2011

Emerging M&S Application in Risk Management

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Keywords: Risk modeling, risk management, Risk analysis

Abstract

There has been compelling signs of the great potential of building further synergy with academics, researchers, and industry practitioners from the areas of Modeling and Simulation (M&S) managing risk events. This paper provides an introduction to risk management and how M&S has permeated the risk management process. The trend has been to harness the advantages of M&S tools and techniques in terms of efficiency and effectiveness in managing risks. However, the more important contribution of M&s may be in how it provides a way for specialists in various disciplines or industries interact to manage risks that required multi-disciplinary approach.

1. INTRODUCTION TO RISK

In 2009, the Emerging Risk Initiative at Old Dominion University (ERI@ODU) was established with the vision to create next generation body of knowledge in risk management for current and future systems and organizations characterized by uncertainty, emergence, complexity, and interdependence. The term emergent can be synonymous growing, adapting, changing, and as such emergent risk can be pertain to any type of risks that is less understood than others AND will increase in importance as time passes.

The primary challenge facing researchers at ERI@ODU has been to identify tools and techniques that can be used by risk management practitioners in dealing with emergent risks. In the search for these tools and techniques, an observable trend arose – many of the tools and techniques in modeling and simulation (M&S) are finding their way into the realms of risk management.

This paper will explore this trend of how M&S has been applied to problems particularly addressing risks and trends on future trends.

1.1. Introduction to Risk

The concept of risk is strongly hinged on the concepts of undesirable events, consequences, and uncertainty. Pinto, McShane, and Kadi (2010) pointed out that the presence of many different usage of the term risk can be due to how desirability varies from one person, organization, or systems to another. Financial risk as an example emphasizes that undesirability has more to do with the held objective rather than on the value of the event. The importance of recognizing objectives is thereof a precursor to any form of risk analysis, assessment or management. In essence, there is indeed little consensus on the definition of risk. However, this lack of consensus is in fact a property consistent of an in an aggregation of systems with multiple and often opposing objectives.

Nonetheless, the commonly held description of quantitative risk famously forwarded by Kaplan (1997) as:

R = F(S, L, X)
where
S – risk scenarios
L – likelihood of the scenarios
X – damage of resulting consequences

However, it was pointed out by more recent articles (e.g. Damodoran 2008, Hoftetter 2002, etc.) that there are multitudes of description of risks from various fields, disciplines within a field, perspectives within disciplines, and even evolving through times. Possibly more meaningful information is how engineers are managing the concept supposedly termed as risk. Garvey (2008) presented a description more appealing to engineering:

> *"The objectives of engineering risk management are the early and continuous identification, management, and resolution of risks such that the engineering of a system is accomplished within cost, delivered on time, and meets user needs. "* (Garvey 2008, p. 2)

The above description considers the notion of systems development as a conscious effort, notion of tradeoffs and project management goals.

The four typical categories of risk are as follows.

- Pure/Hazard risks are risks in which the only possible outcomes are loss or no change, that is, no possibility for gain.
- Financial risks are risks in which there is a possibility of gain and can typically be transferred using derivative products.
- Operational risks are defined as exposure to direct or indirect potential losses suffered due to inadequate or failed internal processes, people, and systems or from external events.
- Strategic risk is the risk of a loss arising from a poor strategic business decision, for example, related to damage to reputation, competition, demographic trends, technological innovation, capital availability and regulatory trends.

Managing risk is a process generally made up of four steps: risk identification, risk assessment, selection of the appropriate risk management technique, and the implementation and monitoring. Risk identification and assessment can be summarized by posing the following questions: what can go wrong, what is the likelihood that it could go wrong, and what are the consequences. Selection of risk management techniques can also be summarized in terms of three questions (Haimes, 1998): What can be done, what are the tradeoffs, and what are the impacts on future options. Finally, implementation and monitoring involves asking: are the techniques effective and are there other things that can go wrong.

Table 1. Steps and questions to be answered in a risk management process

Risk Management	Questions to be Answered
1. Risk identification 2. Risk assessment	– What can go wrong? – What is the likelihood that it could go wrong? – What are the consequences?
3. Selection of the appropriate risk management technique	– What can be done? – What are the tradeoffs? – What are the impacts on future options?
4. Implementation and monitoring	– Are the techniques effective? – Are there other things that can go wrong?

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1.2. Risk and Uncertainty

In mathematics, randomness has particular meaning. This is most evident in describing variables that change every time it occurs or is observed. In the common language, uncertainty implies doubt, ambiguity, lack of knowledge, and others. It is often useful to further describe sources of uncertainty: aleatory and epistemic. Epistemic uncertainty refers to uncertainty in our state of knowledge about phenomena. This is also known as reducible uncertainty, pertaining to its property to be reduced through investigation, reasoning, and other forms of analyses. Aleatory uncertainty, on the other hand, is due purely to the variation in outcomes of randomness. This is also known as irreducible uncertainty, pertaining to its property of not being reduced by further investigation, reasoning, and other forms of analyses. It should be pointed out that aleatory uncertainty is predicated by the acceptance that randomness truly exists.

Uncertainty and risk are undoubtedly closely related concepts that both practitioners and academics have struggled to define and distinguish. Current practices in engineering and management espouse more the notion that risk is not equal but has a dependency relationship with uncertainty and the cause-and-effect nature of the problem domain lend themselves more towards the notion that risk is caused by uncertainty.

2. M&S, RISK, AND UNCERTAINTY

Modeling and simulation (M&S) has been described as one of the most promising tool in risk assessment (Pinto and Kirchner, 2011). Gone are the days when stove-piped management of risk is sufficient in addressing engineering and management problems. Recent events all over the globe have shown the need for a more systems-based approach in dealing with modern-day emerging risks. The increasing role of M&S in risk management can be seen in several ways. In particular, these trends can be presented as to how M&S contributes to answering the question in a typical risk management process shown in Table 2.

Table 2. Application of M&S towards answering the risk management questions

Risk Management Questions	M&S Application
What can go wrong?	Describe scenarios that has not happened before
What is the likelihood that it could go wrong?	More accurate estimates of likelihood Better communication of rare and extreme events
What are the consequences?	Better description of scenarios and ripple effects
What can be done?	Better description of effectiveness of strategies prior to implementation
What are the tradeoffs?	Comparison of alternative strategies
What are the impacts on future options? (Are the techniques effective?)	Better analysis of sequential decision scenarios
Are there other things that can go wrong?	Describe scenarios that has not happened before

2.1. What can go wrong?

The first and most pivotal step in the risk management process is the identification of events that can go wrong, i.e. risk events. This step is the starting point of the risk management process and a very significant part of the remainder of the process is determined by how these events are described, e.g. what constitutes a wrong event.

For the most part, identifying risk events is primarily done by looking back on what has gone wrong in the past and what are foreseeable to go wrong in the future. However, there are instances when there is a need to identify risk events that has not happened yet. This may be due to reasons that the system is a first of its kind, or possibly an old system that will operate in a totally new environment. M&S tools and techniques are currently being explored to provide better identification of risk events when traditional system identification may not be effective. As an example, consider describing possible interaction between a particular combination of livestock and farm crop to identify harmful interactions (Thornton and Herrero, 2001).

M&S also allows a more systematic approach to modeling the objectives and the corresponding anti-objectives, aka anti-goals (Pinto, et al. 2010). This is particularly important in systems engineering where risk analysts and systems engineer can work side-by-side throughout the process of developing systems architecture, i.e. charting system goals, capabilities, functionalities, and eventual sub-systems. Figure 1 shows how the hierarchy of modeling systems architecture can complement the identification of risk events during systems architecture development.

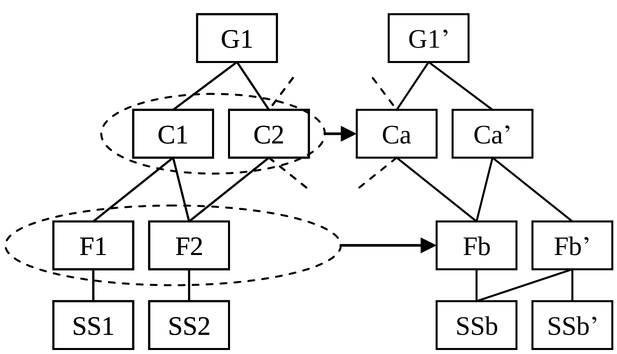

Figure 1. Mirror-image of a system hierarchy and the role in risk management

The application of M&S in identifying risk scenarios cascades down to the latter risk management processes of implementation and monitoring, i.e. asking the questions what are the impacts on future options, are the techniques effective, and are there other things that can go wrong.

2.2. What is the likelihood that it can go wrong?

Estimating likelihood or probabilities of risk events is a popular application for M&S. Particularly in the realm of extreme and rare risk events where historical data are sparse, efficient and relatively accurate estimation of likelihood are major challenges for risk analysts. M&S tools and techniques coupled with fast computing resources enable such estimation. Consider as examples the prediction of extreme stock market performance (Živković 2009) predicting the likelihood of extreme weather (Wehner, et al. 2010).

Aside from efficient and accurate estimation of likelihood, another contribution of M&S is in the communication of this information to facilitate making decisions. This is particularly important in cases where there the decision-making scenario involves tacit knowledge that need to complement any estimates of likelihood. Examples of these decision scenarios are in planning for H1N1 vaccination during a pandemic (Lee, et al. 2010) and how to manage spread of food-born health hazards (Garido, et al. 2010).

2.3. What can be done?

Similar to identifying previously unknown risk events, M&S can also be applied towards better description of effectiveness of strategies prior to implementation. This is possibly the most common application of M&S in risk management because this shares the typical objective of M&S of how to make things right. There numerous examples of how M&S are applied to assess effectiveness prior to actual implementation. Consider as an example the assessment of field exercises involving military personnel and armored vehicles (Hongbing et al. 2010) and the simulated urban planning for more sustainable development (Yan et al. 2010).

2.4. What are the tradeoffs?

A natural extension of the capability to model risk alternative plans prior to implementation is the trade off analysis among competing alternatives. Nonetheless, the challenge often lies on how to make alternatives comparable in terms of similar operating variables and performance parameters. Herein is the need for a well planned and systematic modeling of alternatives making sure that relevant variables are captured and modeled uniformly across alternatives. Such trade off analysis abounds in the field of manufacturing and logistics, e.g. risk of supply chain alternatives (Prakash,. Deshmukh 2010 and Kesavan, at al. 2010), in microbiology, e.g. alternative ways to process DNA and resulting risks (Brümmer, et al. 2010), and risks of investing in the energy sectors in developing countries (Pindonriya, et al. 2009).

3. FUTURE OF M&S AND RISK MANAGEMENT

The fact that M&S has permeated all aspects of the risk management process, as discussed in the previous section, is a proof of its suitability to analyzing risk events. However, its greatest contribution may lie on how M&S tools and techniques facilitate communication among various specialists involved in analyzing the same risk event.

An acknowledged difficulty in risk management is the stove-piped treatment of risks as implied by the types of risks described in Section 1. Such categorization of risks into types imply that one type hardly affects the others or that one type requires different treatment that the others. This is not withstanding the common experience that consequence of risk events goes far beyond any categorization or type. There are several reasons to this stove-piping, but the overriding reason seems to be the difficulty of transcending traditional boundaries marked by disciplined, organizational and professional structures, etc. Nonetheless, it has been shown that in a truly effective risk management, clarifying the affected stakeholders and setting the boundaries of analysis are the most important first steps (Hatfield and Hipel 2002).

Aside from the inherent advantages M&S tools and techniques provide risk managers in terms of more efficient and effective analysis, the more important emerging contribution of M&S is to allow risk analysts from various fields a venue. This interaction among specialists in various fields may make it easier to perform a real multi-disciplinary and systems approach to analyzing risks.

4. SUMMARY

There has been compelling signs of the great potential of building further synergy with academics, researchers, and industry practitioners from the areas of Modeling and Simulation (M&S) managing risk events. M&S's potential goes far beyond its power to tell us how systems may, would, and should work. And for this same reason, M&S also has a great and still untapped power to tell us how complex systems may fail and to enable specialists from various field of discipline to interact. Nonetheless, there needs to be the conscious and deliberate attempt to harness this power by bringing together current knowledge and game-changing ideas from the best academics, researchers, and industry practitioners in M&S and risk management.

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Acknowledgement

The authors would like to acknowledge the support of Old Dominion University (ODU) Office of Research through its 2010 Multidisciplinary Seed Grant, ODU's Department of Engineering Management and Systems Engineering, the National Centers for System of Systems Engineering, and the Emergent Risk Initiative at ODU, and ODU's Batten College of Engineering and Technology through the dean's faculty development grant.

Biography

C. Ariel Pinto is an Associate 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. He co-founded Emergent Risk Initiative at Old Dominion University in 2009.