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Preface

Computational simulation and risk analysis: An introduction of state of the art research

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ABSTRACT

In recent years, risk management and analysis has attracted a great deal of attention from both researchers and practitioners. Enterprise risk management has become an important topic in today's more complex, interrelated global business environment, replete with threats from natural, political, economic, and technical sources. This survey and introductory article addresses computerized tools used for risk management and analysis. Risks are studied from perspectives of different disciplines, with a discussion of how various methods and tools are used to optimize risk management.

1. Introduction

Risk management can be defined as the process of identification, analysis and either acceptance or mitigation of uncertainty in investment decision making. The utilization of high technology for loss-prevention and control systems in natural disasters or fires, accidents and quantitative models in derivatives for insurances and finance, has expanded substantially in the past decade. Encouraged by traumatic recent events such as 9/11/2001 and business scandals to include Enron and WorldCom [2], risk management has not only developed a control focus, but most importantly it remains a tool to enhance the value of systems, both commercial and communal. Integrated approaches to manage risks facing organizations have been developed along with new business philosophies of enterprise risk management (ERM, [3,24,42]). Risks arise naturally, as in the Asian tsunami of 2004 [5]. Risks are also endemic in economics. The recent crisis beginning in late 2007 caused a panic that rippled across global markets and practically froze credit markets in 2008. Many researchers have attributed the crisis to the "failure of conventional risk management in financial institutions" [54–56,17]. Risk management has also been a major factor in business, important to both top industry executives and also government regulators [34].

ERM seeks to provide means to recognize and mitigate risks. The field of insurance developed to cover a wide variety of risks, related to external and internal risks covering natural catastrophes, accidents, human error, and even fraud [16]. Financial risk has been controlled through hedge funds and other tools over the years, often by investment banks. With time, it was realized that many risks could be prevented, or their impact reduced, through loss-prevention and control systems, leading to a broader view of risk management.

This article is organized as follows: Section 2 briefly presents types of risk. Section 3 presents each of the techniques that we found in the literature by categories and discusses different perspectives and various tools to risk management. Section 4 concludes the paper.

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2. Types of risk

There are many aspects of risks. In general, *Risk* is defined as the unknown change in the future value of a system. Risks can be viewed as threats, but businesses exist to cope with specific risks. Thus, if they encounter a risk that they are specialists in dealing with, the encounter is viewed as an opportunity. Risks have been categorized into five groups [15]:

1. **Opportunities**- events presenting a favorable combination of circumstances giving rise to the chance for beneficial activity;
2. **Killer risks**- events presenting an unfavorable combination of circumstances leading to hazard or major loss or damage resulting in permanent cessation of operations;
3. **Other perils**- events presenting an unfavorable combination of circumstances leading to hazard of loss or damage leading to disruption of operations with possible financial loss;
4. **Cross functional risks**- common risks leading to potential loss of reputation;
5. **Business process unique risks**- risks occurring within a specific operation or process, such as withdrawal of a particular product for quality reasons [31].

We propose the following general classification of risks: Field based and Property based.

- Field based classification

  Financial risks, which basically includes all sorts of risks related to financial sectors and financial aspects in other sectors; these are, but not restricted to, market risk, credit risk, operational risk, operational risk, liquidity risk. Nonfinancial risks, which includes risks from sources that are not related to finance. These include, but are not restricted to, political risks, reputational risks, bioengineering risks, and disaster risks.
- Property based classification

  Risks can have four properties: uncertainty, dynamics, interconnection/dependence and complexity. The first two properties have been widely recognized in inter-temporal models from the behavioral decision and behavioral economics areas (Baucells et al. 2009); the last two properties are well studied in finance disciplines.

  Risk probability applies probability theory and various distributions to model risks. This approach can be dated back to the 1700s, leading to Bernoulli, Poisson, and Gaussian models of events and general Pareto distributions and general extreme value distributions to model extreme events. Dynamics of risks mainly uses stochastic process theory in risk management. This can be dated back to 1930s where Markov processes, Brownian motion and Levy processes were developed. Interconnection/Dependence of risks deals with correlation among risk factors. Various copula functions are built and Fourier transformations are also used. Risk complexity need be handled by use of various complexity science theory such as agent-based modeling approaches.

2.1. Risk management

Fig. 1 gives the number of Publications on "enterprise risk" since 2000. The figure was created by searching for the words "enterprise risk" in both Scopus and ISI Web of Science and retaining those publications that indeed present techniques for managing various enterprise risks. Data we used from Scopus are obtained by searching subject areas "Social Sciences & Humanities" and "health science". Data we used from ISI Web of Science includes three data sources: Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI) and Arts & Humanities Citation Index (A&HCI). Both trend curves suggest that published articles in enterprise risk management area continue to increase during the last decade.

Various areas that relate to enterprise risk can be identified in the literature. This section presents survey on five key areas, along with its associated techniques.

3. Different perspectives and tools

Global competition, technological change, and continual search for competitive advantage have motivated risk management in supply chains [47]. Supply chains are often complex systems of networks, reaching hundreds or thousands of participants from around the globe in some cases (Wal-Mart or Dell). The term has been used both at the strategic level (coordination and collaboration) and tactical level (management of logistics across functions and between businesses) [35]. In this sense, risk management can focus on identification of better ways and means of accomplishing organizational objectives rather than simply preservation of assets or risk avoidance. Supply chain risk management is interested in coordination and collaboration of processes and activities across functions within a network of organizations. Various optimization tools are used in supply chain risk management, to include various operations research models such as programming and game theory [55].

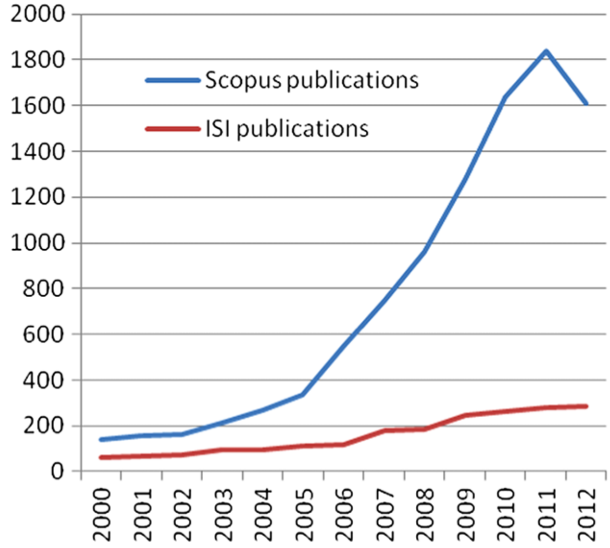

Fig. 1. Publications on ''enterprise risk'' since 2000.

3.1. Engineering risk analysis based on optimization tools

Optimization tools are fundamental to engineering efforts to design better systems [4]. The existence of uncertainty violates many of the required assumptions for many optimization models. The presence of risk implies the presence of uncertainty, making development of optimization models more difficult. However, there have been models presented to optimize engineering systems. Ahmadi and Kumar [1] gave a model considering the increased probability of failure in mechanical systems due to aging. Buurman et al. [7] gave a framework for dynamic strategic planning of engineering systems using real options analytsis, finding that this approach had considerable advantages over static design. Popovic et al. [46] applied complex optimization to maintenance systems involving risk.

3.2. Performance evaluation under uncertainties

A number of papers already cited have dealt with assessing and predicting risk in various contexts. Warenski [53] provided another application of loan-risk analysis, in this case demonstrating financial modeling in the paper and pulp industry. Groves et al. [21] more specifically studied risk management within the production industry when they looked at corporate social responsibility for lifecycle risk management involving nanotechnology. They concluded that emerging technologies lead to a requirement for businesses to adopt more open analyses involving stakeholders.

3.3. Decision making and industry modeling under uncertainty

Computer tools to aid in making decisions have been widely studied in the information systems field as decision support systems since the 1970s [28,51]. Otim et al. [43] provide a recent analysis specifically addressing the evaluation of value and risk in information technology investments. Such investments involve complex sets of stakeholders, leading to the need to consider organizational politics. Kozhikode and Li [29] studied to role of political pluralism in the expansion of commercial banks in India, including consideration of risk management. Industrial decision making not only involves multiple stakeholders, but also multiple criteria [41], driven in part by the very existence of these multiple stakeholders. Silvestri et al. [49] provided a multiple criteria risk assessment technique for risk analysis in manufacturing safety. Lakemond et al. (2013) gave a method for consideration of risk in product development, enabling early assessment of risk and other challenges [9,30].

3.4. Portfolio management

The events of 2008 beginning in the housing industry spread to seriously threaten the entire global banking industry. Risk management as an academic field has focused primarily on the financial industry, although there have been many efforts to expand that study to other fields, to include aspects of industry to include supply chains and information technology [42]. However, there continues to be a steady stream of articles addressing portfolio risk management. Chen [11] examined the use of derivatives in the hedge fund industry following the mortgage meltdown. A mean-variance model was used by DeMiguel et al. [14] to examine 14 models across 7 datasets to compare their relative efficiency considering return and risk.

The role of incentives in mutual fund investment was studied by Massa and Patgiri [33], finding that high-incentive contracts lead to investors taking on greater risks. This supported the traditional economic theory that risk and performance are positively correlated. Miccolis and Goodman [37] sought to update financial theory with respect to financial planning, specifically addressing the role of risk. Demarzo et al. [13] developed an analytic model seeking to update financial theory in light of recent events, confirming that investment decreases with idiosyncratic risk. Miccolis and Goodman [37] suggested improved means to manage portfolio risk following the 2008 financial meltdown.

3.5. Game based risk analysis

John Nash provided one of the most popular works in game theory (1950), studying the role of competitive strategy. This well-studied field is active in industrial risk management. Zhao and Jiang [58] considered a non-cooperative complete information game model considering multiple emerging risks in a project management environment. Merrick and Parnell [36] etended game theoretic models to include probabilistic risk analysis in the context of counterterrorism. Their application involved container screening for radiological materials. Lin et al. [32] used game theory to model vertical differentiation in online advertising, finding that a higher ad revenue rate may lead to lower service prices. Game theory has also been applied to small and medium-sized enterprise risk management by Gnyawali and Park [20,40].

3.6. Credit scoring decisions

The financial industry's primary tasks in risk management is to assess probability of default. Gurnÿ and Tichÿ [22] presented a scoring model for US banks using linear discriminant analysis. Chen et al. [12] offered another study, in this case using the Six Sigma DMAIC methodology to reduce financial risk. Wu and Olson [57] demonstrated how predictive scorecards have been used for large bank risk management of credit worthiness. Caracota et al. [8] gave a scoring model for small and medium enterprises seeking a bank loan. Poon [45] reviewed the effectiveness of government sponsored enterprise (Freddie Mac and Fannie Mae) credit scoring, showing how credit bureau scoring led to support of opposing strategies of risk averse and risk avaricious investment.

3.7. Data mining in enterprise risk management

Data mining has become a very popular means to apply statistical and artificial intelligence tools to analysis of large data sets. Among the many applications to risk management, Shiri et al. [48] applied data mining tools to corporate finance, to include management fraud detection, credit risk estimation, and corporate performance prediction. Jans et al. [26] focused their data mining study to address the risk of internal fraud, finding that data mining tools provided better results than univariate analysis. Holton also addressed occupational fraud, applying text mining to support fraud audits. In other industries, Nateghi et al. [39] applied data mining techniques to better predict power outages, especially those related to hurricanes. Ghadge et al. [18] reviewed text mining applications to support risk management in supply chains. Two studies specifically addressed use of data mining to reduce the risk of occupational injury [6,38,25].

3.8. Agent-based supply chain risk management

Artificial intelligence is often implemented through use of agent-based systems, having computers emulate human decision makers. This approach has been applied to risk management in supply chains by Smeureanu et al. [50] with specific examination of peer partner company risk of bankruptcy. Giannakis and Louis [19] also addressed supply chain risk management through agent models, in this case examining the inherent risks in both demand and supply of resources in economic downturns [27].

3.9. Other decision science methods and applications for enterprise risk management

There are a number of risk analyses that are more general than the above modeling categories. Srinivasa Raghavan and Mishra [52] discussed the negotiation between retailers and manufacturers within supply chains, involving risk of cash inventories. The insurance industry faces risks inherently, as risk management is what insurance does. Pauly et al. [44] modeled multi-period insurance to protect health insurance buyers from premium changes through guaranteed renewability. Information systems also involve high levels of risk. Hahn et al. [23] focused on the risk of outsourcing management information systems in terms of host country risk. Chen et al. [10] discussed the risks of implementing enterprise resource planning (ERP) systems.

4. This issue

We are very pleased at seeing this special issue of Mathematical and Computer Modelling. Over the past several decades, risk management has attracted a great deal of attention from both researchers and practitioners. Our call for papers cited substantial and important growth in the application of quantitative analysis, to interdisciplinary problems arising in Computational simulation and risk analysis. We seek to provide the primary forum for both academic and industry researchers and practitioners to propose and foster discussion on state-of-the-art research and development quantitative analysis in the areas of risk management. This special issue includes the broad coverage we were seeking, with theoretical modeling research of parametric VaR for the banking sector in an emerging market and in a developed one, an empirical paper using optimizing risk management in bond market, a practical application for computing the capital charge for operational risk of a bank, and a paper considering inventory models. a study simultaneous spectrophotometric estimation of Atorvastatin Calcium using Artificial Neural Networks and examination of single-integrator kinematics and double- order-integrator dynamics consensus protocols.

Herick Fernando Moralles et al. discuss parametric VaR (Value-at-Risk) with goodness-of-fit tests based on EDF statistics for extreme returns. Parametric VaR is said to be widely used due to its simplicity and easy calculation. However, the normality assumption, often used in the estimation of the parametric VaR, does not provide satisfactory estimates for risk exposure. Authors therefore suggest a method for computing the parametric VaR based on goodness-of-fit tests using the empirical distribution function for extreme returns, and compare the feasibility of this method for the banking sector in an emerging market and in a developed one. Authors also discuss possible theoretical contributions in related fields like enterprise risk management (ERM).

Lu investigate how the large deviation approach is used for computing the capital charge for operational risk of a bank. Firstly, the negatively - associated structure is utilized to measure the dependence structure between distinct operational loss cells. Secondly, in this framework, the lower and upper bounds about of the tail distribution function of total aggregated loss processes are given respectively determined. Moreover, In addition, the first order approximations using a Value-at-Risk measure are derived. Finally, an important example of calculating the capital charge for operational risk under the class of a heavy-tailed distribution is provided.

Bian and Liu analyze the optimal investment strategy in a corporate (defaultable) bond, a stock and a bank account in a continuous time model. Authors model the corporate bond price through a reduced-form approach and solve the dynamics of its price. A general risk-averse utility function is used in an optimal investment process, with which an optimal strategy is presented using martingale methods. The optimal investment strategy is analyzed numerically for the CARA utility. Wang, Yiu and Mak address problems in the traditional inventory models that focus on characterizing replenishment policies in order to maximize the total expected profit or to minimize the expected total cost over a planned horizon. However, for many companies, total inventory costs could be accounting for a fairly large amount of invested capital. Authors provide this perspective on inventory management that treats inventory problems within a wider context of financial risk management under a VaR constraint. The financial portfolio theory has been used to model the dynamics of inventories. A diverse portfolio consists of raw material inventories, which involve market risk because of price fluctuations as well as a risk-free bank account. The value-at-risk measure is applied thereto to control the inventory portfolio's risk. The inventory control problem is thus formulated as a continuous stochastic optimal control problem with fixed and proportional transaction costs under a continuous value-at-risk (VaR) constraint. The optimal inventory policies are derived by using stochastic optimal control theory and the optimal inventory level is reviewed and adjusted continuously.

Sohrabi et al. study simultaneous spectrophotometric estimation of Atorvastatin Calcium and Amlodipine Besylate in Amostatine® tablets using UV-Vis spectroscopic and Artificial Neural Networks (ANN). Absorption spectra of two components were recorded in 200–350 (nm) wavelengths region with an interval of 4 nm. The calibration models were thoroughly evaluated at several concentration levels using the spectra of synthetic binary mixture. Three layers feed-forward neural networks using the back-propagation algorithm (B.P) has been employed for building and testing models. A general statistic function, Sum Square Error (SSE), was selected to evaluate the training process of ANN. The results showed a very good agreement between true values and predicted concentration values.

Feng et al. consider single-integrator kinematics and double-order-integrator dynamics consensus protocols. These consensus protocols with memory are presented by introducing the last state information (such as position, velocity) of multi-agent. The numerical results show that these protocols have high convergence speed.

5. Conclusion

Review of a sample of recent work in these topics clearly shows a widespread interest in computational risk management in several aspects. As our world and economy both become more complex, involving interactions of diverse actors, it is necessary to utilize ever more complex modeling approaches. However, there clearly have been advances enabling more informed decision making in managing of all aspects of risk.

There is an increasing tendency toward an integrated or holistic view of risks. Enterprise Risk Management (ERM) is an integrated approach to achieving the enterprise's strategic, programmatic, and financial objectives with acceptable risk. The philosophy of ERM generalizes these concepts beyond financial risks to include all kinds of risks beyond disciplinary silos [42].

Maintaining a certain level of risk has become a key strategy to make profits in today's economy. Risk in industry can be quantified and managed using various models. Models also provide support to organizations seeking to control enterprise risk.

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