2009-03-18

An Investigative Study of the Difficulties Experienced by Engineers Transitioning into Leadership/Management Positions

Joseph Alan Wilde
Brigham Young University - Provo

AN INVESTIGATIVE STUDY OF THE DIFFICULTIES EXPERIENCED BY ENGINEERS TRANSITIONING INTO LEADERSHIP/MANAGEMENT POSITIONS

by
Joseph A. Wilde

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

School of Technology

Brigham young University

April 2009

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Joseph A. Wilde

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Val D. Hawks, Chair
Date	Ronald Terry, Member
Date	Steven Benzley, Member

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Joseph A. Wilde in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date	Val D. Hawks Chair, Graduate Committee

Accepted for the Department

Barry Lunt
Graduate Coordinator

Accepted for the College

Alan R. Parkinson
Dean, Ira A. Fulton College of Engineering and Technology

ABSTRACT

AN INVESTIGATIVE STUDY OF THE DIFFICULTIES EXPERIENCED BY ENGINEERS TRANSITIONING INTO LEADERSHIP/MANAGEMENT POSITIONS

Joseph A. Wilde

School of Technology

Master of Science

The traditional engineering career has been defined by two career paths: technical and managerial. An entry level engineer typically did not elect his/her career path until at least five years into a career. This meant that only a portion of engineers needed to learn management and leadership skills and then usually not until in the professional environment. Since this career distinction was not made until years into an engineer's professional life universities were not developing leadership/management skills in their students.

Times have changed. With the globalization of the economy, and the increased competition in the marketplace, companies have realized that they need entry level engineers that are capable of working on multi-functional and multi-cultural teams,

leading small work groups, and understanding the business and societal impact of engineering decisions. These skills are so critical that every engineer, regardless of their chosen track will need them to have a successful career. Universities are now being pressured to develop these skills in all of their engineering students.

The purpose of this study was to gain a better understanding of the difficulties experienced by engineers as they transition into formal management positions in order to help universities and industry direct their efforts in the development of key leadership/management skills. The survey used for this study was centered on two works of research. The first is research conducted by Allen Howard for his PhD dissertation in which he identifies 9 common points of difficulty, or pain points, experienced by engineers transitioning into management. The second is a managerial aptitude test developed by Hans Thamhain. The survey was distributed to 220 engineering managers at a large engineering company.

The results of the survey were statistically analyzed and significant results were found among a number of factors. Among the independent variables found to significantly affect the transition were engineering discipline, graduate degrees, one’s managerial aptitude, the reason one chose to enter management, and graduation year. Perhaps the most beneficial result is that one pain point was found to be highly correlated to every other pain point.

ACKNOWELDGEMENTS

I thank my loving wife Laura for her patience and understanding while I have dedicated so much of my time to this work. Without her love and support I would never have been able to accomplish this. I am grateful for my good friend, Ryan Darby, who aided me with the data analysis. I especially need to thank Allen Howard and National Instruments without whom this research could not have been completed. Finally, I express gratitude to Dr. Hawks, my advisor, for not giving up on me and helping me to see this through to the end.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Engineering

Engineering has been defined by ABET (The Accreditation Board for Engineering and Technology) as the “profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind”(Smith, Butler, and LeBold, 1983) It is the primary job of an engineer to apply the scientific method to the solution of problems. Engineers solve problems by using critical thinking skills in the application of natural laws. Though engineering is one of the youngest professions (compared to law, medicine, etc.) it has made many significant contributions to mankind. These contributions include but are not limited to the space program, medical advances, energy-development, and digital equipment.

1.2 Engineering in Transition

“The world is relying increasingly on technology for growth and job development but the nation is making the difficult transition of refocusing a significant amount of its technology investment from national security to international economic competitiveness”(ASEE, 1994). The flattening world economy (Friedman, 2007) is forcing a change in the engineering environment of the United States. This change is occurring in two related but different areas.

The first condition which is being affected by the flattened economy is that of business competition. US engineering firms are now competing with firms from across the globe, rather than with just domestic companies. The increase in number of competitors affects the firms by flooding the markets with a myriad of products. The increased number of products on the market forces companies to reduce product development time and introduce new products to market faster than ever. As a result, the engineering of a product must be completed in significantly less time than before. One of the processes being used by businesses to help shorten the development cycle of new products is concurrent design. This process involves the participation of individuals from marketing, research and development, design, operations, and distribution departments working together on teams to develop new products. These new development teams present a new way for working for engineers. The days of working on a design for months while hidden away in a cubicle and upon completion, tossing the whole package over the wall to the next department are gone. The new environment is one of high interaction where leadership skills play a key role in individual and firm success. In this environment engineers must possess the following (Bowman and Farr, 2000):

- An ability to function on multidisciplinary teams
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- The broad education necessary to understand the impact of engineering solutions in a global/societal context

- A recognition of the need for, and an ability to, engage in lifelong learning
- A knowledge of contemporary issues

The engineer must also be able to, “effectively communicate [his/her] vision to public participants and decision makers spanning the global continuum of cultures” (Bowman and Farr, 2000).

The labor market is the second condition being affected by the flattened economy. As US companies compete with firms from across the globe there is increased pressure to reduce costs. Many of the firms with whom the US companies compete are located in countries with significantly lower labor rates. The difference in labor rates, which at times contributes up to 65% of product costs, can be a huge liability when a customer rewards a contract to the lowest bidder. This price pressure has contributed to the fact that many US based engineering firms have begun moving engineering positions to India and China. The Chinese and Indian engineering workforces are well-qualified and demand a much lower salary than their peers in the United States. In fact, on average an entry-level engineer in the US costs a firm on average $50,000 in annual salary, whereas an engineer with the same qualifications costs only $10,000-$12,500 in China and India (Costlow, 2007).

While the savings on labor are significant it would be unfair to suggest that this is the only reason firms are sending what seems to be an ever-increasing amount of work overseas. The fact is that the engineering labor pool is not large enough in the United States to fill all of the engineering jobs (Jackson, 2003). It is a well-established fact that the number of science and engineering graduates in this country has been in decline for a number of years. As a result of this decline and other factors, such as the decreased number of technical work visas, US firms have to look outside of the US in order to fill all of their positions (Lofgren, Nyce, and Schieber, 2003). They are fortunate that there now seems to be a surplus of technical labor in India and China where the labor rates are significantly lower than at home.

As a result of American firms employing an increasing number of engineers overseas the engineers in the domestic offices are faced with the task of working with and in many cases managing the foreign engineering teams. This international work environment means that engineers must "understand and [work well with] other countries and cultures" (King, 2006). Additionally, in order to remain viable, engineers must now, "produce several times the value-added to justify wage differentials [between them and their foreign counterparts]" (Duderstadt, 2008).

These two flattened economy factors, global competition and labor, are the driving force behind the transition in American engineering careers. American engineers are now facing a career of interfacing and working well with nearly all departments within a firm as well as working on teams with and managing engineers half way across the globe.

The United States is still producing engineers and US firms are still hiring domestic engineers, however the roles that they are being hired into are different than they were twenty five years ago. Historically an engineering graduate's professional career may have looked like this (Lannes, 2001):

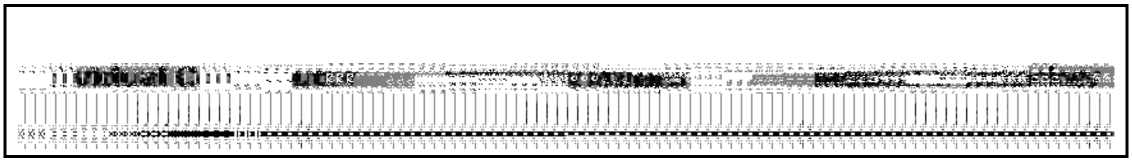

Figure 1- Historical Engineering Career

In today's marketplace the American engineering graduate is being placed into project management positions much earlier than in the past. Engineering graduates must be prepared to work in cross-functional and cross-cultural teams.

Now an engineering graduate should expect something a little more like this:

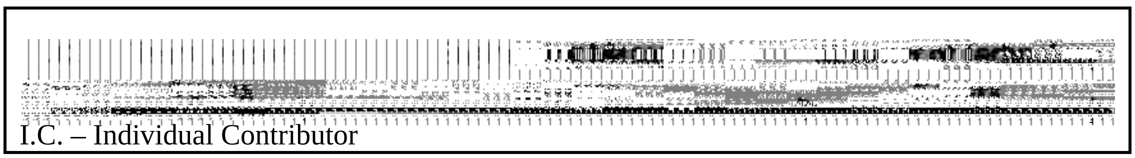

Figure 2- Contemporary Engineering Career

The role of team leader consists of working on cross-functional and multi-national teams. This role requires several leadership and management skills which previously were not needed by an engineer until entering a formal engineering management position. This is a significant change because this skill set has not been emphasized in engineering education since before the Second World War.

1.3 Need for Leadership/Management Skills

It is apparent from the previous section that today's engineer needs to possess more than just technical expertise. Today's engineer must understand business processes, be able to contribute to cross-functional teams and use "soft" skills to relate to peers, superiors and subordinates both in the office and across the globe. In 2000 an engineering vice president of a US company was quoted as saying, “We look for people who can lead a team, someone who can get a small team-four to six people-motivated and a person who can quickly learn which people are best at doing what. It’s hard enough to find a good engineer; one who can lead a team and speak well in front of customers is really hard” (Costlow, 2000). This quote reinforces Farr’s statement from 1997: “Because of the changing nature of modern engineering, young technical or staff engineers must grow into leadership roles faster than their predecessors” (Farr, Walesh, and Forsythe, 1997).

In addition to needing more management and leadership skills in the workplace, there is a growing need for engineers to accept more of a leadership role in society. This need arises from the fact that, “the issues with which engineers engage have become more and more multidimensional, interacting with public policy and public perceptions, business and legal complexities, and government policies and regulations, among other arenas. This is the natural result of technology becoming more and more pervasive in society and politics” (King, 2006). Despite the growing prevalence of technology into everyday life and politics there is a shockingly low number of P.E.s (professional engineers) participating in regulatory and political affairs. In 2005, of the 535 members of Congress only five of them were P.E.s (Tenner, 2005). Of the approximately 6,000 state legislative seats in the United States in 1997, only 36 of them were registered P.E.s (Weingardt, 1997). Weingardt believes that P.E. representation is so low due to engineers’ inherent tendency to “keep to [them]selves, talk only to [them]selves, and stay ensconced in the ivory tower of their immediate colleagues and professional associations.”

For engineers to be more comfortable in stepping up and seeking to be actively involved in their communities and politics they must develop these same management and leadership skills that are being called for by industry.

1.4 Engineers Not Well Prepared

It is interesting to note that as early as 1993 studies were showing that a majority of engineers found themselves in some type of managerial position within three to five years after graduation (Lyons, Anselmo, and Kuller, 1993). In his report Lyons goes on to say that “Management responsibilities for engineering professionals are an unavoidable part of working in modern commercial industries.” Clearly leadership and management skills are crucial to the success of engineers.

While it is clear that the contemporary engineer needs a diverse set of skills (technical, communication, business, leadership and management) to succeed, the engineering education system has been focused on the development of technical expertise. As a result of the education system engineers are entering the workforce ill-prepared to excel in the work environment (Katz, 1993). Since the 1990’s industry has been pleading with educational institutions to increase the leadership skills (these leadership skills have been defined in many ways but for this paper leadership skills will refer to business process understanding, communication skills, and management concepts) of their graduates. A study completed in 1995 by ASEM (American Society of Engineering Management) indicated that of all the “perceived gaps in the value of the organization versus preparedness for new BS engineers,” that of leadership skills was the largest (ASEM. 1995). Another report published in 1994 by ASEE (American Society of

Engineering Education) acknowledged leadership education as one of the areas in need of special attention in order to meet modern industrial needs (ASEE, 1994).

The lack of leadership skills in engineering education is tied to the history and support for engineering in US history. After World War II when the US economy was the only world power much of the funding for scientific research was generated by the government as it labored to develop strong national defense and space programs. As a result of the majority of research funds coming from the government, and not industry, universities have focused their research and curriculum on material that will help generate more research funds from the government. This culture has developed a very research focused environment within our institutions of higher learning. Professors' primary responsibilities are to create original research, be published, and be awarded grants in order to continue their lines of research. This results in less attention being paid to preparing students for the reality of a career in the industrial sector. It may be very difficult for engineering professors to prepare students for an industrial career when you consider the fact that the majority of professors have little to no industrial experience (Lyons, Anselmo, and Kuller, 1993). They are grooming their students to be successful in the way that they know how to be successful.

1.5 Relevance of Research

Within engineering there are typically two career paths which an engineer can follow: technical and managerial. A technical career is the career for which students are prepared during their college programs. Technical expertise is necessary and often as a career progresses the technical expertise becomes more and more specialized. This is the career path by which the stereotypical engineer is defined. A managerial career is quite different. While engineering managers are almost always engineers who have crossed career paths, the requisite skills to be a successful engineering manager are vastly different than those to be a successful technical engineer. This difference in skill sets is what makes the transition from technical/individual contributor to that of a manager/leader so difficult for many engineers. The difficulties experienced can result in some serious "pain points" for the person transitioning functions.

The goal of this research was to discover whether or not there is a set of difficulties common to a large portion of transitioning engineers and to see if there are characteristics of engineers that will signal to upper management that a particular engineer will struggle more than others in the transition. This information can be used by industry and academia to better prepare managerial candidates for their future careers.

Additionally, with the changing world economy even engineers who choose the technical career path are being required to use skills that fall in the realm of leadership skills as they interact with team members from other organizations within their firm and with colleagues across the globe. Therefore, the need for effective leadership skills no longer rests only with those choosing the management career path.

1.5.1 Transitional Pain Points

It has been established that in today's competitive and global environment American engineers need not only be technically capable but that they must also understand business concepts, possess primary management skills, be able to effectively communicate, comprehend and understand decision-making from a global context, and develop and articulate a vision. We have also presented the historical lack of additional training from universities beyond technical material. This gap presents a problem for engineering graduates.

Technical skills simply are not sufficient to be successful in today's competitive market. "Highly successful professional engineers are not only technically astute, but also often possess some of the "extra" or "soft" skills that many experts believe are necessary for engineers and scientists to increasingly embrace as we move forward in the 21st century"(Hissey, 2000). These "extra" or "soft" skills referred to by Hissey are some of the same leadership skills presented earlier in this chapter.

It is inevitable that in each engineer's career there will be a time when he/she is placed into a managerial/leadership role or at least will need to exercise some of those skills in his/her tasks and assignments. In the past a company could take time and mentor engineers into these positions but doing so is now more difficult. As a result of flattening organizations, reduced development times, the trend of employee empowerment, and global pressure, less time is able to be directed to the development of leadership skills in young engineers (Farr, 1997).

The skill set and the type of thinking required to be successful as a manager/leader are so inherently different from those required to be an individual contributor (what BS programs prepare graduates for) that many technically gifted and brilliant engineers cannot make a successful change – or they have to put substantial effort into re-equipping themselves in order to be effective leaders. Despite the contrasting skill sets the predominant method for selecting engineering managers is their ability to thrive as an individual contributor (Fetzer, 2005).

What is so different between being an engineer and an engineering manager? In 1986 Peggy Morrison conducted a study to determine the main differences in these two roles. Her findings were summarized by Porbahaie:

> Engineers mainly focus on things that are technical or scientific. They apply physical laws, as a basis, to solve problems through known procedures. They are autonomous and their achievements are through the individual accomplishment in one project at a time.
>
> Managers spend a larger proportion of their time interacting with people. For them an understanding of human behavior becomes as important as knowledge of technical details. Managers must deal with problems that are ambiguous, intuitive and emotional. They tend to be team-oriented and their sense of accomplishment is through directing and coordinating the work of others to accomplish goals.(Porbahaie, 1994)

In summary, engineering managers need the leadership skill set described earlier. Of course not every engineer is going to face all of these elements in their first or second assignment. However, these elements are creeping into the careers of young engineers earlier than in the past and too many engineers are not well prepared. Education and industry must be aware of the difficulties in the transition so that they can help engineers be successful as they are placed into these positions.

While many papers have addressed the difficulty of the transition into management there have been very few studies which explore exactly what makes the transition difficult. One paper which does investigate this very thing presents nine common challenges faced by engineers transitioning into management. These challenges are (Howard, 2003):

1. So much going on: the engineering manager role involves balancing many more responsibilities, tasks, and priorities than the engineering role
2. Relationship changes: personal relationships, interaction, dynamics, and engineer perceptions of you have changed

3. Delegation: the challenge of leaving the hands on technical behind and learning to work through others
4. Increased stress and pressure associated with increased responsibility
5. Developing new skills: discovered the need for a new set of skills as a manager
6. Resources and getting the work done: finding the time, the staff and other resources to get it done
7. The new guy in management: change from being a technical expert to being new in management and having a lot to learn
8. Organizational issues: in a new organizational level with its associated issues
9. Choosing the management career path: the concerns before deciding and questions experienced during or after the transition

These "pain points" as they have been coined served as the foundation of this study.

1.6 Problem Statement

Over 50% of engineers serve in a management or leadership position during their career (Porbahaie, 1994). Engineering education is strongly focused on the development of technical skills over management/leadership skills. As a result, engineers moving into management and leadership positions face a very difficult transitional period. Howard identified nine pain points of this transition. This research had several goals. The first goal was to determine whether or not Howard's pain points are distributable to a larger population of engineers. The second goal was to look for characteristics that can help predict the level of difficulty experienced by an engineer transitioning into a leadership/management position. Another goal was directed toward identifying opportunities for academe and industry to ease the transition process for engineers. The final goal was to discover whether or not the curriculum changes, associated with EC2000, within universities are easing the transition process for the younger generation of engineers.

1.7 Method

The foundational study for this research is that completed by Allen Howard for his PhD dissertation. Howard's research found that there were nine common challenges among five aerospace engineers as they transitioned into the position of engineering manager. Howard was concerned that there was not a sufficient body of knowledge regarding the nature of this transition. Therefore his research was conducted with the use of qualitative interviews in the form of a phenomenological study[1]. In the case of Howard's research the phenomenon was the transition of an individual contributor engineer into engineering management.

One goal of this thesis was to discover whether or not Howard's findings were distributable to a larger population of engineers and therefore the research method had to be different. Howard's study documented the experiences of five aerospace engineers in New York City. The purpose of this thesis was to gain understanding of the transition from individual contributor to engineering manager from a larger sample of engineers. While Howard's research was conducted through a phenomenological study, this approach is not appropriate for a sample size of over 25(Leedy and Ormrod, 2005).

The data for this research was collected using the survey method. This method was deemed acceptable because our goal was to better understand the attitudes, characteristics and previous experiences (Leedy and Ormrod, 2005) of a large group of individuals who have transitioned into an engineering management role from that of an individual contributor. The survey was distributed to 220 engineering managers all employed by the same company. The survey was administered through an online survey

---

[1] A qualitative method that attempts to understand participants' perspectives and views of social realities

service. The online administration of the survey allowed prompt responses and an automated tabulation of the survey results.

1.8 Delimitations

The scope of this research is limited to 220 engineering managers at National Instruments who were invited to participate in the study. The results cannot be attributed to engineering as a whole. To attribute the results to all engineers a much broader sample would have to be selected. While much has been written about engineers being expected to fulfill management responsibilities informally, the survey was only distributed to engineers who were at the time in a formal management position. This was done to ensure that every participant had experience in the individual contributor to manager/leader transition being studied. As a result this research does not claim to address how individual contributors handle the extra management responsibilities that they are being asked to complete. Nor does this study address the participants' abilities or capabilities in comprehensive leadership skills. The focus of the study is limited to the defined set of leadership and management skills described in Howard's pain points.

2 Literature Review

2.1 Introduction

The role of an engineer is to analyze, design and build or create cities, transportation systems, energy, consumer goods, etc. In the past, much of this work has been completed by engineers in isolation. In fact, engineers have developed a stereotype of being incapable of normal human interaction. They are seen as being gifted technically but lacking when it comes to social skills. Historically, many engineers have enjoyed their isolation or at least that has been the belief. Times have changed. The world’s economies are melding into one interconnected economy, organizations are conducting business in countries across the globe, and technology is becoming more and more pervasive in society (King, 2006). These changes are impacting the engineering career, and the place and role of an engineer in organizations and society.

2.2 The Engineering Career

2.2.1 Historical Perspective

The traditional engineering career consisted of being hired into an entry-level position and after several years making the decision between the technical and managerial career paths. The technical career path is designated for those individuals who want to continue their specialization in a technical field and prefer not to deal with managerial issues or prefer to remain in the analytical and technical aspects of problem identification and solution. The management track is intended for those engineers who want to gain a broader set of knowledge, are willing to manage people, wish to gain and practice leadership skills and don't feel a need to stay as intimately involved in the technical aspects of engineering issues.

The amount of time, on average, that passes until this choice presents itself is typically five to seven years (Gautschi, 1976). Some survey research found that engineering managers recommend an average of 5.9 years of technical work before entering the management career path (Hood, 1990).

The technical career path is usually chosen by engineers who like to work with things rather than with people, and who are "turned on" by the technical aspects of their work (Gautschi, 1976). Gautschi suggests that those who are the most successful in the technical career path are usually those with the higher GPA in college (Gautschi, 1976), have acquired at least one advanced technical degree and continue to be involved in state-of-the-art educational activities.

The managerial track is selected by engineers who want to broaden their knowledge base and are willing to "devote time and energy to management [and leadership] tasks like planning, staffing, directing, controlling, reviewing, and budgeting"(Gautschi, 1976). It is at this point that a need for training in management skills is recognized as important and companies often provide internal training courses or reimburse for courses to be taken off-site.

As a result of this dual-path career model engineers have not been concerned with the development of people or managerial skills until they selected the managerial career path. In fact in an introduction to engineering textbook written in 1983, for use in the college classroom, the authors pose the question: "What skills do engineers need?" Their response: technical competence. They emphasize the need for an engineer to "accept ideas of the exactness of Nature's laws", and the ability to deal with technological problems (Beakley, 1982). There is no mention of people or managerial skills.

2.2.2 Modern Perspective

An engineering graduate in 2008 faces a different work environment when compared to his/her counterpart from 20 years ago. Today's engineers, "enter the job market not as traditional engineers but as project managers, technical salespeople, and lead systems engineers" (Kotnour and Farr, 2005). In fact, engineers are being given engineering management tasks earlier and earlier in their careers (Lannes, 2001). Another significant change is illustrated by Bowman and Farr, "sources from both educational and corporate arenas indicate that the role of the engineer, from journeyman to senior engineer, is indeed increasingly expanding beyond technical issues to the larger domain of leadership" (Bowman and Farr, 2000).

The change in the scope of engineering careers can be attributed to a number of factors. Among these factors is global competition and the globalization of industry, (King, 2006) or the new global "open market" economy (Hissey, 2000).

The new global "open market" economy is changing the makeup of modern engineering enterprises. Before, companies had a national presence – they were usually founded, operated, and hired all in the same country. Now, companies are being founded, operating, and hiring in diverse countries all across the globe. This change requires that engineers be comfortable and effective at working in “geographically dispersed and multi-cultural” (Kotnour and Farr, 2005) teams. In order to work in this environment individuals must be able to communicate effectively within a broad spectrum of cultures (Bowman and Farr, 2000; King, 2006). In order to succeed, engineers need oral and written communication skills as well as an understanding and appreciation of different cultures.

The increased global competition is affecting industry in a number of ways. Among these effects are: shortened product development and life cycles and a flattening of organizations. As a result middle-management positions are disappearing (Kotnour and Farr, 2005; Youst, 1990) and companies are realizing that “success comes from multi-disciplined teams” (Hawley, 2001). The contemporary engineer must be able to function on these teams and at times lead them. This means that he/she must be equipped with at least a basic understanding of marketing and business finance (Hissey, 2000). In addition to these additional business skills a new dimension of communication must be learned. Bellinger states that dealing with “non-technical people…requires a unique ability to communicate” (Bellinger. 1998).

These factors are changing what it takes to be a successful engineer. It has been stated by multiple sources that “soft skills” are just as important to an engineer’s career as the technical skills (Costlow, 2000; Porbahaie, 1994). In a study published in 2004 Wearne found that: “compared with 1979, managerial skills and expertise have become relatively more important in engineers’ jobs,” and that these management skills and knowledge are required much earlier in engineers' careers (Wearne, 2004). Indeed Lannes was correct when he observed that, "the engineering phase (see Figure 3), is under considerable pressure to be shortened" (Lannes. 2001).

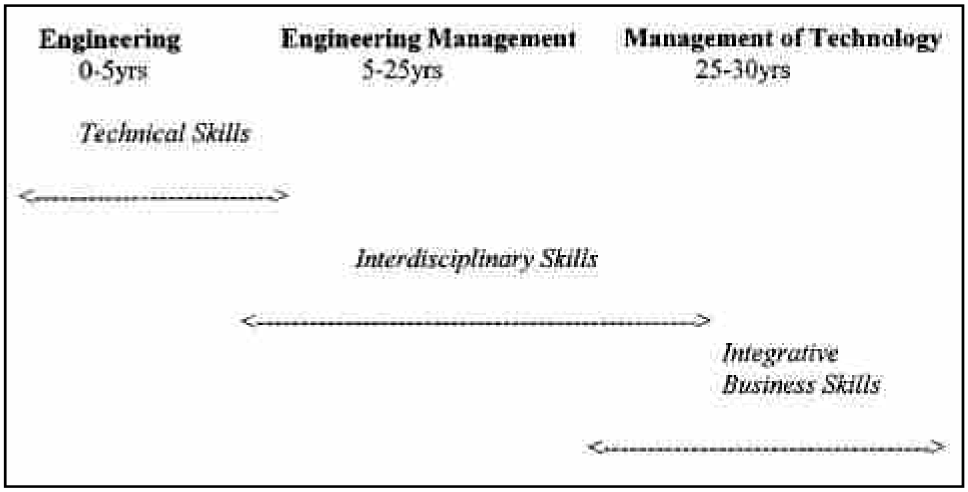

Figure 3 - Typical Engineering Career Path

As the role of an engineer is shifting in the global workplace there is not much support for additional training. This lack of support can be attributed to the competitive global environment "requiring companies to hold the line on costs and to maximize productivity" (Bowman and Farr, 2000). The lack of training means that many engineers are being given greater responsibilities and are being placed in sink-or-swim positions (Hood, 1990).

2.3 Engineering Management

Entering the role of engineering manager represents the transition "from the reduction approach to problem-solving (practiced by engineers) to the practice of management problem-solving, which generally requires knowledge that is more holistic and integrative” (Lannes, 2001). Being a successful engineering manager requires the utilization of skills and thought processes which may be considered diametrically opposed to those of a good engineer (Hood, 1990).

The significant differences between an engineering manager and an engineer are well described by Morrison in Table 1 (Morrison, 1986):

While engineers usually have a choice whether or not to pursue a formal career in management, the truth is that the majority of engineers are faced with some type of management responsibilities regardless of the career path that is chosen. In 1994 a survey showed that over 50% of engineering graduates were in management positions within five years of graduation (Porbahaie, 1994). A more recent study shows that 80% of engineers across all disciplines and ages need leadership and project management skills for their current position (Wearne, 2004). No longer are engineering managers the only engineers who need to be concerned with leadership and management skills.

The skills needed to be an effective engineering manager coincide with the skills needed to be developed by engineers to be better prepared to step into social leadership positions. The lack of these skills in engineering graduates and the call from industry to academe to develop these skills in their students are addressed later in the paper.

Table 1 - Engineer vs Engineering Manager

Position	Focus	Decision Making	Involvement	Process Outcomes	Effectiveness	Dependency	Responsibility	Creativity	Bottom Line
Engineer	More concerned with things technical or scientific	Makes decisions with much information, under conditions of greater certainty	Works on tasks and problem solving personally	Work based on facts with quantifiable outcomes	Depends on personal technical expertise, attention to detail, mathematical and technical problem solving and designing	Experiences role as autonomous	Individual accomplishment in one project, task, or problem at a time	Creative with products, designs materials	Will it work?
Engineering Manager	More concerned with people	Makes decisions often with inadequate information, under conditions of great uncertainty	Directs the work of others to accomplish goals	Work based on fewer facts, less measurable outcomes	Depends on interpersonal skills in communication, conflict management, getting ideas across, negotiating, and coaching	Experiences role as interdependent	Many objectives at once, requiring orchestrating a broad range of variables and organizational entities	Creative with people and organizations	Will it make/save money for the organization?

2.4 Engineering Education

2.4.1 Historical Perspective

Compared to the history of several other professions, the history of a formal engineering profession is rather short. It is generally accepted that the first school to offer formal engineering education was established in France in the year 1747. The first engineering school in the United States was established 55 years later in 1802. Since that time, engineering education in America has evolved with society and has proven capable of adapting to the needs of the day.

The French approached engineering education very formally. As early as the 16th century, the French government was building government-sponsored institutions dedicated to the education of engineers. “Increasingly, the education provided at these state funded schools shifted away from apprenticeship as a means to train engineers and instead emphasized scientific and mathematical principles as the underlying guides to the profession” (Reynolds, 1991). By the time America established engineering schools, the French had fully developed a method of engineering education that was proven successful.

Within Europe, however, there was another well-developed system for educating engineers. The British engineer did not receive his education in the classroom; rather, his education came from working alongside an experienced engineer and learning from hands-on experience. Before the formalization of engineering schools within America, American engineers gained their expertise through on-the-job training, working on private or local projects, “which were characteristics shared with British engineering tradition” (Reynolds, 1991).

Throughout the 19th century, both schools of thought played important roles in establishing the American tradition of engineering. By the early 20th century, American engineering education combined the British and French styles of education into a style unique to America. The French style of mathematical and science theory being taught in lecture was an integral part of the American engineer’s education as well as the British method of physical hands-on learning accomplished in the lab (Suckarieh and Krupar, 2005). Practical knowledge was just as important as science. In fact it was expected of faculty to have worked in industry before beginning to teach. Research was not a normal activity for most engineering faculty in the early 20th century (Seely, 1999). It was this style of education, theory combined with practical application in the lab that dominated the American engineering education system through the First World War.

2.4.2 American Engineering Education Post-WWI

As engineering education developed during the early decades of the 20th century, its focus shifted from academic and scholarly development towards filling the requirements of postgraduate professional practice.

Educators believed that they were in the business of preparing young engineers to enter industry. A.A. Potter, dean of Purdue University from 1920 – 1953, played a major role in bringing industry and education together. Under Potter’s watch, Purdue developed the most “elaborate personnel and placement system” to date. The system was a database of “extensive information about students and alumni.” The information collected included school grades, career aspirations, teacher evaluations, employer references, "character profiles," and many other bits of information companies found useful in selecting new employees. In 1926 at the Bell System Educational Conference, R.I. Rees, AT&T's vice-president in charge of education applauded Potter's ability to supply engineers to the specification requested by AT&T (Noble, 1977).

During this period of cooperation among engineering educators and industry, engineering programs paid great attention to seeing that engineers received not only sufficient technical training but that they also received social-science training for future management responsibilities (Noble, 1977). According to Grayson, following World War I, there was a "marked increase in emphasis on the administrative and economic sides of engineering…The place given to economics in all curricula was augmented, and business electives were more generally provided" (Grayson, 1980).

2.4.3 American Engineering Education Post WWII

As engineering education in America focused on the preparation for a career in industry several European immigrant professors were stunned by the lack of theory and science being taught in the classroom. Through the influence of these Europeans, who gained respected faculty positions at some of the top engineering schools, engineering science (theory based learning and research) was introduced back to the American education system (Seely, 1999).

Though introduced in the late 1920's engineering science did not make major inroads into the engineering education system until after WWII. "The war produced an increased awareness of the importance of academic research, which…lead to the establishment of [engineering] research programs conducted by faculty members, and graduate students" (Grayson, 1980). "Within a decade, the entire educational enterprise had been transformed" (Seely, 1999). The funding for these new research projects came primarily from the federal government. In the past, trade associations had been the primary contributors of funds, and a few thousand dollars a year was considered by the universities to be a decent contribution. Now the government issued federal research grants worth "hundreds of thousands or even millions of dollars a year" (Seely, 1999). Not only was the funding coming from a different place and significantly increased, but the research questions were of a different nature. The federal government was not looking for practical solutions to problems; they wanted to develop new technology. "The military was concerned with cutting-edge technologies, such as computers and electronics, nuclear power, jet propulsion and rockets, and exotic materials…With little known about the technologies both scientists and engineers were funded" to do the research (Seely, 1999). Engineering science moved into the mainstream of engineering education.

With engineering science being mainstream universities shifted their attention from preparing students to enter professional jobs in industry to ensuring the continuation of funding through research. Whereas before (in 1927) the average engineering teacher averaged 1.3 hours a week spent on research projects (Brown, 1936), a study published in 2008 but representing data from 2004 -2005 states that engineering professors spent approximately 19.5 hours each week on research and only 16.7 hours per week focused on education (Link, Swann, and Bozeman, 2008).

2.5 Current Educational Reform

Beginning in the 1990's there has been a call for yet another reform in engineering education. The reform being sought is not evolutionary. The reformists are suggesting a return to the past in order to better prepare for the future. There is an overwhelming sentiment that universities are out of touch with reality. For over four decades the federal government has been the major source for research funding and our university faculties, who are "charged with educating and training our entry-level engineers", have lost touch with "the commercial world of competitive industry" (Lyons, Anselmo, and Kuller, 1993). It is felt that this focus on research has distracted engineering educators "from their main mission, that of the training of the entry-level graduate engineer for our technology-based industries" (Lyons, Anselmo, and Kuller, 1993). In contrast to the pre-WWII teaching environment the majority of university professors today have little to no industry experience.

In 1994 the ASEE (American Society for Engineering Education) published a report stating: "While U.S. engineering education has served the nation well, there is broad recognition that it must change to meet new challenges. This is fully in keeping with its history of changing to be consistent with national needs…colleges must educate their students to work as part of teams; to communicate well; and to understand the economic, social, environmental, and international context of their professional activities" (ASEE, 1994). In 1996 one engineering professor candidly stated that the current system, "encourages us to turn our backs on engineering as practiced by the students we educate; it encourages us to think of ourselves as scientists and to ignore the creative, business, and interpersonal skills needed to deliver real products and services in the real world" (Goldberg, 1996).

Much of this demand for change is coming from industry. In 1997 Dr. Farr stated that industry needs engineers with a broadened skill set that includes the following (Farr, 1997):

- Team skills;
- Communication skills;
- Leadership;
- A systems perspective;
- An understanding and appreciation of diversity;
- An appreciation of different cultures and business practices;
- A multidisciplinary perspective;
- A commitment to quality, timeliness, and continuous improvement;
- An understanding of the societal, economic, and environmental impacts of engineering decisions;
- Ethics

In 2003 Dr. Wulf, then President of the National Academy of Engineers, stated that, "engineering is now practiced in a global, holistic business context, and engineers must design under constraints that reflect that context. In the future, understanding other cultures, speaking other languages, and communicating with people from marketing and finance will be just as fundamental to the practice of engineering as physics and calculus" (Wulf, 2004). One of Dr. Wulf's areas of emphasis for the NAE was to improve the undergraduate engineering curricula. Dr. Wulf became passionate about this subject when he returned to academe, after working in industry, and discovered that the engineering curriculum was nearly identical to when he had earned his baccalaureate degree 30 years previously.

As a result of this gap in what industry (the largest employer of engineering graduates) wants in entry-level engineers and what the education system has been producing, ABET (Accreditation Board for Engineering and Technology) developed and released new accreditation requirements entitled EC2000. EC2000 was implemented around the turn of the century. One of the accreditation criteria requires that graduates possess knowledge of the11 attributes or outcomes listed below (Lattuca, Terenzini, and Volkwein, 2006):

a) An ability to apply knowledge of mathematics, science, and engineering
b) An ability to design and conduct experiments, as well as to analyze and interpret data
c) An ability to design a system, component, or process to meet desired needs
d) An ability to function on multi-disciplinary teams
e) An ability to identify, formulate, and solve engineering problems
f) An understanding of professional and ethical responsibility
g) An ability to communicate effectively
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context
i) A recognition of the need for, and an ability to engage in life-long learning
j) A knowledge of contemporary issues
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

According to Kumar elements d-j are closely related to the most common dimensions of an engineering leader (Kumar and Hsiao, 2007):

1. Ability to build successful teams and work with team members to accomplish project goals;
2. Ability to motivate, inspire, respect, and reward the team members;
3. Ability to evaluate potential risk and willingness to take calculated risk for the success of the project;
4. Thorough understanding of duties of an engineer including service to community;
5. Sound technical skills within his/her area of expertise, and ability to identify and recruit other team members with skills needed for successful completion of the project;
6. Clear vision of potential outcomes and ability to strategize to achieve them;
7. Value transparency, honesty, integrity, and high ethical standards in decision making;
8. Ability to communicate effectively, both written and oral;
9. Ability to listen carefully and learn from others;

10. Understand the importance of responsiveness to his/her clients, both internal and external; and
11. Empathy for what he or she does.

Kumar suggests that a careful review of these lists suggests that ABET has placed significant emphasis on preparing engineering students as leaders.

2.6 Gap

The current reform movement within engineering education has been initiated due to a pronounced gap between what industry expects in graduate engineers and what the universities have been producing.

Engineering graduates have noticed that they are not well prepared for their first jobs after graduation. In regards to the many "soft skills" required one engineering student who took the time to write an opinion article for a journal stated, "Although many courses involve the use of these skills, they rarely include an explicit effort to teach them. It is assumed that students will pick them up as needed. It does not follow that students are learning them well. An overall plan for development of skills is needed for control of assessment and to know that improvement is required at each stage, so it can be addressed explicitly" (Donaldson, 2005). Indeed it has been said that "an engineer is hired for his or her technical skills, fired for poor people skills, and promoted for leadership and management skills" (Russell et al., 1996). In 2002 a study showed that in addition to technical skills over half of the engineers surveyed reported the following skills as critical to their success (Bellinger, 2002):

- Written reports for internal use
- Team leadership
- Resolution of technical tradeoff
- Oral presentation
- Project management
- Setting of project deadlines.

As a follow up to Bellinger's study Summers found that "engineers report that their university engineering curriculums did not provide them with the requisite leadership skills required to function effectively in today's changing environment" (Summers, Davis, and Tomovic, 2004).

In addition to graduates noting the lack of preparation for the new workplace, academics and academic societies have also noticed the gap. In 1996 a group of engineering educators and practitioners gathered and discussed the needs of the engineer in the 21st century. They concluded that the gap in skills that needed to be addressed included: "written and oral communication skills; an ability to frame engineering problems in terms of legal, social, political, environmental, sustainable, and life cycle systems; and a basic understanding of business and project management, marketing, financial management, professional liability issues, business ethics, and engineers' responsibility to the public and to the profession." As a result of this discussion it was concluded that current engineering programs are "probably too specialized at the undergraduate level, offering too many undergraduate courses and not integrating non-engineering studies well" (Bakos, 1997).

Perhaps the most significant event is that ABET recognized the gap. During the late 20th century ABET conducted numerous studies to identify the skill gaps between engineering graduates and entry-level job requirements. The most common skills identified were, "project management, teamwork, engineering economics, organizational behavior, decision-making, and communications" (Davis, 2004). From its findings ABET adapted its accreditation requirements to include more of these skills in undergraduate engineering education, the new standard is referred to as EC2000. In response to EC2000 several universities are developing new courses and finding creative ways to help students learn these new skills (Suckarieh and Krupar, 2005; Tener and Fisher, 1997; Bond. 1998; McCuen, 1999).

2.7 Transition

For this thesis the word transition will be used to refer to the experience of when an engineer is first placed into a formal management position. There are three sections of transition to be discussed: selection, difficulties, and consequences.

Selection is an interesting and important subject. While it is well documented that engineering skills and those of management are two very different sets of skills, it is a common practice for companies to promote the engineer "who performs best in technical tasks" (Long, 1997) to a managerial position. This technique is interesting considering that in one man's opinion, "management is the most difficult, the most important and the most pivotal profession in our society" (Mayer, 1971). Mayer goes on to state that in many fields, people are placed into management positions without the necessary training or skills, and that this is especially true "for science and engineering". It is true that "most companies don't have a way to determine whether an engineer would make a good manager" (Tan, 2005). This type of selection process can prove disastrous considering that "the types of thinking and skills necessary for management success are so inherently different than those needed for [engineering] success that many good [engineers] cannot make a successful change" (Fetzer, 2005) .

Being placed into a management role can prove very difficult for even the brightest engineer. The nature of this difficulty is described by Mayer: "His direct responsibility, instead of being inanimate things, becomes people. He leaves a structured world obeying scientific laws and enters an unstructured world governed, to an extent, by insight and 'art'" (Mayer, 1971). Many skills needed to be successful in this new role are ones that can be learned once one enters the role with little negative consequences to one's work. However, if an engineer is not equipped with good people skills before entering management this can be detrimental to the work project and to his/her career. "Engineering managers frequently believe their only task is to get things done by commanding their employees, forgetting the underlying people issues" (Naguib, 2007) . According to a study conducted by Electronic Engineering Times (EET), "people" issues have proven to be the toughest business skill for engineers to master. EET defined "people" issues as "Leading [people]. Persuading [people]. Communicating with [people]" (Bellinger, 1998). Of the top five characteristics of a productive engineering manager three of them can be classified as "people" issues. These three characteristics are communicate skillfully, support and guide subordinates in their work efforts, and handle problems (Hood, 1990).

Poor preparation for a management role leads to micromanagement and second-guessing of subordinates or peers (Proctor, 2004). On the other hand an engineer who is prepared for management can gain great satisfaction from success in this arena and may find that he actually enjoys this type of work more than the technical work (Gautschi, 1976).

The consequences of failure in the transition can be significant. There are three parties with a vested interest in the process. The obvious parties are the employer and the employee. If the engineer fails to find success in the transition he/she can experience dissatisfaction, poor job performance, and boredom (Hall, Munson, and Posner, 1992). There is even the risk of becoming derailed on the career path. Derailment refers to the failure to meet expectations or simply, rising to one's level of incompetence (Proctor, 2004; Yeh, 2008). The employer can be faced with disgruntled employees, the loss of a good engineer, project overruns, and possibly even project failure. The third and less obvious party is the engineer's alma mater. A graduate from a university will carry the name of that university for the rest of his/her life. A university's reputation will forever be judged by the performance of its graduates. If an engineer is promoted to a management position and fails, this failure can damage his/her alma mater in a number of ways. Repercussions include the questioning of employers (and potential students) of the appropriateness of the curriculum and perhaps the most important – damage to the university's image and reputation as a professional school (Hall, Munson, and Posner, 1992).

2.8 Framework Studies

This research was framed on two previous research works. The primary one was a study done by Howard and reported in, "From Engineer to Engineering Manager: A Qualitative Study of Experiences, Challenges, and Individual Transitions for Engineering Managers in Aerospace Companies." This is from a doctoral dissertation of Allen Howard published in 2003. The second is an article written by Hans J. Thamhain titled, "From Engineer to Manager" and published in Training & Development in 1991.

2.8.1 Howard

The topic of Howard's dissertation was the transition by an engineer from the role of individual contributor to that of an engineering manager. Howard states that there are several articles written on the fact that this is a difficult transition for many engineers to make; however he was dissatisfied by the lack of evidence describing why the transition is difficult. Howard's research was completed using the phenomenological approach. He conducted several intimate interviews with 5 engineering managers who had recently undergone the transition. His research revealed nine themes (areas of difficulty) associated with the transition. These themes are (Howard, 2003):

1. So much going on: the engineering manager role involves balancing many more responsibilities, tasks, and priorities than the engineering role
2. Relationship changes: personal relationships, interaction dynamics and engineer perceptions of you have changed
3. Delegation: the challenge of leaving the hands on technical behind and learning to work through others
4. Increased stress and pressure associated with increased responsibility
5. Developing new skills: discovered the need for a new set of skills as a manager
6. Resources and getting the work done: finding time, the staff and other resources to get it done
7. The new guy in management: change from being a technical expert to being new in management and having a lot to learn
8. Organizational issues: in a new organizational level with its associated issues
9. Choosing the management career path: the concerns before deciding and questions experienced during or after the transition

Each theme was identified as a result of the interviews with the five engineers. Howard conducted three extensive interviews with each of his five participants during which he carefully recorded the details associated with the transition. Each of the five participants was screened against the following criteria:

1. Must have an engineering or related technical degree
2. Must have started as an engineer (at least 5 years as engineer) and then transitioned from engineer into an engineering manager role
3. Must not have pursued business degrees prior to the transition into management
4. Must have transitioned to manager in the last 1-5 years
5. Must work for an aerospace company on Long Island, New York.

After the initial interviews Howard sorted through his notes and identified common experiences among the engineers. These experiences were placed into similar groups which became the nine themes introduced earlier. Once these themes were developed Howard validated them with four of the five participants. During the validation meeting Howard also asked each of the participants to rank the themes according to difficulty. The above list of themes is numbered from most to least difficult.

In his conclusions Howard recommends that the themes be separated into three groups. Themes 1-3 were shown to be the most difficult of themes, each participant indicated that each of these themes was difficult and each one received at least one vote for being the most difficult. These are referred to as the primary challenges. Themes 4-7 were also each indicated as being difficult but they were ranked lower than themes 1-3. Howard refers to this group as the common challenges. The final group contains themes 8 and 9. Of all of the themes these were the least challenging, and in fact some of the engineers indicated that they were not difficult at all. Howard characterized this group as possible challenges.

These 9 themes were used in this research to quantify the difficulty of the transition for each participating engineer. Each engineer was asked to identify the difficulty of experienced with each theme on a 1-7 Likert scale ranging from very easy to very difficult.

2.8.2 Thamhain

Thamhain was an associate professor of management at Bentley College who was aware of the struggle of engineers with the transition into management positions. Responding to engineers' and managers' interest in tools to help assess technical-management potential he developed an engineering-management aptitude test.

The research used in the development and validation of the test was rigorous. The development of the survey involved questionnaires and surveys being administered to 450 research, development, and engineering managers. From these data Thamhain identified five characteristics of engineers who made the successful transition into management. These characteristics are:

1. Personal desire to be a manager
2. People skills
3. Technical knowledge
4. Administrative skills
5. Business Acumen.

Thamhain developed 10 statements that can be used to describe each of the categories and asked each respondent to rate his/her level of agreement with each statement on a 10-point Likert scale. Validation was completed through the administration of a survey to 210 managers and 640 of their subordinates in 55 technology-oriented companies, which span the spectrum of product offerings. Thamhain also asked supervisors to rank their subordinates in the same fashion. It was Thamhain's conclusion that those engineers who are rated well in these five aptitudes will make successful engineering managers (Thamhain, 1991). Ten questions were adapted from Thamhain's research and used to ascertain the managerial aptitude of the engineering managers that participated in the study.

3 Method

3.1 Introduction

The goal of this research was to develop a better understanding of the transition to leadership/management roles in a technical setting. The research plan was two-fold. First, determine whether or not the themes identified by Howard are distributable to a larger population of engineering managers. Second, assess the level of difficulty for an engineer in transitioning to a management position in relation to his/her self-assessed score from portions of Thamain's engineering-management aptitude test. The research was conducted through the administration of an online survey (a copy of the survey is provided in Appendix B).

3.2 Pain Points

Howard's research, conducted by interviewing five engineering managers, identified nine themes of difficulty in the transition process. For this research project eight themes were chosen. These themes were chosen as a result of at least three of the five engineers identifying them as a challenge. The ninth theme (Organizational issues: in a new organizational level with its associated issues) was only identified by two engineers. The eight themes selected for the study were (Howard, 2003):

1. So much going on: the engineering manager role involves balancing many more responsibilities, tasks, and priorities than the engineering role
2. Relationship changes: personal relationships, interaction dynamics and engineer perceptions of you have changed
3. Delegation: the challenge of leaving the hands on technical behind and learning to work through others
4. Increased stress and pressure associated with increased responsibility
5. Developing new skills: discovered the need for a new set of skills as a manger
6. Resources and getting the work done: finding time, the staff and other resources to get it done
7. The new guy in management: change from being a technical expert to being new in management and having a lot to learn
8. Choosing the management career path: the concerns before deciding and questions experienced during or after the transition

These themes have been coined “pain points”. Each engineer was asked to rank their experience with each theme on a 7-point Likert scale ranging from very easy to very difficult. Each engineer was also given the opportunity to identify any other area of difficulty associated with the transition and to rank it on the same scale. Each engineer was also asked to rank each of the items from most to least challenging.

3.3 Managerial Aptitude

In “From Engineer to Manager” Thamhain presented a relationship with the score on an engineering-management aptitude test with success as an engineering manager. In order to perhaps better understand which engineers may or may not struggle transitioning into management, several questions from Thamhain’s engineering-management aptitude test were included in the survey. These questions consisted of a simple statement and engineers were asked to express how strongly they agreed with each statement. There are two questions from each of Thamhain’s five global aptitude categories included in the survey (Thamhain, 1991):

Personal desire to be a manager

1. Managing people is professionally more interesting and stimulating to me than solving technical problems
2. I am willing to invest considerable time and effort in to developing managerial skills

People skills

1. I can effectively solve conflict over technical and personal issues, and don't mind getting involved
2. I am a good liaison person to other departments and outside organizations

Technical knowledge

1. I understand the product applications, markets, and economic conditions of my business area
2. I have a systems perspective in my area of technical work

Administrative skills

1. I am familiar with techniques for planning, scheduling, budgeting, organizing, and personnel administration, and can perform them well
2. I can estimate and negotiate resources effectively

Business skills

1. I feel comfortable working in dynamic environments associated with uncertainty and change
2. I would be good at directing the activities of my department toward the overall business objectives of my company

Agreement was expressed on a scale of 1 – 10 (1 – strong disagreement, 10 – strong agreement). This scale differs from that used to ascertain the difficulty associated with each pain point. The 10-point scale was used in order to administer the questions consistently with how Thamhain developed the questionnaire.

3.4 Possible Research Methods

There are two basic classifications of research: quantitative and qualitative. It is important to make sure that the best method is selected to aid in answering the research question. The following sections provide an overview of each method and an explanation for the selection of the method used in this research.

3.4.1 Qualitative

Qualitative studies are described as non-numerical. Qualitative studies are generally used for exploratory purposes, where little information is known in advance. The goal is to understand the subject not to measure it (Rasmussen, 2006). Qualitative studies are often conducted as a precursor to a quantitative study (Robson, 2002). Since this research was centered on measuring the difficulty in transitioning into leadership/management positions based on a limited number of previously identified factors a qualitative approach is inappropriate.

3.4.2 Quantitative

Quantitative studies are described as numerical. Quantitative studies are used to measure the subject material. The results are usually numeric and therefore lend themselves easily to statistical analysis. “The main aim of carrying out a quantitative study is to be able to generalize – i.e. to be able to draw conclusions from a small part of a larger group that will apply to the whole group” (Rasmussen, 2006). Two principle methods for collecting quantitative data are surveys and historical data sources.

3.4.2.1 Surveys

Surveys are ubiquitous in today’s society. While it may be difficult to provide a concise definition of a survey, there are three typical central features of surveys (Robson, 2002):

1. The use of a fixed, quantitative design;
2. The collection of a small amount of data in standardized form from a relatively large number of individuals;
3. The selection of representative samples of individuals from known populations.

While this is a good generalization there are of often exceptions to features two and three.

Surveys are generally used as part of non-experimental fixed designs. Surveys are useful in descriptive and explanatory studies. They are not well suited for exploratory purposes.

Surveys can be implemented using one of two methods: self-administration and interview. Robson provides a good list of advantages and disadvantages of each type of survey and surveys in general (Robson, 2002): This list is provided as Figure 4

3.4.2.2 Historical Data

Secondary data can be in the form of documents, film, photos, speeches, databases, etc. The distinguishing characteristic of secondary data is that it does not come from “observing, or interviewing, or asking someone to fill in a questionnaire.” It is instead, “something produced for some other purpose” (Robson, 2002).

There are advantages and disadvantages to using secondary data. A summary of these is provided in Figure 5:

Disadvantages
General to all surveys using respondents 1. Data are affected by the characteristics of the respondents (e.g. their memory; knowledge; experience; motivation; and personality). 2. Respondents won't necessarily report their beliefs, attitudes, etc. accurately (e.g. there is likely to be a social desirability response bias - people responding in a way that shows then in a good light). Self-administered surveys 3. Typically have a low response rate. As you don’t usually know the characteristics of non-respondents, you don't know whether the sample is representative. 4. Ambiguities in, and misunderstandings of, the survey questions may not be detected. 5. Respondents may not treat the exercise seriously, and you may not be able to detect this. Interview surveys 6. Data may be affected by characteristics of the interviewers (e.g. their motivation; personality; skills; and experience). There may be interviewer bias, where the interviewer, probably unwittingly, influences the responses (e.g. through verbal or non-verbal cues indicating 'correct' answers). 7. Data may be affected by interactions of interviewer/respondent characteristics (e.g. whether they are of the same or different class or ethnic background). 8. Respondents may feel their answers are not anonymous and be less forthcoming or open.
Advantages
General to all surveys using respondents 1. They provide a relatively simple and straightforward approach to the study of attitudes, values, beliefs and motives. 2. They may be adapted to collect generalizable information from almost any human population. 3. High amounts of data standardization. Self-administered surveys 4. Often this is the only, or the easiest, way of retrieving information about the past history of a large set of people. 5. They can be extremely efficient at providing large amounts of data, at relatively low cost, in a short period of time. 6. The allow anonymity, which can encourage frankness when sensitive areas are involved. Interview surveys 7. The interviewer can clarify questions. 8. The presence of the interviewer encourages participation and involvement (and the interviewer can judge the extent to which the exercise is treated seriously).

Figure 4 - Advantages and Disadvantages of Surveys

Advantages
• When based on existing documents, it is unobtrusive. You can 'observe' without being observed. • The data are in permanent form and hence can be subject to reanalysis, allowing reliability checks and replication studies. • It may provide a low cost form of longitudinal analysis when a run or series of information of a particular type is available.
Disadvantages
• The information available may be limited or partial. • The information has been created for some purpose other than for the research, and it is difficult or impossible to allow for the biases or distortions that this introduces. • It is very difficult to assess causal relationships.

Figure 5 - Advantages and Disadvantages of Historical Data

3.5 Chosen Research Method

A self-administered online survey was chosen for this research because it provided for collection of information from a large population of engineers to investigate relationships with a number of variables and engineer descriptors.

Self-administration of the survey was deemed appropriate due to the nature of the questions and to mitigate time constraints on the respondents and the researcher. The nature of the questions used in the survey was such that an engineer’s response should not be affected by the means by which the question is asked. The questions were demographic, recollective, and self-descriptive. Great effort was used to make sure that the questions were easy to understand and clear in their meaning.

The online administration allowed the surveys to be emailed to each participant and completed at his/her convenience. This served in collecting a considerable amount of data in a short period of time. The survey is outlined in Chapter 4 and is also included as Appendix B.

3.6 Survey Population

The population for this survey was selected from National Instrument's employee base. National Instruments was a willing participant in the study because of their interest in developing programs to aid engineers in this transition. National Instruments currently has an Engineering Leadership Program (ELP) which is used to help prepare engineers for management positions. The engineering managers selected to participate in the survey are all of the managers in NI's Research and Development department. 220 engineers were identified to participate in the study.

3.7 Survey Administration

Each engineer selected to participate in the survey was sent an email explaining the nature and the objective of the survey from NI's Training and Development department. A copy of this email is included in Appendix A. Several minutes after this email was sent each engineer received another email with a brief description of the survey and a link to access the survey through the internet. The survey was distributed on the 21st of November 2008. Participants were sent reminders on the 4th and the 9th of December. The survey was closed on the 11th of December. Drafts of the reminder and thank you message are also a part of Appendix A. Of the 220 samples 4 contacted the researcher and gave legitimate reasons as to why they did not belong on the survey sample. As a result the surveyed population was truly 216. From those 216 samples 121 completed the survey, giving a response rate of 56%. This is an excellent response rate. In a recent study it was found that the average response rate for emailed surveys is about 40% (Cook, Heath, and Thompson, 2000).

4 Results

4.1 The Survey

The survey consisted of 27 questions. The styles of questions used include close-ended, partially open-ended, and Likert rating scales. Each question was designed to fulfill one of two purposes: classify the engineers into comparable groups or to increase understanding of the transition experience for each engineer. Of the 216 dispatched surveys 121 (56%) were completed.

4.1.1 Background Information

Questions 1-12 were background gathering questions. The nature of these questions is preparation and demographics. Below is a summary of these questions and responses.

4.1.1.1 Question 1

In what year did you complete your undergraduate degree?

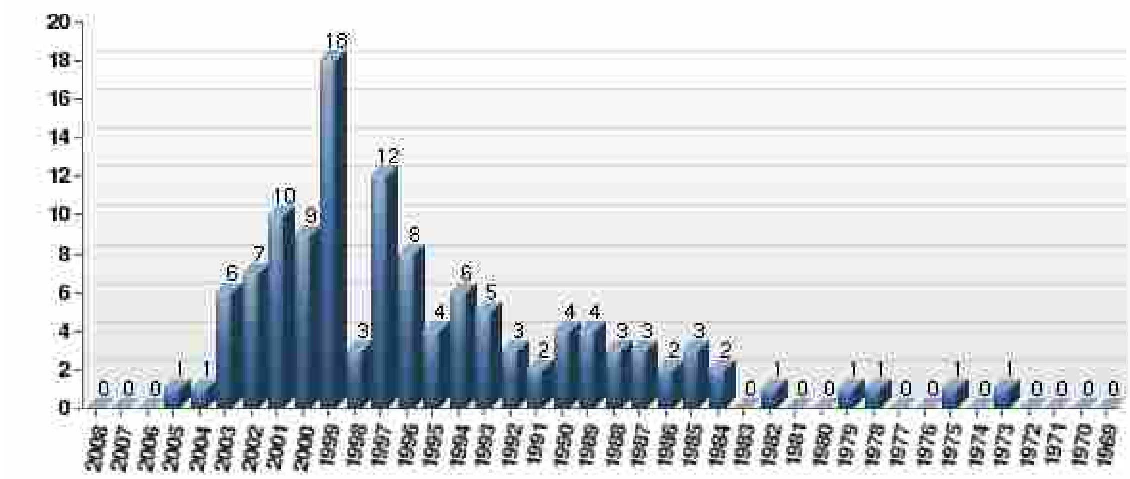

Figure 6 - Undergraduate Graduation Year of Respondent

4.1.1.2 Question 2

Select the category that best describes your engineering degree:

#	Answer		Response	%
1	Mechanical		9	7%
2	Electrical		59	49%
3	Chemical		2	2%
4	Manufacturing		0	0%
5	Industrial		2	2%
6	Petroleum		0	0%
7	Civil		0	0%
8	Computer		40	33%
9	Other		9	7%
	Total		121	100%

Figure 7 - Undergraduate Degree Type of Respondents

4.1.1.3 Question 3

My primary workplace is:

#	Answer		Response	%
1	Austin office		107	88%
2	Branch office		14	12%
	Total		121	100%

Figure 8 - Workplace of respondents

4.1.1.4 Question 4

Have you completed any advanced degrees?

#	Answer		Response	%
1	Yes		43	36%
2	No		78	64%
	Total		121	100%

Figure 9 - Do the Respondents have an Advanced Degree

4.1.1.5 Question 5

Please enter the type of advanced degrees you have earned. (Note: respondents only saw this question if the respondent answered yes to question 4.)

#	Answer		Response	%
1	MBA		7	16%
2	MS		37	86%
3	PhD		1	2%
4	JD		0	0%

Figure 10 - Advanced Degree Type

There are 45 responses to this question as opposed to the 43 who indicated having earned an advanced degree because two respondents have earned two advanced degrees.

4.1.1.6 Question 6

In what year did you complete your most recent degree? (Note: this question was only asked if the respondent answered yes to question 4.)

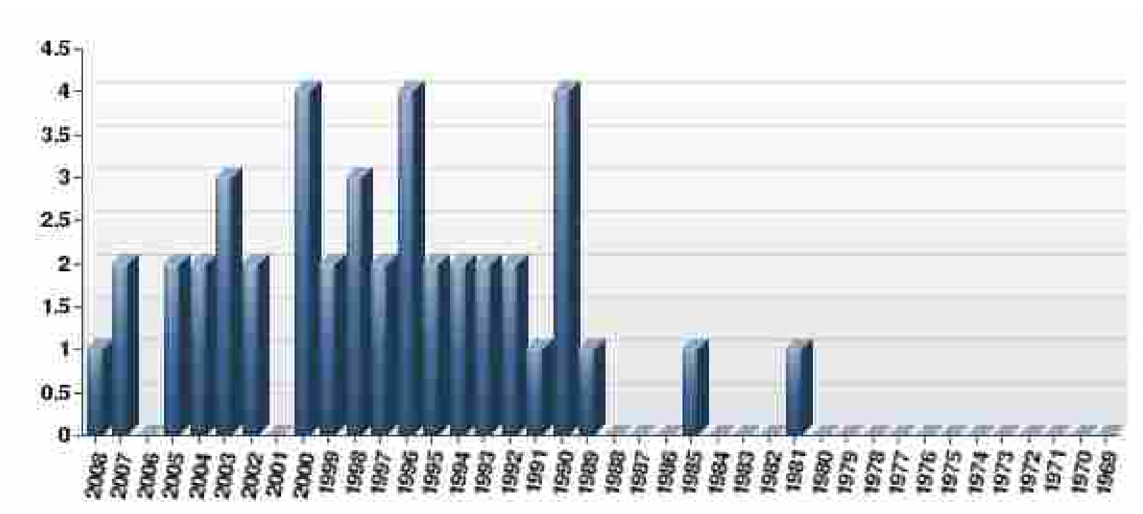

Figure 11 - Year of Most Recent Degree

4.1.1.7 Question 7

When did you enter your first management role?

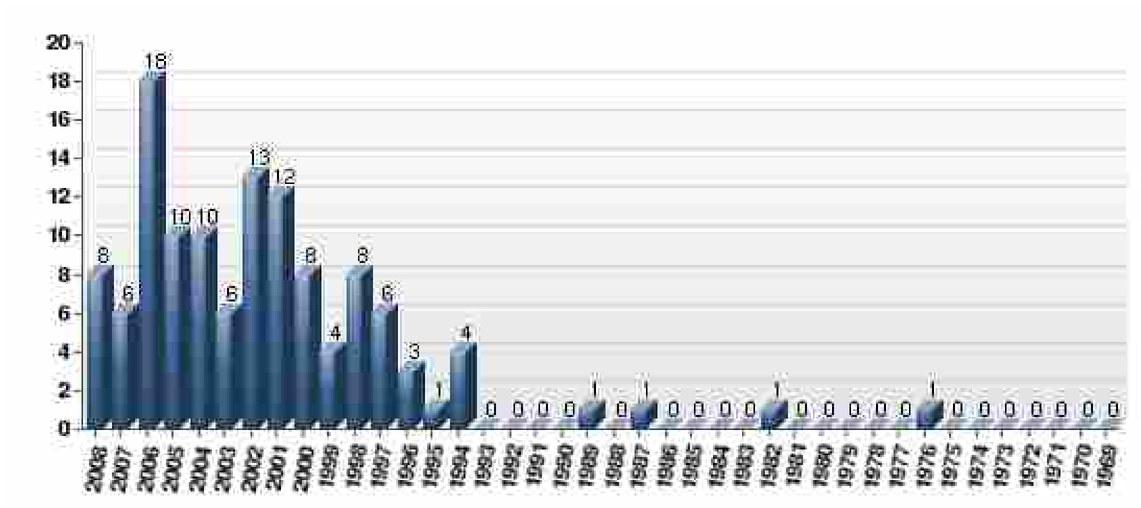

Figure 12 - Year Respondents Entered Management

4.1.1.8 Question 8

What is your main area of focus?

#	Answer		Response	%
1	Hardware		46	38%
2	Software		75	62%
	Total		121	100%

Figure 13 - Respondents Main Area of Focus

4.1.1.9 Question 10

Select your training preference for learning new material.

#	Answer		Response	%
1	Internal classes/training		77	64%
2	External classes/training		44	36%
	Total		121	100%

Figure 14 - Respondents Training Preference

4.1.1.10 Question 11

Why did you decide to enter the management ranks? (Note: Respondents were asked to select all that apply.)

#	Answer		Response	%
1	Better pay		10	8%
2	Looking for a change		18	15%
3	I was asked to		55	45%
4	Personal development		80	66%
5	Other		23	19%

Figure 15 - Why Respondents Entered Management

4.1.1.11 Question 12

Did you participate in National Instrument's Engineering Leadership Program (ELP)?

#	Answer		Response	%
1	Yes		54	45%
2	No		67	55%
	Total		121	100%

Figure 16 - Did the respondents Participate in ELP

This question was included for NI's benefit and was not used for any analysis presented in this thesis.

4.1.2 Transition Questions

The next series of questions were focused on understanding the respondents' experience as they transitioned from individual contributors to managers. This section consists of questions 14-16.

4.1.2.1 Question 14

This question consists of the eight of the nine pain points identified in Howard's work which at least three of the five engineers identified. Each engineer was asked to rank each pain point's level of difficulty on a scale from 1-7, 1 being very easy and 7 being very difficult. These results are shown in Table 3. The respondents also had the opportunity to include a pain point which they experienced which was not one of the original eight. This was included as pain point number nine and was assigned the designation of "other". Table 2 contains a list of the "others" that were included.

Table 2 - Other Pain Points

Other
Managing communication to head office
Decision making
Personnel performance problems
Building understanding of appropriate pay, etc.
Reading the mind of upper management. Upper mgmt communicates very poorly.
Lack of direct development experience
Understanding the expectations of my new role
Grow leaders inside group
Understanding where I'm adding value
New dynamics of different department
Finding training on tasks for new role
Learning HW process
"Do as I say, not as I do" mentorship

Table 3 - Eight Pain points

#	Question	Very Easy (1)	Easy (2)	Somewhat Easy (3)	Neutral (4)	Somewhat Difficult (5)	Difficult (6)	Very Difficult (7)	Responses	Mean
1	Balancing all of the responsibilities	2	16	17	16	33	30	7	121	4.49
2	Changes with relationships	8	27	26	27	23	9	1	121	3.50
3	Leaving behind the technical work	5	8	14	20	33	23	18	121	4.73
4	The increased stress and pressure	2	13	21	26	40	16	3	121	4.23
5	Developing the managerial skill set	2	26	26	21	34	10	2	121	3.80
6	Managing resources	1	21	31	19	35	11	3	121	3.92
7	Being the new guy in the ranks of management	7	38	28	21	18	7	2	121	3.28
8	Making the choice to enter the management career path	18	30	21	23	18	7	4	121	3.25
9	Other (see instructions)	80	0	0	24	4	8	5	121	2.31

4.1.2.2 Question 15

For this question each respondent was asked to rank order each of the pain points from most to least difficult (1 being the most difficult and 9 being the least).

Table 4 - Rank Order Scoring of Pain Points

#	Answer	1	2	3	4	5	6	7	8	9
1	Balancing all of the responsibilities	31	20	22	19	13	7	4	5	0
2	Changes with relationships	9	9	6	19	16	18	24	17	3
3	Leaving behind the technical work	29	18	17	10	12	6	16	9	4
4	The increased stress and pressure	18	26	15	17	17	19	6	2	1
5	Developing a new skill set	7	13	19	17	17	25	13	10	0
6	Managing resources	9	17	24	24	19	10	11	7	0
7	Being the new guy in the ranks of management	6	7	7	2	17	25	24	31	2
8	Making the choice to enter the management career path	6	8	8	12	10	11	22	39	5
9	Other	6	3	3	1	0	0	1	1	106

4.1.2.3 Question 16

Each of the pain points from Howard’s study had one or more elements (situations that typified the pain point) associated to it. Only those elements which three of the five of Howard’s engineers identified were included in this survey. Each participant was asked to identify all of the elements which caused them difficulty during their transition.

#	Answer		Response	%
1	A shift from being focused on just technical work to being responsible for several functions related to a project		36	30%
2	The requirement to balance and prioritize many tasks and roles		56	46%
3	The firefighting necessary to keep a project moving		47	39%
4	Having to spend a lot more time in meetings		60	50%
5	The new relationship with former peers; Rather than a friend, being the adversary		24	20%
6	Resentments or jealousy from some engineers that you were promoted instead of them		5	4%
7	The need to work through others: a mindset change from 'doing' to 'managing'		57	47%
8	No longer being a technical problem solver		27	22%
9	Allowing engineers to do their own design: learning that your way is not the only way (or the best way)		18	15%
10	The increased responsibility: ownership of something much larger and impact of decisions increased		39	32%
11	The amount of pressure and stress		50	41%
12	Underdeveloped people skills		14	12%
13	The number of hours required to work		26	21%
14	An inability to secure sufficient resources to complete projects on time		35	29%
15	The move from technical expert to management novice		30	25%
16	The lack of a willing and able mentor		33	27%
17	A lack of training or preparation for the new role		35	29%
18	The need to adapt management theories developed as an engineer		10	8%
19	The need to develop new domain knowledge		31	26%
20	Making the final decision to enter the management role		18	15%
21	None of these caused me any difficulty		2	2%

Figure 17 - Elements Identified as Difficult by Respondents

4.1.3 Management Aptitude

Thamhain developed an engineering management aptitude test which has proven successful in selecting engineers who thrive in the engineering manager profession. The next ten questions have been selected from Thamhain’s instrument. The intent of using these questions was to determine whether or not engineers’ managerial aptitude scores affected their transition into management.

Respondents were asked to state the degree with which they agreed to the following ten statements. The scale for these questions was 1 – 10 (1 being strongly disagree and 10 being strongly agree).

4.1.3.1 Question 18

Managing people is professionally more interesting and stimulating to me than solving technical problems.

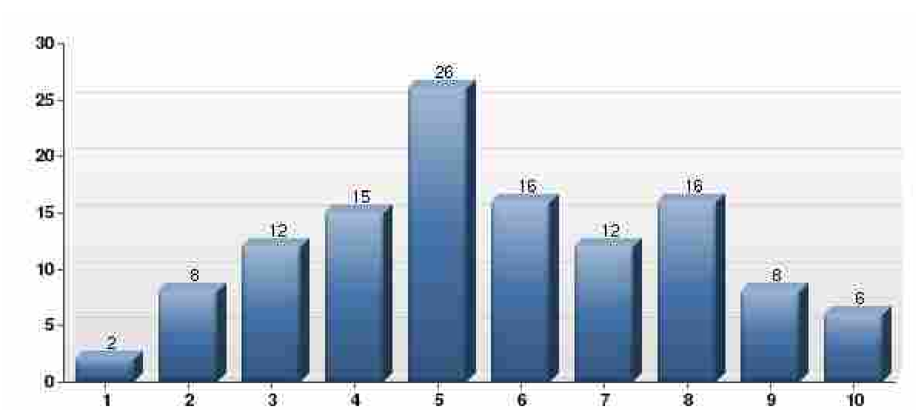

Figure 18 - Question 18 Results

4.1.3.2 Question 19

I understand the product applications, markets, and economic conditions of my business area.

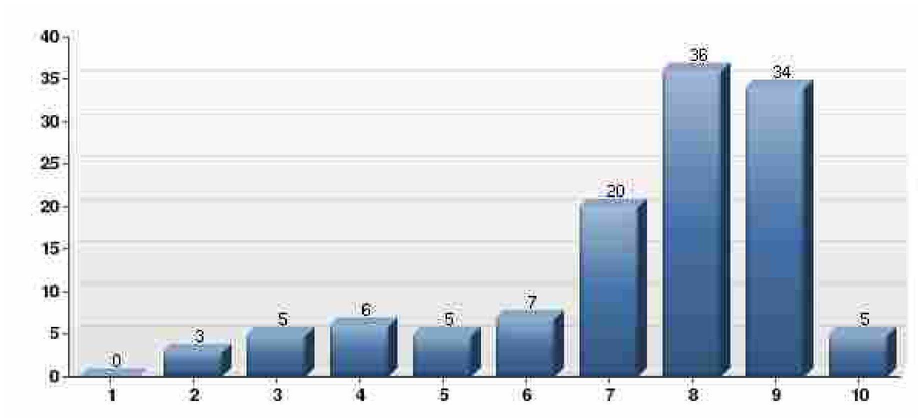

Figure 19 - Question 19 Results

4.1.3.3 Question 20

I am willing to invest considerable time and effort into developing managerial skills.

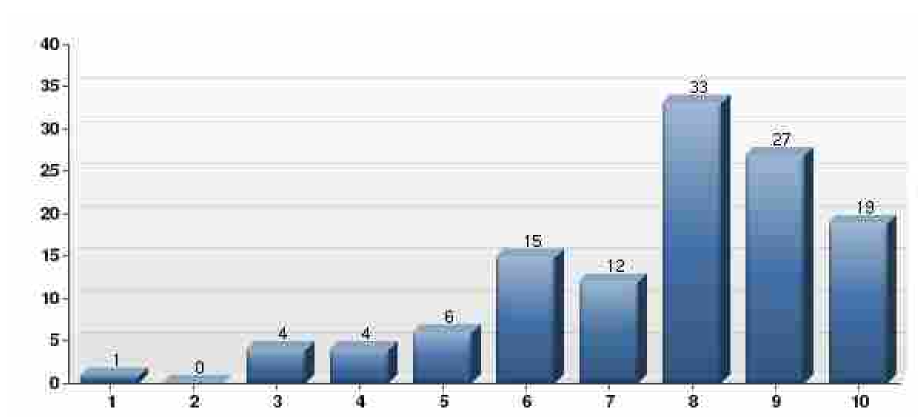

Figure 20 - Question 20 Results

4.1.3.4 Question 21

I feel comfortable working in dynamic environments associated with uncertainty and change.

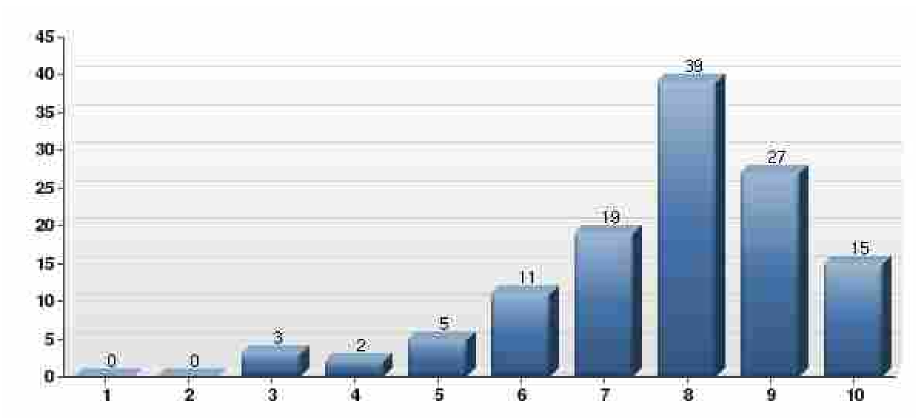

Figure 21 - Question 21 Results

4.1.3.5 Question 22

I can effectively solve conflict over technical and personal issues, and don't mind getting involved.

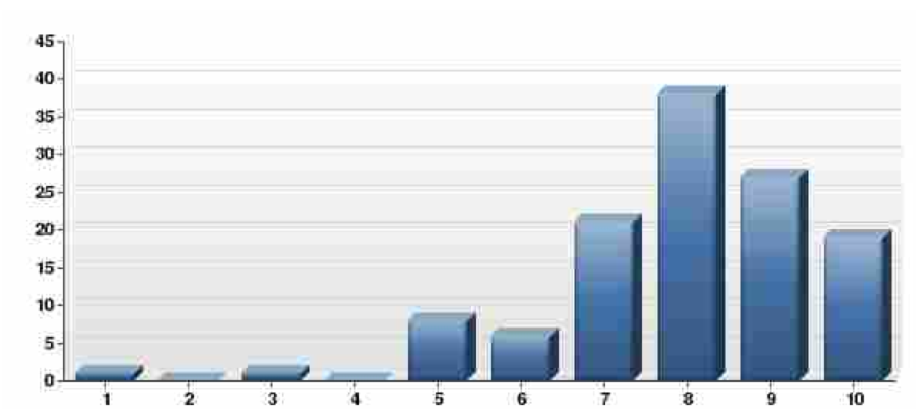

Figure 22 - Question 22 Results

4.1.3.6 Question 23

I am familiar with techniques for planning, scheduling, budgeting, organizing, and personnel administration and can perform them well.

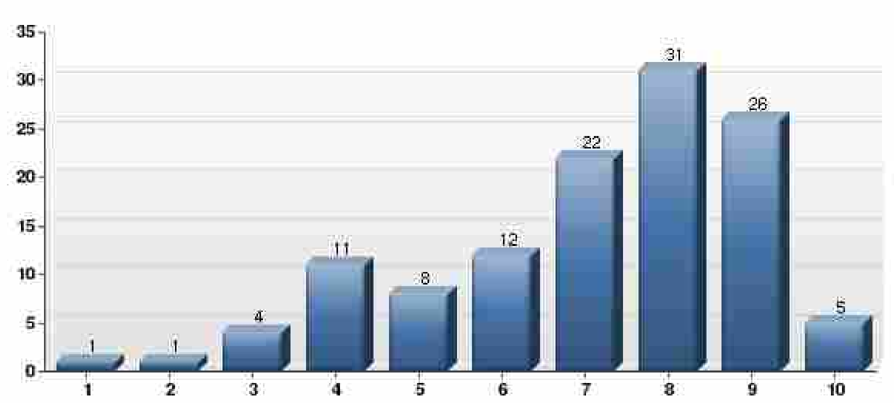

Figure 23 - Question 23 Results

4.1.3.7 Question 24

I have a systems perspective in my area of technical work.

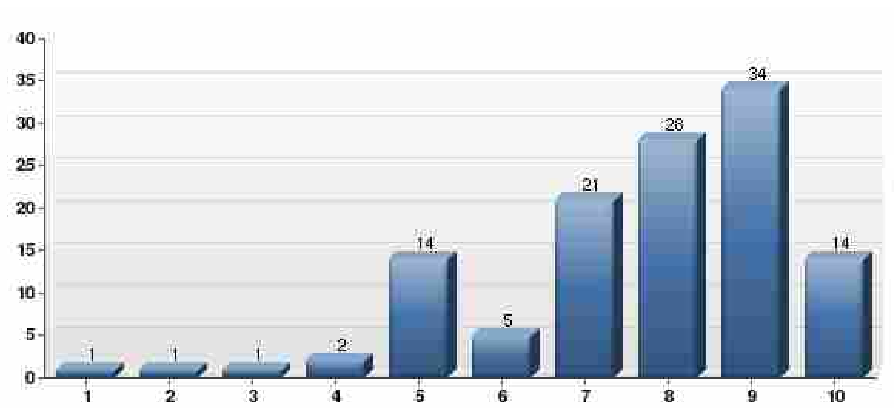

Figure 24 - Question 23 Results

4.1.3.8 Question 25

I can estimate and negotiate resources effectively.

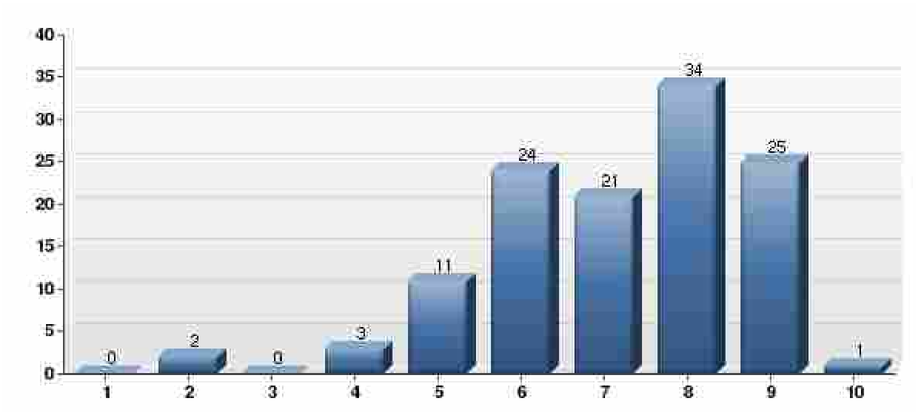

Figure 25 - Question 25 Results

4.1.3.9 Question 26

I would be good at directing the activities of my department toward the overall business objectives of my company.

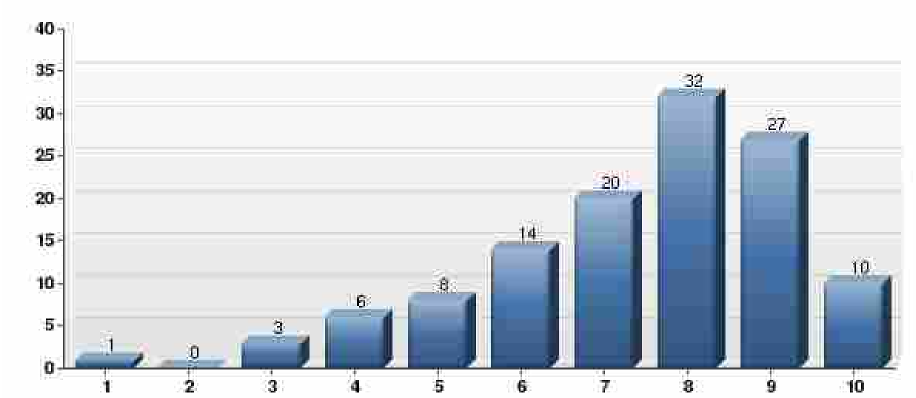

Figure 26 - Question 26 Results

4.1.3.10 Question 27

I am a good liaison to other departments and outside organizations.

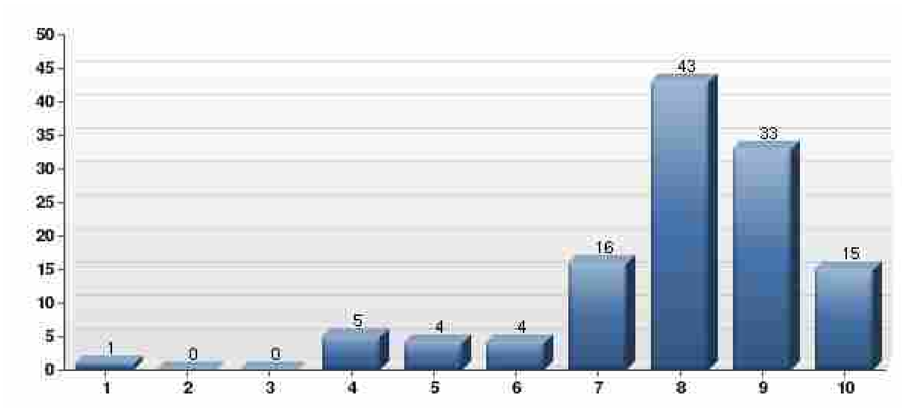

Figure 27 - Question 27 Results

4.1.4 Miscellaneous Questions

These three questions were included in the survey in order to gain more information about the respondents and do not fit into the other three categories.

4.1.4.1 Question 9

Please select your top three preferences for continuing your education:

#	Answer		Response	%
1	read professional books		89	74%
2	read newspapers or technical journals/magazines		67	55%
3	self-learn		95	79%
4	attend academic conferences		26	21%
5	attend seminars		63	52%
6	join professional societies		10	8%

Figure 28 - Preferences for Continuing Education

4.1.4.2 Question 13

How prepared were you for the new role of management?

#	Answer		Response	%
1	Very Prepared		11	9%
2	Prepared		52	43%
3	Neutral		38	31%
4	Unprepared		16	13%
5	Very Unprepared		4	3%
	Total		121	100%

Figure 29 - Preparedness for Management

4.1.4.3 Question 17

In which of the following areas have you gained leadership experience?

#	Answer		Response	%
1	Scouting		24	20%
2	Volunteer organizations		37	31%
3	School government		18	15%
4	Religious service organizations		28	23%
5	College clubs		48	40%
7	Other		25	21%
6	None of these		31	26%

Figure 30 - Leadership Development Activities

Table 5 - Other Areas of Leadership Experience

Other
Amateur performing arts organizations
US military
HOA director
Organizing rec. activities/sports
Leadershape
High school band
Previous jobs
Athletic teams
Coaching sports
Team projects as part of courses, senior design project
Leadership international exchanges
Landmark education

4.2 Statistical Analysis

Several variables were investigated in looking for significant relationships between managerial aptitude (For the sake of ease in analysis the 10 managerial aptitude questions have been combined to create a single score of managerial aptitude. The value of this variable has a range of 0 – 100.), the amount of difficulty associated with each major pain point (Likert 1 – 7) and the number of elements each engineer selected as difficult. The tables in this section are highlighted in two shades: the ________ highlight indicates a significant relationship at the .05 level, the ________ color indicates data that were close to significant which the researcher felt worthy of mention.

4.2.1 Testing Methods

All of the statistical tests run on the data set were completed using one of three methods. These methods included one-way ANOVA, T-tests, and correlations. Each of these methods is described below:

- T-tests – used to compare the differences between two independent groups based on variance between their means.
- One-way ANOVA – used to compare the difference between three or more independent groups based on variance between their means.
- Correlation – indicates the strength and direction of a linear relationship between two random variables.

4.2.2 Why the Respondents Entered Management Positions

This section of analysis investigates whether or not the reason selected by engineers for entering management is an indicator of the amount of difficulty associated with the transition.

The independent variable for this analysis was why engineers elected to enter the management ranks. This information was gathered from question number 11, engineers were asked to select all of the reasons that were applicable. Two tests were run.

4.2.2.1 One-way ANOVA of "Why", Asked

For this test all respondents were placed into one of three categories. Category 1 consists of the engineers who only selected the fact that they were asked to enter management. Category 2 includes those who selected that they were asked and at least one other reason. All engineers who did not indicate their "being asked" as a reason for entering management were placed in Category 3. The following tables summarize the significant and notable results.

Table 6 – ANOVA Why, Asked Managerial Aptitude

Asked (Why)	n	Mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only asked	24	68.21	2	4.22	0.017	0.004	0.084	0.318
asked and other	31	73.61						
not asked	66	76.11						

Table 7 – ANOVA Why, Asked Balancing of Responsibility

Asked (Why)	N	Mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only asked	24	5.29	2	8.64	0.000	0.000	0.328	0.005
asked and other	31	4.9						
not asked	66	4						

Table 8 - ANOVA Why, Asked Developing Management Skills

Asked (Why)	n	Mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only asked	24	4.62	2	6.17	0.003	0.001	0.027	0.297
asked and other	31	3.81						
not asked	66	3.5						

Table 9 - ANOVA Why, Asked Deciding to Enter Management

Asked (Why)	n	Mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only asked	24	3.75	2	4.66	0.011	0.018	0.925	0.013
asked and other	31	3.71						
not asked	66	2.85						

There were several significant relationships discovered between these variables. Table 6 shows us that those who did not select Asked as compared to those who only selected Asked as the reason for entering management scored higher on the managerial aptitude questions. While not significant it is also interesting to note that the difference between those who only indicated Asked and those who indicated Asked and other variables is nearly significant.

Of the eight pain points three of them showed significantly different scores when compared to this variable. These pain points are the balancing of responsibility, development of managerial skills, and deciding to enter management (See Table 7, Table 8, and Table 9).

4.2.2.2 T-Test of "Why", Asked

T-Tests are designed to compare differences between two groups. For this set of tests the survey responses were grouped into two groups: those who indicated Asked and those who did not indicate Asked as a reason for entering management. Below are the tables that summarize the significant and notable findings.

Table 10 – T Why, Asked Number of Difficulties

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	5.82	119	1.883	0.062
not asked	66	4.94			

Table 11 - T Why, Asked Managerial Aptitude

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	71.25	119	2.307	0.023
not asked	66	76.1			

Table 12 - T Why, Asked Balancing of Responsibility

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	5.07	119	4.04	0.000
not asked	66	4			

Table 13 - T Why, Asked Leaving Technical Work

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	5.04	119	1.941	0.055
not asked	66	4.47			

Table 14 - T Why, Asked Developing Management Skills

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	4.16	119	2.661	0.009
not asked	66	3.5			

Table 15- T Why, Asked Deciding to Enter Management

Asked (Why)	n	Mean	df	t-stat	Significance
asked	55	3.73	119	3.065	0.003
not asked	66	2.85			

Similar to the ANOVA tests these tests showed a significant difference in managerial aptitude and the same three pain points. Additionally these tests show significance in the number of elements which caused difficulty and the additional pain point of “Leaving Technical Work”.

4.2.2.3 One-Way ANOVA of "Why", Development

For this test all respondents were placed into one of three categories. Category 1 consists of the engineers who indicated that the only reason they entered management was for personal development. Category 2 includes those who selected personal development along with other reasons. Those engineers who did not indicate personal development as a reason for entering management were placed in Category 3. The following tables summarize the significant and notable results.

Table 16 - ANOVA Why, Dev Managerial Aptitude

Development (Why)	n	mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only dev	31	78.55	2	5.71	0.004	0.001	0.128	0.039
dev and others	49	74.57						
not dev	42	69.59						

Table 17 - ANOVA Why, Dev Level of Preparedness

Development (Why)	n	mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only dev	31	2.26	2	2.59	0.080	0.045	0.044	0.946
dev and others	49	2.69						
not dev	42	2.71						

Table 18 - ANOVA Why, Dev Balancing of Responsibility

Development (Why)	n	mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only dev	31	3.87	2	4.576	0.012	0.003	0.075	0.149
dev and others	49	4.49						
not dev	42	4.95						

Table 19 - ANOVA Why, Dev Developing Management Skills

Development (Why)	n	mean	df	F	Significance	1 & 3	1 & 2	2 & 3
only dev	31	3.42	2	3.551	0.032	0.013	0.421	0.052
dev and others	49	3.67						
not dev	42	4.24						

Similar to whether or not being asked was a reason the engineers entered management, whether or not the engineers went into management for personal development shows a significant difference in their managerial aptitude scores (Table 16). The significant differences exist between groups 1 & 3 and 2 & 3. The difference between groups 1 & 2 is not significant. This implies that so long as an engineer had personal development as a reason for entering the management ranks it did not matter if he had other reasons as well.

Those engineers who only selected personal development showed a significant difference in their preparedness for management when compared to those who selected personal development along with other reasons and those who did not select personal development (Table 17).

The pain points for which there were significant results include balancing of responsibility and developing managerial skills (Table 18 and Table 19).

4.2.2.4 T-test of "Why", Development

For this set of tests the survey responses were grouped into two groups: those who indicated personal development and those who did not indicate personal development as a reason for entering management. Below are the tables that summarize the significant and notable findings.

Table 20 - T Why, Dev Managerial Aptitude

Development (Why)	n	Mean	df	t-stat	Significance
development	80	76.11	119	2.993	0.003
not development	41	69.59			

Table 21 - T Why, Dev Balancing of Responsibility

Development (Why)	n	Mean	df	t-stat	Significance
development	80	4.25	119	2.441	0.017
not development	41	4.95			

Table 22 - T Why, Dev Developing Management Skills

Development (Why)	n	Mean	df	t-stat	Significance
development	80	3.58	119	2.543	0.012
not development	41	4.24			

Table 23 - T Why, Dev Deciding to Enter Management

Development (Why)	n	Mean	df	t-stat	Significance
development	80	3.05	119	1.893	0.061
not development	41	3.63			

These t-test results are similar to the ANOVA results with two exceptions. The first exception is the absence of a significant or notable difference in the level of preparedness between the two groups. The second exception is a notable result in the difference between the levels of difficulty experienced in making the decision to enter management.

4.2.3 Type of Degree

Within our sample of 121 engineers, there were a variety of undergraduate engineering degrees earned. The independent variable was set to types of degree; information gained in question 2, and the dependent variables which were investigated included preparedness, difficulty of each theme, frequency of each element, and managerial aptitude.

4.2.3.1 One-way ANOVA of Undergraduate Degree Type

There were two notable results from these tests. There appears to be a significant difference between a number of degree types and managerial aptitude and the level of difficulty associated with the pain point of Being the New Guy in Management. The validity of these results however are suspect because of the small sample sizes of some of the types of undergraduate degrees earned. Below are the tables summarizing the results:

Table 24 - ANOVA Undergrad Degree Managerial Aptitude

Type of Degree	n	Mean	df	F	Significance	1 & 4	4 & 6	5 & 6
1 Mechanical	9	68.33	5	2.142	0.065	0.045	0.027	0.017
2 Electrical	59	73.58						
3 Chemical	2	74.50						
4 Industrial	2	86.50						
5 Computer	40	76.65						
6 Other	9	66.44						

Table 25 - ANOVA Undergrad Degree Being the New Guy

Type of Degree	n	Mean	df	F	Significance	1 & 2	1 & 4	1 & 5	1 & 6
1 Mechanical	9	4.56	5	2.142	0.065	0.013	0.020	0.004	0.012
2 Electrical	59	3.31							
3 Chemical	2	4.50							
4 Industrial	2	2.00							
5 Computer	40	3.05							
6 Other	9	2.89							

Table 24 and Table 25 indicate that of all of the engineering disciplines mechanical engineering graduates appear to have the lowest managerial aptitudes and the most difficulty being the new guy in management. There were no other significant relationships than the ones shown above.

4.2.3.2 T-test of MS and No MS

Since several of the respondents indicated that they had earned a graduate degree similar tests were run using the type of graduate degree as the independent variable. While no significant differences were found there were two notable differences. These are illustrated in the tables below.

Table 26 - T-test Deg MS Developing Management Skills

MS or no MS	n	Mean	df	t-stat	Significance
MS	37	4.16	119	1.900	0.06
No MS	84	3.64			

Table 27 - T test Deg MS Deciding to Enter Management

MS or no MS	n	Mean	df	t-stat	Significance
MS	37	3.65	119	1.818	0.072
No MS	84	3.07			

These tables show that it was notably more difficult for those engineers who had earned an MS to develop the necessary management skills and to make the decision to enter management than it was for engineers without an MS.

4.2.4 Undergraduate Graduation Year

Graduation year was tested against the same dependent variables: Difficulty with each pain point, the frequency of each element, management aptitude score, and the level to preparedness to enter management ranks.

4.2.4.1 Correlation

A significant correlation was found between graduation year and Managerial aptitude. The table shows that this is a negative correlation; this means that as the graduation year decreases in value the respondents' managerial aptitude increases. The graduation year values were determined by setting the year 2008 equal to 1 and increasing the value as the years go back in time. This means that the most recent college graduates had higher managerial aptitude scores than their peers who graduated before them.

Table 28 - Correlation, Grad Year and Managerial Aptitude

Pearson Correlation	Significance	N
-.218	0.017	121

A significant correlation was also found between graduation year and preparedness to enter management. This was a positive correlation indicating that the more recent graduates felt more prepared to enter management than their peers who graduated before them.

Table 29 - Correlation Grad Year and Preparedness

Pearson Correlation	Significance	N
0.204	0.025	121

4.2.4.2 One-way ANOVA of Undergraduate Graduation Year

In order to run these tests the graduation year responses had to be grouped into time periods. The time periods selected for testing were 2008-2001 as group 1, 2000-1996 as group 2, and 1996-1973 as group 3. The time period for group 1 was selected to coincide with EC2000 instituted by ABET in 2000. The time periods for groups 2 and 3 were determined to create groups of similar size. Significant differences between these three groups were found in the following variables: preparedness for entering management and deciding to enter management.

Table 30 - ANOVA Grad Year Preparedness

Graduation Year	n	Mean	df	F	Significance	1 & 3	1 & 2	2 & 3
2001-2008	25	2.32	2	2.079	0.130	0.049	0.340	0.208
1996-2000	50	2.54						
1973-1995	46	2.78						

Table 31 - ANOVA Grad Year Deciding to Enter Management

Graduation Year	n	Mean	df	F	Significance	1 and 3	1 and 2	2 and 3
2001-2008	25	2.60	2	4.238	0.017	0.005	0.166	0.077
1996-2000	50	3.14						
1973-1995	46	3.72						

A student graduating after 2000 felt better prepared for management and made the decision with less difficulty than his/her peers who graduated before 1996.

4.2.4.3 T-test of Undergraduate Graduation Year

For these tests similar groupings to the ANOVA tests were used. Group 1 remained the same and Groups 2 and 3 were combined to create one group. This affectively separated engineers who graduated under EC2000 from all of the earlier graduates. The tables below indicate the significant findings.

Table 32 - T Being the New Guy

Graduation Year	n	Mean	df	t-stat	Significance
2001-2008	25	3.80	119	1.883	0.041
1973-2000	96	3.15			

Table 33 - T Deciding to Enter Management

Graduation Year	n	Mean	df	t-stat	Significance
2001-2008	25	2.60	119	2.307	0.025
1973-2000	96	3.42			

While these test confirmed the findings from the ANOVA test about graduates after 2000 being able to make the decision to enter management with less difficulty than their peers, they do not confirm the greater level of preparedness. It is also observed that graduates after the year 2000 faced greater difficulty with being the new guy in the ranks of management.

4.2.5 Managerial Aptitude

The final statistical test ran was designed to determine whether or not there is correlation between Thamhain's managerial aptitude test results and difficulty for an engineer transitioning into a management position. The results are shown in Table 34.

Table 34 - Correlations between Managerial Aptitude and the 8 Pain Points

	Pearson Correlation	Significance	N
Balancing of Responsibility	-0.216	0.017	121
Changes with Relationships	-0.039	0.672	121
Leaving Technical Work	-0.218	0.017	121
Increased Stress and Pressure	-0.168	0.065	121
Developing Managerial Skills	-0.232	0.010	121
Managing Resources	-0.177	0.202	121
Being the New Guy in Management	-0.117	0.202	121
Deciding to Enter Management	-0.266	0.003	121

As Table 34 illustrates four of the pain points were found to be significantly correlated with the managerial aptitude scores. Another pain point while not significant was notable. The negative correlations indicate that as the managerial aptitude score increases the level of difficulty associated with each pain point decreases.

4.2.6 Pain Point Correlation

The question can be asked: Does difficulty with one pain point correlate with difficulty in other pain points? The answer is yes. In fact, it was discovered that each pain point had at least one or more significant positive correlations with other pain points. The surprising discovery was that there is one pain point, the development of managerial skills, which has highly significant correlations with each and every other pain point. In addition to these strong correlations the development of managerial skills is also strongly correlated with managerial aptitude, number of difficulties, and preparedness level for entering a management position. These correlations are all shown in Table 35.

Table 35 - Correlations with Development of Managerial Skills

	Pearson Correlation	Significance	N
Managerial Aptitude	-0.232	0.010	121
Number of Difficulties	0.327	0.000	121
Level of Preparedness	0.366	0.000	121
Balancing of Responsibility	0.438	0.000	121
Changes with Relationships	0.426	0.000	121
Leaving Technical Work	0.186	0.041	121
Increased Stress and Pressure	0.322	0.000	121
Managing Resources	0.526	0.000	121
Being the New Guy in Management	0.262	0.004	121
Deciding to Enter Management	0.322	0.000	121

4.3 Conclusion

This research resulted in the discovery of several significant factors related to engineers and the transition into management positions. The categories found to have the most affect on the transition are year of undergraduate graduation, engineering degree type, an engineer’s motivation for entering the management profession, and an engineer’s self assessed managerial aptitude. The correlation of the development of managerial skills to every other pain point is also significant. The next chapter summarizes the conclusions of the study.

5 Conclusion

5.1 Conclusions

On the subject of factors that contribute to the relative ease or difficulty with which individually contributing engineers transition into management positions there are several reasonable conclusions that can be stated as a result of this survey. These conclusions will be presented in five categories: the presence of common pain points, why engineers selected to enter the management ranks, the type of degree earned, the year of undergraduate graduation, and the respondents' managerial aptitude scores.

5.1.1 Common Pain Points

Recall from an earlier section that Howard established a ranking, based on difficulty for the pain points. The eight pain points used in this study are listed below, in order from most to least difficult as established by Howard:

1. So much going on: the engineering manager role involves balancing many more responsibilities, tasks, and priorities than the engineering role
2. Relationship changes: personal relationships, interaction dynamics and engineer perceptions of you have changed
3. Delegation: the challenge of leaving the hands on technical behind and learning to work through others
4. Increased stress and pressure associated with increased responsibility
5. Developing new skills: discovered the need for a new set of skills as a manager
6. Resources and getting the work done: finding time, the staff and other resources to get it done

7. The new guy in management: change from being a technical expert to being new in management and having a lot to learn
8. Choosing the management career path: the concerns before deciding and questions experienced during or after the transition.

One of the stated objectives of this research was to determine whether or not Howard's findings were distributable to a larger population of engineers. This research ranked the pain points using three different methods. The first method of ranking consisted of using the mean value of the 7-point Likert scale of each pain point. The second method uses the results from asking each manager to rank the pain points in order from most to least difficult. Finally, each pain point has been ranked according to the percentage of engineers who identified the relevant elements (see section 4.1.2.3) from each pain point as difficult. For example, "Balancing all of the responsibilities" has four elements from question 16 associated with it. These four elements were identified as being difficult 199 times. With 121 responses and four elements the total possible number of selections is 484. "Balancing all of the responsibilities" total percentage is then 199/484 or 41%. The results of these rankings are displayed in Table 36.

Table 36 - Three Rank Orders of Pain Points

Pain Points	Likert Score Ranking	Rank Ordering	Element Selection
Leaving behind the technical work	1	3	3
Balancing all of the responsibilities	2	1	1
The increased stress and pressure	3	2	2
Managing resources	4	4	4
Developing the managerial skill set	5	5	8
Changes with relationships	6	6	7
Being the new guy in the ranks of management	7	7	5
Making the choice to enter the management career path	8	8	6

The Likert scale ranking fit exactly in line with Howard's findings. The participants' rank ordering matches Howard's for the bottom five pain points, and the top three are consistent but in a different order. The final ranking, element selection, also agrees with Howard's three most difficult pain points (in the same order as the participants' rank ordering). This method does however place the bottom four pain points in a unique order. These results confirm Howard's research and can be used as a guide for industry and academe as to how they can help ease the transition in the future.

5.1.2 Why Engineers Enter Management

In question 11 of the survey each engineer was asked to select the reasons that he/she decided to enter the management ranks. The possible selections were: I was asked to, personal development, better pay, looking for a change, and other. During the analysis each of these responses was tested to find significant effects on managerial aptitude, the difficulty associated with each pain point, perceived preparedness for management, and the number of difficult elements identified. In the table a blank cell represents no statistical significance and a +, or – represent a significant positive or negative relationship, respectively.

Table 37 shows that a relevant factor affecting an engineer's transition into management is his/her motivation for entering management. It is important to note here that all of the significant markers for "I was asked to" were negative effects. The pain points were more difficult and managerial aptitude and perceived preparedness were lower. On the other hand all of the significant markers for "personal development" were positive. The pain points were less difficult and managerial aptitude was higher. If an engineer enters management primarily because he/she was asked tot by a supervisor that transition will be markedly more difficult than if the engineer's motivation was any other tested reason. Conversely, if an engineer's main motivation for entering management is personal development this study concludes that the transition will be smoother than for others. There could be several reasons that this is true. Here are a few possibilities. This could be tied to intrinsic versus extrinsic motivation. An engineer who decides to enter management because of a desire to improve himself/herself may have already been working on the development of different skills that aid in the transition, Another possibility is that the engineer who goes into management for personal development encounters the same challenges and difficulties as his/her counterpart, but since he/she decided to enter management for development purposes he/she views the challenges in a more positive manner.

Table 37 - Summary of Significance Affected by Why Engineers Enter Management

Significant Factors	I was asked to	Better Pay	Personal Development	Looking for a change	Other
Managerial Aptitude	-		+		
Number of difficulties					
Preparedness	-				
Pain Points					
Balancing all of the responsibilities					
Changes with realtionships	-		+		
Leaving behind the technical work					
The increased stress and pressure					
Developing a new skill set	-		+		
Managing resources	-		+		
Being the new guy in management	-				
Deciding to enter Management			+		

(-) indicates a significant negative relationship (+) indicates a significant positive relationship

5.1.3 Type of Degree Earned

This section will be split into two parts. The first part will discuss the effect of the engineering degree discipline on an engineer's transition into management. The completion of graduate degree will be addressed in the second section.

5.1.3.1 Engineering Degree Discipline

According to the data the discipline of engineering degree does not have an overall significant effect on an engineer's transition into management. Table 38 summarizes the few effects that were found when comparing each discipline to all others. In the table a blank cell represents no statistical significance and a + or – represent a significant positive or negative relationship, respectively.

5.1.3.2 Graduate Degree

Whether or not the engineers earned a graduate degree surprisingly effected their transition into management. While the results were not quite significant it is important to discuss the implications of the results.

The results indicate that the most prevalent graduate degree was an MS with 37 (there were also 7 MBAs and 1 PhD). The transition factor affected most by having an MS was the development of management skills. This is logical since an MS in engineering is designed to increase and hone an engineer's technical skills. The more technical training an engineer receives, the more difficult it becomes for him/her to develop soft managerial skills. Now, the difference in the difficulty with this particular pain point was not significant, but it was close with a significance rating of 0.06. The importance of this finding is that the means of the difficulty for the two groups (MS and no MS) crosses the point of neutrality. The scoring system was 1-7 with 1-3 being degrees of ease, 4 being neutral, and 5-7 being degrees of difficulty. The mean scores for these two groups, MS and no MS, were 4.16 and 3.64 (see Table 26 in Chapter 4).

5.1.4 Year of Undergraduate Graduation

Since the implementation of EC2000 engineering educators have been paying more attention to teaching management and leadership skills as part of the undergraduate curriculum. As a result, one would expect those engineers who graduated after 2000 to have an easier time transitioning into management positions.

Initially it appeared as though the data supported this belief. There was a significant positive correlation found between graduation year and self-evaluated preparedness level for entering management. This means that as the graduation year became more recent the engineers felt more prepared to transition into management.

In order to determine whether or not this change could be attributed to EC2000 another statistical test was run. Graduates were separated into three groups by graduation year (2008-2001, 2000-1996, 1995-1973) and a one-way ANOVA test was performed. Two significant differences were found.

Those respondents in group 1 (2008-2001) indicated a higher level of preparedness than their counterparts in group 3 (1995-1973). The difference in preparedness between group 1 and group 2 (1996-2000) was not significant. The other input significantly affected among these three groups was making the decision to enter

Table 38 - Engineering Discipline Effect on Transition

Significant Factors	Mechanical	Electrical	Chemical	Manufacturing	Industrial	Petroleum	Civil	Computer	Other
Managerial Aptitude									-
Number of difficulties								+	
Preparedness								+	
Pain Points									
Balancing all of the responsibilities					-				
Changes with relationships									
Leaving behind the technical work									
The increased stress and pressure									
Developing a new skill set									
Managing resources					-				
Being the new guy in management	+								
Deciding to enter Management									

(-) indicates a significant negative relationship (+) indicates a significant positive relationship

EC2000 was fully implemented in 2000 only the group 1 respondents have participated in any EC2000 directed education programs (it is possible that engineers may have been educated at a pilot school for EC2000. Several schools started implementing EC2000 starting in 1998. Approximately 51 schools had implemented the criteria by the year 2000. This study did not control for this variable (Yeargan, 1999).) The lack of significant difference between groups 1 and 2 indicates that EC2000 may not increase an engineer's own perceived preparedness for a management role or the ease with which an engineer decides to enter management.

5.1.5 Managerial Aptitude

Thamhain developed his managerial aptitude test in order to aid in the selection of engineers to management positions. The purpose for its inclusion in this research was to see if engineers with a higher managerial aptitude score experienced less difficulty in the transition process.

The analysis presented in section 4.3.4 indicates that there is a strong negative correlation between managerial aptitude scores and the difficulty experienced by engineers in the transition as measured using the eight pain points (see Table 34). Thamhain's managerial aptitude test appears to be a strong indicator of the level of difficulty that will be experienced by engineers as they transition into management positions.

5.2 Recommendations

This study should serve as a stepping stone to further research. There are several areas of this research that can be improved to aid in better understanding the difficulties inherent in the transition process. These areas include timing, sampling, method, and topics.

5.2.1 Timing

The participants for this research were selected simply by the fact that they were currently in an engineering management position. No consideration was paid to the recency of their transition from an individual contributor. The time span from transition to participating in the survey ranges from 1 to 22 years. Humans can have a hard time recalling details to events less than 48 hours after their occurrence. The expectation that the participants in this research could remember events as far back as 22 years is a stretch. Any additional research should try to include participants who have all recently experienced the transition.

There is another element of timing that can be approved. The managerial aptitude scores for participants should be assessed prior to the transition when possible. The fact that the managerial aptitude scores were collected after the transition raises some concerns to the validity of their inclusion in analyzing the transition. As stated previously some managers have currently been managing for more than 10 years; it is very likely that their managerial aptitudes have increased in this period of time.

5.2.2 Sampling

The goal of this research was to investigate whether or not Howard’s findings were distributable to a larger population of engineers. Howard’s research was completed with the involvement of five aerospace engineers. This current research involved 121 engineers from mechanical, electrical, chemical, industrial, and computer engineering disciplines. However, 82% of the participants were from either the electrical or computer disciplines. This distribution is a result of the nature of the participating company. Further research should include a better balanced sample from each discipline or be conducted within each discipline specifically.

5.2.3 Method

While the method used for this research, an online survey, was effective in reaching a large population in a short period of time and receiving answers to focused questions it was perhaps ineffective in avoiding ambiguity and ensuring that each participant fully understood the context of each question and option. This is in total contrast to the method used by Howard. Howard's research method, multiple long personal interviews, limited the number of participants he could include but ensured a clear and concise understanding of every aspect of the research by each participant. Further research should find a balance somewhere in the middle. One recommendation is to use a survey but to have it administered in person. This allows a large number of participants and creates an easy opportunity for participants to have questions and confusions resolved.

5.2.4 Topics

The results and conclusions of this research point to several other interesting areas of research. First, it would be interesting to look at the differences in engineering discipline degrees more directly. This study was able to show a few significant results when the disciplines were compared to each other and a few more when each discipline was compared to the rest of the group as a whole. The validity of these results however is questionable due to the sample sizes of each discipline. The sample sizes of each group: mechanical, electrical, chemical, manufacturing, industrial, petroleum, civil, computer, and other were 9, 59, 2, 2, 40, and 9 respectively. A new study should be designed to target a fair population from each discipline so that valid conclusions can be drawn.

Second, investigation should be made into how the top three pain points are overcome. Perhaps a study could be focused on determining the effect of helping engineers develop managerial/leadership skills before they begin the transition. This would be interesting because although the development of these skills was ranked no higher than 5th most difficult among the eight pain points (see Table 36), it was the only pain point highly correlated with the level of difficulty of all of the other pain points (see Table 35). If research can develop a plan to help engineers overcome the top three pain points quickly and perhaps painlessly, the transition will become easier for companies and engineers.

An interesting result of this research was the fact that no significant differences were found between the engineers graduating between the years of 1996- 2000 and those who graduated between 2001 and 2008. Considering the emphasis that EC2000 places on the development of leadership/managerial abilities one would expect that students taught within an EC2000 system would be better prepared to make this transition. However, the tests on the data indicate that the correlations between graduation year and managerial aptitude and preparedness are more a result of changing times than the implementation of new curricula around the turn of the century. A new study should be designed specifically to quantitatively measure the effect EC2000 is having on engineering undergraduates' careers. This study will need to account for the year of graduation of its participants along with whether or not their alma mater had instituted the EC2000 learning outcomes prior to each participants' graduation.

5.3 Closing Thoughts

Several definitive statements can be made as a result of this study. First, Howard's pain points were found to be distributable to a larger population of engineers. Second, the three most difficult pain points identified in this study were the same three identified as the most difficult in Howard's research. Third, the more recent college graduates have higher managerial aptitude scores and feel more prepared to enter management/leadership positions than their older peers. Fourth, the pain point of "developing the managerial skill set" is correlated with every other factor tested: the pain points, managerial aptitude, level of preparedness, and frequency of difficult elements. This final statement may provide the most insight into how academe and industry can work to ease this transition for engineers.

How is it that the pain point ranked no higher than 5 and as low as 8 on the rank orders of difficulty is more crucial to easing the transition than the three pain points consistently identified as the three most difficult(rank orders are presented in Table 36)? This situation can be compared to that of a person visiting a hospital with two broken bones and a weak heart. When this patient is asked where the most pain is, chances are that he will identify the broken bones. If the doctors are notified of the heart condition they would probably address the heart problem first because though it is not causing the patient the most pain, it is the most severe. If the doctors are unaware of the heart condition, they will treat the broken bones and they will run the risk of the patient dying as a result of his weak heart. The three most difficult pain points relate to the broken bones and "developing the managerial skill set" is analogous to the weak heart.

Academe and industry should focus their efforts on identifying the managerial skill set needed by engineering managers/leaders. Once this skill set is understood efforts need to be made to help engineers develop these skills. By so doing, academe and industry will do more to ease the pain associated with the transition than if they focused their efforts on the three most difficult pain points.

References

American Society for Engineering Education (ASEE). Engineering Education for a Changing World. *ASEE Prism* , December (1994): 20-27.

American Society of Engineering Management (ASEM). "The Engineering Leader and Leading Change". *Spec. Rep. ASEM 1995 Nat. Conf.* Washington, D.C. (1995).

Bakos, J. D. Communication Skills for the 21st Century. *Journal of Professional Issues in Engineering Education and Practice* 123, no. 1 (1997): 14-16.

Beakley, G. C. *Engineering: An Introduction to a Creative Profession.* 4th ed. New York: Macmillan Pub. Co.; 1982.

Bellinger, R. "The Way We Work: Product Development Stunted." *Electronic Engineering Times*, no. 1238 (2002): 46-51.

Bellinger, R. "Which Business Skills Pay Off." *Electronic Engineering Times*, no. 1023 (1998): 124.

Bond, R. "Enhancing the Career Impact of Design Courses." *IEEE Transactions on Education* 41, no. 4 (1998): 350.

Bowman, B. A., J. V. Farr. 2000. "Embedding Leadership in Civil Engineering Education." *Journal of Professional Issues in Engineering Education and Practice* 126, no. 1 (2000): 16-20.

Brown, E. L. *The Professional Engineer.* New York: Russell Sage Foundation, 1936.

Cook, C., F. Heath, and R. L. Thompson. "A Meta-Analysis of Response Rates in Web- or Internet-Based Surveys." *Educational and Psychological Measurement* 60, no. 6 (2000).

Costlow, T. "Careers: Hiring Heats Up." *IEEE Spectrum* 44, no. 7 (2007): 57-60.

Costlow, T. “Engineers Take Hard Look at Soft Skills.” *Electronic Engineering Times* , no. 1126 (2000): 153.

Davis, B. “The Recognition of and Increasing Value of Professional Engineering Skills. In *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*. USA: (2004).

Donaldson, T. “Transforming Students into Professional Engineers.” *Engineers Australia* 77, no. 1 (2005): 30-31.

Duderstadt, J. *Engineering for a Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education.* USA: University of Michigan, 2008

Farr, J. V. “Education Reform: Pros and Cons.” *Journal of Management in Engineering* 13, no. 6 (1997): 34-36.

Farr, J. V. “Engineering Education - The Challenge of Reform.” *Journal of Management in Engineering* 13, no. 6 (1997) : 3-4.

Farr, J. V., S. G. Walesh, and G. B. Forsythe. “Leadership Development for Engineering Managers.” *Journal of Management in Engineering* 13, no. 4 (1997): 38-41.

Fetzer, J. “Changing Hats....Becoming a Supervisor or Manager.” *Analytical & Bioanalytical Chemistry* 382, no. 7 (2005) : 1449-1450.

Friedman, T. L. *The World is Flat a Brief History of the Twenty-First Century.* 3rd ed. New York: Picador/Farrar Straus and Giroux Distributed by Holtzbrinck Publishers, 2007.

Gautschi, T. F. “Engineering Career Path.” *Tappi* 59, no. 12 (1976)

Goldberg, D. E. “Change in Engineering Education: One Myth, Two Scenarios, and Three Foci. *Journal of Engineering Education* 85, no. 2 (1996): 107-116.

Grayson, L. P. “A Brief History of Engineering Education in the United States”. *Aerospace and Electronic Systems, IEEE Transactions on* AES-16, no. 3(1980): 373-392.

Hall, J. L., J. M. Munson, and B. Z. Posner. “Training Engineers to Be Managers: A Transition Tension Model.” *Engineering Management, IEEE Transactions on* 39, no. 4 (1992):296-302.

Hawley, R. “Were You Born to Lead?” *Engineering Management Journal* 11, no. 6 (2001): 247-248.

Hissey, T. W. "Education and Careers 2000: Enhanced Skills for Engineers." *Proceedings of the IEEE* 88, no. 8 (2000): 1367-1370.

Hood, D. D. "Transition: Engineer to Manager: Specialist to Generalist. *Engineering Management Conference, 1990. Management Through the Year 2000 - Gaining the Competitive Advantage, 1990 IEEE International* (1990): 22-28.

Howard, A. " From Engineer to Engineering Manager: A Qualitative Study of Experiences, Challenges, and Individual Transitions for Engineering Managers in Aerospace Companies. Ph.D. diss., Pennsylvania State University. 2003.

Jackson, S. A. *Envisioning a 21st Century Science and Engineering Workforce for the United States Tasks for University, Industry, and Government.* Washington DC: National Academies Press, 2003.

Katz, S. M. "Entry-level Engineer: Problems in Transition from Student to Professional." *Engineering Education* 82, no. 3 (1993): 171-174.

King, C. J. "Let Engineers Go to College." *Issues in Science & Technology* 22, no. 4 (2006): 25-28.

Kotnour, T., J. V. Farr. "Engineering Management: Past, Present, and Future." *Engineering Management Journal* 17, no. 1 (2005): 15-26.

Kumar, S., J. K. Hsiao. "Engineers Learn "Soft Skills the Hard Way": Planting a Seed of Leadership in Engineering Classes." *Leadership & Management in Engineering* 7, no. 1 (2007): 18-23.

Lannes, W. J. "What is Engineering Management?" *Engineering Management, IEEE Transactions on* 48, no. 1 (2001): 107-115.

Lattuca, L. R., P. T. Terenzini, and F. Volkwein. "*Engineering Change: A Study of the Impact of EC2000.* USA: ABET, (2006).

Leedy, P. D., and J. E. Ormrod. "*Practical Research: Planning and Design."* USA: Pearson Prentice Hall, 2005.

Link, A. N., C. A. Swann, and B. Bozeman. "A Time Allocation Study of University Faculty." *Economics of Education Review* 27, no. 4 (2008): 363-374.

Lofgren, E. P., S. A. Nyce, and S. J. Schieber. "Designing Total Reward Programs for Tight Labor Markets." In *Benefits for the workplace of the future.* Edited by Anonymous Philadelphia [Pa.]: University of Pennsylvania Press, 2003.

Long, R. P. "Preparing Engineers for Management." *Journal of Management in Engineering* 13, no. 6 (1997): 50.

Lyons, W. C., P. C. Anselmo, and R. G. Kuller. "Engineering Education for Competitive International Economy." *Journal of Professional Issues in Engineering Education and Practice* 119 (1993): 378-395.

Mayer, R. J. "From Technical Man to Manager." *Training & Development Journal* 25, no. 10; 10 (1971): 20.

McCuen, R. H. "A Course on Engineering Leadership." *Journal of Professional Issues in Engineering Education & Practice* 125, no. 3 (1999): 79.

Morrison, P. "Making Managers of Engineers." *Journal of Management in Engineering* 2, no. 4 (1986): 259-264.

Naguib, R. "People Skills for Engineers." *ASHRAE Journal* 49, no. 10 (2007): 78-80.

National Academy of Engineers. *The Engineer of 2020:Visions of Engineering in the New Century.* USA: National Academies Press, 2004.

Noble, D. F. *America by Design.* New York, NY: Alfred A. Knopf Inc., 1997.

Porbahaie, M. A. "Engineers and Managerial Challenges: A Transitional Perspective." *Civil Engineering* 64, no. 6 (1994): 73-74.

Proctor, S. I. "Leadership: The Skill Most Needed." *Chemical Engineering Progress* 100, no. 6 (2004): 52-56.

Rasmussen, E. S. "*Essentials of Social Science Research Methodology.*" Odense: University Press of Southern Denmark, 2006.

Reynolds, T. S. ed. "*The Engineer in America.*" Chicago, IL: The University of Chicago Press, 1991.

Robson, C. "*Real World Research: A Resource for Social Scientists and Practitioner-Researchers.*" 2nd ed. Oxford UK ;Madden Mass.: Blackwell Publishers, 2002.

Russell, J. S., J. T. Yao, J. V. Farr, J. C. Bishop, and S. Walesh. "Consensus! Students Need More Management Education." *Journal of Management in Engineering* 12, no. 6 (1996): 17-29.

Seely, B. E. "The Other Re-engineering of Engineering Education, 1900-1965." *Journal of Engineering Education* 88, no. 3 (1999): 285.

Smith, R. J., B. R. Butler, and W. K. LeBold. *Engineering as a Career.* USA: McGraw-Hill Book Company, 1983.

Suckarieh, G., J. Krupar. “Leadership and Teamwork Education for Engineering and Technology Students an Experiential Learning and Community Service Approach. In *2005 ASEE annual conference and exposition: The changing landscape of engineering and technology education in a global world*. Portland, OR. (2005): 9511-9519

Summers, M., B. Davis, and C. Tomovic. “When Engineering and Technology Skills are Not Enough: Engineering Leaders Out of Their Element.” In *CIEC conference* ASEE, (2004).

Tan, C. W. “A Case for Credentials.” *Mechanical Engineering* 127, no. 7 (2005): 9-10.

Tener, R. K., K. L. Fisher. “Leading Program for Undergraduate Engineers.” *Journal of Management in Engineering* 13, no. 4 (1997): 24-25.

Tenner, E. “Engineers and Political Power.” *Technology review* 108, no. 4 (2005): 72.

Thamhain, H. J. “From Engineer to Manager.” *Training & Development* 45, no. 9 (1991): 66.

Wearne, S. “Professional Engineers' Needs for Managerial Skills and Expertise.” *Proceedings of the Institution of Civil Engineers: Civil Engineering* 157, no. 1 (2004): 44-48.

Weingardt, R. G. “Leadership: The World is Run by Those Who Show Up.” *Journal of Management in Engineering* 13, no. 4 (1997): 61-66.

Wulf, W. A. “An Urgent Need for Change.” *The Bent of Tau Beta Pi* , no. Spring: (2004): 31-33.

Yeargan, J. “The Effect of ABETS EC2000 on Curriculum: Early Indications.” *Microelectronic Systems Education, 1999. MSE '99. IEEE International Conference* (1999): 97-99.

Yeh, Q. J. “Exploring Career Stages of Midcareer and Older Engineers---When Managerial Transition Matters.” *Engineering Management, IEEE Transactions on* 55, no. 1 (2008): 82-93.

Youst, D. B. “The Technical Ladder Gets Harder to Climb.” *IEEE Spectrum* 27, no. 9 (1990): 46-47.

APPENDICES

Appendix A Emails

5.4 Introductory email sent by upper management to engineering managers

You will be receiving an email from outside NI with a link to a survey about the transition from individual contributor to manager.

- Tim Dehne has approved the distribution of the survey: It will take approx. 6-10 minutes to complete and is voluntary/optional.
- The survey is being run by a university but has been reviewed and adjusted to meet NI's needs by Allen Howard and Cristina Johnson.

Why should you take 10 min. to complete the survey?
Benefits to NI & You

- Understand the challenges of becoming an R&D manager at NI
- Understand related topics that are part of the survey
- See how your experience compares **-** Results will be available to you and will be presented in Brown bag sessions, or other appropriate ways
- Improve and customize the material and training for new managers

When will this happen?
You should receive the email with a link to the survey today. Please complete the survey by Dec. 10th.

Thanks,
Allen and Cristina

Allen Howard, PhD | Sales Training & Performance
Cristina Johnson | R&D Training and Development

5.5 First Reminder Sent to Engineering Managers

Dear NI Manager,

Before the holiday, you received an invitation to take a survey in conjunction with a BYU-National Instruments study. We would really appreciate your taking 10-15 minutes of your time to respond. Please click here https://byu.qualtrics.com//WRQualtricsSurveyEngine?SSID=SS_eR06CT2dAoEeE9S&SVID=Prod to access the survey.

Thanks,

Joseph Wilde
BYU Graduate Student

5.6 Second Reminder Sent to Engineering Managers

NI Manager,

This is a friendly reminder that you have been asked to complete the Individual Contributor to Manager Transition Survey by Dec. 10. Tomorrow will be the final day that the survey will be available (Your link to the survey will expire at 11:59 pm MST). Please set aside 10-15 minutes of your time and contribute to this research. The data collected will be used by National Instruments to aid in the development of processes to make this transition easier in the future. BYU will also use the data to support curriculum changes within the College of Engineering and Technology.

Follow this link to the Survey:
https://byu.qualtrics.com//WRQualtricsSurveyEngine?SSID=SS_abdDvmDYZmLlfaA&SVID=Prod

Thank you,

Joseph Wilde
BYU Graduate Student

5.7 Thank You Note Sent to Everyone Who Completed the Survey

NI Manager,

Once again I want to thank you for participating in our research effort. Your contribution is greatly appreciated. If you are interested in the results of the survey there will be an opportunity for you to review them. The review may be carried out during Brown bag sessions or it may be done through other appropriate means. It will be a couple of months before the results will be available for distribution. Thanks again for sharing your time with us.

Regards,

Joseph Wilde
BYU Graduate Student

Appendix B The Survey

BYU

BRIGHAM YOUNG

UNIVERSITY

Default Question Block

1. In what year did you complete your undergraduate degree?

Options are 2008 - 1969

2. Select the category that best describes your engineering degree.

Options are Mechanical, Electrical, Chemical, Industrial, Computer, Manufacturing, Petroleum Civil, and other

3. My primary workplace is:

- Austin office
- Branch office

4. Have you completed any advanced degrees?

- Yes
- No

5. Please enter the type of advanced degrees you have earned (select all that apply).

- MBA
- MS
- PhD
- JD

6. **In what year did you complete your most recent degree?**

Options are 2008 - 1969

7. **When did you enter your first management role?**

Options are 2008 - 1969

8. What is your main area of focus?
(If you work in both areas, select the primary one. Mechanical should pick Hardware)

- Hardware
- Software

9. Please select your top 3 preferences for continuing your education:

- attend academic conferences
- attend seminars
- read newspapers or technical journals/magazines
- self-learn
- join professional societies
- read professional books

10. Select your training preference for learning new material.

- Internal classes/training
- External classes/training

11. Why did you decide to enter the management ranks? Select all that apply.

- Looking for a change
- Personal development
- Better pay
- I was asked to
- Other

12. Did you participate in National Instrument's Engineering Leadership Program (ELP)?

- Yes
- No

13. How prepared were you for the new role of management?

- Very Prepared
- Prepared
- Neutral
- Unprepared
- Very Unprepared

14. Please spend a few minutes to reflect on your transition from a technical/individual contributor to a manager.

Now share with us how difficult you found each of the following themes:

If you can think of one other item that ranked as at least Somewhat Difficult please type it into the other "Other" box and click the appropriate box.

If you can not think of another item leave the "Other" box blank and select "Very Easy"

	Very Easy	Easy	Somewhat Easy	Neutral	Somewhat Difficult	Difficult	Very Difficult
Managing resources							
Balancing all of the responsibilities							
Making the choice to enter the management career path							
Leaving behind the technical work							
The increased stress and pressure							
Changes with relationships							
Being the new guy in the ranks of management							
Developing the managerial skill set							
Other (see instructions)							

15. Please rank each of the themes from most to least difficult (1 being the most difficult)

Drag and Drop each statement to its appropriate position.

If you entered an item in the "Other" box in the previous question, type the same response in this "Other" box and rank all items appropriately. Otherwise leave "Other" at the bottom of this list.

The increased stress and pressure	1
Leaving behind the technical work	2
Being the new guy in the ranks of management	3
Balancing all of the responsibilities	4
Developing a new skill set	5
Making the choice to enter the management career path	6

Managing resources	7
Changes with relationships	8
Other	9

16. **Which of the following, if any, caused you difficulty during the transition from technical/individual contributor to manager**

- ☐ The increased responsibility: ownership of something much larger and impact of decisions increased
- ☐ The number of hours required to work
- ☐ No longer being a technical problem solver
- ☐ The need to develop new domain knowledge
- ☐ The requirement to balance and prioritize many tasks and roles
- ☐ The lack of a willing and able mentor
- ☐ Allowing engineers to do their own design: learning that your way is not the only way (or the best way)
- ☐ A lack of training or preparation for the new role
- ☐ Making the final decision to enter the management role
- ☐ The firefighting necessary to keep a project moving
- ☐ Resentments or jealousy from some engineers that you were promoted instead of them
- ☐ The need to adapt management theories developed as an engineer
- ☐ The amount of pressure and stress
- ☐ The new relationship with former peers; Rather than a friend, being the adversary
- ☐ The need to work through others: a mindset change from 'doing' to 'managing'
- ☐ An inability to secure sufficient resources to complete projects on time
- ☐ Underdeveloped people skills
- ☐ A shift from being focused on just technical work to being responsible for several functions related to a project
- ☐ The move from technical expert to management novice
- ☐ Having to spend a lot more time in meetings
- ☐ None of these caused me any difficulty

17. In which of the following areas have you gained leadership experience?

- ☐ College clubs
- ☐ Volunteer organizations
- ☐ Scouting

- [ ] School government
- [ ] Religious service organizations
- [ ] Other ____________
- [ ] None of these

In the following section please rank the degree with which you agree with the following statements
(1 = strong disagreement; 10 = strong agreement)

18. Managing people is professionally more interesting and stimulating to me than solving technical problems.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

19. I understand the product applications, markets, and economic conditions of my business area.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

20. I am willing to invest considerable time and effort into developing managerial skills.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

21. I feel comfortable working in dynamic environments associated with uncertainty and change.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

22. I can effectively solve conflict over technical and personal issues, and don't mind getting involved.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

23. I am familiar with techniques for planning, scheduling, budgeting, organizing, and personnel administration, and can perform them well.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

24. I have a systems perspective in my area of technical work.

1	2	3	4	5	6	7	8	9	10

25. I can estimate and negotiate resources effectively.

1	2	3	4	5	6	7	8	9	10

26. I would be good at directing the activities of my department toward the overall business objectives of my company.

1	2	3	4	5	6	7	8	9	10

27. I am a good liaison to other departments and outside organizations.

1	2	3	4	5	6	7	8	9	10