

ICDRiA

INTERNATIONAL CENTER FOR
DECISION AND RISK ANALYSIS

Annual Meeting

1 December 2009

The School of Management
THE UNIVERSITY OF TEXAS AT DALLAS



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Table of Contents

<u>Section</u>	<u>Page</u>
I. AGENDA	5
II. ICDRIA ADVISORY BOARD MEMBERS	7
III. ACTIVITY REPORT	9
1. INTRODUCTION	9
2. EXPANSION: HONG KONG AND KOREA BRANCHES	9
3. EDUCATION PROGRAM	10
4. RESEARCH PROGRAM	10
4.1 Risks and Uncertainties in Information Systems	10
4.2 Risks in Supply Chain Management	11
4.3 Risks in Financial and Economic Systems	11
4.4 Risks on Technical Systems	12
5. PRESENT ACTIVITIES IN THE SECURITY IN INFORMATION SYSTEMS DOMAIN	12
5.1 Information Security in Networked Supply Chains: Impact of Network Vulnerability and Supply Chain Integration on Incentives to Invest	12
5.2 Impact of Competition on Firms' Decisions to Outsource Security	13
5.3 An Analysis of the Impact of Passenger Profiling for Transportation Security	13
5.4 Economics of User Segmentation, Profiling, and Screening in Security	13
5.5 Privacy in E-commerce Channels: Impacts of Customer Addressability and Search Costs	14
5.6 Cyber Security Risk Management: Public Policy Implications of Correlated Risk and Imperfect Ability to Prove Loss	14
5.7 Configuration of and Interaction between Information Security Technologies: The Case of Firewalls and Intrusion Detection Systems	15
5.8 Configuration of Detection Software: A Comparison of Decision and Game Theory Approaches	15
5.9 The Value of Intrusion Detection Systems (IDSs) in Information Technology Security Architecture	16
5.10 Intrusion-Detection Policies for IT Security Breaches	16
5.11 Evaluation of Intrusion Detection Systems under an Inspection Constraint	16
5.12 Privacy Preservation Techniques for Distributed Transactional Databases	17
5.13 Optimal and Heuristic Approaches to Sanitizing Large Transactional Databases	17
5.14 Maximizing Accuracy when Modifying Transactional Databases to Hide Sensitive Association Rules	18
5.15 A Data Perturbation Approach to Privacy Protection in Data Mining	18
5.16 Protecting Privacy against Re-identification by Record Linkage	18
5.17 Intrusion Prevention in Information Systems: Reactive and Proactive Responses	19
6. PRESENT ACTIVITIES IN THE SUPPLY CHAIN DOMAIN	19
6.1 Partially Observed Inventory Systems	19
6.2 Computation of Approximate Optimal Policies in Partially Observed Inventory Model with Rain Checks	19
6.3 Optimal Policy and Value of Information in an Inventory Model with Lost Sales and Demand Updates	20
6.4 Optimal Ordering Policies for Stochastic Inventory Problems with Observed Information Delays	20
6.5 Numerical Analysis of Partially Observable Inventory System: Economic Loss from Mean Based Policy	20
6.6 Assessing the Loss due to Parsimony	21
6.7 Optimal Transshipments and Orders: A Tale of Two Competing and Cooperating Retailers	21
6.8 Inventory Sharing with Positive Transshipment and Replenishment Lead Times	21
6.9 Forecasting Sales for Heating, Ventilating and Air Conditioning (HVAC) Products	22
6.10 Contracting and Coordination under Asymmetric Production Cost Information	22
6.11 On the Selection of Supply Chain Coordinating Contracts: The Role of Capital Constraints	22
6.12 Coordination of Supply Chains with Risk-Averse Agents	23
6.13 Channel Coordination with a Risk-Neutral Supplier and a Downside-Risk-Averse Retailer	23
6.14 A Two-Stage Newsvendor Problem with a Service Constraint	23
6.15 The Machine Maintenance and Sale Age Model of Kamien and Schwartz Revisited	23
6.16 Cooperative Advertising and Pricing in a Dynamic Stochastic Supply Chain: Feedback Stackelberg Strategies	24
6.17 A Supply Chain with a Service Requirement for Each Market Signal	24
6.18 Coordination Mechanism for the Supply Chain with Leadtime Consideration and Price-Dependent Demand	24

6.19 Procurement Flexibility under Price Uncertainty	25
6.20 Inventory Management: Information, Coordination and Rationality	25
6.21 New Policies for the Stochastic Inventory Control Problem with Two Supply Sources	25
6.22 Asymptotic Optimality of Order-Up-To Policies in Lost Sales Inventory Systems	26
7. PRESENT ACTIVITIES IN FINANCE AND ECONOMICS	26
7.1 Real Options and Game Models	26
7.2 Value of Population in Economic Growth Models	26
7.4 Cash Management	27
7.5 Mutual Insurance	27
V. PUBLICATIONS	29
VI. RISK AND DECISION ANALYSIS	33
VII. INTERNATIONAL RESEARCH FORUM, 15-17 DECEMBER 2010.....	35
VIII. ICDRIA ACTIVITIES AND DEVELOPMENT – ALAIN BENSOUSSAN	42



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Alain Bensoussan
Distinguished Research Professor
Director

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Advisory Board Meeting December 1, 2009

I. Agenda

- **Message from the ICDRiA Chair**
 - **Bill Krenik, Chief Technologist, Standard Linear and Logic Products, Texas Instruments**
- **Presentation of Participants**
- **ICDRiA Activities and Development Strategy**
 - **Alain Bensoussan**
 - **Sumit Sarkar**
 - **Raghunathan Srinivasan**
 - **Metin Çakanyildirim**
 - **Hylan Lyon**

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II. ICDRiA Advisory Board Members

Industry Members

Chair: Bill Krenik, Wireless Advanced Architectures Manager, TI
John Carrier, President, Essilor North America
Monty Humble, Vice President and General Counsel, Mesa Power Group
David Kohl, Senior Vice President, Roach Howard Smith & Barton
Christophe Lamarsaude, VP Innovation, Strategy, and Alliance, Alcatel
Hylan Lyon, Managing Director of Research, Dumas Capital Partners LLC.
Advisor for Development, ICDRiA, UTD
Tahar Mjigal, Representative, Global Association of Risk Professionals (GARP)
Laslo Olah, President/CEO, TxIS
Daniel Parry, Chief Credit Officer, Exeter Finance Corp.
Arun Ratnam, Representative, Global Association of Risk Professionals (GARP)
Peter Reid, Chief Privacy Officer, EDS
Ray Russo, Civil Works Program Manager, USACE
Harolde Savoy, President/CEO, Blueline/Rediform
Represented by: Greg Turi, Blueline/Rediform
David Shaw, President, Global Uni-Docs Corporation
Yoram Soloman, Senior Director for Marketing and Industry Relations, TI
Jean Paul Vignal, Partner, JP2Consultants
Yi Zhao, Vice President, Future Wei

UTD Academic Members

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Bruce Gnade, Vice President for Research
Hasan Pirkul, Dean, School of Management
Metin Çakanyildirim, Operations Management
Ganesh Janakiraman, Operations Management
Murat Kantarcioglu, Computer Science
Robert Kieschnick, Finance and Managerial Economics
Vijay Mookerjee, Information Systems
Ozer Ozalp, Operations Management
Suresh Radhakrishnan, Accounting and Information Management; Director of Research, Institute for Excellence in Corporate Governance
Srinivasan Raghunathan, Information Systems
Divakar Rajamani, Managing Director of the Center for Intelligent Supply Networks
Sumit Sarkar, Information Systems
Suresh Sethi, Director of the Center for Intelligent Supply Networks
Bhavani Thuraisingham, Director of Cyber Security Research Center
Janos Turi, Department of Mathematics
Mathukumalli Vidyasagar, Mechanical Engineering

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Alain Bensoussan
School of Management
ICDRiA Activity Report (August 1, 2008- October 31, 2009)
Date: December 1, 2009

III. Activity Report

1. Introduction

The International Center for Decision and Risk Analysis was created in September 2004, as a Research Center of the School of Management. Its objective is to develop education and research programs in the field of Risk Analysis and Decision Making. We report in this document the accomplishments during the period fall 2008 and year 2009.

2. Expansion: Hong Kong and Korea Branches

Since January 2009, Alain Bensoussan has a joint appointment with UTD and the Hong Kong Polytechnic University, Graduate School of Business and Department of Logistics and Maritime Studies. At PolyU he is Chair Professor of Risk and Decision Analysis. It is extremely positive that this joint appointment is considered by both Universities as a strong commitment to develop all kinds of cooperation. In particular, the research activities that ICDRiA is pursuing should be coordinated with those at PolyU. This is materialized by the fact that a Hong Kong branch of ICDRiA will be opened and hosted by the ICMS, the International Center of Maritime Studies, headed by Professor John Liu.

An additional opportunity occurred when Ajou University in Korea won a national competition in the domain of Financial Engineering under the World Class University program. It was decided to formalize a tri-lateral agreement between the three Universities to open ICDRiA branches both in Hong Kong and in Korea. The Korean branch will be hosted by the Department of Financial Engineering (World Class University Project and Graduate Department of Financial Engineering, WCUP-GDFE) of Ajou University.

The activities will begin in earnest in 2010. The general idea is to have common programs with local funding to avoid any difficulty in transferring funds. This is an initiative created at the ground-level, and while the respective universities of those involved endorse the initiative, the universities themselves are not committed beyond ICDRiA's activities. It is expected that this initiative will cover a broad spectrum academically by pooling expertise from different countries and become an example of how to implement the concept of networked universities.

An international conference is among the immediate joint activities. The conference will be held in Hong Kong in December 2010. The title of the conference—"What can the Academic Community learn from the global crisis?"—indicates the objective is to encourage scientists to look at the global crisis as they would an experiment. This hopefully will lead to new concepts, models, educational activities, as well as,

transfer actions. New York University, College de France and Imperial College have joined PolyU.,UTD and Ajou to form the group of sponsoring institutions.

3. Education Program

Risk Analysis is now included in the education programs of the School of Management. Unfortunately, in 2009, Alain Bensoussan was on a leave of absence and was unable to teach the class. It is important to find another Faculty to replace him.

The course “Introductory Mathematical Finance” has been offered as a part of the Master in Finance for Fall 2008 and Fall 2009. The class attracts motivated students and is attended by doctoral level students as well; some of which are from the Mathematics Department.

Alain Bensoussan is among the group of Faculty supervising the new program on Systems Engineering, which is a joint initiative of the School of Engineering and the School of Management. Risk Analysis is included in the program.

4. Research program

The center has four main directions of research and applications. The first is *Risks and Uncertainties in Information Systems*; the second is *Risks in Supply Chain Management*; the third is *Risks in Financial and Economic Systems*; and the fourth concerns *Risks in Technical Systems*.

4.1 Risks and Uncertainties in Information Systems

The center benefits from the activity of a group of faculty focused on security issues in information systems, a major strength of the School of Management. The center cooperates also with the Cyber-security Center of the School of Engineering, headed by Professor Bhavani Thuraisingham. In this context, we have been associated to a MURI project obtained by this center, on *Assured Information Systems sharing*. Our activities in this domain concern managerial aspects at both the design phase and the operational phase.

We have proposed a model of access to information based on a scoring procedure which has analogies with that of a credit score. There are some common issues in both situations; one of which is the idea of building trust. Based on a good or bad score (using the score as an indicator of trust) the access to information (as the access to credit) is more or less difficult.

Another example of the project in this domain concerns the development of models representing defense against hackers’ activity. The challenge is to design information systems which protect an organization against hackers using a cost benefit point of view. There is an optimal dynamic policy to be put in place optimizing a payoff combining expenses to improve security with benefits in lowering the damages caused by intrusions.

Many models can be implemented. One can think of optimization problems or game problems, deterministic or stochastic models, continuous evolution of the indicator of resistance, or evolution with shocks.

In addition, a new and important area of research has been proposed by Murat Kantarcioglu. It concerns the problem of botnets. This extends the framework of defense against hackers, which is a game with two players, in which the motivation of the hacker may not be financial. In the botnet model, there is a market

of malignant actions. An entity interested in being harmful to another entity buys the services of a botnet dealer, which will install bots in the victim's information system. It is a game with three players. We have so far only preliminary elements of a realistic model.

4.2 Risks in Supply Chain Management

In the "supply chain" area, the center relies mainly on the expertise of the Operations Management department. Risk arises from uncertainties at all stages of the supply chain. In particular, there are uncertainties on key variables needed to make decisions. For instance, one does not know the inventory and one must decide on the level of replenishment. Uncertainties on inventories have been at the core of our research since 2005, when we were awarded an NSF grant to support the research in this topic over a period of three years. It is now completed and the final report has been sent to NSF.

This grant supported four post-doc and doctoral students. We developed a general methodology which provides the optimal policy for managing inventories in the context of uncertainties. This is an original result, which was not known before. We have shown numerically that this optimal policy provides a real improvement in lowering cost compared to a policy based on the best estimate of the inventory. We have also introduced efficient and easy-to-implement approximate policies based on the mean and the variance of the inventory. This research was also funded by a two-year grant awarded by the ARP-ATP program of the state of Texas.

We now would like to explore other sources of uncertainties around demand in addition to the inventory. Demand is of course an essential source of risk for companies and also provides a wide diversity of modeling possibilities. We have had successful cooperation in this area with BlueLine-Rediform using statistical methods to deal with seasonality factors. As a major outcome, the student supported on this grant has been hired by the company. His work is at the origin of a new approach to forecast the demand that is now operational.

After much success, we face now the difficulty that this research is closer to development than to fundamental research. Therefore, NSF is no longer the appropriate agency. However, industry will be reluctant to fund such a development. (BlueLine-Rediform has been an exception in the focused area of forecasting the demand).

4.3 Risks in Financial and Economic Systems

In the third direction, we have considered several questions. Financial Engineering is a particularly challenging domain, and the present crisis will transform the needs. We expect many opportunities in the mid- and long-term. More research is needed that would make stronger connections between financial decisions and risk management and between the financial world and the 'real world'. This objective is at the core of the future activities in common between the three universities as partners of ICDRiA. This objective is also at the core of the reflection underpinning the 2010 conference.

At this stage in our efforts, we are identifying trends. In the context of coupling the financial world to the real world, we are particularly interested in the use of "Real options," which aims at adapting techniques from financial engineering in project risk management. We have seen in particular that the pharmaceutical industry and the aeronautical industry are making use of these methods for R&D projects. We want to apply this theory to investments in energy and water resources problems.

Thanks to a support from the University of Texas at Dallas, we have financed a post-doc to study desalination projects, applying concepts and methods from real options theory. A former PhD student

associated with the center and presently Assistant Professor at the American University of Beirut is cooperating with us in this domain.

The funding expected from the authorization included in the Water Resource Development legislation has not yet led to an appropriation in 2009 or 2010. However, since we expect cooperation with EDF (Electricité de France), we focus on the domain of wind power. In the first phase we will limit ourselves to modeling wind uncertainties. This is a very rich domain in itself with abundant literature and substantial possibilities of improvement.

Of course, considering wind uncertainties is limited, although an indispensable stage. There are many other types of uncertainty in water resource development which affect the decision making. So while our effort is not a risk management approach, it is an important and necessary component of a risk management approach.

4.4 Risks on Technical Systems

In the fourth domain, we work on technical risk management. This research was initiated by a contract with the French Atomic Energy Agency (CEA) to study the effect of vibrations on mechanical structures. This potentially leads to assessing the risk of collapse of buildings subject to seismic vibrations. We have developed new methods and new mathematical tools, which were sufficiently promising to justify a proposal to NSF which was awarded in July 2007. The CEA has also increased its support to our group. We have supported a master student, who is going to start a PhD both at UTD and in the University Pierre et Marie Curie. This research is done in cooperation with Professor Janos Turi, from the Mathematics Department. In relation with the NSF contract, we have obtained an extension to cooperate with the Hungarian Academy of Sciences.

5. Present Activities in the Security in Information Systems Domain

5.1 Information Security in Networked Supply Chains: Impact of Network Vulnerability and Supply Chain Integration on Incentives to Invest

Participants: Tridib Bandhopadhyay, Varghese Jacob, Srinivasan Raghunathan

Recent supply chain reengineering efforts have focused on integrating firms' production, inventory and replenishment activities with the help of communication networks. While communication networks and supply chain integration facilitate optimization of traditional supply chain functions, they also exacerbate the information security risk: communication networks propagate security breaches from one firm to another, and supply chain integration causes breach on one firm to affect other firms in the supply chain. We study the impact of network security vulnerability and supply chain integration on firms' incentives to invest in information security. We find that even though an increase in either the degree of network vulnerability or the degree of supply chain integration increases the security risk, they have different impacts on firms' incentives to invest in security. If the degree of supply chain integration is low, then an increase in network vulnerability induces firms to reduce, rather than increase, their security investments. A sufficiently high degree of supply chain integration alters the impact of network vulnerability into one in which firms have an incentive to increase their investments when the network vulnerability is higher. Though an increase in the degree of supply integration enhances firms' incentives to invest in security, private provisioning for security always results in a less than socially optimal security level. A liability mechanism that makes the responsible party partially compensate for the other party's loss induces each firm to invest at the socially optimal level. If firms choose the degree of integration, in addition to security

investment, then firms may choose a higher degree of integration when they decide individually than when they decide jointly, suggesting an even greater security risk to the supply chain.

5.2 Impact of Competition on Firms' Decisions to Outsource Security

Participants: Huseyin Cavusoglu, Asunur Cezar, Srinivasan Raghunathan

The scale and scope of information security outsourcing has been on the rise. Security experts predict that most firms are likely to outsource information security function in the future as they do IT development and operations currently. These experts cite reasons such as cost saving from economy of scale, quality improvements because of aggregation of expertise, and security audits and regulatory compliance for information security outsourcing. We posit risk correlation as an explanation for outsourcing security. One of the costs that a firm incurs when its security is breached, but the competitor's is not, is the loss of customers to the competitor. If both firms are breached or both firms are not breached, then one firm may not gain at the expense of the other. Firms prefer higher risk correlation when risk exceeds the reward and lower risk correlation otherwise. We perform the analysis using a simple two-firm, one-security-provider model.

5.3 An Analysis of the Impact of Passenger Profiling for Transportation Security

Participants: Huseyin Cavusoglu, Byungwan Koh, Srinivasan Raghunathan

Selective screening of passengers based on their profiles has been touted as a solution to efficiently and effectively provide transportation security, while simultaneously minimizing the inconvenience caused to normal passengers that do not have any incentive to attack. The proponents of profiling claim that a targeted allocation of screening efforts by adopting screening systems with possibly different configurations for likely attackers and normal users will reduce security cost, improve detection of attackers, increase the reliability of signals from screening devices, and lead to a reduction in the inconvenience of normal users. In this paper, we theoretically assess the above claims. We find that, contrary to the claim of proponents of profiling, profiling does not improve the overall reliability of signals from the screening devices. More importantly, profiling increases the inconvenience cost to normal users. On the other hand, profiling increases the fraction of attackers detected and decreases the overall cost of security. An increase in the quality of the profiler enhances the detection of attackers and reduces the cost of security, but may also exacerbate the inconvenience cost to normal users. On the other hand, an increase in the quality of the screening device diminishes the need for a profiler. The results suggest that the benefits of profiling to a firm come at the expense of normal users, and offer support to profiling opponents based on economic rather than traditionally used legal criteria.

5.4 Economics of User Segmentation, Profiling, and Screening in Security

Participants: Srinivasan Raghunathan, Huseyin Cavusoglu, Bin Mai

User profiling is touted as an effective and efficient tool to detect security breaches because it allows firms to target their inspection efforts at likely attackers and reduce inspection of likely normal users. However, because profiling uses superficial individual-specific criteria, it is susceptible to gaming by attackers who may be able to fake their attributes to trick the profiler into classifying them as normal users. We first analyze the impact of gaming by attackers on the firm for two types of profiling commonly used in practice – the profiler separates out attackers and the profiler separates out normal users. For both of these cases, we show that profiling hurts the firm if the profiling accuracy is sufficiently low. Surprisingly, we find that profiling may hurt the firm also when the profiling accuracy is sufficiently high. The latter result occurs because an increase in the profiling accuracy makes faking more attractive

to attackers. Therefore, even when profiling is better than not profiling, the optimal profiling accuracy, which depends on the faking cost, could be less than 100%. A lower faking cost expands the region in which the firm realizes a lower payoff when it uses profiling than when it does not. We also find that, contrary to the conventional wisdom, as the firm becomes better at discriminating attackers and normal users, the inspection rates for the two groups become more similar when faking is an issue. We show that the negative effects of profiling can be mitigated if the firm uses two screening devices, one for each user group. However, the additional cost of operating a second screening device may offset the gain.

5.5 Privacy in E-commerce Channels: Impacts of Customer Addressability and Search Costs

Participants: Bin Mai, Nirup Menon, Srinivasan Raghunathan, and Sumit Sarkar

In electronic markets, because a seller knows the identity of customers and is able to observe the manner and content of a customer's search, product selection, and price paid during online shopping, private information of a customer such as product preferences and valuation (willingness to pay) is often "leaked" to the seller. When the seller is able to use the valuation information to price discriminate a customer in the future, the impact on the customer's surplus is negative; this is the customer's loss resulting from loss of privacy. On the other hand, when the seller uses preferences information to target a product-price offering to a customer, the customer's search costs are reduced, thus benefiting the customer. We examine the problem where a seller chooses a product-price offer to induce participation from a customer, and the customer is aware that participation would lead to leakage of information. We show that, contrary to the conventional wisdom, strategic customers are not worse off in e-commerce channels compared to conventional channels, and customer surplus never decreases when search cost decreases in e-commerce channels. On the other hand, myopic customers are not better off in e-commerce channels compared to conventional channels, and their surplus never increases when search cost decreases. These results reject the view that e-commerce channels hurt customers, and simultaneously offer strong theoretical support for the efforts of privacy advocates in converting myopic customers to strategic ones. E-commerce channels benefit sellers also because they are able to extract the customer's search cost; thus, the social welfare is higher in e-commerce channels than in conventional channels. We find that, from the seller's perspective, customers' preference and valuation information behave as complements.

5.6 Cyber Security Risk Management: Public Policy Implications of Correlated Risk and Imperfect Ability to Prove Loss

Participants: Hulusi Ogut, Nirup M. Menon, Srinivasan Raghunathan,

Correlated security breach risks and imperfect ability to prove loss from a breach to an insurer, among others, have posed significant challenges to cyber security risk management. Cyber security risks are correlated because IT infrastructures of firms are dominated by a few technologies exposing firms to similar vulnerabilities. Firms' reliance on shared public networks to conduct business also contributes to risk correlation. Firms have an imperfect ability to prove loss from a security breach to an insurer because a significant portion of the loss from a security breach is intangible and, more importantly, firms fail to detect security breaches. Risk correlation and the imperfect ability to prove loss force firms to make socially sub-optimal levels of investments in self-protection and insurance. We show that the appropriate social intervention policy to induce firms to invest at socially optimal levels depends on whether insurers can observe and verify firms' self-protection levels. If self-protection can be observed so that an insurer can design a contract contingent on the self-protection level, then self-protection and insurance behave as complements, which forces firms to invest less than the optimal level in self-protection and insurance coverage. In this case, a social planner can induce firms to choose socially optimal self-protection and insurance levels by offering a subsidy on self-protection, but cannot do so by providing a subsidy on

insurance. If self-protection cannot be observed, then self-protection and insurance behave as substitutes and firms buy more than the socially optimal insurance coverage and invest less than the socially optimal level in self-protection. In this case, a social planner should tax insurance premium to achieve socially optimal results. The results hold when the insurance market is perfect, implying that solely reforming the currently imperfect insurance market is insufficient to achieve the efficient outcome in cyber security risk management.

5.7 Configuration of and Interaction between Information Security Technologies: The Case of Firewalls and Intrusion Detection Systems

Participants: Huseyin Cavusoglu, Srinivasan Raghunathan, Hasan Cavusoglu

Proper configuration of security technologies is critical to balance the needs for access and protection of information. The common practice of using a layered security architecture that has multiple technologies amplifies the need for proper configuration because the configuration decision about one security technology has ramifications for the configuration decisions about others. Furthermore, security technologies rely on each other for their operations, thereby affecting each other's contribution. In this paper, we study configuration of and interaction between a firewall and an IDS. We show that deploying a technology, whether it is the firewall or the IDS, could hurt the firm if its configuration is not optimized for the firm's environment. A more serious consequence of deploying the two technologies with sub-optimal configurations is that even if the firm could benefit when each is deployed alone, the firm could be hurt by deploying both. Configuring the IDS and the firewall optimally eliminates the conflict between them, ensuring that if the firm benefits from deploying each of these technologies when deployed alone, it will always benefit from deploying both. When optimally configured, we find that these technologies complement or substitute each other. Further, we find that while the optimal configuration of an IDS does not change whether it is deployed alone or together with a firewall, the optimal configuration of a firewall has a lower detection rate (i.e., allowing more access) when it is deployed with an IDS than when deployed alone. Our results highlight the complex interactions between firewall and IDS technologies when they are used together in a security architecture, and hence the need for proper configuration in order to benefit from these technologies.

5.8 Configuration of Detection Software: A Comparison of Decision and Game Theory Approaches

Participants: Huseyin Cavusoglu, Srinivasan Raghunathan

Firms are increasingly relying on software to detect fraud in domains such as security, financial services, tax, and auditing. A fundamental problem in using detection software for fraud detection is achieving the optimal balance between the detection and false positive rates. Many firms use decision theory to address the configuration problem. Decision theory is based on the presumption that the firm's actions do not influence the behavior of fraudsters. Game theory recognizes the fact that fraudsters do modify their strategies in response to a firm's actions. In this paper, we compare decision and game theory approaches to the detection software configuration problem when firms are faced with strategic users. We find that under most circumstances firms incur lower costs when they use the game theory as opposed to the decision theory because the decision theory approach frequently either "over"- or "under"-configures the detection software. However, firms incur the same or lower cost under the decision theory approach compared to the game theory approach in a simultaneous move game if configurations under decision theory and game theory are sufficiently close. A limitation of the game theory approach is that it requires user specific utility parameters, which are difficult to estimate. Decision theory, in contrast to game theory, requires the fraud probability estimate, which is more easily obtained.

5.9 The Value of Intrusion Detection Systems (IDSs) in Information Technology Security Architecture

Participants: Huseyin Cavusoglu, Birendra Mishra, Srinivasan Raghunathan

The increasing significance of IT security to firms is evident from their growing IT security budgets. Firms rely on technologies such as firewalls and intrusion detection systems to manage IT security risks. While the literature on the technical aspects of IT security is proliferating, a debate exists in the IT security community about the value of these technologies. In this paper, we seek to assess the value of intrusion detection systems in a firm's IT security architecture. We find that the IDS configuration represented by detection (true positive) and false alarm (false positive) rates determines whether a firm realizes a positive or negative value from the IDS. Specifically, we show that a firm realizes a positive value from an IDS only when the detection rate is higher than a critical value, which is determined by the hacker's benefit and cost parameters. When the firm realizes a positive (negative) value, the IDS deters (sustains) hackers. However, irrespective of whether the firm realizes a positive or negative value from the IDS, the IDS enables the firm to better target its investigation of users, while keeping the detection rate the same. Our results suggest that the positive value of an IDS results not from improved detection per se, but from an increased deterrence enabled by improved detection. Finally, we show that the firm realizes a strictly non-negative value if the firm configures the IDS optimally based on the hacking environment.

5.10 Intrusion-Detection Policies for IT Security Breaches

Participants: Hulusi Ogut, Huseyin Cavusoglu, Srinivasan Raghunathan

Intrusion-detection systems (IDSs) form an important component of IT security architectures, but the low proportion of hackers in the user population severely limits the usefulness of IDSs. Thus, even when the IDS is good, an intrusion signal may not imply that the user is more likely to be a hacker than a normal user. Ignoring the low base rate for the proportion of hackers results in acting on every intrusion signal, which is costly because of high rate of false alarms. This problem is known as the base-rate fallacy in IDSs. On the other hand, ignoring intrusion signals renders them useless. We propose and analyze waiting-time policies, which specify a response to signals from IDSs. We formulate the problem as a stochastic dynamic programming model and derive the optimal waiting time before acting upon an intrusion signal. Because the optimal policy is difficult to implement in many situations, we also derive and theoretically analyze a myopic policy. Our simulations suggest that the behavior of the myopic policy is qualitatively similar to that of the optimal policy. Further, the myopic policy performs better than other policies often used in practice, such as the Bayes policy and m-strike policies. The myopic policy can be implemented easily in a decision support system that supplements an IDS to mitigate the base-rate fallacy, and improve the value of the IDS.

5.11 Evaluation of Intrusion Detection Systems under an Inspection Constraint

Participants: Young U. Ryu, Hyun-Suk Rhee

An intrusion detection system (IDS) plays an important role in a firm's overall security protection. The IDS's main purpose is to identify potentially intrusive events and alert the security personnel to the danger. A typical intrusion detection system, however, is known to be imperfect in detection of intrusive events, resulting in high false-alarm rates. Nevertheless, current intrusion detection models unreasonably assume that upon alerts raised by a system, an information security officer responds to all alarms without any delay and avoids damages of hostile activities. This assumption of responding to all alarms with no time lag is often impracticable. As a result, the benefit of an IDS can be overestimated by current

intrusion detection models. In this article, we extend previous models by including an information security officer's alarm inspection under a constraint as a part of the process in determining the optimal intrusion detection policy. Given a potentially hostile environment for a firm in which the intrusion rates and costs associated with intrusion and security officers' inspection can be estimated, we outline a framework to establish the optimal operating points for IDSs under security officers' inspection constraint. The optimal solution to the model will provide not only a basis of better evaluation of IDSs but also useful insights into operations of IDSs. The firm can estimate expected benefits for running IDSs and establish a basis for increase in security personnel to relax security officers' inspection constraint.

5.12 Privacy Preservation Techniques for Distributed Transactional Databases

Participants: Jing Hao, Syam Menon, Sumit Sarkar

An increasing number of firms are sharing point-of-sale data with their business partners. While the advantages of such sharing can be significant, most data owners recognize the need to hide sensitive information prior to sharing. Frequently, the data being shared originates as distributed data collected from different locations or regions. Differences in customer characteristics across regions lead to sensitive information that is region-specific, and all region-specific sensitive information will need to be hidden, in addition to that at the consolidated (corporate) level. However, existing research considers hiding sensitive information only at the corporate level. We formulate the problem of maximizing the accuracy of a consolidated database containing sensitive information both at the corporate and regional levels. As the formulations are usually too large to be solved directly, we propose three heuristics that exploit the distributed nature of the data by decomposing the larger problem into a series of smaller ones. Many of these smaller problems have multiple optima, and we modify the original procedures to select solutions that lead to better overall accuracy. Extensive computational testing shows that these procedures can solve problems that are too large to be solved optimally, with the modified procedures often identifying the optimal solutions.

*Nominated for best paper, WITS, 2007

5.13 Optimal and Heuristic Approaches to Sanitizing Large Transactional Databases

Participants: Syam Menon, Sumit Sarkar

The need to conceal sensitive information prior to sharing databases is well recognized. Sensitive information in transactional databases is typically based on relationships derived from frequently occurring itemsets. Prior work in this area includes optimal approaches to maximize the accuracy of shared databases, while hiding all sensitive itemsets. These optimal approaches were shown to solve problems involving up to 10 million transactions. However, many transactional databases are considerably larger and, as system memory becomes a critical bottleneck preventing the large integer programs from being generated and stored, no effective solution procedure exists for such databases. This paper first identifies a common structure that exists in these problems, and then presents an optimal solution procedure based on branch-and-price that takes advantage of this structure. This procedure is observed to identify optimal solutions relatively quickly, even on problems which cannot be solved to optimality via existing approaches. However, even this approach becomes impractical as the size of the database increases beyond a point, and we introduce a heuristic variant to identify good solutions when the optimal procedure will not work. Computational experiments show that the heuristic identifies near-optimal solutions quickly in all problems where the optimal solution is known. In addition, it enables the solution of problems much larger than those considered previously.

5.14 Maximizing Accuracy when Modifying Transactional Databases to Hide Sensitive Association Rules

Participants: Syam Menon, Sumit Sarkar

Many organizations share point-of-sale data with business partners, as effective analysis of this data can often lead to competitive advantage. A common technique used to glean information from these transactional databases is the mining of association rules. While the potential benefits of sharing data can be considerable, many researchers have noted that the negative consequences of revealing association rules that are confidential can also be significant. In this paper, we focus on the problem of hiding those association rules that represent sensitive information to the owner of the data. Hiding is usually achieved through a process called sanitization, by which appropriately selected transactions are altered in such a way that they no longer support the sensitive association rules. In this paper, we introduce a formulation to maximize the accuracy of the modified database, given a sanitization approach. We then identify some conditions under which the size of the formulation can be reduced. Some sanitization approaches are better than others, and a sanitization procedure that results in the most accurate modified database is desirable. We represent the sanitization problem as an integer program and present a heuristic to solve it efficiently. Experimental results indicate that the approach is very effective, identifying solutions which result in accuracies of about 99.9% in less than a second.

5.15 A Data Perturbation Approach to Privacy Protection in Data Mining

Participants: Xiao-Bai Li, Sumit Sarkar

Advances in data mining techniques have raised growing concerns about privacy of personal information. Organizations that use their customers' records in data mining activities are forced to take actions to protect the privacy of the individuals involved. A common practice for many organizations today is to remove the identity related attributes from the customer records before releasing them to the data miners or analysts. In this study, we investigate the effect of this practice and demonstrate that a majority of the records in a dataset can be uniquely identified even after identity related attributes are removed. We propose a data perturbation method that can be used by organizations to prevent such unique identification of individual records, while providing the data to analysts for data mining. The proposed method attempts to preserve the statistical properties of the data based on privacy protection parameters specified by the organization. We show that the problem can be solved in two phases, with a linear programming formulation in phase one (to preserve the marginal distribution), followed by a simple Bayes based swapping procedure in phase two (to preserve the joint distribution). The proposed method is compared with a random perturbation method in classification performance on two real world datasets. The results of the experiments indicate that it significantly outperforms the random method.

5.16 Protecting Privacy against Re-identification by Record Linkage

Participants: Xiao-Bai Li, Sumit Sarkar

Record linkage is a valuable technique for data analysis. However, it can also be used to re-identify records in de-identified data and thus raises privacy concerns. We propose a data masking method for protecting privacy against such re-identification by record linkage. Our method recursively partitions a dataset into smaller subsets based on the maximum variance dimension represented by the first principal component in each partitioned set. Values of selected attributes of each record in a subset are then masked using a rank-based swapping approach. Experiments conducted on three real datasets demonstrate the effectiveness of the approach.

5.17 Intrusion Prevention in Information Systems: Reactive and Proactive Responses

Participants: Metin Çakanyildirim, Wei T. Yue

Intrusion prevention requires effective identification of and response to malicious events. In this paper, we model two important managerial decisions involved in the intrusion prevention process: the configuration of the detection component and the response by the reaction component. The configuration decision affects the number of alarms the firm has to investigate. It is well known that the traditional intrusion detection system generates too many false alarms. The response decision determines whether alarms are going to be investigated or rejected outright. By jointly optimizing these two decision variables, a firm may apply different strategies in protecting its informational assets: slow but accurate, rapid but inaccurate, or a mixture of the two strategies. We use the optimal control approach to study the problem. Unlike previous literature, which studied the problem with a static model, in our model, the decision on balancing the desire to detect all malicious events with the opportunity costs required to do so is time dependent. Furthermore, we show how the choice of an optimal mixture of reactive and proactive responses depends on the values of cost parameters and investigation rate parameters. We find that in our model, a high damage cost does not immediately translate to a preference of proactive response, or a high false rejection cost does not translate to a preference of reactive response. The dynamics of the problem, such as how fast alarms accumulate and how fast they can be cleared, also affect the decisions.

6. Present Activities in the Supply Chain Domain

6.1 Partially Observed Inventory Systems

Participants: Alain Bensoussan , Metin Çakanyildirim, Suresh Sethi

In some inventory control contexts, such as Vendor Managed Inventories, inventory with spoilage, misplacement, or theft, inventory levels may not always be observable to the decision makers. However, shortages, delayed inventory/demand observations are observable and are called signals. The signals provide partial information. We study such inventory control problems, where orders must be decided on the basis of partial information to minimize costs.

6.2 Computation of Approximate Optimal Policies in Partially Observed Inventory Model with Rain Checks

Participants: Alain Bensoussan, Metin Çakanyildirim, Suresh Sethi, Ruixia Shi

We study a periodic review inventory system in which the inventory manager (IM) does not know the inventory level when it is positive. But, when the inventory level becomes negative, the IM issues rain checks to customers, thus making the shortages fully observable to him. The IM's task is to determine the optimal order quantities in this partial information setting where the inventory level, when positive, is represented in terms of an infinite dimensional probability distribution. We approximate this distribution by Chebyshev polynomials to compute the optimal order quantity/cost for our system. Moreover, we use Fast Fourier Transforms along with an appropriate discretization of backorder levels to speed up the computations. We also propose a heuristic termed a base mean-stock policy. The order quantity for the heuristic policy is computed by regarding the mean of the inventory level as the inventory level in a fully observed inventory system, and then using a base stock policy. We show numerically that the optimal order quantity is very close to the base mean-stock order quantity, when the variance of the inventory distribution is small. When the mean of the inventory distribution is large, the optimal order quantity is

more than the base mean-stock quantity, it is the other way around when the mean is small or there are backorders.

6.3 Optimal Policy and Value of Information in an Inventory Model with Lost Sales and Demand Updates

Participants: Alain Bensoussan, Metin Çakanyildirim, Qi Feng, Suresh Sethi

Under many circumstances, demand observations are often censored due to the lack of tracking lost sales caused by stockouts. To understand the impact of the lost sales information on the ordering decisions, a periodic-review inventory model is formulated in which only the sales information is obtained immediately upon the realization of the demand. Subsequently, the lost sales information is obtained after a delay. In the resulting model, an optimal policy, if exists, reveals a very complex structure. By decomposing the derivative of the value function, we demonstrate two different roles of inventory in our model: satisfying the demand and deducing the demand information. We show that the optimal inventory levels under the delayed observation of the lost sales are always higher than those for which the demands are fully observed. Moreover, as illustrated in numerical examples, the optimal policy possesses a counterintuitive behavior with respect to the problem parameters. To understand the key drivers of the optimal decisions, we further compare the costs under different demand observations. Two important observations are made. First, a lower cost is obtained when the realized demand is observed than when the demand is only observed to be higher than that level, and, furthermore, the cost difference represents the value of demand information. Second, if the demand observation is censored, improved demand information may not always be desirable as it may actually lead to an increased expected cost.

6.4 Optimal Ordering Policies for Stochastic Inventory Problems with Observed Information Delays

Participants: Alain Bensoussan, Metin Çakanyildirim, Qi Feng, Suresh Sethi

Information delays exist in an inventory system when it takes time to collect, process, validate, and transmit inventory/demand data. A general framework is developed in this paper to describe the information flow in an inventory system with information delays. We characterize the sufficient statistics for making optimal decisions. When the ordering cost is linear, the optimality of a state-dependent base-stock policy is established even when information flows are allowed to cross over time. Additional insights into the problem are obtained via a comparison between our models and the models with stochastic order lead times. We also show that inventory can substitute for information and vice versa.

6.5 Numerical Analysis of Partially Observable Inventory System: Economic Loss from Mean Based Policy

Participants: Alain Bensoussan, Metin Çakanyildirim, Celine Hoe, Suresh Sethi

In this paper we provide numerical solutions for a partially observed inventory system named Zero Balance Walk Model. In this model, demand is not observed, inventory level is observed only when it reaches zero, and orders are made to minimize the total discounted cost. We prove that solutions can be obtained in a Hilbertian framework and propose a numerical procedure combining a Chebyshev representation of the conditional density of the inventory level and a policy iteration algorithm. Extensive numerical examples are studied to analyze the economic loss if the model is misspecified by the mean-based policy. An approximation scheme is introduced for the computation of costs. Numerical results show that the loss is significant and is positively related to the discount factor as well as the uncertainty

embedded in the inventory level. Our study thus suggests inventory managers the importance of their awareness to the partially observable inventory system.

6.6 Assessing the Loss due to Parsimony

Participants: Alain Bensoussan, Metin Çakanyildirim, Leunglung Chan, Celine Hoe, Suresh Sethi

In standard inventory models, the inventory level was assumed to be deterministic or fully observed. However, in reality, inventory levels are always not fully observed. In this paper a single-period inventory model with a partially observation is considered. We use a uniform distribution, an exponential distribution and a lognormal distribution for the demand and any arbitrary distribution for the inventory. The optimal order quantity and the value function are derived. We analyze the economic loss if the model is misspecified by the mean-based policy. The order quantity difference and the value difference between the mean-based policy and the partially observed policy are derived. Some properties of the order quantity difference and the value difference such as bounds are discussed. The sensitivity analysis of the economic loss associated with different variables is also discussed.

6.7 Optimal Transshipments and Orders: A Tale of Two Competing and Cooperating Retailers

Participants: Metin Çakanyildirim, Nagihan Çömez, Kathryn Stecke

A decentralized system of two competing and cooperating retailers that order and sell the same product is studied. When a customer demand occurs at a stocked-out retailer, that retailer can request a unit to be transshipped from the other retailer. If this request is rejected, the unsatisfied customer may go to the other retailer with a demand overflow probability. Each retailer maximizing his/her own profit makes two types of decisions: initially the order quantity from a manufacturer and afterwards transshipment request accept/reject decisions. We show that retailers' transshipment policies are characterized by chronologically non-increasing inventory hold-back levels. Order quantity decisions form a non-cooperative game, whose payoffs are shown to be submodular for omniscient retailers who have enough negotiating power to reap all of the profits from transshipments that they accept. The submodularity has implications on the value of a retailer's inventory, as the other retailer stocks more. It also yields the existence of a pure strategy equilibrium. Such an equilibrium can also be obtained by approximating the payoffs at fractional order quantities, if the retailers are not omniscient. This approximation works better for retailers with high order quantities, where rounding of fractional quantities is insignificant. Retailers always benefit more from our optimal transshipment policies than with complete sharing or no sharing. The manufacturer also benefits in all but a handful of over 3000 numerically tested instances. We also analytically study the magnitude of hold-back levels in order to derive interesting insights, such as smaller retailers and geographically distant retailers benefit more from transshipments. Given these benefits, the retailers and manufacturer can justify optimal transshipments in settings where an extreme policy, either complete sharing or no sharing, is not desirable.

6.8 Inventory Sharing with Positive Transshipment and Replenishment Lead Times

Participants: Metin Çakanyildirim, Nagihan Çömez, Kathryn Stecke,

We study a centralized inventory sharing system of two retailers, which are replenished periodically by a manufacturer. Between two replenishments, a unit can be transshipped to a stocked-out retailer from another retailer, but it arrives a transshipment time later. During this time, the stocked-out retailer incurs a backorder cost. If the transshipment is not possible, a backorder cost is incurred until the next replenishment. Since the transshipment time is shorter than the time between two replenishments, transshipments can reduce the backorder cost at the stocked-out retailer, while decreasing the holding

costs at the other retailer. The system is directed by a centralized decision maker, who optimizes the total system costs consisting of replenishment, inventory holding, backorder, and transshipment costs. The transshipment policy is characterized by hold-back inventory levels, which are non-increasing in the remaining time until the next replenishment. The obtained transshipment policy differs from those in the literature because we allow for multiple in-cycle transshipments with positive transshipment times and backorder costs. We also discuss the challenges associated with considering a positive replenishment lead time. In this case, upper and lower bounds of the expected long-run average cost are developed. By an extensive numerical study, the bounds are shown to have a 1.1% average gap.

6.9 Forecasting Sales for Heating, Ventilating and Air Conditioning (HVAC) Products

Participants: John Beckett, Metin Çakanyildirim, Divakar Rajamani, Andrew Royal

Furnaces, Air conditioners, Coil blowers and Heat pumps are major heating, ventilation and air conditioning (HVAC) products. The HVAC manufacturers whose total U.S. revenues are about 18 billion dollars search for better ways of forecasting the sales for HVAC products. One of the ways to improve forecasts is to use easily observable, independent variables that drive the demand. In this paper, we investigate the effect of some of these variables which include monthly average cooling degrees and housing starts. By using real-life data, we test the accuracy improvements achieved with these and as well as additional variables such as prices. We eventually suggest a forecasting model that provides a good compromise between complexity and accuracy. The model is implemented in open-source R software facilitates its adaptation.

6.10 Contracting and Coordination under Asymmetric Production Cost Information

Participants: Metin Çakanyildirim, Xianghua Gan, Suresh P. Sethi

We study a supply chain consisting of a supplier and a retailer who faces a newsvendor problem. The supplier has better knowledge of his unit production cost than the retailer has. We model this problem as a game of adverse selection. In this model the retailer (principal) offers a menu of contracts, each of which consists of two parameters: the ordering quantity and the supplier's proportion of the channel profit. The supplier (agent), who has an alternative opportunity, either chooses one from the menu of contracts or rejects them all. We derive an optimal contract menu for the retailer under a general assumption about the supplier's reservation profit. Also we find that in some cases the optimal contract coordinates the supply chain even with asymmetric information.

6.11 On the Selection of Supply Chain Coordinating Contracts: The Role of Capital Constraints

Participants: Yi Xu, Jun Zhang

This paper considers a supply chain with a manufacturer and a financially constrained retailer, and examines the implications of the retailer's capital constraint on the selection of supply chain coordinating contracts. We demonstrate that the well-accepted result that buy-back, quantity discount, quantity-flexibility, sales-rebate, and revenue-sharing contracts can coordinate the supply chain and arbitrarily allocate the supply chain profit needs to be reexamined. Taking the retailer's capital constraint into account, we show that arbitrary allocation of the supply chain profit is no longer possible for all the contract forms, and that these contract forms are quite different in the flexibility in coordinating the supply chain and in allocating its profit. Surprisingly, there is a set of allocations of the supply chain profit that cannot be achieved by any of the existing contract forms. We then propose and study a new coordinating contract form: manufacturer financing contract in which the manufacturer provides financing for the retailer's purchase. We find that the manufacturing financing contract complements the

existing contract forms in supply chain coordination and in profit allocation. Our study indicates that the financial status of the retailer, the gross margin of the product, and the power structure of a supply chain are important factors that influence the selection of coordinating contracts.

6.12 Coordination of Supply Chains with Risk-Averse Agents

Participants: Xianghua Gan, Suresh P. Sethi, Houmin Yan

The extant supply chain management literature has not addressed the issue of coordination in supply chains involving risk-averse agents. We take up this issue and begin with defining a coordinating contract as one that results in a Pareto-optimal solution acceptable to each agent. Our definition generalizes the standard one in the risk-neutral case. We then develop coordinating contracts in three specific cases: (i) the supplier is risk neutral and the retailer maximizes his expected profit subject to a downside risk constraint, (ii) the supplier and the retailer each maximizes his own mean-variance trade-off, and (iii) the supplier and the retailer each maximizes his own expected utility. Moreover, in case (iii) we show that our contract yields the Nash Bargaining solution. In each case, we show how we can find the set of Pareto-optimal solutions, and then design a contract to achieve the solutions. We also exhibit a case in which we obtain Pareto-optimal sharing rules explicitly, and outline a procedure to obtain Pareto-optimal solutions.

6.13 Channel Coordination with a Risk-Neutral Supplier and a Downside-Risk-Averse Retailer

Participants: Xianghua Gan, Suresh P. Sethi, Houmin Yan

We investigate how a supply chain involving a risk-neutral supplier and a downside-risk-averse retailer can be coordinated with a supply contract. We show that the standard buy-back or revenue-sharing contracts may not coordinate such a channel. Using a definition of coordination of supply chains proposed earlier by the authors, we design a risk-sharing contract that offers the desired downside protection to the retailer, provides respective reservation profits to the agents, and accomplishes channel coordination.

6.14 A Two-Stage Newsvendor Problem with a Service Constraint

Participants: Alain Bensoussan, Qi Feng, Suresh Sethi

We extend the classical newsvendor problem by introducing a service constraint and a demand forecast update. The newsvendor orders an initial amount and has the possibility to adjust the initial order after she observes a demand updating signal. She also commits to a target service level before any forecast update is available. The resulting problem does not permit a dynamic programming formulation. We use the method of Lagrange multiplier to solve the problem, and we derive an analytical expression for the optimal ordering decisions. Various properties of the optimal policy are discussed, and numerical results are presented to provide further insights into the newsvendor's behavior.

6.15 The Machine Maintenance and Sale Age Model of Kamien and Schwartz Revisited

Participants: Alain Bensoussan, Suresh Sethi

In this paper, we revisit the well-known machine maintenance and replacement model of Kamien and Schwartz involving a machine subject to failure. Kamien and Schwartz formulate and solve the problem as a deterministic optimal control problem. Thus, they obtain an open-loop solution. We study the underlying stochastic model. While we provide conditions for existence and sufficiency of an optimal solution, it nevertheless turns out that our solution does not differ from that of Kamien and Schwartz. We

also clarify the relationship between our value function with full observation to that of Kamien and Schwartz obtained with the assumption that the failure of the machine is not observed.

6.16 Cooperative Advertising and Pricing in a Dynamic Stochastic Supply Chain: Feedback Stackelberg Strategies

Participants: Xuili He, Ashutosh Prasad, Suresh Sethi

Cooperative (co-op) advertising is an important instrument for aligning manufacturer and retailer decisions in supply chains. In this, the manufacturer announces a co-op advertising policy, i.e., a participation rate that specifies the percentage of the retailer's advertising expenditure that it will provide. In addition, it also announces the wholesale price. In response, the retailer chooses its optimal advertising and pricing policies. We model this supply chain problem as a stochastic Stackelberg differential game whose dynamics follows Sethi's stochastic sales-advertising model. We obtain the condition when offering co-op advertising is optimal. We provide in feedback form the optimal advertising and pricing policies for the manufacturer and the retailer. We contrast the results with the advertising and price decisions of the vertically integrated channel, and suggest a method for coordinating the channel.

6.17 A Supply Chain with a Service Requirement for Each Market Signal

Participants: Suresh Sethi, Houmin Yan, Hanqin Zhang, Jing Zhou

We study a single-period two-stage service-constrained supply chain with an information update. The buyer has two procurement opportunities with the second one after observing a market signal, which updates the demand forecast. He also commits to a service level after observing the market signal. We derive his optimal ordering decisions and show that the critical market signal, the optimal first-stage order quantity, and the optimal expected profit are monotone with respect to the target service level. We also discuss the impact of the forecast quality on the optimal decisions. We show that the optimal first-stage order quantity may not be monotone with respect to information accuracy, as is in the case without the service constraint. In addition, we extend our analysis to the situation when an order cancellation is allowed upon the observation of the market signal. We also compare the results obtained for the problems with and without an order cancellation. Finally, we discuss the supply chain coordination issue and find that a buyback contract can also coordinate the supply chain in the presence of the service constraint.

6.18 Coordination Mechanism for the Supply Chain with Leadtime Consideration and Price-Dependent Demand

Participants: Haoya Chen, Youhua Chen, Tsan-Ming Choi, Suresh Sethi

We study a coordination contract for a supplier-retailer channel producing and selling a fashionable product exhibiting a stochastic price-dependent demand. The product's selling season is short, and the supply chain faces great demand uncertainty. We consider a scenario where the supplier reserves production capacity for the retailer in advance, and permits the retailer to place an order not exceeding the reserved capacity after a demand information update during the leadtime. We formulate a two-stage optimization problem in which the supplier decides the amount of capacity reservation in the first stage, and the retailer determines the order quantity and the retail price after observing the demand information in the second stage. We propose a three-parameter risk and profit sharing contract that coordinates the supply chain. The proposed contract permits any agreed-upon distribution of the supply chain profit to the channel members.

6.19 Procurement Flexibility under Price Uncertainty

Participants: Qi Feng, Suresh Sethi

This chapter examines the interaction between supply price uncertainty and demand uncertainty. We consider a manufacturer who sources a key component using different procurement options: a long-term order on a price-only contract, short-term orders on an adjustment contract, and short-term purchases directly from the market. At the beginning of the planning cycle, the manufacturer places a long-term order and reserves a certain amount of supply capacity for the purpose of adjusting the long-term order, if needed. Before the selling season, the manufacturer has multiple options to place supplementary orders from the reserved capacity or from the market. We compare two types of capacity arrangements: dedicated capacity and overall capacity. Under a dedicated capacity arrangement, the manufacturer reserves capacities separately for different adjustment opportunities. On the other hand, under an overall capacity arrangement, she keeps the flexibility of using the reserved capacity within the given period for possibly multiple adjustments. We discuss the optimal procurement strategies and the criteria for capacity allocations, as well as the policy behavior and service performance in different situations.

6.20 Inventory Management: Information, Coordination and Rationality

Participant: Ozalp Ozer

The success of a product in today's global marketplace depends on capabilities of firms in the product's supply chain. Among these capabilities, effective inventory management is a capability necessary to lead in the global marketplace. The chapter provides a discussion of four fundamentals of effective inventory management. First, it requires managers to know how best to use available information. Second, managers need to quantify the value of information. Third, they need to coordinate decentralized inventory operations. Finally, effective inventory management requires decision tools that can be embraced by their users. The chapter's emphasis is on the use of information, and the role of new information technologies in inventory management. Previous research on inventory management played an important role in the advancement and development of new technologies and processes. Today more research is needed because new technologies (such as RFID Radio-Frequency Identification) and new management methods (such as collaborative forecasting and planning) are emerging and evolving faster than ever before. Inventory management and research will continue to play a central role in the success of a product and the firms in its supply chain. The chapter brings together separate but inherently related streams of research in inventory management. By doing so, we highlight potential research opportunities that lie on the boundaries.

6.21 New Policies for the Stochastic Inventory Control Problem with Two Supply Sources

Participants: Anshul Sheopuri, Ganesh Janakiraman and Sridhar Seshadri

We study an inventory system under periodic review in the presence of two suppliers (or delivery modes). The emergency supplier has a shorter lead-time than the regular supplier, but the unit price he offers is higher. Excess demand is backlogged. We generalize the recently studied class of Dual Index policies (Veeraraghavan and Scheller-Wolf (2008)) by proposing two classes of policies. The first class consists of policies that have an order-up-to structure for the emergency supplier. We provide analytical results that are useful for determining optimal or near-optimal policies within this class. This analysis and the policies which we propose leverage our observation that the classical "Lost Sales inventory problem" is a special case of this problem. The second class consists of policies that have an order-up-to structure for the regular supplier. Here, we derive bounds on the optimal order quantity from the emergency supplier, in any period, and use these bounds for finding effective policies within this class. Finally, we undertake

an elaborate computational investigation to compare the performance of the policies we propose with that of Dual Index policies. One of our policies provides an average cost-saving of 1.1 % over the Best Dual Index policy and has the same computational requirements. Another policy which we propose has a cost performance similar to the Best Dual Index policy but its computational requirements are lower.

6.22 Asymptotic Optimality of Order-Up-To Policies in Lost Sales Inventory Systems

Participants: Woonghee Tim Huh, Ganesh Janakiraman, John A. Muckstadt and Paat Rusmevichientong

Abstract: We study a single-product single-location inventory system under periodic review, where excess demand is lost and the replenishment lead time is positive. The performance measure of interest is the long-run average holding cost and lost sales penalty cost. For a large class of demand distributions, we show that when the lost sales penalty becomes large compared to the holding cost, the relative difference between the cost of the optimal policy and the best order-up-to policy converges to zero. For any given cost parameters, we establish a bound on this relative difference. Numerical experiments show that the best order-up-to policy performs well, yielding an average cost that is within 1.5% of the optimal cost when the ratio between the lost sales penalty and the holding cost is 100. We also propose a heuristic order-up-to level using two newsvendor expressions; in our experiments, the cost of this order-up-to policy is 2.52% higher, on an average, than the best order-up-to policy.

7. Present Activities in Finance and Economics

7.1 Real Options and Game Models

Participants: Alain Bensoussan, David Diltz, Celine Ho

We consider optimal investment strategies for projects under uncertainty, when there is competition. We study the situation of complete and incomplete markets. The game structure is a Leader-Follower Stackelberg game. The approach of real options bears similarity with that of American options in financial engineering. A major component of the decision is when to invest (or to enter into the market). It is a random time. Each of the players has to decide when to enter, however the follower cannot enter before the leader. There is in addition a regulation which clarifies how they share the market, if they decide both to compete. The assumption of complete or incomplete markets plays a fundamental role in defining the objective functions of both players.

As it is customary for optimal stopping time problems, Dynamic Programming leads to Variational Inequalities. However, new structures arise with interesting mathematical questions. In most cases, we are able to solve completely the problems and to obtain optimal stopping strategies. But the results are not intuitive.

7.2 Value of Population in Economic Growth Models

Participants: K.J. Arrow, Alain Bensoussan Qi Feng, Suresh Sethi

Traditional economic growth models are based on capital as the state variable. It is clear that modern economies must take into account other state variables. Population is a very important one. Following models developed by K.J. Arrow, we have considered an economy in which the rate of change of population depends on population policy decisions. This requires population as well as capital as state variables. By showing the algebraic relationship between the shadow price of the population and the shadow price of the per capita capital stock, we are still able to depict the optimal path and its

convergence to the long-run equilibrium on a two-dimensional phase diagram. Moreover, we derive explicitly the expression of genuine savings in our model to evaluate the sustainability of the system.

7.4 Cash Management

Participants: Alain Bensoussan, Suresh Sethi, A. Chutani

We consider problems of consumption and investment, with transaction costs. These transaction costs are materialized in the evolution of cash, considered as a state variable. The return on the investment is random. The decision variables are the rate of consumption, as well as the amount of cash invested in the stocks. This approach is centered on the cash management, whereas traditional approaches in Finance tend to eliminate the cash and to center on the portfolio management. The major advantage is to introduce the transactions costs as proportional to the rate of transformation of cash into stocks. Our theory is so far limited to one stock. In this case, we characterize the optimal strategy of investment, with several assumptions on the random behavior of the return on the stock.

7.5 Mutual Insurance

Participants: Alain Bensoussan, J. Liu, J. Yuan

This research takes place at PolyU.

We consider a mutual insurance system whose reserve evolves as a Brownian motion, as a consequence of the occurrence of hazards. The controller tries to minimize the total cost by increasing or reducing the reserve by instant jumps. Both cases of zero and positive fixed costs are investigated. We apply the theory of Quasi-variational inequalities and make the connection between singular control and impulse control. The procedures to solve these systems are also studied. Mutual insurance is widely used in maritime transport.

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V. Publications

2007

Bensoussan, A., Cakanyildirim, M., and Sethi, S.P., "Partially Observed Inventory Systems: The Case of Zero-Balance Walk," *SIAM Journal of Control and Optimization*, 46(1), March 2007, 176-209.

Bensoussan, A., Cakanyildirim, M., and Sethi, S.P., "Optimal Ordering Policies for Inventory Problems with Dynamic Information Delays," *Production and Operations Management*, 16(2), March-April 2007, 241-256.

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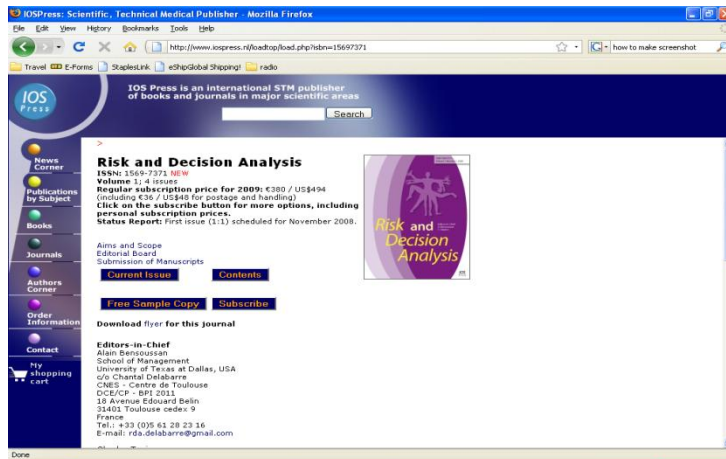
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VI. Risk and Decision Analysis

Issues 1-3 of Volume 1 are available at <http://www.iospress.nl/loadtop/load.php?isbn=15697371>.



A comprehensive framework is necessary to develop the new scientific area of risk and decision analysis. This implies convergence between finance, industry, the environment, security, cyber security and the many domains which are concerned by risks and decision analysis. The objective of the journal *Risk and Decision Analysis* published by IOS Press, is to fill this need. –Saskia van Wijngaarden, IOS Press

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VII. International Research Forum, 15-17 December 2010

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INTERNATIONAL RESEARCH FORUM

15-17 December 2010 The Hong Kong Polytechnic University, Hong Kong

WHAT CAN THE ACADEMIC COMMUNITY LEARN FROM THE GLOBAL CRISIS?
Models, Methods and Transfer

Introduction

The Hong Kong Polytechnic University and the University of Texas at Dallas have partnered to host a research forum on 15-17 December 2010. The forum will address how the current global economic crisis will impact education programs and the orientation of research in the future. This initiative will also consider the growing role of Asia in economic activities which is also apparent in research and education.

The forum will be a milestone in a continuous process and will be preceded by a team effort to establish the most pressing questions. We are calling for contributions in the form of position papers and suggestions concerning new problems and new training initiatives.

This forum encourages an interdisciplinary momentum, coherent with the nature of crisis. All disciplines are concerned, and one should encourage all scientists to contribute to the debate. Although the reflection concerns primarily the Academic Community, the input of practitioners will be essential to have their vision of the needs.

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Virginia Tech

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