and process is repetitive and no suitable tasks. (DM)

Because we are a small organisation we would not meet our inspirational needs to the students benefit. (DS)

Note: However our organisation is small and we could best help by having students learn at our works. (BM)

We quite often have university students on work experience. They take up a lot of time and staffing resources. (BS)
If time available

However, I am a “one man band” working in remedial waterproofing and building rectification. I guess all they would see is the result of poor work practices. (BS)

This may be difficult given our mine sites are overseas, but I believe this aspect of undergraduate development needs to be seriously looked at. (AL)
APPENDIX 2

STATISTICAL ANALYSIS AND DATA REORDERING
A2.1 Data Reordering

The initial statistical analysis did not reveal a large number of statistically relevant data. The data in the mid ranges of the questions that required a “To some degree” as part of the answer, was not highlighted. This data was reassembled with the “To some degree” answers combined to give a third possibility. Using the three possible answers the data was then found to be statistically relevant in the vast majority of cases. This data is incorporated in results for each question.

The results shown in this Appendix 2 are those of Appendix 1(page 221) which have been recoded. The “Yes” results have been placed after 5 on the Likert Scale where 5 was to a major degree i.e. close to a “Yes” answer. The “No” results where placed before the 1 on the Likert Scale. This gave a graded answer from a firm “Yes” through “To some degree” to a firm “No”.

Statistical analysis has been carried out on all questions. To simplify presentation of results a typical set of analysis has been included for each group of questions that were analysed in the same manner.

For questions requiring a “Yes” or “No” answer this data is presented as recorded.

A2.2 Statistical Analysis – All responses for Statistical Significance

The statistical analysis carried out in the first stage was to ensure all responses to each individual question were statistically significant. As the results were voluminous the various questions, which were treated in a similar manner, have been grouped together. An example of the analysis is presented below together with a summary of the results for all similar questions.

The results for the other statistical analysis where there were comparisons between various sized organisations (e.g. medium and large organisations compared to small organisations) and between various segments (e.g. consulting and manufacturing) are dealt with in a similar manner.
Table A2.1  Statistical Results for Questions 1 - 8, 12, 13, 17, 19, 20 and 21.

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#### Chi Squared Tests

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<th>Exp</th>
<th>Obs-Exp</th>
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Hₐ: In the population, responses are equally allocated among the three categories. Rejected, P(Chi Squared) = 0.00026.

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H₀: In the population, responses are equally allocated among the seven categories. Rejected, P(Chi Squared) = 3.46x10⁻13.

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<td>5.200</td>
<td>5.200</td>
<td>5.200</td>
<td></td>
</tr>
<tr>
<td><strong>o-e</strong></td>
<td>-3.200</td>
<td>3.800</td>
<td>5.800</td>
<td>-1.200</td>
<td>-5.200</td>
<td></td>
</tr>
<tr>
<td><strong>(o-e)^2/e</strong></td>
<td>1.96923</td>
<td>2.77692</td>
<td>6.46923</td>
<td>0.27692</td>
<td>5.20000</td>
<td></td>
</tr>
<tr>
<td>Chi Sq</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.f</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(Chi Sq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.002217912</td>
</tr>
</tbody>
</table>

H₀: In the population, responses are equally allocated among the five ranks. Rejected, P(Chi Squared) = 0.002. There is significant clustering of responses into the central three ranks.
Table A2.2  Statistical Results for Questions 9 and 10 (All Attributes)

<table>
<thead>
<tr>
<th>Question 9</th>
<th>Administration</th>
<th>NR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>To 20</td>
<td>No responses</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Consulting</td>
<td>To 20</td>
<td>1 1 1 2</td>
<td>1 8</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>2 1 2 2</td>
<td>1 8</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>1 2 1</td>
<td>4</td>
</tr>
<tr>
<td>Construction</td>
<td>To 20</td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>No responses</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>No responses</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>To 20</td>
<td>1 1 1 2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>1 4 5 2</td>
<td>1 1</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>6 1 1 1</td>
<td>9</td>
</tr>
<tr>
<td>PS and U</td>
<td>To 20</td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>1 1</td>
<td>2</td>
</tr>
<tr>
<td>Transport</td>
<td>To 20</td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>21 - 99</td>
<td>3 1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>100 +</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>0 0 5 15 21 12 6 1</td>
<td>60</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>0.0 0.0 8.5 25.4 35.6 20.3 10.2</td>
<td>100.0</td>
</tr>
</tbody>
</table>
### Question 9: Administration

<table>
<thead>
<tr>
<th>Percent of responses</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed No. of Responses</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>15</td>
<td>21</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>(0-e)^2/e</td>
<td>8.429</td>
<td>8.429</td>
<td>1.395</td>
<td>5.123</td>
<td>18.751</td>
<td>1.513</td>
<td>0.700</td>
</tr>
</tbody>
</table>

Chi Squared = 44.339
Deg of freedom = 6
P(Chi Squared) = 6.33E-08

H₀: (Population ranks responses 1 to 7 equally) is rejected

The respondents ranked Administration skills as being moderately unimportant to highly important with scores ranging from 3 to 7 on the Likert scale, with the mode being 5 which had 35.6% of the responses while 4 had 25.4% and 6 had 20.3%.

This is very significantly different from an equal spread over all seven scores; P(Chi Squared) = 6.33x10⁻⁸.
### Table A2.3  Statistical Results for Questions 15, 16, 17, 18, 22, and 23

<table>
<thead>
<tr>
<th>Question 15</th>
<th>Yes</th>
<th>No</th>
<th>No Response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mining</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 - 99</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>100 +</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Consulting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>4</td>
<td>4</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>21 - 99</td>
<td>4</td>
<td>4</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>100 +</td>
<td>2</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>100 +</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>21 - 99</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>100 +</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td><strong>PS and U</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>100+</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 20</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21 - 99</td>
<td>2</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>100 +</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>37</td>
<td>20</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>64.9</td>
<td>35.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>57</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
$H_0$ is $\Pr(Yes) = 0.5$

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>64.9</td>
<td>35.1</td>
</tr>
</tbody>
</table>

$p = 0.6491228$
$1-p = 0.3508772$

$n = 57$

$s.d. - 0.068227$
$z = 2.251705$
$P(z) = 0.98783$
$1-P(z) = 0.01217$

Chi Squared Tests

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Exp</th>
<th>o-e</th>
<th>(o-e)^2/n</th>
<th>Chi Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37</td>
<td>28.5</td>
<td>8.5</td>
<td>2.5350877</td>
<td>5.0701754</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>28.5</td>
<td>-8.5</td>
<td>2.5350877</td>
<td></td>
</tr>
</tbody>
</table>

$d.f. = 1$
$P(Chi Sq) = 0.0243409$

$H_0$: Population proportion of “Yes” responses = 0.5

$H_0$ is rejected, “Yes” responses significantly exceed “No” responses.

95% confidence interval for population proportion of Yes responses using the Wilson score interval (Wilson 1927) is $0.6397 \pm 0.1203$
Table A2.4  Tests for Non-Random Responses of ‘No’, ‘To some degree’ or ‘Yes’

<table>
<thead>
<tr>
<th>Question</th>
<th>Chi Squared</th>
<th>d.f.</th>
<th>p(Chi Sq.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.508</td>
<td>2</td>
<td>0.00027</td>
</tr>
<tr>
<td>2 (a)</td>
<td>16.407</td>
<td>2</td>
<td>0.00026</td>
</tr>
<tr>
<td>2 (b)</td>
<td>20.068</td>
<td>2</td>
<td>0.00004</td>
</tr>
<tr>
<td>3</td>
<td>20.068</td>
<td>2</td>
<td>0.00004</td>
</tr>
<tr>
<td>4</td>
<td>18.034</td>
<td>2</td>
<td>0.00012</td>
</tr>
<tr>
<td>5</td>
<td>3.085</td>
<td>2</td>
<td>0.21387</td>
</tr>
<tr>
<td>6</td>
<td>31.559</td>
<td>2</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>7</td>
<td>15.898</td>
<td>2</td>
<td>0.00035</td>
</tr>
<tr>
<td>8</td>
<td>21.797</td>
<td>2</td>
<td>0.00002</td>
</tr>
<tr>
<td>9</td>
<td>Administrative</td>
<td>44.339</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>104.136</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Conceptual</td>
<td>60.475</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Decision Making</td>
<td>66.644</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Diagnostic</td>
<td>70.915</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Flexible</td>
<td>51.932</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Human Skills</td>
<td>65.695</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Interpersonal</td>
<td>61.241</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>Administrative</td>
<td>40.582</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>125.207</td>
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<tr>
<td></td>
<td>Conceptual</td>
<td>64.862</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Decision Making</td>
<td>76.690</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Diagnostic</td>
<td>72.103</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Flexible</td>
<td>52.552</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Human Skills</td>
<td>64.211</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Interpersonal</td>
<td>59.069</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>13.321</td>
<td>2</td>
<td>0.00128</td>
</tr>
<tr>
<td>13</td>
<td>21.333</td>
<td>2</td>
<td>0.00002</td>
</tr>
<tr>
<td>15</td>
<td>5.070</td>
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<td>0.2434</td>
</tr>
<tr>
<td>16</td>
<td>26.684</td>
<td>1</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>17</td>
<td>20.643</td>
<td>1</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>18</td>
<td>Financial</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>Human Skills</td>
<td>26.684</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>11.789</td>
<td>2</td>
<td>0.00275</td>
</tr>
<tr>
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<td>15.474</td>
<td>2</td>
<td>0.00044</td>
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<td>21</td>
<td>4.073</td>
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<td>0.13050</td>
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<tr>
<td>22</td>
<td>24.018</td>
<td>1</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>23</td>
<td>2.667</td>
<td>1</td>
<td>0.10247</td>
</tr>
</tbody>
</table>

Responses to all questions significantly differ from random except where marked N.S.
A2.3 Statistical Analysis – All responses for Size of Organisation

The data was analysed for the two major segments – Consulting and Manufacturing for the possibility of differing responses when considering the size of the organisation. The method of analysis varied as shown in Appendix A2.2 (page 244), so the same range of example results will be shown.

Table A 2.5 Analysis of the Data by Size of the Organisation - Questions 1 - 8, 12, 13, 17, 19, 20, and 21.

Question 1 Chi Squared Test for different responses from medium and large organisations.

<table>
<thead>
<tr>
<th>Size of Organisation</th>
<th>No</th>
<th>To some degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>4</td>
</tr>
<tr>
<td>1 to 99</td>
<td>Expected</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>obs-Exp</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)2/Exp</td>
<td>0.079454</td>
</tr>
<tr>
<td>100 +</td>
<td>Observed</td>
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</tr>
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<td></td>
<td>Expected</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>obs-Exp</td>
<td>-0.53</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)2/Exp</td>
<td>0.180979</td>
</tr>
<tr>
<td>Total Obs</td>
<td>5</td>
<td>26</td>
</tr>
</tbody>
</table>

Chi Squared = 0.776

Note: There are some cells with expected frequencies less than 5, so we combined columns.

P(Chi Squared) = 0.6784 Not Significant
### Size of Organisation

<table>
<thead>
<tr>
<th>Size of Organisation</th>
<th>No or To some degree</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>Expected</td>
<td>21.54</td>
<td>19.46</td>
</tr>
<tr>
<td>Obs-Exp</td>
<td>1.46</td>
<td>-1.46</td>
</tr>
<tr>
<td>(Obs-Exp)^2/Exp</td>
<td>0.098628</td>
<td>0.109195</td>
</tr>
<tr>
<td>1 to 99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Expected</td>
<td>9.46</td>
<td>8.54</td>
</tr>
<tr>
<td>Obs-Exp</td>
<td>-1.46</td>
<td>1.46</td>
</tr>
<tr>
<td>(Obs-Exp)^2/Exp</td>
<td>0.224652</td>
<td>0.248722</td>
</tr>
<tr>
<td>100+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Obs**

|                | 31   | 28  |

**Chi Squared =** 0.681  
**No. of d.f. =** 1  
**P(Chi Squared) =** 0.4092  
**Not Significant**

For two-tailed Fisher's Exact test, **P = 0.5721**  
**Not Significant**
Table A2.6  Analysis of the Data by Size of the Organisation - Questions 9 and 10.

<table>
<thead>
<tr>
<th>Question 9</th>
<th>Flexible Analysis by size of organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Two-Tailed Fisher's Exact Test

<table>
<thead>
<tr>
<th>Observed Counts</th>
<th>1 to 5</th>
<th>6 or 7</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size 1 to 99</td>
<td>13</td>
<td>27</td>
<td>40</td>
</tr>
<tr>
<td>Size 100+</td>
<td>8</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Column Total</td>
<td>21</td>
<td>37</td>
<td>58</td>
</tr>
</tbody>
</table>

P = 0.3946 Not significant

P(response of 6 or 7 | size 1 to 99) = 0.675

P(response of 6 or 7 | size of 100+) = 0.556

This difference is not statistically significant at the 5% level.
### Table A2.7 Analysis of the Data by Size of the Organisation - Questions 15, 16, 18, 22 and 23.

#### Question 18

Chi Squared Test for different responses from medium sized and large organisations

<table>
<thead>
<tr>
<th>Financial Size of Organisation</th>
<th>No</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 99 Observed</td>
<td>4</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>Expected</td>
<td>4.21</td>
<td>35.79</td>
<td>40</td>
</tr>
<tr>
<td>Obs-Exp</td>
<td>-0.21</td>
<td>0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>(Obs-Exp)^2/Exp</td>
<td>0.010526</td>
<td>0.001238</td>
<td>0.012</td>
</tr>
<tr>
<td>100 + Observed</td>
<td>2</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Expected</td>
<td>1.79</td>
<td>15.21</td>
<td>17</td>
</tr>
<tr>
<td>Obs-Exp</td>
<td>0.21</td>
<td>-0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>(Obs-Exp)^2/Exp</td>
<td>0.024768</td>
<td>0.002914</td>
<td>0.028</td>
</tr>
<tr>
<td>Total Obs</td>
<td>6</td>
<td>51</td>
<td>57</td>
</tr>
</tbody>
</table>

Chi Squared = 0.039

No. of d.f. = 1

P(Chi Squared) = 0.8426 Not Significant

For two-tailed Fisher's Exact test P = 1.000 Not Significant

Note: There are some cells with expected frequencies of less than 5, so Chi Test is not reliable.
A2.4 Analysis of the Data by the type of Organisation (Consulting and Manufacturing)

The data was reviewed for differences within two differing Segments – Consulting and Manufacturing and examples of the results are listed below:

Table A2.8 Analysis of the Data by the type of Organisation (Consulting and Manufacturing)
Questions 1 - 8, 12, 13, 17, 19, 20, and 21

Question 3

Chi Squared Test for different responses from Consulting and Manufacturing

<table>
<thead>
<tr>
<th></th>
<th>Consulting</th>
<th>Manufacturing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No or Some</strong>*</td>
<td>Observed</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>12.52</td>
<td>16.48</td>
</tr>
<tr>
<td></td>
<td>0bs-Exp</td>
<td>2.48</td>
<td>-2.48</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)^2/Exp</td>
<td>0.4901</td>
<td>0.3724</td>
</tr>
<tr>
<td><strong>Yes</strong></td>
<td>Observed</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>6.48</td>
<td>8.52</td>
</tr>
<tr>
<td></td>
<td>0bs-Exp</td>
<td>-2.48</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)^2/Exp</td>
<td>0.9474</td>
<td>0.7201</td>
</tr>
</tbody>
</table>

Total Obs 19 25 44

Chi Squared = 2.5300
No. of d.f. = 1
P(Chi Squared) = 0.1117 Not Significant

* To some degree
For two-tailed Fisher's Exact Test p = 0.1985; not significant
Table A2.9  Analysis of the Data by the Type of Organisation (Consulting and Manufacturing). Questions 9 and 10.

Comparison of responses from Consulting and Manufacturing

<table>
<thead>
<tr>
<th>Question 9</th>
<th>Decision Making</th>
<th>1 to 5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consulting</td>
<td>expected</td>
<td>6.477</td>
<td>6.477</td>
<td>6.045</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>o-e</td>
<td>0.523</td>
<td>0.523</td>
<td>-1.045</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(o-e)^2/e</td>
<td>0.042185</td>
<td>0.042185</td>
<td>0.180793</td>
<td>0.265163</td>
</tr>
<tr>
<td></td>
<td>observed</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>expected</td>
<td>8.523</td>
<td>8.523</td>
<td>7.955</td>
<td>25</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>o-e</td>
<td>-0.523</td>
<td>-0.523</td>
<td>1.045</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(o-e)^2/e</td>
<td>0.032061</td>
<td>0.032061</td>
<td>0.137403</td>
<td>0.201524</td>
</tr>
</tbody>
</table>

| Chi Squared | 0.466687 |
| d.f.        | 2        |
| p(Chi Squared) | 0.791882 | Not significant |
Table A2.10 Analysis of the Data by the type of Organisation (Consulting and Manufacturing)
Questions 15, 16, 18, 22 and 23

Question 23

Chi Squared Test for different responses from Consulting and Manufacturing

<table>
<thead>
<tr>
<th></th>
<th>Consulting</th>
<th>Manufacturing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Observed</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>7.65</td>
<td>9.35</td>
</tr>
<tr>
<td></td>
<td>Obs-Exp</td>
<td>-2.65</td>
<td>2.65</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)^2/Exp</td>
<td>0.9180</td>
<td>0.7511</td>
</tr>
<tr>
<td>Yes</td>
<td>Observed</td>
<td>13</td>
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<td></td>
<td>Expected</td>
<td>10.35</td>
<td>12.65</td>
</tr>
<tr>
<td></td>
<td>Obs-Exp</td>
<td>2.65</td>
<td>-2.65</td>
</tr>
<tr>
<td></td>
<td>(Obs-Exp)^2/Exp</td>
<td>0.6785</td>
<td>0.5551</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>22</td>
</tr>
</tbody>
</table>

Total Obs

Chi Squared = 2.9027

No. of d.f. = 1

P(Chi Squared) = 0.0884 Not Significant

For two-tailed Fisher's Exact Test P = 0.1159; not significant
APPENDIX 3

SURVEY QUESTIONNAIRE
University of Wollongong  Sydney Business School

Management Education for Engineers – Is it Imperative?

What effect has it on Business Performance?

For the purpose of this survey a graduate engineer is considered to be a university graduate who possesses a bachelor degree in any one of the various engineering disciplines.

As a probable employer of graduate engineers you may have already formed an opinion on the attributes and skills they possess or should possess on graduation.

The following questionnaire seeks your opinion on whether the graduate engineers you have employed meet these attributes and whether they are, in fact, the most suitable for your activities or industry. All information obtained will be treated in the strictest confidence and in accordance with the University of Wollongong’s policies. No identifying information will be published without the relevant person’s permission.

We ask you to answer each question, by using the method indicated, which best reflects your opinion of the questions asked. Some seek comments or opinions and your input would be greatly appreciated.

It is estimated it should take approximately 15 - 20 minutes to complete.

Even if you do not employ graduate engineers please complete this survey as your comments will be appreciated.

A review of literature concerning management skills has produced the following questions on what a range of authors believe to be essential to the management of both people and assets. These are listed with a definition of what that particular skill refers to. Also we have listed some questions on your industry and the number and type of engineers you may employ.

Thank you for your time and patience. Your input is greatly valued.

Please note that this questionnaire is printed on both sides of the paper.

If you wish, you may attach (on a separate page) any comments you would like to make regarding this survey. If you have any queries with any section or wish clarification please contact the researcher on the email address listed at the end of the survey.

If you have any complaints regarding the way in which the research is or has been conducted please contact the University of Wollongong Ethics Officer on (02) 42214457.
Questionnaire

In your opinion are the following skills and attributes (as defined before each question) present or absent, either totally or partially in the engineers you have employed as new graduates within the past 5 years. Please indicate your answers using the method described? If you choose the answer “To some degree” please indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree?

Question 1 - Decision Making Ability

To be able to assess and decide between competing solutions to a particular problem. This skill will have been taught in relation to their technical skills but not necessarily in relation to the decision that a manager needs to make.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □       No □       To some degree
□ □ □ □ □  
 1  2  3  4  5

Question 2 - Human Skills

a) To be able to work with, communicate, negotiate and relate to others both within the organisation as well as outside the organisation.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □       No □       To some degree
□ □ □ □ □  
 1  2  3  4  5

b) Also be able to teach others, work in groups and with individuals at various levels of management. Resolve conflicts.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree. Please comment on the individual elements of the question if you wish to.
Question 3 - Communication

Be able to send and receive information, thoughts and feelings, which create common understanding and meaning.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □ No □ To some degree □ □ □ □ □
1 2 3 4 5

Question 4 - Interpersonal

Ability to develop and maintain a trusting and open relationship with superiors, subordinates, peers and external personnel to facilitate the free exchange of information and provide a productive work setting.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □ No □ To some degree □ □ □ □ □
1 2 3 4 5

Question 5 - Conceptual

Ability to see the organisation as a whole and to solve (organisational) problems from a systematic point of view.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.
Yes □  No □  To some degree
□ □ □ □ □
1 2 3 4 5

Question 6 - Diagnostic

Ability to determine the probable cause(s) of a problem from examining the relevant data and observations by the manager.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □  No □  To some degree
□ □ □ □ □
1 2 3 4 5

Question 7 - Flexible

Ability to deal with ambiguous and complex situations and rapidly changing demands.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □  No □  To some degree
□ □ □ □ □
1 2 3 4 5

Question 8 - Administration

Ability to follow policies and procedures, process paper work in an orderly manner and manage expenditures within the limits set by budgets.

In your opinion is this skill present in your employed engineers? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □  No □  To some degree
□ □ □ □ □
1 2 3 4 5
**Question 9**

Please indicate the importance each of these attributes has to your **industry** by circling the appropriate number, with one (1) being least important and seven (7) being most important? If you have no viewpoint or consider the skills as irrelevant to your industry please circle 1 (one).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision making</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Skills</td>
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<td></td>
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<tr>
<td>Communication</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Interpersonal</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Diagnostic</td>
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</tr>
<tr>
<td>Flexible</td>
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</tr>
<tr>
<td>Administration</td>
<td></td>
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</tr>
</tbody>
</table>

**Question 10**

Please indicate the importance each of these attributes has to your **firm** by circling the appropriate number, with one (1) being least important and seven (7) being most important? If you have no viewpoint or consider the skills as irrelevant to your firm please circle 1 (one).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision making</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Skills</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Communication</td>
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<tr>
<td>Interpersonal</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic</td>
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</tr>
<tr>
<td>Flexible</td>
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<td></td>
</tr>
<tr>
<td>Administration (financial)</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

264
Please provide the following additional information that will allow for the categorisation of your firm and industry? Answer each question by the appropriate method.

**Question 11**

Nominate from which discipline your engineers originated. Indicate the approximate numbers in the area allocated. If you employ zero engineers in any of the disciplines please enter zero.

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number employed within the last five years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td></td>
</tr>
<tr>
<td>Civil</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
</tr>
<tr>
<td>Mechatronics</td>
<td></td>
</tr>
<tr>
<td>Other disciplines</td>
<td></td>
</tr>
</tbody>
</table>

**Question 12**

Are you satisfied with the skills of the engineers you employ? Please mark the relevant box. If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □ No □ To some degree □ □ □ □ □
1 2 3 4 5

If you are dissatisfied, what skills do you believe they lack apart from those mentioned in Question 9? List in order of importance.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
Question 13

Can these skills be learnt on the job? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □ No □ To some degree □ □ □ □ □

1 2 3 4 5

Question 14

If you answered “No” to Question 13 what skills do you feel need to be provided with formal training? Please list in order of importance.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Question 15

a) Do you feel the skills and attributes required of an engineer will change in the short term future (within the time frame of up to 5 years)? For example – sustainability issues. If your answer is “Yes” please comment on the way you see engineering attributes changing.

Yes □ No □

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Question 16

Do you feel the skills and attributes required of an engineer will change in the long term (beyond 5 years)? For example – sustainability or environmental issues. If your answer is “Yes” comment on the way you see engineering attributes changing.

Yes □ No □

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

The following section covers the perceived effect that engineer’s management skills (or lack of them) can affect the financial and economic well being of an organisation. If you believe management skills of current engineers are satisfactory then do not complete.
this section. However any views you do have in this area would be gratefully appreciated.

Question 17

Do you believe a newly graduated engineer could be required to assume junior management roles within six months of joining your firm? Please circle your answer.

Yes □ No □ Within 12 months □ Later □

Question 18

In your opinion do you believe a newly graduated and employed engineer should have a basic understanding of financial and human resource aspects of management so they can successfully fill their position? Please tick your answer.

Financial Yes □ No □

Human Resources Yes □ No □

Question 19

Is it your opinion that engineers, as currently trained to bachelor level, are ready to fully participate in and contribute to the successful running of your organisation? If your answer is “To some degree” indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

Yes □ No □ To some degree

□ □ □ □ □
1 2 3 4 5

Question 20

Do you believe that graduate engineers, as currently trained, have all the necessary skills to integrate into your organisation? If your answer is “To some degree” please indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.
If your answer is “No” or “To some degree”, what skills do you believe are required to become fully effective? Indicate, in order of importance, those skills you consider important with 1 being very important and 7 being of little importance. Mark all skills you believe are important.

<table>
<thead>
<tr>
<th>Skill</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>Decision making</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Human Skills</td>
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</tr>
<tr>
<td>Communication</td>
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<td>Interpersonal</td>
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<tr>
<td>Flexible</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Administration (financial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 21**

In your experience do junior engineers or newly graduated engineers profess a disinterest in management activities? If your answer is “To some degree” please indicate the degree by marking the appropriate box with 1 being to a minor degree and 5 being a major degree.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>To some degree</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Question 22**

Do you think employers should have a direct role in developing and teaching curricula?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>
Question 23

Would you be prepared to partner with an Engineering Faculty in allowing students to undertake assessed tasks in the workplace that are directly aimed at developing realistic and practical management skills?

Yes □ No □

Thank you for completing this survey. Your input is highly valued. Please put the completed survey in the provided return addressed envelope and post it to the address indicated. Should you wish to receive more information about the results of this survey please contact the undersigned.

It would be appreciated if you can return the completed survey by 30 August 2010.

Peter Childs
Sydney Business School
University of Wollongong

Email address peter_childs@uow.edu.au
APPENDIX 4

ENGINEERS AUSTRALIA
A4.1 Introduction

Phone discussions were held with Professor Emeritus Bradley who outlined the competency standards required of a Professional Engineer. Engineers Australia was, at the time, finalising a revision of these requirements and Professor Bradley provided a draft of the new guidelines. Subsequently they were finalised and a copy is attached to these notes. Details follow.

General discussion on management skills elicited the comment that EA set general guidelines and then it was up to the relevant University Faculty to translate these into specific subjects and then justify these subjects to the accrediting body.

The competency standard mentions management only in general terms. Below is an example of the areas where management (other than Project management) is mentioned.

2.4. Application of systematic approaches to the conduct and management of engineering projects.

   a) Contributes to and/or manages complex engineering project activity, as a member and/or as leader of an engineering team.

   c) Accommodates relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management.

   d) Proficiently applies basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard.

3.2. Effective oral and written communication in professional and lay domains.

   a) Is proficient in listening, speaking, reading and writing English, including: -

3.4. Professional use and management of information

Engineers Australia is an organisation dedicated to the needs and the future of all engineering graduates, and so it should be, however there is an apparent need for engineers to be given more than a token course in Management skills. EA needs to review their current attitude and consider whether they should review their competency standards and incorporate a competency that includes training in the skills of customer approach, marketing and in general dealing with and being a part of the general business/commerce world.
STAGE 1 COMPETENCY STANDARD FOR PROFESSIONAL ENGINEER

ROLE DESCRIPTION - THE MATURE, PROFESSIONAL ENGINEER

The following characterises the senior practice role that the mature, Professional Engineer may be expected to fulfil and has been extracted from the role portrayed in the Engineers Australia - Chartered Status Handbook.

Professional Engineers are required to take responsibility for engineering projects and programs in the most far-reaching sense. This includes the reliable functioning of all materials, components, sub-systems and technologies used; their integration to form a complete, sustainable and self-consistent system; and all interactions between the technical system and the context within which it functions. The latter includes understanding the requirements of clients, wide ranging stakeholders and of society as a whole; working to optimise social, environmental and economic outcomes over the full lifetime of the engineering product or program; interacting effectively with other disciplines, professions and people; and ensuring that the engineering contribution is properly integrated into the totality of the undertaking. Professional Engineers are responsible for interpreting technological possibilities to society, business and government; and for ensuring as far as possible that policy decisions are properly informed by such possibilities and consequences, and that costs, risks and limitations are properly understood as the desirable outcomes.

Professional Engineers are responsible for bringing knowledge to bear from multiple sources to develop solutions to complex problems and issues, for ensuring that technical and non-technical considerations are properly integrated, and for managing risk as well as sustainability issues. While the outcomes of engineering have physical forms, the work of Professional Engineers is predominantly intellectual in nature. In a technical sense, Professional Engineers are primarily concerned with the advancement of technologies and with the development of new technologies and their applications through innovation, creativity and change. Professional Engineers may conduct research concerned with advancing the science of engineering and with developing new principles and technologies within a broad engineering discipline. Alternatively, they may contribute to continual improvement in the practice of engineering, and in devising and updating the codes and standards that govern it.

Professional Engineers have a particular responsibility for ensuring that all aspects of a project are soundly based in theory and fundamental principle, and for understanding clearly how new developments relate to established practice and experience and to other disciplines with which they may interact. One hallmark of a professional is the capacity to break new ground in an informed, responsible and sustainable fashion.

Professional Engineers may lead or manage teams appropriate to these activities, and may establish their own companies or move into senior management roles in engineering and related enterprises.

STAGE 1 COMPETENCIES

The three Stage 1 Competencies are covered by 16 mandatory Elements of Competency. The Competencies and Elements of Competency represent the profession's expression of the knowledge and skill base, engineering application abilities, and professional skills, values and attitudes that must be demonstrated at the point of entry to practice.

The suggested indicators of attainment in Tables 1, 2 and 3 provide insight to the breadth and depth of ability expected for each element of competency and thus guide the competency demonstration and assessment processes as well as curriculum design. The indicators should not be interpreted as discrete sub-elements of competency mandated for individual audit. Each
element of competency must be tested in a holistic sense, and there may well be additional indicator statements that could complement those listed.

**STAGE 1 COMPETENCIES and ELEMENTS OF COMPETENCY**

1. **KNOWLEDGE AND SKILL BASE**

1.1. Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.

1.2. Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.

1.3. In-depth understanding of specialist bodies of knowledge within the engineering discipline.

1.4. Discernment of knowledge development and research directions within the engineering discipline.

1.5. Knowledge of contextual factors impacting the engineering discipline.

1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.

2. **ENGINEERING APPLICATION ABILITY**

2.1. Application of established engineering methods to complex engineering problem solving.

2.2. Fluent application of engineering techniques, tools and resources.

2.3. Application of systematic engineering synthesis and design processes.

2.4. Application of systematic approaches to the conduct and management of engineering projects.

3. **PROFESSIONAL AND PERSONAL ATTRIBUTES**

3.1. Ethical conduct and professional accountability

3.2. Effective oral and written communication in professional and lay domains.

3.3. Creative, innovative and pro-active demeanour.

3.4. Professional use and management of information.

3.5. Orderly management of self, and professional conduct.

3.6. Effective team membership and team leadership.
Table 1 Knowledge and Skill Base: Elements and Indicators

ELEMENT OF COMPETENCY

INDICATORS OF ATTAINMENT

1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.

a) Engages with the engineering discipline at a phenomenological level, applying sciences and engineering fundamentals to systematic investigation, interpretation, analysis and innovative solution of complex problems and broader aspects of engineering practice.

1.2 Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.

a) Develops and fluently applies relevant investigation analysis, interpretation, assessment, characterisation, prediction, evaluation, modelling, decision making, measurement, evaluation, knowledge management and communication tools and techniques pertinent to the engineering discipline.

1.3 In depth understanding of specialist bodies of knowledge within the engineering discipline.

a) Proficiently applies advanced technical knowledge and skills in at least one specialist practice domain of the engineering discipline.

1.4 Discernment of knowledge development and research directions within the engineering discipline.

a) Identifies and critically appraises current developments, advanced technologies, emerging issues and interdisciplinary linkages in at least one specialist practice domain of the engineering discipline.

b) Interprets and applies selected research literature to inform engineering application in at least one specialist domain of the engineering discipline.

1.5 Knowledge of contextual factors impacting the engineering discipline.

a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.

b) Is aware of the founding principles of human factors relevant to the engineering discipline.

c) Is aware of the fundamentals of business and enterprise management.

d) Identifies the structure, roles and capabilities of the engineering workforce. e) Appreciates the issues associated with international engineering practice and global operating contexts.

1.6 Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the engineering discipline.

a) Applies systematic principles of engineering design relevant to the engineering discipline.
b) Appreciates the basis and relevance of standards and codes of practice, as well as legislative and statutory requirements applicable to the engineering discipline.

c) Appreciates the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline.

d) Appreciates the social, environmental and economic principles of sustainable engineering practice.

e) Understands the fundamental principles of engineering project management as a basis for planning, organising and managing resources.

f) Appreciates the formal structures and methodologies of systems engineering as a holistic basis for managing complexity and sustainability in engineering practice.

Notes:

1. ‘engineering discipline’ means the broad branch of engineering (civil, electrical, mechanical, etc.) as typically represented by the Engineers Australia Colleges.

2. ‘specialist practice domain’ means the specific area of knowledge and practice within an engineering discipline, such as geotechnics, power systems, manufacturing, etc.

Table 2 Engineering Application Ability: Elements and Indicators

<table>
<thead>
<tr>
<th>ELEMENT OF COMPETENCY</th>
<th>INDICATORS OF ATTAINMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Application of established engineering methods to complex engineering problem solving.</td>
<td></td>
</tr>
</tbody>
</table>

a) Identifies, discerns and characterises salient issues, determines and analyses causes and effects, justifies and applies appropriate simplifying assumptions, predicts performance and behaviour, synthesises solution strategies and develops substantiated conclusions.

b) Ensures that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic.

c) Competently addresses engineering problems involving uncertainty, ambiguity, imprecise information and wide-ranging and sometimes conflicting technical and non-technical factors.

d) Partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the paramount consideration.

e) Conceptualises alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice.

f) Critically reviews and applies relevant standards and codes of practice underpinning the engineering discipline and nominated specialisations.

g) Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline.
h) Interprets and ensures compliance with relevant legislative and statutory requirements applicable to the engineering discipline.

i) Investigates complex problems using research-based knowledge and research methods.

2.2 Fluent application of engineering techniques, tools and resources.

a) Proficiently identifies, selects and applies the materials, components, devices, systems, processes, resources, plant and equipment relevant to the engineering discipline.

b) Constructs or selects and applies from a qualitative description of a phenomenon, process, system, component or device a mathematical, physical or computational model based on fundamental scientific principles and justifiable simplifying assumptions.

c) Determines properties, performance, safe working limits, failure modes, and other inherent parameters of materials, components and systems relevant to the engineering discipline.

d) Applies a wide range of engineering tools for analysis, simulation, visualisation, synthesis and design, including assessing the accuracy and limitations of such tools, and validation of their results.

e) Applies formal systems engineering methods to address the planning and execution of complex, problem solving and engineering projects.

f) Designs and conducts experiments, analyses and interprets result data and formulates reliable conclusions.

g) Analyses sources of error in applied models and experiments; eliminates, minimises or compensates for such errors; quantifies significance of errors to any conclusions drawn.

h) Safely applies laboratory, test and experimental procedures appropriate to the engineering discipline.

i) Understands the need for systematic management of the acquisition, commissioning, operation, upgrade, monitoring and maintenance of engineering plant, facilities, equipment and systems.

j) Understands the role of quality management systems, tools and processes within a culture of continuous improvement.

Table 2 (cont.) Engineering Application Ability: Elements and Indicators

<table>
<thead>
<tr>
<th>ELEMENT OF COMPETENCY</th>
<th>INDICATORS OF ATTAINMENT</th>
</tr>
</thead>
</table>

2.3 Application of systematic engineering synthesis and design processes.

a) Proficiently applies technical knowledge and open ended problem solving skills as well as appropriate tools and resources to design components, elements, systems, plant, facilities and/or processes to satisfy user requirements.

b) Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.

c) Executes and leads a whole systems design cycle approach including tasks such as:
determining client requirements and identifying the impact of relevant contextual factors, including business planning and costing targets;

- systematically addressing sustainability criteria;

working within projected development, production and implementation constraints;

- eliciting, scoping and documenting the required outcomes of the design task and defining acceptance criteria;

- identifying assessing and managing technical, health and safety risks integral to the design process;

writing engineering specifications, that fully satisfy the formal requirements;

ensuring compliance with essential engineering standards and codes of practice;

partitioning the design task into appropriate modular, functional elements; that can be separately addressed and subsequently integrated through defined interfaces;

- identifying and analysing possible design approaches and justifying an optimal approach;

- developing and completing the design using appropriate engineering principles, tools, and processes;

- integrating functional elements to form a coherent design solution;

- quantifying the materials, components, systems, equipment, facilities, engineering resources and operating arrangements needed for implementation of the solution;

- checking the design solution for each element and the integrated system against the engineering specifications;

- devising and documenting tests that will verify performance of the elements and the integrated realisation;

- prototyping/implementing the design solution and verifying performance against specification;

- documenting, commissioning and reporting the design outcome.

d) Is aware of the accountabilities of the professional engineer in relation to the ‘design authority’ role.

2.4 Application of systematic approaches to the conduct and management of engineering projects.

a) Contributes to and/or manages complex engineering project activity, as a member and/or as leader of an engineering team.

b) Seeks out the requirements and associated resources and realistically assesses the scope, dimensions, scale of effort and indicative costs of a complex engineering project.

c) Accommodates relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management.
d) Proficiently applies basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard.

e) Is aware of the need to plan and quantify performance over the full life-cycle of a project, managing engineering performance within the overall implementation context.

f) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.

Table 3 Professional and Personal Attributes: Elements and Indicators

<table>
<thead>
<tr>
<th>ELEMENT OF COMPETENCY</th>
<th>INDICATORS OF ATTAINMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Ethical conduct and professional accountability</td>
<td>a) Demonstrates commitment to uphold the Engineers Australia - Code of Ethics, and established norms of professional conduct pertinent to the engineering discipline.</td>
</tr>
<tr>
<td></td>
<td>b) Understands the need for ‘due-diligence’ in certification, compliance and risk management processes.</td>
</tr>
<tr>
<td></td>
<td>c) Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment.</td>
</tr>
<tr>
<td></td>
<td>d) Is aware of the fundamental principles of intellectual property rights and protection.</td>
</tr>
<tr>
<td>3.2 Effective oral and written communication in professional and lay domains.</td>
<td>a) Is proficient in listening, speaking, reading and writing English, including: - comprehending critically and fairly the viewpoints of others; - expressing information effectively and succinctly, issuing instruction, engaging in discussion, presenting arguments and justification, debating and negotiating - to technical and non-technical audiences and using textual, diagrammatic, pictorial and graphical media best suited to the context; -representing an engineering position, or the engineering profession at large to the broader community; -appreciating the impact of body language, personal behaviour and other non-verbal communication processes, as well as the fundamentals of human social behaviour and their cross-cultural differences.</td>
</tr>
<tr>
<td></td>
<td>b) Prepares high quality engineering documents such as progress and project reports, reports of investigations and feasibility studies, proposals, specifications, design records, drawings, technical descriptions and presentations pertinent to the engineering discipline.</td>
</tr>
<tr>
<td>3.3 Creative, innovative and pro-active demeanour.</td>
<td>a) Applies creative approaches to identify and develop alternative concepts, solutions and procedures, appropriately challenges engineering practices from technical and non-technical viewpoints; identifies new technological opportunities.</td>
</tr>
</tbody>
</table>
b) Seeks out new developments in the engineering discipline and specialisations and applies fundamental knowledge and systematic processes to evaluate and report potential.

c) Is aware of broader fields of science, engineering, technology and commerce from which new ideas and interfaces may be drawn and readily engages with professionals from these fields to exchange ideas.

3.4 Professional use and management of information.

a) Is proficient in locating and utilising information - including accessing, systematically searching, analysing, evaluating and referencing relevant published works and data; is proficient in the use of indexes, bibliographic databases and other search facilities.

b) Critically assesses the accuracy, reliability and authenticity of information.

c) Is aware of common document identification, tracking and control procedures.

3.5 Orderly management of self, and professional conduct.

a) Demonstrates commitment to critical self-review and performance evaluation against appropriate criteria as a primary means of tracking personal development needs and achievements.

b) Understands the importance of being a member of a professional and intellectual community, learning from its knowledge and standards, and contributing to their maintenance and advancement.

c) Demonstrates commitment to life-long learning and professional development.

d) Manages time and processes effectively, prioritises competing demands to achieve personal, career and organisational goals and objectives.

e) Thinks critically and applies an appropriate balance of logic and intellectual criteria to analysis, judgment and decision making.

f) Presents a professional image in all circumstances, including relations with clients, stakeholders, as well as with professional and technical colleagues across wide ranging disciplines.

3.6 Effective team membership and team leadership.

a) Understands the fundamentals of team dynamics and leadership.

b) Functions as an effective member or leader of diverse engineering teams, including those with multi-level, multi-disciplinary and multi-cultural dimensions.

c) Earns the trust and confidence of colleagues through competent and timely completion of tasks.

d) Recognises the value of alternative and diverse viewpoints, scholarly advice and the importance of professional networking.

e) Confidently pursues and discerns expert assistance and professional advice.

f) Takes initiative and fulfils the leadership role whilst respecting the agreed roles of others.
APPENDIX 5

AUSTRALIAN BUREAU OF STATISTICS – AUSTRALIAN AND NEW ZEALAND STANDARD INDUSTRIAL CLASSIFICATION (ANZSIC)
The firms chosen for the survey were selected using the Australian Bureau of Statistics – Australian and New Zealand Standard Industrial Classification (ANZSIC) ABS listing. The classifications used are as listed below. These were chosen as the most likely firms to employ engineers.

**Mining**

**Division B**

**Subdivision**

<table>
<thead>
<tr>
<th>Division</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>Coal Mining</td>
</tr>
<tr>
<td>07</td>
<td>Oil and Gas Extraction</td>
</tr>
<tr>
<td>08</td>
<td>Metal Ore Mining</td>
</tr>
<tr>
<td>09</td>
<td>Non-Metallic Mineral Mining and Quarrying</td>
</tr>
<tr>
<td>10</td>
<td>Exploration and Other Mining Support Services</td>
</tr>
</tbody>
</table>

**Manufacturing**

**Division C**

**Subdivision**

<table>
<thead>
<tr>
<th>Division</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Food Product Manufacturing</td>
</tr>
<tr>
<td>12</td>
<td>Beverage and Tobacco Product Manufacturing</td>
</tr>
<tr>
<td>13</td>
<td>Textile, Leather, Clothing and Footwear Manufacturing</td>
</tr>
<tr>
<td>14</td>
<td>Wood Product Manufacturing</td>
</tr>
<tr>
<td>15</td>
<td>Pulp, Paper, and Converted Paper Product Manufacturing</td>
</tr>
<tr>
<td>16</td>
<td>Printing (including the Reproduction of Recorded Media)</td>
</tr>
<tr>
<td>17</td>
<td>Petroleum and Coal Product Manufacturing</td>
</tr>
<tr>
<td>18</td>
<td>Basic Chemical and Chemical Product Manufacturing</td>
</tr>
<tr>
<td>19</td>
<td>Polymer Product and Rubber Product Manufacturing</td>
</tr>
<tr>
<td>20</td>
<td>Non-Metallic Mineral Product Manufacturing</td>
</tr>
<tr>
<td>21</td>
<td>Primary Metal and Metal Product Manufacturing Metal</td>
</tr>
<tr>
<td>22</td>
<td>Fabricated Metal Product Manufacturing</td>
</tr>
<tr>
<td>23</td>
<td>Transport Equipment Manufacturing</td>
</tr>
<tr>
<td>24</td>
<td>Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>25</td>
<td>Furniture and Other Manufacturing</td>
</tr>
</tbody>
</table>

**Electricity, Gas, Water and Waste Services**

**Division D**

**Subdivisions**

<table>
<thead>
<tr>
<th>Division</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Electricity Supply</td>
</tr>
<tr>
<td>27</td>
<td>Gas Supply</td>
</tr>
<tr>
<td>28</td>
<td>Water, Sewerage and Drainage Supply</td>
</tr>
<tr>
<td>29</td>
<td>Waste Collection, Treatment, and Disposal Services</td>
</tr>
</tbody>
</table>

**Construction**

**Division E**

**Subdivision**

<table>
<thead>
<tr>
<th>Division</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Building Construction</td>
</tr>
<tr>
<td>31</td>
<td>Heavy and Civil Engineering Construction</td>
</tr>
<tr>
<td>32</td>
<td>Construction Services</td>
</tr>
</tbody>
</table>
### Transport, Postal and Warehousing  Division I

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Road Transport</td>
</tr>
<tr>
<td>47</td>
<td>Rail Transport</td>
</tr>
<tr>
<td>48</td>
<td>Water Transport</td>
</tr>
<tr>
<td>49</td>
<td>Air Transport and Space</td>
</tr>
<tr>
<td>50</td>
<td>Other Transport</td>
</tr>
</tbody>
</table>

### Professional, Scientific and Technical Services  Division M

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>Professional, Scientific and Technical Services, (Except Computer System Design and Related Services)</td>
</tr>
</tbody>
</table>

### Public Administration and Safety  Division O

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>Public Administrations</td>
</tr>
<tr>
<td>76</td>
<td>Defence</td>
</tr>
</tbody>
</table>
APPENDIX 6

SAMPLING SCHEDULE
A6.1 Potential Population of Respondents

As discussed in Chapter 16 Methodology (page 29) the ABS (ANZSIC) and the onesource web sites were used to identify potential respondents. For details of the Classification see Appendix 5 (page 280). A total of 18,115 firms were chosen from the various segments in proportion to the number of firms in that segment. A sample of 1000 firms were randomly chosen and then culled to remove firms which were not considered to be potential employers of engineers (e.g. a firm of legal consultants). This culling reduced the number of firms in the sample to 770, the final sample size.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Small Firms (1 -20 employees)</th>
<th>Medium sized firms (21 – 99 employees)</th>
<th>Large firms (above 100 employees)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistical Population</td>
<td>Chosen Sample</td>
<td>Actual Sample</td>
<td>Statistical Population</td>
</tr>
<tr>
<td>Consulting</td>
<td>3113</td>
<td>171</td>
<td>126</td>
<td>1423</td>
</tr>
<tr>
<td>Construction</td>
<td>614</td>
<td>34</td>
<td>26</td>
<td>690</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2766</td>
<td>152</td>
<td>101</td>
<td>3546</td>
</tr>
<tr>
<td>Mining</td>
<td>463</td>
<td>26</td>
<td>26</td>
<td>203</td>
</tr>
<tr>
<td>Public services and Utilities</td>
<td>294</td>
<td>16</td>
<td>16</td>
<td>506</td>
</tr>
<tr>
<td>Transport</td>
<td>155</td>
<td>9</td>
<td>9</td>
<td>260</td>
</tr>
<tr>
<td>Total</td>
<td>7405</td>
<td>408</td>
<td>304</td>
<td>6628</td>
</tr>
</tbody>
</table>

Statistical Sample Total 999  Culled Sample Total 770
### A6.2 Identification

To ensure the survey remained confidential there was no formal identification of where each survey was sent. However each survey was identified by two letters on the first page to allow identification on its return. The key to this identification system is as below:

<table>
<thead>
<tr>
<th>Industry segment</th>
<th>Identification letter</th>
<th>Size of the organisation (by the number of employees)</th>
<th>Identification Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>A</td>
<td>Number of employees</td>
<td></td>
</tr>
<tr>
<td>Consulting</td>
<td>B</td>
<td>1 – 20</td>
<td>S</td>
</tr>
<tr>
<td>Construction</td>
<td>C</td>
<td>21 – 99</td>
<td>M</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>D</td>
<td>100 plus</td>
<td>L</td>
</tr>
<tr>
<td>Public services and Utilities</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus an identification **BS** indicates a small consulting company and **DM** a large manufacturing organisation.