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The Institute for Integrating Statistics in Decision Sciences

Games and Decisions in Reliability and Risk Analysis

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From the Editors:

Games and Decisions in Reliability and Risk Analysis

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The objective of this special issue is to introduce the new theme, use of game and decision theory in reliability modeling and risk analysis, which was the focus of the First Symposium on Games and Decisions in Reliability and Risk (GDRR) held at the George Washington University on May 27-28, 2009. The issue considered papers presented at the Second Symposium on GDRR, (http://www.mi.imati.cnr.it/conferences/gdrr11.html), held at the Hotel Villa Carlotta, Belgirate (VB), Lake Maggiore, Italy, on May 19–21, 2011 and also was open to the public for submission of papers relevant to the theme. The contributors to the special issue include Sevillano, Rios Insua, and Rios; Delquié; Foschi and Spizzichino; French; Bhattacharjya and Deleris; Bhattacharjya and Shachter; Lejeune; Cheung and Zhuang; Smith and Dodd; Sribhashyam and Montibeller; and Paté-Cornell.

Key words: decision analysis; adversarial risk analysis; aggregation of expert judgment; ageing; airline industry; analytics; applications: security; asymmetry; Bayesian models; Bayes net; burn-in; coal mining; competition between companies; counter-terrorism; decision circuit; decision making; decision tree; defender-attacker models; disaster; enhanced indexation expected utility; failure probability; fault tree circuit;

formulation; game analysis; game theory; Gini's mean difference; influence diagram; meta-analysis; mixed strategy; multiattribute utility theory; nuclear power; national security; nuclear proliferation; oil spill; piracy; practice; principal-agent model; public participation; pure strategy; regulation; reliability; reliability diagnosis; risk; risk analysis; risk measures; sensitivity analysis; state-dependent priorities; stochastic optimization; stochastic orderings; textbook problem; terrorism; terrorist threats; utility functions; value of information; value models; editorial

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As presented in the Call for Papers (Keller et al., 2011), "The objective of this special issue is to introduce a new theme, the use of game theory and decision theory in reliability analysis and risk analysis. The special issue aims to bring together novel research from disciplines that have the potential to contribute to this theme, including (but not limited to) economics, engineering, finance, mathematics, medical sciences, military sciences, probability, and statistics." Papers tackle a problem in risk or reliability using the tools of decision theory or game theory (or both). The issue considered papers presented at the Second Symposium on Games and Decisions in Reliability and Risk[1] (GDRR), and also was open to the public for submission of papers relevant to the theme. The papers from the First Symposium on GDRR appeared in a special issue (http://onlinelibrary.wiley.com/doi/10.1002/asmb.v27.2/issuetoc) of the journal *Applied Stochastic Models in Business and Industry*.

Jason Merrick, Fabrizio Ruggeri, and Refik Soyer served as the three guest editors for this special issue. Jason Merrick is an associate editor for *Decision Analysis*. His prior contributions to *Decision Analysis* include Merrick and McLay (2010) on screening cargo containers, Merrick (2009) on Bayesian simulation, Merrick et al. (2005a) on watershed improvement needs, Merrick et al. (2005b) on correlated expert judgments, and Merrick (2008) on the right mix of experts. Fabrizio Ruggeri specializes in Bayesian statistics and its applications (mostly industrial ones). Along with Simon French and David Rios Insua, Fabrizio Ruggeri contributed to *Decision Analysis* in French et al. (2007) on "e-participation" in democratic systems. Refik Soyer's research focuses on statistical and decision theoretic aspects of reliability analysis and Bayesian statistics. Soyer was the guest editor of the special issue of the *Applied Stochastic Models in Business and Industry* on GDRR.

Our first article, "Adversarial Risk Analysis: The Somali Pirates Case," by Juan Carlos Sevillano, David Rios Insua, and Jesus Rios addresses the current practical problem of ocean piracy. Sevillano et al. (2012) show how Adversarial Risk Analysis (ARA) can be used to formulate and solve a sequential game involving a ship owner and pirates as the two players. The authors consider a defend-attack-defend formulation of the problem where the ARA approach enables the ship owner to model uncertainty about pirates' actions.

Prior papers in *Decision Analysis* by these authors include Rios and Rios Insua (2009) on "Supporting Negotiations over Influence Diagrams," and David Rios Insua's other prior contribution to *Decision Analysis,* French et al. (2007), on "*e*-Participation" in democracies. David Rios Insua serves on the *Decision Analysis* editorial board. A recent paper on ARA in *Decision Analysis* is by McLay et al. (2012) entitled "Robust adversarial risk analysis: A Level-*k* approach."

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[1] The conference was held at the Hotel Villa Carlotta, Belgirate (VB), Lake Maggiore, Italy, on May 19–21, 2011 http://www.mi.imati.cnr.it/conferences/gdrr11.html.

The second paper is by Philippe Delquié on "Risk Measures from Risk-Reducing Experiments." Delquié (2012) considers derivation of risk measures using experiments that reduce uncertainty in a gamble. The proposed approach provides risk measures to order gambles without consideration of any utility function or attitude for risk. The author shows that well-known risk measures such as lower absolute semi-deviation and Gini mean difference can be obtained using risk-reducing experiments.

In a prior related paper, Delquié (2008) examined the value of information and intensity of preference. An earlier *Decision Analysis* paper related to risk measures is by Denuit and Eeckhoudt (2010) on bivariate stochastic dominance and substitute risk-(in)dependent utilities. Delquié is on the *Decision Analysis* editorial board, and has served as an associate editor, see Keller et al. (2011).

The paper by Rachele Foschi and Fabio Spizzichino is on "Interactions between Ageing and Risk Properties in the Analysis of Burn-in Problems." Foschi and Spizzichino (2012) consider the determination of optimal burn-in time, an important decision problem in life testing. In so doing, the authors point out a connection between ageing properties of survival functions and risk aversion and present a characterization of ageing properties based on the notion of risk-aversion. The characterization is used to obtain the optimal burn-in time for some ageing properties. The authors consider different reward functions and point out that the characterization can be used to obtain bounds for optima in some cases.

An earlier paper in *Decision Analysis* on reliability is by Paté-Cornell and Dillon (2006) who considered use of risk analysis methods to increase safety and reliability of systems.

The next article is by Simon French on "Expert Judgement, Meta-Analysis and Participatory Risk Analysis." French (2012) focuses on the *textbook problem* in using expert judgments in decision and risk analysis. The textbook problem involves cases where previously elicited expert judgments in similar contexts are used for a specific decision problem. As pointed out in the paper, to an extent the problem resembles that of using meta-analysis in empirical studies. The author discusses the importance of the textbook problem in societal decision and risk analysis and notes the lack of methodology for developing a solution to the problem. Furthermore, French emphasizes the difficulties associated with the problem and its differences from the empirical studies using meta-analytic approaches. The author presents several examples of contexts where the problem arises including the work of the "Intergovernmental Panel on Climate Change" and identifies publication of expert judgment studies and design of subsequent meta-analyses as two areas that need to be developed.

A prior paper in *Decision Analysis* by Simon French is French et al. (2007) on "e-participation and Decision Analysis." Simon French is a member of the *Decision Analysis* editorial board. A related paper is Gregory et al. (2005) on guiding public policy discussions. Other articles on expert judgments appearing recently in *Decision Analysis* include Abbas (2008, Bordley (2009), Predd et al. (2008), and Merrick (2008).

The next two papers in the special issue address the use of graphical models, one by Debarun Bhattacharjya and Léa A. Deleris on fault tree circuits and the other by Debarun Bhattacharjya

and Ross D. Shachter on decision circuits. These graphical representations are related to the influence diagrams (or Bayes networks) commonly used in decision analysis as an alternative to decision trees. Bhattacharjya and Deleris (2012) present a new method to convert "From Reliability Block Diagrams to Fault Tree Circuits." The authors introduce fault tree circuits which provide a more efficient representation of the reliability block diagrams than what is provided by Bayes networks and show computational benefits of using fault tree circuits. Bhattacharjya and Shachter (2012) point out that decision circuits, that combine benefits of decision trees and influence diagrams, are suitable for asymmetric decision problems that often arise in reliability and risk analysis. The authors show how decision circuits can be constructed directly in decision problems and how they provide more flexibility than decision trees in solving asymmetric decision problems. The implementation of a decision circuit and its benefits are shown by the authors using an example on nuclear plants.

A prior paper in *Decision Analysis* by Ross Shachter is Detwarasiti and Shachter (2005), on influence diagrams for team decision making. A related recent paper in *Decision Analysis* is by Li and Shenoy (2012) who developed an algorithm for approximate solution of a certain class of influence diagrams. Other papers on influence diagrams that have appeared in *Decision Analysis* include Boutilier (2005), Buede (2005), Howard and Matheson (2005ab), Matheson and Matheson (2005), Pauker and Wong (2005), Pearl (2005) that were all in the special issue edited by Horvitz (2005ab), and Cobb (2007), and Rios and Rios Insua (2009).

Our next two articles involve game theoretic modeling. The article by Miguel Lejeune is on a "Game Theoretical Approach for Reliable Enhanced Indexation" and the one by May Cheung and Jun Zhuang analyzes "Regulation Games between Government and Competing Companies: Oil Spills and Other Disasters." Lejeune (2012) presents a stochastic excess return model for developing enhanced index funds subject to relative risk constraints. The proposed approach involves a game theoretic formulation of the enhanced indexation problem and uses a computationally efficient stochastic programming method for the solution. The author illustrates an implementation of the methodology using actual weekly and monthly returns data from 700 stocks. Cheung and Zhuang (2012) consider games where the government is one of the players as a regulator. The authors investigate the effect of competition in such games where more than one company is involved in the game and where the companies are revenue maximizers/loss minimizers. Their findings suggest that competition implies higher risk tolerance for companies and results in stricter regulations. The authors use a game involving oil companies in their development and also discuss potential applications in industries such as airlines, nuclear energy etc.

In a prior paper in *Decision Analysis*, Hausken and Zhuang (2011) presented a two-stage game model between the government and terrorists. Jun Zhuang is a member of the *Decision Analysis* editorial board. Game theory approaches have been used in other *Decision Analysis* papers. Cobb and Basuchoudhary (2009) developed a modified decision theoretic approach to solve two-player games, with each player having a separate decision tree. Cavusoglu and Raghunathan (2004) compared decision theory versus game theory for analyzing detection software, and Lippman and McCardle (2004, 2012) presented a method for dividing an estate.

The next paper is by Jim Q. Smith and Lorraine Dodd on "Regulating Autonomous Agents facing Conflicting Objectives: A Command and Control Example." Smith and Dodd (2012) consider a military command and control (C2) regulator that transfers decision autonomy to field commanders who act as rational expected utility (EU) maximizers in most decision making situations. Smith and Dodd (2012) investigate how and why the commanders sometimes deviate from being subjective EU maximizers. The authors present a two-attribute utility model of the commanders' preferences to study the above issues and illustrate how such deviations arise in military operations using an example from a military conflict. In so doing, they discuss how the C2 regulator can make use of the model to minimize irrational decisions by the commanders.

Other articles on military applications can be found in the *Decision Analysis* papers by Keefer, Kirkwood and Corner (2004), Ewing et al. (2006), and Klimack and Kloeber (2006).

The last two articles deal with terrorism and national security issues. The paper by Sumitra Sribhashyam and Gilberto Montibeller is on "Modeling State-Dependent Priorities of Malicious Agents" and the article by Elisabeth Paté-Cornell is on "Games, Risks and Analytics: Several Illustrative Cases Involving National Security and Management Situations." Sribhashyam and Montibeller (2012) address use of decision analysis models to describe terrorists' behavior. They point out that most of the current literature in decision analysis considers static models that do not take into account changes in terrorists' values and preferences over time. The authors propose a dynamic framework using multi-attribute utility models that incorporate state-dependent utilities to reflect such changes over time. They present their framework and illustrate how state-dependent utility models can be used to predict terrorist behavior. They also discuss how the model can be used to gain additional insights about priorities and preferences by using the Lockerbie bombing case. In the final paper, Paté-Cornell (2012) considers different models in games and risk analysis motivated by national security issues and project management. The common themes of the four cases presented by the author are the presence of uncertainty, involvement of multiple decision makers and risks to the decision maker(s). In addition, all four cases present different levels of complexities due to the dynamic nature of the decision making environment, the uncertainties, preferences and choices. Thus, as pointed out by the author all four situations can be considered as examples in the rising field of *analytics*.

Gilberto Montibeller serves on the *Decision Analysis* Editorial Board. Elisabeth Paté-Cornell's other contributions to *Decision Analysis* include Caswell, Howard, and Paté-Cornell (2011) and Pate-Cornell and Dillon (2006).

Earlier articles in *Decision Analysis* on terrorism and national security issues include Barrett (2010), Caswell et al. (2011), Feng and Keller (2006), Hausken and Zhuang (2011) and von Winterfeldt and O'Sullivan (2006). Other papers in *Decision Analysis* that used game-theoretic approaches to assess risks of terrorism are Wang and Bier (2011) where authors used a multi-attribute utility function for attacker preferences, and Haphuriwat et al. (2011) who considered smuggling of nuclear weapons and Bakir (2008) and Merrick and McLay (2010) on screening of cargo containers.

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