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AN EVALUATION OF RISK MANAGEMENT COURSES OFFERED IN ENGINEERING MANAGEMENT PROGRAMS

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Abstract
For this paper, the authors have surveyed a total of 22 engineering management (EM) programs in the United States (both accredited and non-accredited). The purpose of this study was to analyze the offering of risk management courses as part of the engineering management curriculum. The findings showed that the majority of the programs did not offer a single dedicated course on risk management and merely covered the topic as part of other courses such as project management. The authors have made recommendations that risk management should be included as a required part of the EM curriculum due to the higher prevalence of risk in today's ever changing business environment.

Key Words
Risk, risk management, engineering management, programs

Introduction
"Engineering Management is the art and science of planning, organizing, allocating resources, and directing and controlling activities which have a technological component." (ASEM 2010).

"Risk - The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment" (SRA 2010).

The increasing complexity of engineering systems is undeniably part of the growth and development of economies and the overall society. This increasing system complexity has placed additional demands for engineering managers and systems engineers to design, develop, manage, and improve such systems with ever-increasing functionalities, externalities, interdependencies, and emergence. For the most part, engineers and managers have been able to meet such demands, evidenced by faster communication networks, taller skyscrapers, more efficient and greener houses and office buildings, and more robust organizations. However, there are also monuments of failures – mismanaged automotive safety incidents, pronounced environmental degradation, and the global economic meltdown.

In today's dynamic business environment, these failures and any other types of risks are more pronounced due to globalization, ever changing customer requirements and complex requirements from an increasing number of stakeholders. Due to this phenomenon, risk management has received increased attention in industry in the last decade. It is only rational for practitioners and academicians to examine the preparation of future engineering managers and systems engineers to handle such risk management demands.

This paper presents and discusses an initial exploration into the state of risk management courses in various engineering management (EM) programs in the US. In particular, this paper describes and analyzes the prevalence of risk management courses in EM programs, their roles and importance in these programs, the perception of its importance in the classroom and in practice, and the near-term trends.

Complexity and Risk
There are many definitions of complexity. Some emphasize the complexity of the behavior of a system whereas others concentrate on the structure of the system (Sussman 2000). The approach of thinking of complexity based on the structure of the system is closer to the dictionary definition of "complicated." A system is complicated when it is composed of many parts interconnected in intricate ways.

Views of complexity differ from source to source. Complexity is not inherently a bad property. Rather it is the coin of the realm in systems. Organizations usually have to expend complexity dollars to achieve useful goals such as increased functionality, efficiency or flexibility (Sussman 2000). However, all these useful goals cannot be achieved without taking certain risks.

Another way of viewing complexity is when the system is composed of a group of related units (subsystems), for which the degree and nature of relationships is imperfectly known. Its overall emergent behavior is difficult to predict, even when the behavior of the subsystem is predictable (Sussman 2000). Thus we can say that complexity of a system and risk are associated with each other.

With reference to the present trends and future of systems, operations are becoming more and more

complex, involving a growing number of business functions. When the complexity of the project increases, multiple stakeholders are involved and the behavior of each one is not homogenous. The objective function associated with cost, performance and schedule will vary for different stakeholders. These differences will lead to contention and potentially sub-optimal design solutions, funding allocation, schedule priority and increased risk (Conrow 1995). Since the late 1990s, due to increasing competition from globalization, companies have increasingly gotten involved with more complex projects in order to remain competitive and provide their stakeholders with the best value (Quelin and Duhamel 2003). The complexity of systems' operations assumes several dimensions which all engineering managers should keep in mind while being involved with these projects (Quelin and Duhamel 2003; Karthik Balakrishnana, Mohanb et al. 2008):

(i) The number of stakeholders influenced by the decision increases as compared to when the projects were primarily done in-house.

(ii) The selection criteria are not limited only to cost savings but to overall quality and reduction of risks.

(iii) Contracts are becoming denser, as agreements become more sophisticated in terms of measurements procedures and financial management of transferred assets.

(iv) Managing the transition involves shifting more complex interfaces between the supplier and the organization involved in the project.

(v) Managing the relationship under more detailed "service level agreements" (SLAs) entails more complex operations in terms of control and performance reporting.

Furthermore, any engineering manager who is working on a complex project has to evaluate several factors and attributes. According to Yang and Huang (2000), some of the major factors that could come into play are:

(i) Strategy: Firms need to focus their resources on their core activities and can make strategic alliances with vendors to make up for shortages of resources or technology

(ii) Technology: Firms might have to get the newest technology from external providers and in-house workers could have to learn the new technology of software management and development from the vendor.

(iii) Economics: One of the important causes of systems becoming more complex is for the organization to be able to stay competitive and provide the best value to their stakeholders. In order to do this, the major consideration of the organization is the reduction of costs in the development and maintenance of the system. This goal of cost reduction is often obtained through involvement of external vendors.

(iv) Quality: Most members of management believe that when organizations try to meet the economic goals mentioned in the point above, the quality of the service obtained leaves a lot to be desired (Gupta and Gupta 1992).

Each of the above attributes, if not evaluated carefully, could lead to increased risk associated with the project. The engineering manager is a manager of risk throughout the lifecycle of the project and hence it is important for him/her to understand complexity associated with the system but also be fully aware of the factors and attributes that could affect the overall system (Jobst 2009). One of the challenges that engineering managers face is that even though projects are supposed to perform exactly as per the plan, during actual execution this is practically impossible to ensure (Jobst 2009). Thus it is evident that risk cannot be eliminated completely and it is crucial for engineering managers to understand the risks associated with their projects and also have insights on how to mitigate these risks.

Managing risk can make a difference between finishing a project successfully and not (Jobst 2009). While managing risks, engineering managers not only need to understand the individual risks, but also interactions between them and the external factors that could affect the risks (Gandhi, Gorod et al. 2009).

This leads to the next section in this paper, which discusses the importance of risk management for engineering managers.

Risk Management Process

According to Jobst (2009), sometimes the most neglected area of engineering projects is risk management. This is a fact that has persisted in a significant number of projects but has to be dealt with due to increasing complexity and correspondingly higher risk, as discussed earlier in this paper.

The management of risk is crucial for most projects as it permeates many activities. It can be an informal process without any set guidelines or an institutionalized and codified activity. Regardless of the specifics of the activities or the degree of formalization, applications of risk management have one common objective which is to minimize loss associated with a project (Pinto 2009). Effective risk management is often undertaken concurrent with design and development processes. As products are transformed from mere concepts to full scale deliverables, risks arise and need to be managed in a timely manner (Pinto 2009).

The process of risk management usually begins with a study to identify the potential risks that a project could generate or to which it could be exposed. A formal risk analysis is then conducted to measure the various individual risks as well as the overall risk to the system (Budgen 2009). This exercise could be either quantitative or qualitative, depending on the data available to the engineering manager. These aspects of the risk management procedure should be designed to assess both the frequency or probability of occurrence and the impact.

In order to mitigate risks successfully for complex projects, engineering managers should focus on four critical success factors of risk management: People, Processes, infrastructure and implementation (Hall 1998). People participate in managing risks by implementing the risk management process according to the plan. The process transforms the uncertainty into an acceptable risk, through risk management activities. Infrastructure specifies how the organization requires the use of risk management on projects by establishing policy and standards. Implementation is the actual plan and methodology used to perform risk management on a specific project.

According to Douglas Ashcraft (2004), some of the foundations of risk management in industry are:
(i) Creating a culture of managing risk
(ii) Promoting prevention and proactivity
(iii) Planning
(iv) Communication
(v) Educating managers about risk management
(vi) Clearly defining the scope of the project
(vii) Understanding the compensation and financial damage that the organization would suffer if the risk were to materialize.

Risk Management in Education

From the beginnings in the early 19th century until World War II, engineering education in the US strongly focused on engineering practice. The war effort mandated accelerated technology transfer and great advances were made. The government began investing heavily in engineering research and development and post war industries flourished, creating demand for engineers that exceeded the supply (Lang, Cruse et al. 1999). Newly minted engineering PhDs joined the ranks of academia without industry experience and perpetuated the research emphasis on campuses for the last forty years. While this research has contributed immeasurably to our technological advancement, the widening separation of faculty and curriculum from industry needs and expectations has resulted in a real threat to our competitiveness in the global market (Lang, Cruse et al. 1999).

While there is no doubt that traditional engineering education has served us well during the latter half of the 20th century, there are certain fundamental changes occurring all around us that should make us pause and question whether our existing educational system meets the needs of the 21st century (Djaferis 2004).

A comprehensive examination of many existing engineering curricula will reveal that for the most part, engineering education is unidirectional and not multidisciplinary (Djaferis 2004). More emphasis is placed on the components and the basics of engineering, discipline wise, and little attention is focused on the integration and risk management aspects of engineering projects. The approach is a bottom up approach, where students learn about the fundamentals and then work on components for a number of years.

This is something that should change and according to Ian Watson (1999), technical guidance related to risk management could be summarized as follows:
(i) Understanding the scope and perception of the risk involved
(ii) A thorough knowledge of the responsibilities of the various parties so that everyone working on the project knows what aspect they are responsible for and how their part could reduce overall risk affected with the project
(iii) Having good communications to deal with breakdowns – both internal and external
(iv) Evaluation methods for risk analysis, understanding levels of risk, their impact and technical issues that may arise thereof.
(v) Learning from past disasters

In February 2005, the Canadian Council of Professional Engineers (CCPE 2005) wrote a paper titled "Risk Management: A new area of knowledge for engineers, discusses how risk management, and other related research, applies to the engineering profession both within Canada and abroad. Some of the paper's key recommendations were:
(i) Risk management was emphasized to be an integral part of the undergraduate curriculum for some engineering programs in Canada. Given the magnitude and scope of loss that many companies, employers and others could incur without appropriate risk management practices, it is important for professional engineers to have some knowledge in this area. The paper suggested that the Canadian Engineering Accreditation Board (CEAB) should consider adding

knowledge of risk management to its accreditation criteria to ensure that Canadian engineering students are educated in the area of risk management before completing their undergraduate degrees.
(ii) The paper also suggested that education in the area of risk management could be a way of fulfilling continuing professional development requirements for professional engineering licensure.
(iii) It also suggested that training in risk management could also be part of the internship or engineer-in-training period before an engineering graduate becomes a licensed as a professional engineer.
(iv) Lastly, it also pointed out that the professional engineers of Ontario (PEO) also identified risk management as an important area of study and stated that the engineering profession can play a role in educating engineering students and professional engineers about risk management as it was a very important topic, particularly since our world is changing constantly and risks are so dynamic.

Research Methodology

Due to the importance of engineering education to train engineering managers in the field of risk management, a survey was conducted to survey a number of engineering management programs (both accredited and non-accredited) to find out how many of them offer dedicated course(s) in risk management as part of their curriculum and whether they are part of the core or required courses.

The list of schools targeted was downloaded from the American Society of Engineering Management (ASEM) website and the surveys were sent out to the person in charge of the engineering management (EM) program at all these schools. Some of the questions on the survey included assessing the overall importance of risk management to engineering managers (assessed on a scale of 1-5), how many dedicated courses in risk management were offered and if they were required courses or not. Lastly, the authorities of the EM programs were also questioned about whether they planned to introduce any new or additional courses on risk management.

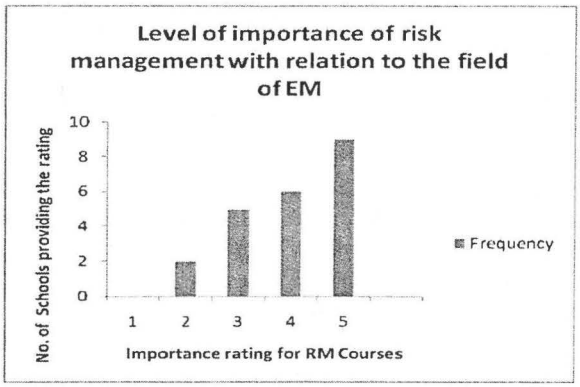
Findings

Out of the 22 schools that were surveyed for this research study, 15 (68.18%) rated the relevance of risk management to engineering managers as important to very important. The average value for this question on the survey, on a scale of 1-5, was calculated to be 4.0. The frequency of the responses collected is shown below in Exhibit 1 and is also shown as a histogram in Exhibit 2.

Exhibit 1. Frequency of importance of risk management to engineering managers

Level of imp for risk management courses	Frequency	Cumulative Frequency
1	0	0
2	2	2
3	5	7
4	6	13
5	9	22

Exhibit 2. Histogram showing the ratings of importance of risk management to engineering managers



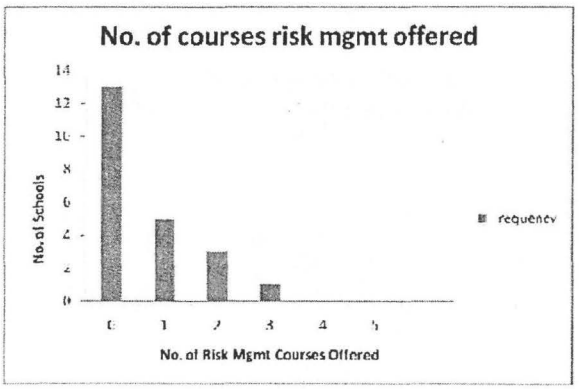
However, despite the fact that the schools surveyed rated risk management as an important tool for engineering managers to have, 13 out of the 22 (59.1%) schools surveyed said they did not have even one dedicated course to risk management. Only another 5 schools offered one course in risk management.

Nonetheless, it is also established, though not covered by the survey, that topics relating to risk management are covered in other engineering management courses. Consider project management courses which are common to most if not all engineering management programs. Discussion of how to manage projects exposes students to the notion of objectives, e.g. accomplish a project within budget, schedule, and required technical performance. Students are also made to recognize that there is always the possibility for project risks contributing to the under-accomplishments of the objectives. Furthermore, how to assess these project risks are discussed as well as alternatives to manage them.

There could be other courses that may in part provide discussion of relevant risk management topics, such as:

- Statistics and probabilities courses cover concepts in expected values, probability distributions, and extreme and rare events;
- Reliability courses cover FMEA, FMECA, fault trees, and event trees
- Decision analysis courses cover decision making under uncertainty or risk, and decision trees, multi-criteria decision analysis, and sensitivity analyses;
- Financial engineering courses cover risk of volatility for derivatives and securities; and
- Engineering economics courses cover time-value of money,

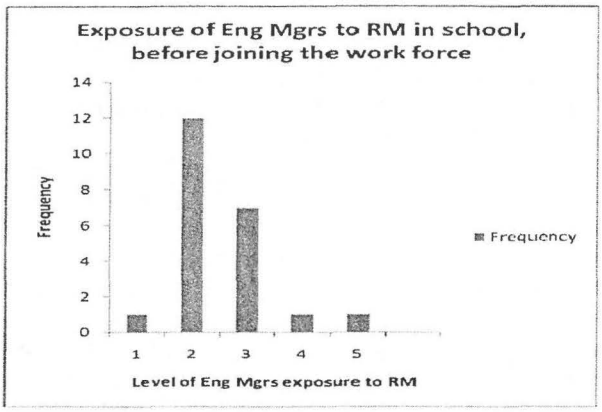
Exhibit 3. Histogram showing risk management course offerings in EM programs across the United States



The encouraging sign from this analysis was that certain engineering management departments did realize the increasing importance of risk management and out of the nine schools that did offer courses on risk management; seven of them offered the courses exclusively.

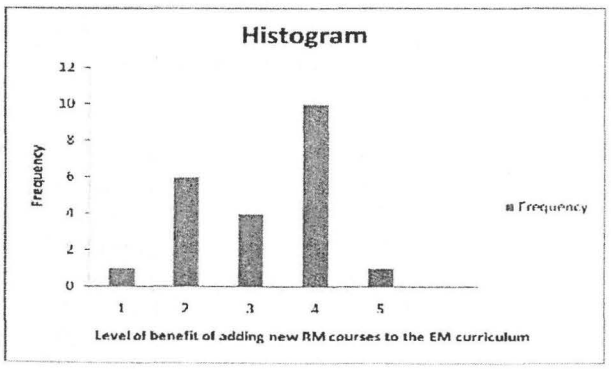
Despite this, a majority of the engineering management school officials thought that engineering management graduates do not get enough exposure to risk management in school before they go out into the work force, as shown in Exhibit 4. The average score for this category, on a scale of 1-5, was 2.5.

Exhibit 4. Extent of EM Graduates to the RM field in school



Lastly, the benefits of adding new courses in risk management to the engineering management curriculum, received an average rating of 3.18 on a scale of 1-5. The frequencies of the ratings are shown in the histogram in Exhibit 5.

Exhibit 5. Expected benefit by adding new courses in RM to the EM curriculum



Conclusions

Based on above findings we can conclude the following:

(i) Risk management is considered an important part of the engineering management curriculum.
(ii) Currently, not all EM programs offer dedicated courses in risk management
(iii) The level of exposure that EM graduates get in the field of risk management is inadequate.
(iv) In cases where there is no dedicated risk management course offered, some topics in managing risks are discussed within other courses in that program
(v) New courses in risk management, if introduced as part of the engineering management curriculum, would

be beneficial to engineering management majors, considering that they will go out and work on real world projects, of which risk is an important component.

Some recommendations based on our findings would be for the engineering management programs in the US to make courses in risk management a required part of the curriculum. Other professional bodies that overlook professional licensure of engineers should follow the path taken by the CCPE in the field of risk management. They have emphasized the importance of risk management and have suggested that education and training in risk management is required to be a professional engineer. Lastly, we fathom that an addition of a risk management course to the EM curriculum would make engineering managers a lot more marketable and could also possibly improve the enrollment numbers in this discipline.

Limitations and Future Research

The majority of the respondents emailed the surveyors and informed them that despite not having a dedicated course on risk management as part of the engineering management curriculum, there were parts of other courses that covered risk management topics. This was an aspect that was not concentrated on in this research project as it only concentrated on finding out about dedicated courses in risk management being offered to EM majors. As part of future research, the investigators plan to evaluate the engineering management programs with a more detailed survey in which it will be looked into and analyzed as to what specific topics of risk management are being covered in the EM curriculum – both through dedicated courses and through sections of other courses that cover topics in risk management. These topics will then be compared to industry requirements for risk management and a comparative analysis will be done to see if the engineering management programs are adequately fulfilling industry needs and this in turn making EM programs more marketable versus a traditional MBA degree.

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