AC 2012-4001: THE IMPORTANCE OF UNDERSTANDING SYSTEMIC RISK IN ENGINEERING MANAGEMENT EDUCATION

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Importance of Understanding Systemic Risk in Engineering Management Education

Abstract

Recent research suggests that despite risk management gaining importance in the business world, a high percentage of multinational companies believe they are not doing all they can to manage risk effectively. The study indicates that large companies are not focusing sufficiently on integrating systemic risk management into business processes. This could be possible due to a significant shortage of engineering managers who understand risk management and an even greater scarcity of engineering managers who understand systemic risk management. The study builds on earlier research, which included distribution of a survey to faculty of engineering management programs to evaluate risk management course offerings across the US. In this paper, the authors discuss systemic risk management and its significance to large multinational organizations. Since the term systemic risk management has only been introduced to the engineering management field recently, despite it gaining recognition, little attention is paid to training engineering managers in systemic risk management. The authors further discuss how systemic risk management can be integrated into engineering management education.

Introduction

Engineering has long been regarded as a set of technical processes that are used to solve problems. Engineering is defined as, "The application of science to practical uses such as the design of structures, machines, and systems." [1]. However, as a result of continual pressure for growth, most companies have expanded their product lines and also the geographic region in which they are offered [2]. Due to this expansion, the complexity associated with projects that most organizations undertake has increased exponentially. According to Jagersma [3], this complexity manifests itself in many forms affecting everything from the day to day operations of the business to senior management's strategic plans. Economies of scale, scope and skills appear to be wiped out by what Jagersma refers to as "economies of complexity [3]."

Increasing complexity has resulted in risks being more prevalent. However, since complexity is a new norm and requires new perspectives, engineering managers today are not fully prepared to manage the risks that arise as a result of these complexities. Managing complexity and the risks associated with it currently represents an unclear territory for businesses globally [4]. According to a study conducted by KPMG at the beginning of last year [5], 94% of senior managers stated that managing complexity is one of the most important success factors for the companies. Furthermore, 70% of executives characterized managing risks as one of the greatest challenges they face. According to Heineman [6], the causes of complexity are expected to shift over the next several years, leading to additional obstacles in identifying and mitigating risks.

Table 1. Examples of Systems with High Levels of Risk

Recent Engineering Failures of Complex Systems	Engineering Domain(s) involved
The 2008 Financial Crisis	Financial Engineering
Japanese Tsunami Disaster	Nuclear & Structural Engineering
Integrated Deepwater Program	Systems Engineering
Denver Airport	Civil Engineering
Boston Big Dig	Civil Engineering

Table 1 illustrates several examples of recent engineering failures of complex systems and while these are isolated situations, they share common underlying patterns that could provide guidance about building more resilient systems and how to more effectively educate future engineers.

In order to understand these patterns and learn from them, we need to go beyond analyzing them as independent incidents, and rather, examine them from a broader systemic perspective to improve how such systems are designed and managed going forward. Unfortunately, a comprehensive study of engineering management programs across the US, conducted by Gandhi and Pinto [7], revealed that less than 1/3 of all programs offered risk management courses. To address this gap in current educational curriculum, the authors discuss existing approaches to include systemic risk management material in engineering management programs.

Systemic risk and its importance to engineering managers

According to Kaufman and Scott [8], systemic risk is thought of as a risk that originates from multiple sources, affects multiple agents and propagates quickly among individual parts or components of the network. The probability of breakdowns at the system level can be caused by the domino effect triggered from a sudden unexpected event. Systemic risk can also be thought of as the risk or probability of breakdowns affecting an entire system and not just a breakdown in individual parts or components and is evidenced by correlations among most or all of the parts. [8]. It could also be considered to be the probability that cumulative losses will accrue from an event that sets in motion a series of successive losses. It is important to understand that systemic risk has a number of constituents which are thought to be interconnected. Further, it consists of external factors that affect the relationships between the various constituents. Some of the constituents of systemic risk that have been identified for the purpose of this paper are: Schedule Risk, Technical Risk, Financial Risk, Vendor Risk, Culture Risk, Reputation Risk, Intellectual Property Risk, Flexibility Risk, Compliance Risk, and Quality Risk [9-16], as shown in Table 2.

Table 2. Constituents of Systemic Risk (Adopted from Gandhi, 2010).

Constituents of Systemic Risk	***Operational Definitions***
Schedule	The inability to deliver the system within the originally specified period of time

Technical	The inability of the technology to provide expected performance
Financial	The inability to deliver the system within a given budget
Vendor	The possibility of choosing an inappropriate vendor that could impact system performance
Culture	Occurrence of shared values and assumptions that govern acceptable behavior and thought patterns which could result in widely differing work ethics and quality standards
Reputation	Negative opinion among system stakeholders
Intellectual Property	The threat of the vendor using ideas to develop a competing system
Flexibility	The inability of a system to adopt to potential internal or external changes in a timely and cost effective manner
Compliance	The inability of system stakeholders to comply with appropriate regulations (local and global)
Quality	The inability of the system to meet customer requirements

All the constituents of systemic risk mentioned in Table 2 are thought to be interconnected and none of them are mutually exclusive. This interconnection creates a network in which the effects of one risk are transmitted to the others [17]. Systemic risk is, therefore, thought to be particularly undesirable because it spills over and could potentially affect multiple nodes in a system. Creating a ripple effect, the damage caused by a systemic risk is much greater than by any of the constituents individually. In addition to these risk constituents, there are several external constituents that can affect the interconnectedness of these risks that are critical to be aware of.

The above mentioned system complexities present a different type of a risk management challenge to engineering managers and necessitates considering a holistic view of the interactions between the various constituents instead of analyzing risks individually. In addition, engineering managers need to understand the influence of external factors and constraints that could affect the overall risk associated with the project they are managing. Implementing systemic risk management, such as demonstrated in Figure 1, engineering managers can improve the adaptability of their projects to the ever changing dynamic environment in which they operate.

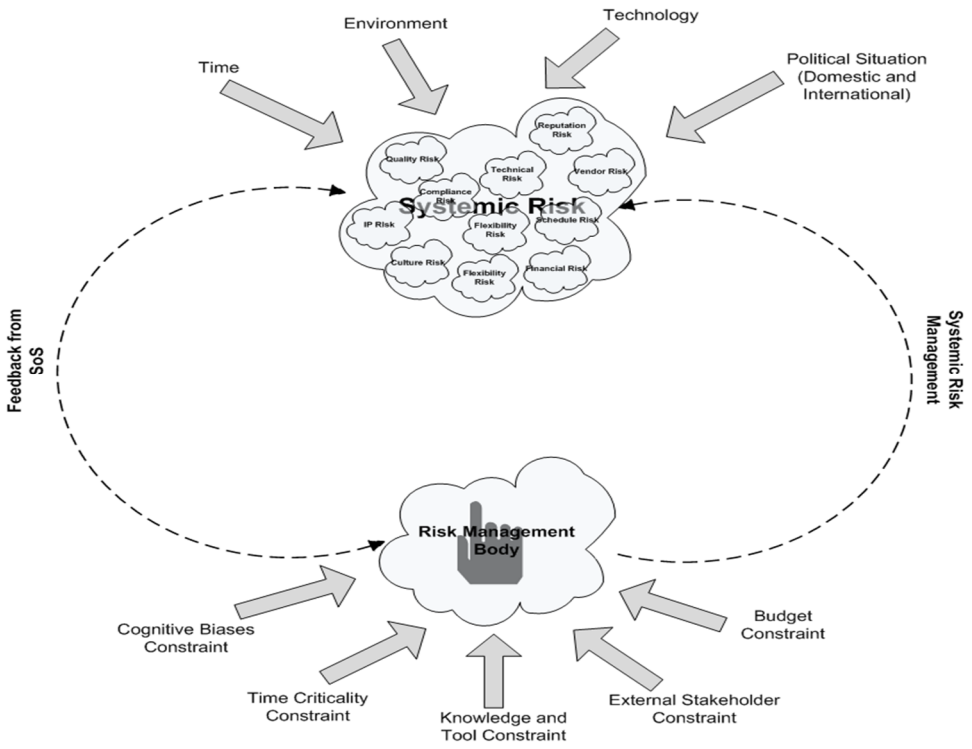

Figure 1: A Systemic Risk Management Framework [18]

In Figure 1, several more dynamic external factors identified by the authors include Time, Environment, Technology, and the political situation surrounding the system.

Current educational offerings related to systemic risk in engineering management education

Despite the fact that systemic risk is gaining increasing recognition in other fields, particularly in finance, it has not received the attention that it should be receiving in the engineering management education domain. While traditional engineering education has served us well during the 20th century, there are certain fundamental changes that need to be made to meet the challenges of the 21st century. One of these is including systemic risk in the engineering management curriculum to produce more effective engineering managers to address growing in complexity problems. This will assist in addressing the fact that engineering education for the most part is unidirectional and not multidisciplinary, with not enough attention being given to integration and risk management [19].

Approaches to include systemic risk management in engineering management programs

In order to address the gaps in engineering management education mentioned in this paper, the authors have suggested various means by which the understanding of systemic risk and systemic risk management can be conveyed to engineering management majors.
The various approaches suggested by the authors are:

a. Offering an in depth course in systemic risk management. This would include an initial understanding of what systemic risk is and the second half of the course would include discussion about the systemic risk management process and various tools that can be used for implementing it. Furthermore, the discussion on risk management tools should be followed by interdisciplinary case studies which could be used to discuss the systemic risk concept. This course could be taught in various delivery modules such as during the regular semester or in a modular format which would be preferable to engineering management students who are already working in industry.
b. The course could also be offered jointly between the business and engineering schools at a university. This would prove beneficial as it would provide varying perspectives of understanding systemic risk. Alternatively, the program could also be offered through joint collaborations with other schools.
c. The material on systemic risk could be offered through an extension of existing courses. This is a particularly useful approach to implement when the course syllabus only allows a certain amount of credits and it is difficult to drop any other currently included course. An example would be to discuss systemic risk concepts as a subsection of a course on risk management or as a section of a project management course. It could be further included as part of a systems integration course or as an introductory course to systems engineering or complex systems.
d. The American Society of Engineering Management (ASEM) could consider making systemic risk a topic in the ASEM certification curriculum. Engineering Managers should be tested on the subject through especially identified scenarios/case studies of complex systems with a series of questions on how to manage the system and mitigate the overall risk associated with it.
e. Systemic Risk could be included as a topic in the ASEM handbook. This proposal has been accepted by the editors of the handbook and it will be included as a chapter in the second edition of the handbook, which will be published in Fall 2012.
f. Considering the fact that an understanding of systemic risk would help engineering managers deal with situations of increasing complexity, it is a topic that is applicable to all domains of engineering. Therefore, ABET could consider the topic to be made a requirement for accreditation [20]. This requirement could be implemented at the specialized or programmatic accreditation level as it evaluates an individual program of study rather than an institution as a whole. This type of accreditation is granted to a specific program at a variety of degree levels (bachelor's and master's). The authors think that it would be particularly beneficial to include systemic risk for the master's level programmatic accreditation because a significant percentage of engineering managers taking graduate level courses and working in the field could apply the material to real life projects.
g. Considering the importance of increasing risk scenarios to all domains of engineering and implementing a similar logic as used for ABET accreditation, the authors propose that systemic risk is made into a topic to be covered for initially obtaining and for renewal of professional engineering licenses. In several states, requirements for renewing the professional engineer license include Professional Development Activities which include, but not be limited to:

    1) Successful completion of a college or university course in the area of professional engineering, related sciences and engineering ethics. The dedicated course

on systemic risk that the authors suggest can serve as one of the courses to be completed at the college or university level in the area of professional engineering.

2) Active participation and successful completion of professional engineering programs, seminars, tutorials, workshops, short courses, on-line or in-house courses. Credit will be given for self-study courses only if an examination has been completed by the licensee and graded by the sponsor – to fulfill this requirement, attending a workshop or tutorial on systemic risk should be accepted by the license renewing state.

Importance of including systemic risk in the engineering management curriculum

According to the authors, there could be a number of potential benefits of including systemic risk management in the engineering management curriculum. Some of these potential benefits are listed below:

1. Most of the 21st century engineering projects are not only "too big to fail", but also extensively interconnected. This can trigger a "butterfly effect" by not mitigating risk effectively, which can be felt throughout the entire project's environment. In order to address this issue, inclusion of systemic risk management in the curriculum enables engineering managers to have a clear understanding of the nature and dynamics of the project.

2. Understanding of systemic risk could enable engineering managers to realize that systems they work on might have a large number of complex interconnections and also help them identify points of vulnerability involved.

3. By understanding systemic risk, engineering managers are also more likely to be flexible and responsive to the dynamic business environment. This makes them more agile when managing overall project risks.

4. The inclusion of systemic risk in the engineering management curriculum addresses the lack of awareness of the topic.

5. Cost of failures in engineering projects is increasing rapidly due to the imbedded complexities. Hence it is imperative for engineering managers to consider systemic risk management as part of their job duties.
6. Due to the size and imbedded complexity of today's engineering projects, the cost of their failures have been increasing rapidly. Therefore, it is imperative for engineering managers to consider systemic risk management as part of their job duties.

7. Engineering managers' responsibilities are increasingly becoming multi-disciplinary. In order to fulfill those responsibilities, engineering managers should consider systemic risk.

Conclusion

In today's dynamic business environment, risk management is increasingly considered to be an imperative part of engineering projects. Managing an engineering project effectively necessitates a substantial amount of risk management, which is currently lacking in engineering and engineering management education. There is even a greater deficiency in engineering education when it comes to engineering managers understanding systemic risk management. In this paper, the authors explain the concept of systemic risk management and recommend possible ways to integrate systemic risk management material into engineering management courses. They further propose development of a new course covering various aspects of the topic to enable engineering managers to meet the challenges of the engineering projects of the 21st century. Lastly, the importance of including systemic risk in the engineering management curriculum has also been discussed.

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