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Baqer Alali
Old Dominion University

C. Ariel Pinto
Old Dominion University

Andreas Tolk
Old Dominion University

Rafael Landaeta
Old Dominion University

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PROJECT AND RISK MANAGEMENT: A SYSTEMATIC APPROACH

Baqer Alali, Old Dominion University
C. Ariel Pinto, Old Dominion University
Andreas Tolk, Old Dominion University
Rafael Landaeta, Old Dominion University

Abstract
The main purpose of this paper is to discuss three related topics of project management, systems management, and risk management. The issue that would be addressed in this paper is how risks are addressed in project and systems management, and how risks are propagated between projects and systems. A framework is proposed to overcome the problem of risk propagation from project to the systems. It was shown that the proposed framework can be deployed to existing risk management process with reasonable interventions (e.g. process prescribed by PMI). Finally a proof-of-concept application shows potential of the framework for various types of systems as well as future research agenda.

Key Words
Risk management, project management, systems management

Introduction

Based on objectives and goals of projects and systems, risk could be identified differently by each. Moreover, the assessment of risk will be different in projects than in system. Identification of risk in project is based on the three main factors of projects: cost, time, and technical performance. Events that are not clearly related to these three factors may not be construed as risks. Nonetheless, these events may have long term effect on the system, even after project is integrated in the system.

As an example, consider a road system and a new bridge-tunnel being built onto it. The location of this project is in a very crowded road intersection. After a few years, the bridge-tunnel *project* was completed and opened to traffic, i.e., it was integrated into the larger road *system.* However, a few weeks after the bridge-tunnel opened, there was a failure with the rain water drainage. The tunnel was closed for few months until this water drainage problem was resolved. Assuming that the lack of proper water drainage capability was not an unmet requirement of the project, then the project was completed within time budget and specification. This case may show a successful project risk management where all the project objectives were met.

However, there could have been a number of un-identified or ignored risk scenarios, one of which may have been to under estimate future rain fall level. What happened is that the tunnel was hit by a heavy rain that caused the tunnel to be full of water and traffic could not go through. This caused a failure of the system objective of providing reliable transportation system to the city even during heavy rain.

Systems & Project Management

Projects and system are words that have distinct meanings in engineering management. There are some generally agreed upon definition of systems. One of which is by Kast and Rosenzweig (1972) which states that the system is a collection of things or parts that interact together to fonn an organized complex unitary whole. Other scholars also provided some other definitions such as Checkland (2000), Eisenberg and Goodall (1993), Kossiakoff and Sweet (2003), Keating (Keating et al. 2001). Moreover, systems engineering was defined by Chase (1974) as "the process of selecting and synthesizing the application of the appropriate scientific and technical knowledge to translate system requirements into system design and subsequently to produce the composite of equipment, skills, and techniques that can be effectively employed as a coherent whole to achieve some stated goal or purpose" (Rhodes and Hastings 2004, p. 2). Other definitions are also given by Ramo (1993) (Rhodes and Hastings 2004) and Kossiakoffand Sweets (2003).

The phrase "Systems management" was used in several papers in the literature; however, none of those has a clear definition of this phrase. As such, this paper is developing a definition that will be used in the context of project management and project risk management. This paper suggests the following description for "systems management" *as the planning and allocation of resources to coordinate, control, communicate, and organize the operation of integrated components to achieve the systems' objectives within the desired performance and quality.*

On the other hand, there are two definitions of a project that this paper is adapting. The first definition is the one proposed by the Project Management Institute

(PMI 2000) which highlights the separation between projects and the systems - *a project is a temporary endeavor undertaken to create a unique product, services, or result that will later be integrated into the larger system.* The other definition is provided by Steiner (1969) which is more general and serves the other objective of the definition of project which state that "Projects generally involve large, expensive, unique or high risk undertakings which have to be completed by a certain date, for a certain amount of money, within some expected level of performance"(Williams 1995, p19). This later definition has emphasizes the three major dimensions of projects which are the limitation of time, cost and performance.

Risk Management

The general phases in a risk management process are:

1. Identification of risk to answer "what can go wrong?"
2. Analysis of risks to answer "what is the likelihood?" and "what are the consequences?"
3. Plan the appropriate action to eliminate the threat and mitigate the consequences of risk.
4. Tracking to address the effectiveness of the proposed action
5. Control risks through feedback to evaluate what actions should be considered.

Risk management is one of the most important processes of project management and success. Raz and Michael (2001) claim that project risk management (PRM) is a process that has to be implemented from the beginning of project (definition phase) through planning, execution and control phases including completion and closure phase. PRM is divided into two stages risk assessment and risk control, (Raz and Michael 2001). These two phases has sub-phases that are divided as follow:

- Risk assessment, which includes risk identification, assessment, and probability of occurrences
- Risk control, which includes risk planning, resolution and monitoring, tracking, and corrective actions

PMI (2004) also suggest similar risk management process which includes: risk management plan, risk identification, qualitative and quantitative risk assessment, risk response and monitoring and control. As expected, the objective of both systems risk management (SRM) and PRM is similar which is to identify, monitor, control and mitigate the risky events. SRM has the objective to achieve its goals and objective with the minimum resources and problems over the lifecycle of the system.

Sequence of Risk Events

The above discussion of PRM and SRM shows that the projects and systems are almost similar. Both consider the identification, assessment, plan or mitigate risk and monitor and control risks. However, the concern is not in the processes of risk management itself within each entity. Rather, the issue is in the difference in the objectives of each.

When the project is completed, integrated, and working well, why do some of those projects outputs, which will be a subsystem of the whole system, fail after a period of time? The following questions address the issues that might be the reason for systems problems:

1. Was there an integration issues?
2. Did the risk in the project consider the risk within the system?
3. Was there an issue within the system that caused subsystem failure?
4. Was there an issue in the project that was not clarified to the system management?

These concerns can be illustrated in Exhibit 1.

Exhibit 1. Sequence of risk event propagation

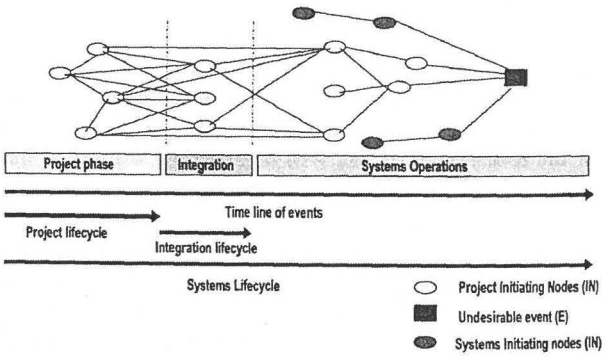


Exhibit 1 indicates that undesirable events in the system can be caused by initiating events from within the system, from the integration phase or even from the project phase. The above discussion raises a legitimate concern, which is that risk events during the systems operation phase can be avoided by managing the initiating events during the project and integration phase. The systems' risk can be reduced by managing the risks of project and integration risks.

Bridging SRM &PRM

The proposed framework is primarily to find a solution to the issue of risk propagation from project to system. Some concepts of the framework were drawn from

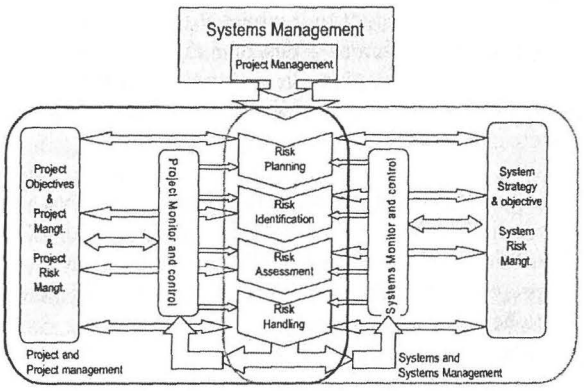
existing risk management processes in projects and systems, while others were from responses from a survey of risk and system managers. These ideas can be summarized on the following list:

- The commonality of risk management processes proposed in academic papers and in practice. These risk processes include the main five phases of risk management: Planning for risk, indentifying risk, assessing the risk, handling the risk and controlling it (Perera, Holsomback et al. 2005), (Haimes and Horowitz 2004), (Conrow 2005), and others.
- There is little interaction between the two risk management processes in projects and systems. In particular, there was good evidence of minimal involvement of systems in the development of the risk management process of the project.
- Some potential system risk events may be ignored when they do not have any effect on a project's factors of schedule, budget and performance (Leung, Rao Tummala et al. 1998).
- Poor and inconsistent application of a risk management process during the project's lifecycle.
- An unclear system's objective to project management is one of the reasons to develop the framework where they should be well communicated during the initiation phase of the project.
- The communications between project and systems during the integration phase is unclear and sometimes vague, which may cause a miscommunication of important risk issues in the project.

Framework Details

The suggested framework presented in Exhibit 2 shows three main sections (adapted from Alali and Pinto 2009). The risk management process (RMP) is at the center of Exhibit 2 with arrows going from both sides to the project strategy and objectives on the left side and to the systems strategies and objectives on the right side. This section will discuss tasks, inputs, outputs and tools used in each phase, as well as the contribution of the projects and systems, demonstrated by the arrows going to each phase of RMP.

Exhibit 2. Proposed process to bridge PRM and SRM.



Planning phase

The primary objective of the planning phase in the RMP is to create a plan for risk management during the lifecycle of the projects or systems that will assure an acceptable level of risk over the life of the project or system (INCOSE 2004). Some of the tasks in the planning phase are:

1. Develop strategies on how to conduct the other RMP phases (i.e. identification, assessment, handling and monitoring)
2. Identify or develop tools or methods to be used for risk identification, assessment and handling (Conrow 2005).
3. Gather historical information from other comparable projects or systems to help in conducting the RMP phases.
4. Set up the required resources (time, budget and human resources) to conduct the RMP.

PMI (2004) describes four inputs to the Planning Phase namely :

1. Project management (PM) plan
2. Project scope statement
3. Organizational process assets, and
4. Environmental factors.

On the other hand, the output of the Planning Phase is the Risk management (RM) plan (which includes strategies of risk process). The RM plan describes roles and responsibilities, methodology of risk management, timing and budgeting, risk categories, risk breakdown structure, and more tracking information of risk. One of the tools used during this phase is probability and impact matrix, also known as a *risk matrix*. This output represents the arrows in Exhibit 2 from the project sides to the RMP phase, which is planning phase.

It is notable that based on the PMI's project risk management framework; systems contribution to this phase is not explicit. This indicates that the planning

phase of the RMP, as per PMI, is focused on the pursuit of project objectives. This is clear from probability and impact tool where the objectives of the project on the columns sides and the ranking on the row side. The value given in each box is only for those affecting the objectives of the project but not for the systems.

The framework suggests that the systems have to have their inputs into risk planning phase. The contribution of the system will be similar to those of the project except that systems strategies and objectives are to be considered, namely:

1. Enterprise environment factors
2. Organizational Process assets
3. Systems' objective
4. Systems management strategy
5. Systems' risk management plans

These contributions of the system are presented by the arrows from the system side to the planning phase of the RMP.

Risk definition phase

The main objective of this phase is to identify the risk and their levels (e.g. low, medium, or high) by monitoring the project structure and requirements. Conrow (2005, p. 8) defined this phase of RMP as "the process of examining the program areas and each critical technical process to identify and document the associated risk". PMI (2004) suggested that the participants in this phase are project manager, project team, users, consultants, stakeholders, and other project managers.

PMI (2004) describes inputs to this phase, namely

1. Environment factors
2. Organizational process assets
3. Project management plan
4. Risk management plan (from planning phase),
5. Project scope statement.
6. Risk register which includes list of identified risks and their potential responses, root causes of risks, and risk categories.

Most of these inputs are contained in the work breakdown structure (WBS) which is a main input to this phase. The tools used on this phase are either document reviews or information gathering techniques, brainstorming, interviewing, Delphi technique, and root cause identification; added to using strength, weaknesses, opportunities and threat (SWOT) analysis technique (PMI 2004).

This represents the project side of the framework shown as arrows going from the project box to the identification phase in Exhibit 2. PMI indicated that stakeholders and users (as systems representatives) are to participate in this phase of RMP which is a good indication and goes on line with the suggested framework. However, the framework considers the participation of the systems should be more effective. Systems representative should participate in the decision process conducted during this phase. This participation ensures that systems objectives and strategies are well considered in identifying the risk that may propagate to the system, such as:

1. Enterprise environment factors
2. Organizational Process assets
3. Systems' objective
4. Systems management strategy
5. Systems risk management plan.

Risk Assessment Phase

The primary objective of the Risk Assessment Phase is to assign the probability and the value of the impact of the risk if it occurs (INCOSE 2004), and can be described as a process of evaluating identified risks or to refine the description of the risk in term of identifying the causes and effects of each risk (Conrow 2005). PMI (2004), however, separated the assessment phase into two parts, namely qualitative and quantitative analysis of the identified risks. The qualitative analysis entails prioritizing the risks based on the probabilities and their impact on project objectives. Quantitative analysis considers the numerical effects of the identified risks on project objectives.

PMI deems that the inputs to the Risk Assessment Phase are as follows:

1. Environnemental factor (qualitative analysais)
2. Process assets (qualitative analysis)
3. Project scope statement (qualitative analysis)
4. Project and risk management plans (qualitative analysis)
5. Risk register (quantitative analysis)
6. Cost and time management plans (quantitative analysis)

The tools used under qualitative assessment are: documentation reviews, information gathering techniques (listed under the above phase), check list analysis, and assumption analysis; added to the techniques using diagrams for analysis that includes: cause and effects diagrams, process flow charts, and influence diagram. On the other hand, the tools used for quantitative analysis are: sensitivity analysis, expected monetary value, decision trees, assessment matrix models, risk profile models, and modeling and simulation. The output of both assessments (qualitative and quantitative) is an update to the risk register that includes the identified risks in the project (PMI 2004).

These inputs, outputs and tools of the Risk Assessment Process correspond to the project left side

of the framework in Exhibit 1. This is the current practices during the project lifecycle. It was proved that these assessments are effective in the success of the project and good implementation provided a better chance of project completion and success. However, this research efforts look after the success of the project which is to be completed with the assigned budget, time and quality. This research discusses the propagation of the risk-initiating events from the project to the systems after they are completed. Therefore, the framework suggests a better involvement of the system in the assessment of the indentified risks. This was symbolized by the arrow from the systems on the right to the assessment phase in the center of Exhibit 2. The participation of the system management in the assessment phase should be a mirror of what was done in the project side or can be coordinated in another way where the participation of the systems is part of the decision process during this phase.

Risk Handling Phase

The primary objective of the Risk Handling Phase of risk management process is to take proper action to mitigate or eliminate the identified and assessed risks. This phase is essentially a process of identification, evaluation, selection and implementation of tools to reduce the risk to acceptable levels within the pre-set constrains of the projects (Conrow 2005). This will consist of what action should be taken, how long it should take, who is assign to do it, and what are the impacts on time and budget. There are several options to handle risks that include assumptions, avoidance, mitigate, and transfer. The issue of available resources is an important issue for project management and has to be available to mitigate those identified risks. Risk handling could start during the design phase of the project where the design can be developed based on low risk solutions. Moreover, recovery planning is also a good option to consider to help make the right handling decisions (INCOSE 2004).

PMI consider only two inputs to this phase:

1. Risk management plan and
2. Risk register.

Risk management plans have the roles and responsibilities of project management team and also have the levels of risk for low, moderate or high. In addition, they have the requirements of time and cost to mitigate the identified risks. Risk register was initiated during the identification phase and it contains the prioritize risks based on the assessment phase input. It also contains root causes of risks, anticipated responses, and owners of risks, symptom, and warning signs to initiate an action to resolve the risk. In addition to the two inputs suggested by PMI, It is ultimately impeded that Project scope statement and project management plans are suppose to be inputs to this phase too. However, the outputs of the handling phase are to update the risk register for those risks that has been handled and those that has been ignored. The other output of this phase is to update the project management plan and a list of any contract used to mitigate the risks. The tools and techniques used in this phase are avoidance (avoiding the risks), transfer (transfer the risk impacts to a third party), mitigate (reduce the probability or the impact of the risk), acceptance (accept to eliminate the risk or take any other action that will not affect project's objectives).

These steps developed above are for the project perspective to handle risk during project lifecycle. These correspond to the arrow coming to the handling phase of RMP from the project box as shown in Exhibit 2. These are used to assure that the project is successful and to be completed within the pre-assigned constraints of time, cost and quality. Which strategy to use to handle risk was based on project objectives and choose the one that will not dramatically affect the schedule or the budget of the project. These notions are used in most of the literatures about project and risk management. The framework, in order to resolve the stated problem under the first objective of this research, suggests entailing systems management in choosing which strategies to handle the risks. This is represented by the arrows from the systems objectives and strategies box to the handling phase box in Exhibit 2. Participation of systems in choosing the strategies to handle the risk will help the system to avoid some risk impacts by using certain handling strategy. The participation of systems management should be to the level that it reflects similar activity that was conducted in the project side. The idea of systems participation this phase is to have the system full aware of the risk-initiating events in the projects and how they were handled to be ready to accommodate those processes when the project is to be integrated.

Risk Control and Monitoring Phase

The objective of this phase is to monitor the whole RMP and provide a feedback to the other phases of the process. This phase is a process of tracking and evaluating the performance of the handling strategies to do the necessary updates and provide a feedback information to the other phases of the process (Conrow 2005). Monitoring and control may suggest to change the current handling strategy, closing the risk, invoking a contingency plan or just continue with the original plans (Perera and Holsomback 2005). PMI looks at the monitoring and control phase as "feedback process of reevaluating, based on recent tracking information, what actions to take concerning a particular risk, and

implementing those decisions. Actions may include changing the current action plan, closing the risk (accepting the residual risk), invoking a contingency plan when the original plan is found to be ineffective or continuing with the original plan and continuing to track the risk. Each of the risks identified, analyzed, planned, and tracked should be periodically reviewed (usually bi-weekly with the ISS program office) to ensure that decisions made are effective and that associated actions remain applicable" (PMI 2004, p. 264). The inputs that considered by PMI to this phase are

1. Risk management plan,
2. Risk register,
3. Approved change requests,
4. Performance report and
5. Work performance information.

However, the outputs are updates to risk management documents and project plans, in addition to requested changes, recommended corrective and perspective actions (PMI 2004). The tools and techniques used during controlling and monitoring phase are risk reassessment, risk audit, variance and trend analysis, technical performance measurement, reserve analysis, and status meetings (PMI 2004).

The framework positioned the monitoring phase of RMP different from the other phases, shown in Exhibit 2. Monitoring and control is affecting each phase of the process. It monitors the identified and assessed risk in the first two phases. Moreover, it monitors and controls the handling strategy and assesses its efficiency and whither it needs to be updated or even changed. There are arrows from monitoring and control phase to each phase of the process providing a feedback on the performance of the process to each phase to take the proper corrective actions. Currently, the corrective action is based on current risk management process outputs and project objectives.

The intervention of project is to reflect any changes in scope or objectives presented by the arrow from the project box to monitoring phase. The framework also suggests that similar intervention has to be implemented from the systems perspective to reflect any change in systems structure, objectives and strategies. The arrow from system box to control and monitoring phase depicts systems participation.

Proof of Concept

The example used to test the application of the framework is the collapse of terminal 2E (the project) of Charles de Gaulle airport (the system) in on May of 2004 where five people died and several more injured. The collapse occurred just after 11 months into the airport's operation. Jonson (2008) related this collapse to the implementation phase of the project. He claimed that it could be caused by the implementation of the project completion and integration phase. The primary reason is that the accident occurred soon enough from project completion.

The consequences of the accident were enormous on the system - the Charles de Gaulle Airport - namely the huge financial loss due to closure of the terminal for several months; significant business disruptions as airline traffic was rerouted to other terminals; and lost credibility of the airport and its management. Overall, the total consequences, including intangible matters were much more than the cost of the project itself.

Literature provided various contributing reasons for the collapse of the terminal, including:

- The enormous number of project stakeholders (400) and contractors each was in charge of a part of the project (Greenway 2004). This will require huge coordination and extensive management.
- The design using a newly structured tunnel-like terminal (Reina 2004).
- The material used for construction was a mix between concrete, carbon material and glass
- A hole in the vault of the concrete roof made to install metal support.

How can the suggested framework help in reducing the probability of terminal collapse? Some of the contributing reasons can be traced back to the project, which is consistent with the assumption of the framework. Consider the first contributing event - the huge number of stakeholders in project execution. This is a definite source of problems since this requires extensive coordination among the stakeholders. In particular, the competing objectives between the contractors may result in critical tradeoffs in the construction of the project. It is a project management decision to choose multiple contractors for construction and design. The possible objective of this decision was to reduce cost and time of the project. The involvement of systems in this issue will demand to minimize the contractors to a better manageable number which in turn will reduce risk possibilities. In other word, systems will demand a more controllable project execution. This will be part of risk management plan which set early in the project lifecycle. Systems objectives and strategy are inputs to this phase which will enable the system to modify project risk management plan. This in turn will affect the number of the contractors executing the project since there might be a conflict with systems strategy and objectives.

The second contributing reason was the more complex methods of tunnel-like construction of the

terminal. Will systems involvement affect this level of complexity? Systems are primarily looking for competitive advantage to improve their profits by minimizing the operational cost. Complex design would have to be weighed against those objectives and may be re-evaluated if it has any effects on systems' objectives. Project design phase is an early phase of the project execution and this means that the systems inputs to this phase has to be early in the risk management process. The participation of systems in mitigating this issue will be in the first two phases of RMP namely planning and identification phases. System management can challenge to have the design complexity as a risk that might affect system performance and have it listed in the risk register. Moreover, system can also add the type of the structure as another risk initiating event. System can have its influence in the first two phases of RMP during project through their inputs to both phases particularly systems objectives and strategy as well systems risk management plans.

Material selection is the third contributing reason. The main factors that affect material selection are the cost and the delivery time. Both of these factors are main constraints to the project. Systems participation will have an effect on this source of risk during project lifecycle. The framework implementation may have some influence on material selection especially if they have a long anticipated life. The project will be a subsystem of the whole system and material selected during project lifecycle has to meet system's standards. Implementing the framework will enable systems management to affect material selection. This type of risk might not be added to risk register if the systems are not involved in risk identification. Involvement of systems in assessment process is also necessary to assure that this risk is not ignored or cancelled. Moreover, they can guarantee that material types and qualities meet systems standards. This can be accomplish if the systems established their inputs to risk identification and assessment phases as

The fourth contributing reason is the hole that caused damage in the concrete roof and consequently caused the collapse of the terminal. Having the system more aware of airport structural risk will have a major role on eliminating the collapse of the terminal. Applying the framework will have systems management be aware of this risk and systems people will be aware of the type of the structure and will not make holes in this type of concrete. Systems management awareness of risk perceived from project will help them create the right procedure to eliminate the propagation of the risk or reducing its probability to materialize. Therefore, the application of the framework will be effective to have systems personal well aware of the right practices when the project is integrated within the system. This risk can be related with the second and third risks, Exhibit 2, control and monitoring phase, clearly explain the participation of systems in this phase. Monitoring phase in the framework has a two sided arrow that shows systems input to RMP and the phase output to the system. The continuous monitoring of the risk will help building good awareness of projects' risks and project structure as well.

Analysis

The application of the framework will require additional time, which project and systems managers may not be accustomed to. Having the systems management involved in every phase of the risk management process will take more time than they may typically spend. This time will be needed to coordinate and evaluate every phase of the project. This additional time may be critical for project management since it may affect one of their primary objectives: the completion schedule. In this situation, project management might resist the application of the framework.

The framework only addresses the specific relation between the project and the system. This means that there are other relations between projects and systems not addressed by the framework. The framework was meant to generalize various industries, making it widely applicable; however, each industry has different characteristics that might cause a change in the way the framework might be applied. As such, if it is applied to different industries, then the output of the framework might vary based on the way it was applied and the relation between a project and system in that particular industry.

The framework suggests a close coordination between project and systems management to pursue their objectives in the application of the risk management process. This will add another dimension to the already complex interaction between those managing the project and the system. This may result in another political and organizational issue between systems management and project management.

The suggested framework is the first of its kind to be suggested and might face resistance from project and systems managers. The framework is now in its theoretical stage, and some of these unfavorable factors in the application of the framework can be attenuated through further evaluation, possibly through pilot-testing, prior to full-scale application. This will assist in making the framework more favorable among

project and system managers. The proposed framework bridges the difference in the inherent objectives between systems and project management; therefore, there has to be a way to manage conflicts that may arise from these differences in objectives. This can be accomplished by establishing a methodology clearly describing the roles and responsibilities of both the project and systems management.

The framework assumes that the coordination between project and system in the application of the risk management process will make the risk-initiating events more controllable during the project and system's lifecycle. The framework was built on this concept where the risk-initiating events might propagate during the project lifecycle under the control of risk managers. However, when risk-initiating events propagate from the project to the system, the sequence of events might not be clear, predictable or controlled.

The framework was developed based on the current risk management processes being practiced in systems and projects (e.g. (Haimes et al. 2002), (Perera and Holsomback 2005), and (Conrow 2005)). The framework assumes that the current risk management processes produce good results based on publications when practiced in projects and systems. However, the framework may provide insights to further refine these current risk management processes in light of the roles of systems management in projects.

The framework tries to capture both project and systems objectives. The framework may play a significant role even early in the requirement management phase of a project development in order to guarantee better results in assessing the requirements and the risks that might emerge during a project's lifecycle. Furthermore, the framework emphasizes the required close relation between projects and systems and for each to pursue its objectives and strategies. Therefore, the project's initial requirements might also be affected by the application of the framework since there is a real emphasis on the effects of project and systems objectives on the framework.

There will be a potential effect of the framework on the current systems development process. Even though the framework primarily deals with risk, it emphasizes the required close relation between projects and systems and for each to pursue its objectives and strategies. As a potential result, the acquisition of particular systems or development standards or practices, e.g. MIL-STD, IEEE, INCOSE, etc. may be affected by the application of the framework.

The framework significantly re-defines the correlation between project and systems. Even though the Project Management Institute (PMI) has firm and well-established project management processes, the framework may affect the PMI standard for a better way of looking into the relation between project and systems risks.

The application of the framework might require some resources in term of budget and time. Therefore, there has to be preparation for the application of the framework from the initial phase of the project. This will help the project management be ready for systems input and consider their requirements.

Participation of the systems management in the framework will have several advantages besides identifying and assessing risk. A system' representatives will be able to communicate the dynamic strategies and objectives of the system to and from the project.

Another benefit of the systems' involvement in the framework is to participate in evaluating external sources of risk caused by the changing environment. Systems management might have a better experience with environmental issues compared to the projects. The same idea applies when there are changes in the government's roles and regulations.

As shown in the framework, the risk management process consists of five phases. It will be much safer to move from one phase in the PRM to another with the participation of the systems, as suggested by the framework. For example, when the assessment phase is being conducted, the participation of systems management will give a more accurate assessment compared to limiting the assessment to project management only.

Conclusion

It has been shown that there can be improvements on how risk management is performed within the context of PRM and SRM. A framework was developed to address gaps to minimize the propagation of risk from projects into systems. This framework was compared to the process prescribed by the Project Management Institute. A proof-of-concept application of the framework was developed and presented. Finally, insights into the application of the framework, including limitations and future research agenda were identified.

The main contribution of this paper to the engineering management knowledge is the framework that suggests a different way of executing the risk management process during the project and systems lifecycle. The framework highly considers the contribution of the systems management in the implementation of the risk management process during project execution time frame.

Future Work

- Develop a method to assess and analyze the sequence of events that tend to propagate to the system.
- Apply the framework to real case studies from different industries such as the auto, oil and construction industries.
- Find out how the framework can be used in the project development process.
- Develop quantitative and qualitative tools for SoS based on established and generally accepted methods, e.g. those developed by Kaplan (1997), Haimes and Horowitz (2004), and others.

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About the Authors

Baqer Alali is a PhD Student in Engineering Management and Systems Engineering Department of Old Dominion University. He received his Master degree in Engineering and Technology Management form Portland State University on August 2007. He received his Bachelor degree in Electrical Engineering from King Fahad University of Petroleum and Minerals, Dhahran Saudi Arabia on January of 1992.

C. Ariel Pinto is Assistant Professor in the Department of Engineering Management and Systems Engineering at Old Dominion University. His research is in the areas of risk management in engineered systems, project risk management, risk valuation and communication, and analysis of extreme-and-rare events. He received his Ph.D. in Systems Engineering from the University of Virginia, and Master and Bachelor degrees in Industrial Engineering from the University of the Philippines.

Andreas Tolk is Associate Professor for Engineering Management and Systems . Engineering at Old Dominion University, Norfolk, Virginia. He is also a Senior Re-search Scientist at the Virginia Modeling Analysis and Simulation Center (VMASC). He holds a M.S. in Computer Science (1988) and a Ph.D. in Computer Science and Applied Operations Research (1995), both from the University of the Federal Armed Forces of Germany in Munich. He is a member of ASEM, ACM SIGSIM, SCS, SISO, MORS, and NDIA.

Rafael Landaeta is Associate Tenured Professor in the department of Engineering Management and Systems Engineering. He holds a M.S. in Engineering Management and a Ph.D. in Industrial Engineering from the University of Central Florida. He received a B.S. in Mechanical Engineering from UNITEC, Venezuela. He has performed applied research for the U.S. Department of Homeland Security, the U.S. Army Program Executive Office Soldier, The U.S. Army Core of Engineers, Siemens-Westinghouse Power Generation, Walt Disney World-Information Technology, NASA-Kennedy Space Center, The National Centers for Systems of Systems Engineering, The Institute of Simulation and Training, and the Industrialized Housing Partnership of the U.S. Department of Energy.