# GERAD

Group of Research in Decision Analysis

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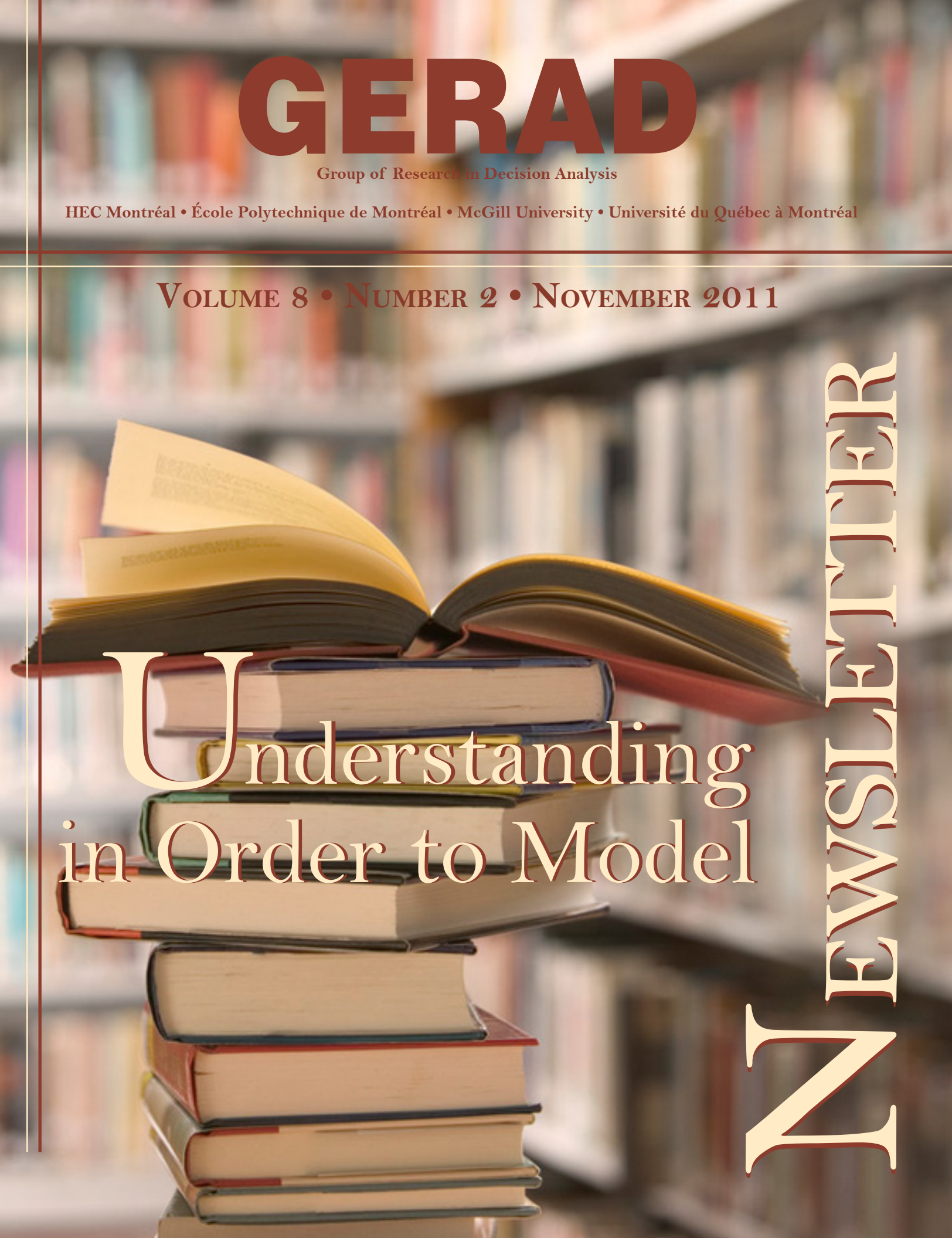

# Understanding in Order to Model

# NEWSLETTER

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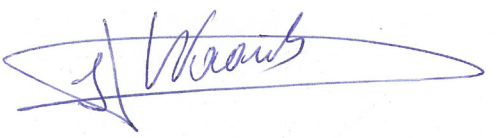
# Editorial by Jean-Philippe Waaub

This issue of the Newsletter features two interviews that offer more insight into Luc-Alain Giraldeau (UQAM) and Mehmet Gümüş (McGill). Luc-Alain Giraldeau is a professor with the Biology Department and Associate Dean, Research, in the Faculty of Science at UQAM. For some 30 years, he has been using game theory to study how animals make decisions. He joined GERAD a year ago and is open to doing collaborative work. There are indeed several GERAD researchers developing operational research applications in the area of the life sciences. Mehmet Gümüş became a professor with the Operations Management Department at McGill University in 2007, after completing a Master's in Economics and a Ph.D. in Industrial Engineering and Operational Research at Berkeley. He works most notably on issues of informational asymmetry in supply-chain management, dynamic price-setting mechanisms, and risk management.

Readers will also enjoy the five research reports on the following topics: power supply in an era of expanding renewable energy systems and smart grids (M.F. Anjos); modeling changing heat-wave trends in a context of increased extreme-weather events (D.J. Dupuis); the risks and guarantees between suppliers and buyers in the competitive supply chains (M. Gümüş et al.); the use of a robust approach with the TIAM-World model to address Europe's energy-supply security (R. Loulou et al.); solving optimization problems with complementarity constraints (Z. Coulibaly and D. Orban); and, the benefit of cooperation in two-stage production systems like those of the automotive industry (E. Wagneur et al.).

This issue's editorial is also an opportunity for me to say how much I have been enjoying working with the GERAD team. I also want to thank Roland Malhamé, my predecessor as GERAD director, for the work he accomplished and particularly for his critical involvement in renewing our FQRNT strategic group grant for 6 years.

Enjoy your reading.



Jean-Philippe Waaub
Director of GERAD

# Interview with Luc-Alain Giraldeau

## Of pigeons and intuition

by Véronique Pagé

Luc-Alain Giraldeau has been working on decision analysis for close to thirty years. A professor at UQAM since 2000, he is now vice-dean for research there. Surprisingly, though, he only joined GERAD about a year ago. In fact it is perhaps not so surprising... considering Mr. Giraldeau is a biologist who studies decision-making processes in animals!

Admittedly, pigeons follow the markets less closely than they do the position of food morsels. But to study their "decisions", Luc-Alain Giraldeau inevitably uses mathematical tools similar to the ones favoured by more traditional GERAD researchers. So when Roland Malhamé, GERAD director at the time, suggested he becomes a member, Mr. Giraldeau gladly accepted the offer. His take on the decision problem is evidently somewhat unconventional: "Decision analysis generally aims at formulating recommendations, eventually for decision-makers, so it focuses on finding the best choices. I work in the opposite direction: I look at the decision-taking agent and I try to understand how a decision was taken, what the biases and limits were."

"Decision analysis generally aims at formulating recommendations, eventually for decision-makers, so it focuses on finding the best choices. I work in the opposite direction: I look at the decision-taking agent and I try to understand how a decision was taken, what the biases and limits were."

### The wisdom of intuition

For Luc-Alain Giraldeau, decision-making in animals is solely an intuitive process. But meaningless or insignificant, it certainly isn't. Intuition, for the researcher, is the end result of the natural selection process, and gives the best mechanisms to reach a stable solution to a game that has been played for generations. Following John Maynard Smith, who first introduced the concept in the seventies, Luc-Alain Giraldeau indeed makes extensive use of game theory to study animal behaviour: "A theoretician, for example in GERAD, uses game theory to find a real-time, optimal solution. When you look at animals, this whole complicated calculation to reach the "right answer", well it has already been made by natural selection. It has eliminated all the inaccurate decision-making processes. Evolutionary game theory here helps me understand what is the solution that is stable from an evolutionary perspective." Animal behaviour, therefore, is expected to mirror game theory predictions.

Is that to say intuition always holds the answer, and that animals, as opposed to humans, never make mistakes? "No, of course not. There are stochastic variations, for one thing, and so all we can say is that intuition works well on average. But more importantly, if we take an animal completely outside of the context for which its intuition has evolved, then it might well make mistakes." The animal finds itself misinterpreting the information it is gathering from the environment.

Knowing the equilibrium solution towards which the animal is going, it is possible to divert its behaviour. Bullfighting is an interesting example: "Toreadors are not all that brave! Well, let me rephrase this: I would never go in an arena myself, but I know that toreadors have a very efficient trick." Let's agree they supplement their courage with a dash of knowledge about bull behavior. The cape they use, once waved about, imitates the bowed head of a bull. "This is a clue for the bull to attack this "head", not the toreador, who is nonetheless the real source of danger."

### Scrounger pigeons

The producer-scrounger game has been of particular interest to Luc-Alain Giraldeau for a number of years. Imagine a group of pigeons pecking about. It looks as though all the pigeons are trying to find food; when one does find something, all the other quickly fly to the productive spot. "But if you carefully identify the pigeons, you realize that in fact, food is always found by the same individuals. Not that they are better at it, but they simply are the only ones actually searching!" Everybody else is doing very little outside of waiting for the producers to find something, so they can be there quick when they do and steal their find. The more producers there are, the more tempting it is to scrounge; but if everybody is waiting for somebody else to find, someone,

somewhere, is bound to decide it is time to go back to work. There is therefore an equilibrium point, a Nash equilibrium, for which no individual sees an interest in changing its role. When this equilibrium is reached, "we're stuck. Nothing will change." Each individual situation is optimized, though the group productivity might not be.

Evidently this equilibrium only stands for a certain array on conditions. As these inevitably change, animals need to be equipped with a means to decide when it is worth changing their role. This decision again depends on the choice of the other individuals. If everyone keep re-evaluating their options, it becomes impossible to gather the information necessary for the decision-making process. Luc-Alain Giraldeau has found there is an optimal number of conservative individuals, who simply never change their role, no matter what. These "non-learners" form the base information needed by the other group members to choose what they should become next.

He indeed sees his implication in GERAD as a possibility "to really bring the full power of game theory and decision analysis to this question of decision-making processes in agents that have evolved to function in social environments."

**A serious game**

Over the last thirty years, Luc-Alain Giraldeau's work has inevitably been affected by the evolution of computing power. "It has allowed us to ask more complicated questions, to obtain answers which we simply would never have been able to obtain otherwise."

Taking our producer-scrounger game again, but replacing pleasant pigeons with ferocious predators, offers a illustrative example. Whichever animal is the prey of this group of predators would benefit from them having a small number of producers (the only ones really looking for food) so the overall productivity of the group would be low. To influence the predators' group composition, the prey might themselves want to form groups. This solution might be ideal in nature, but leads to some serious modeling complication! "We used two combined genetic algorithms, one for the prey, one for the predator. This would have been impossible thirty years ago." The solution came somewhat unexpected. The researcher imagined larger prey groups would be favoured: "but we didn't realize that in such a case, once the prey group is discovered by predators, the casualties can be fatal... to the whole species! There is therefore an optimal prey aggregation which maximizes the number of scrounger predators while minimizing the risks of extinction."

**Searching for food... and collaborations**

For Luc-Alain Giraldeau, GERAD offers stimulating perspectives. He already supervises a Ph.D. student under a GERAD scholarship, Mohammad Afshar. Mr Afshar came to biology from artificial intelligence, so "he obviously is able to push our simulations even further. He came to us equipped with all the tools of decision analysis, which he had used in a robotic context, but now applies to animal behaviour. It opens up many possibilities; I have great hopes that Mohammad will make the field of individual decision-making progress." He indeed sees his implication in GERAD as a possibility "to really bring the full power of game theory and decision analysis to this question of decision-making processes in agents that have evolved to function in social environments." This, of course, will only happen if Luc-Alain Giraldeau's GERAD colleagues are aware of his somewhat original specialization... Which should not be an issue anymore! ■

**Luc-Alain Giraldeau**
*Vice-Dean of Research*
*Faculty of Science*
*Université du Québec à Montréal and GERAD*

# Interview with Mehmet Gümüş

## A passion for information

by Véronique Pagé

Ten years ago, there was an officer of the Turkish navy who was reading a lot. Reading, it seems, anything he could get his hands on: books about economics, theoretical physics (but that's another story), and about industrial engineering, in which he had obtained a degree a few years earlier. When it became clear that all this reading would not yet quench his curiosity, our naval officer decided to apply for a PhD in Industrial Engineering across the world, at the University of California at Berkeley.

> "Usually, firms are not alone in production decisions. A Canadian retailer buys products from a Chinese manufacturer, who buys products from a Vietnamese supplier... As we go further and further on the globalization path, the supply chain keeps lengthening."

Now an assistant professor at Desautels Faculty of Management at McGill University, former navy officer Mehmet Gümüş has visibly not lost an ounce of his enthusiasm and curiosity (although he does struggle to find Montreal winters interesting at all). Since arriving at McGill in 2007, he has been focusing on a variety of problems that divide in two main strands: information asymmetry and pricing.

### Secrets and lies

Information asymmetry is a major issue in a globalized world: "Usually, firms are not alone in production decisions. A Canadian retailer buys products from a Chinese manufacturer, who buys products from a Vietnamese supplier... As we go further and further on the globalization path, the supply chain keeps lengthening." The retailer (and for that matter, the customer) can well find itself five, ten links away from the original supplier. It might be well informed about their first supplier, but it is likely it will know very little, if anything at all, about the other links of the chain. How would it be informed about strikes faced by the Chinese manufacturer or floods affecting the Vietnamese supplier? The converse is also true: manufacturers and suppliers might well know nothing at all about the ultimate customer of their product.

From the first link to the last one, information therefore often does not flow, and if it does, it is unlikely to be freely. Indeed, in such an environment, what to do with any piece of information is a loaded question: "One thing I have noticed is that when people have private information, they tend to either not share it at all, or to only share it distorted. They fear any piece of information will be used against them. So I looked for incentives that could lead to credible information sharing." Unfortunately, the researcher uncovered, this fear is valid, and sharing information can indeed be detrimental. While "downstream" information sharing, towards the initial supplier end, does not lead to competitive disadvantage, "upstream" information sharing by suppliers can be very disadvantageous.

### Moral hazards

But one piece of information any retailer is bound to want is whether their suppliers are doing a good job. This is similar to the relationship between a manager and her employees. While the manager wants to make sure employees are working well, she cannot monitor them constantly. Moreover, their incentives are inevitably different from hers: "This particular situation of information asymmetry is called a 'moral hazard'. A Ph.D. student and myself are looking at the moral hazard question within the supply chain." Imagine a supplier with dated, slightly inefficient production methods that affect profits in the whole supply chain. The manufacturer asks the supplier to improve the situation. While the benefits of the improvements will be shared by many in the supply chain, the costs have to be covered by the supplier only. Not receiving its fair share of the investment, the supplier is likely to do nothing. What can be done to encourage the supplier to do the necessary adjustments?

Mehmet Gümüş and his student are looking at three different scenarios. The first one is a baseline, *laisser-faire* scenario, in which nothing is done to either monitor or encourage good behaviour. In the second scenario, the manufacturer introduces a penalty contract. The third case involves the manufacturer sending in their inspectors. The question is whether the second and third scenarios

*Learn more about his research in* ***page 12***

do better than the baseline one, considering the additional costs incurred, especially for sending in inspectors.

In the situation described above, "a penalty scheme actually allows the supplier to get their fair share of the benefits. So this is a case where both supplier and manufacturer become better off." But surprisingly, "while this is still a work in progress, we've already identified situations where *laisser-faire* is actually the best strategy." A penalty scheme is only efficient, Mr. Gümüş explains, if it differentiates clearly between a supplier that is really trying to improve its ways, and one that is simply wanting everybody else to believe it is doing so: "A lazy guy, knowing he is lazy, will always try to imitate a hard working guy." To avoid this, it might be that a manufacturer needs to offer very substantial rewards to well-behaved suppliers. So substantial, in fact, that they offset the benefits. The same can sometimes be said of the work and effort involved in monitoring. In such cases, simply hoping to fall on a sensible supplier, and moving on when doubts arise, could well be the most profitable decision.

**Vital information**

Information problems also arise outside the field of management. Needless to say, these also grab the attention of the researcher: "Since 9/11, the USA and other countries have been trying to preempt terrorist attacks before they happen. It appears there are two key pieces of information defense agencies are trying to obtain." One is what the next target is going to be. The other one is of special interest to Mehmet Gümüş, as it relates to a subject he first had contact with during his Ph.D.: customer behaviour. "Terrorists, like customers, do not always behave rationally. Sometimes, when choosing targets or attack strategies, you can see they are acting irrationally." The actions of a rational terrorist can be inferred by a rational government official, while trying to figure out what an irrational terrorist is planning is simply a waste of time and resources. Accordingly, the second information that is crucial to defense agencies is whether they are faced with a rational terrorist group or not. "What I am working on is trying to understand which piece of information is more crucial, and under which circumstances it is."

> "There is a huge customer sensitivity, for example, to "free shipping", even when the price is higher so as to cover the shipping cost. We have to model this customer irrationality."

**Amazonian cannibals**

The importance of customer behaviour is also apparent in the other strand of research Mehmet Gümüş is following: pricing. The advent of online stores such as book retailer Amazon raises intriguing issues: "There is a huge customer sensitivity, for example, to "free shipping", even when the price is higher so as to cover the shipping cost. We have to model this customer irrationality." Online stores have also brought about the selling of used goods in the immediate proximity of new ones; indeed used products are becoming more popular thanks to this new possibility. When a brand new product is introduced (say an iPhone 5), there is no competing "used version" of it available. But with online sellers, it does not take very long for such competing products to appear: it can be a matter of weeks. "So the used version will start competing with the new version. The manufacturing company is now seeing the cannibalizing effect, where their products are cannibalizing their own." This inevitably affects the value of the traditional return policy, which in turns changes the power relationship between retailers and manufacturers, skewing it, perhaps surprisingly, towards the manufacturer.

With all these projects (and many others) going on at once, Mehmet Gümüş is clearly enjoying himself since his arrival at McGill. Joining GERAD was the icing on the cake, as it opened up the possibility of even more interactions and collaborations. Clearly Mr. Gümüş will continue to be fascinated by everything he sets eyes upon (snow excepted) for a very long time indeed. ■

**Mehmet Gümüş**
*Desautels Faculty of Management*
*McGill University and GERAD*

# Keeping the Lights On

Miguel F. Anjos, James Ostrowski and Anthony Vannelli

Electricity is fundamental to nearly all aspects of our daily lives. The electricity supply has been working so well for so many years that we do not think much about it. Its importance in our lives is only fully appreciated when the power goes out! Indeed, our society almost comes to a standstill without electricity, as millions of people in Quebec realized in March 1989 and January 1998.

Our smoothly functioning power systems are quite complex and were developed over decades. One of the fundamental issues is to match supply with demand. This problem must be solved for different time scales that vary from extremely short (real-time operation) to extremely long (decades-ahead planning of generation to meet ever-growing demand). For a time scale of a few days, this problem is usually called the unit commitment (UC) problem.

The typical UC problem is concerned with scheduling the operation of approximately 200 electric power generating units over a horizon of one day to one week in order to meet demand at minimum cost. The solution must satisfy the requirements of each generating unit (for instance, its physical limits on how quickly it can ramp the production level up or down) and the requirements of the system as a whole (for example, there must be sufficient reserves in the system in case of unexpected increases in demand). Each generating unit has different operating costs, and in some cases variable availability (such as for wind power). The problem is further complicated by the fact that demand for electricity varies significantly in different seasons and at different times of the day. Moreover, electricity has to be consumed immediately upon production because the storage capacity is extremely limited.

The result is a optimization problem that, for any realistic application, is large in scale and requires significant computational time to solve. However, better UC decisions can result in significant economic benefits. Optimization-based techniques have been used for many years to solve the UC problem, and considerable effort has been invested to develop methods that improve the solution quality. Indeed, given the costs involved and the recurring need to solve UC problems, even small improvements translate into substantial savings.

> The need to better understand the possible combinations of the binary variables in UC solutions was the motivation for this paper.

The UC problem is generally modeled as a mixed-integer linear programming problem. As computational power has increased over the years, so has the complexity of UC formulations. A major difficulty in solving these problems is the presence of binary variables to model key elements such as the on/off state of each generating unit.

The need to better understand the possible combinations of the binary variables in UC solutions was the motivation for this paper. In this article, we considered a basic formulation of UC as a mixed-integer linear programming problem and began by conducting a computational comparison of the common UC formulations in the literature. Our results showed that a recent formulation that reduces the number of binary constraints by 66% is actually much less efficient in practice than other formulations that keep all the binary constraints. This seemingly counterintuitive claim is explained

by the fact that a greater number of binary constraints means that the algorithm has more choices for variables to branch on, which results in better branching decisions. Furthermore, the selection of inequalities that can be added to improve the quality of the formulation is also much greater, and this is helpful as well.

The choice of the inequality constraints to include in the formulation is in fact a critical ingredient to the success of any algorithm to solve problems like UC. The best-possible inequalities are those that are facets of the convex hull of all possible combinations of values for the binary variables. In general, the more closely we can describe this convex hull, the more easily the problem can be solved. In the second part of this paper, we studied the convex hull of power generation schedules and discovered several groups of inequalities that significantly strengthen the basic UC formulation. Several of these new inequalities are strictly better than the corresponding inequalities in the basic formulation. Moreover, the improved inequalities related to the ramping constraints mentioned above capture some of the facet information of the problem. Finally, our computational results show that the resulting formulation can considerably decrease the solution time for large instances of UC.

The best-possible inequalities are those that are facets of the convex hull of all possible combinations of values for the binary variables.

Much work remains to be done on UC and related problems in electricity management. New optimization techniques are critical to the success of major changes happening in the electricity sector, such as the expansion of renewable energy sources and the advent of the smart grid. These changes will make UC even more challenging! Fortunately, there is great promise in an optimization technique called semidefinite programming. This is a generalization of linear programming that is much more effective for many problems with binary variables. GERAD researchers are working on modelling techniques and algorithms for semidefinite programming that are expected to have a significant impact on our ability to solve hard problems such as UC and thus make an important contribution to our environment and our society as a whole. ■

To appear in *IEEE Transactions on Power Systems*

Original title:
*Tight Mixed Integer Linear Programming Formulations for the Unit Commitment Problem*

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# Modeling Waves of Extreme Temperature:
## The changing Tails of Four Cities

Debbie J. Dupuis

Extreme weather and climate events negatively impact our society and environment. Heat waves, loosely defined as periods of unusually hot weather, are especially unforgiving for societies and infrastructures unable to cope or adapt. Stress from heat waves has been linked to excess human mortality and morbidity, violent behavior, drought, forest fires, tornadoes, decreased agricultural and livestock productivity, construction and transportation difficulties, and reduced electrical power supply.

To combat the negative impacts of heat waves on our society and environment, governmental and nongovernmental organizations need to ensure adequate socioeconomic conditions for the vulnerable and dedicate the necessary resources to address problems. Policy decisions at local, national and international levels, from those on issuing heat advisories to those on the proper dimensioning of engineering works, need to be based on good estimates of the recurrence probability of heat waves of different intensities and length. We need to provide these estimates and measures of their accuracy and uncertainty, along with projections of how they may change in the future. The former, along with estimating changes in recurrence probabilities of heat waves over 50 years, are the object of this paper.

To combat the negative impacts of heat waves on our society and environment, governmental and nongovernmental organizations need to ensure adequate socioeconomic conditions for the vulnerable and dedicate the necessary resources to address problems.

While there are many different technical definitions of heat waves, most include a period of consecutive days, sometimes called a *run*, during which some measure of heat stress, e.g. maximum daytime temperature or minimum nighttime temperature, is above a pre-specified unusually high value. As early as Mearns, Katz and Schneider (1984) there is interest in computing the probability of an extreme *run event*. A criterion is set for the run event and the relative frequencies of occurrence of the events over the observed data are estimates of these probabilities. Many authors have followed the original path of this article by adopting a heat wave definition and *counting* heat waves to show patterns in space or trends in time. All the analyses are on past observations, Global Climate Models data, or on both. While these authors adopt various definitions of heat waves, they all show either an observed increase in the occurrence of heat waves over time and/or project increases in the number of heat waves for the next century.

Extreme value theory provides approximate probabilistic models allowing one to model and make inferences for extreme values. While there have been many important developments in extreme value theory in the last 50 years, the

## *Modeling Waves of Extreme Temperature: The Changing Tails of Four Cities* (continued)

analysis of extreme temperature events remains very challenging. Some have found models for annual maximum temperatures, but modeling annual maxima is insufficient for the study of heat waves and we have to work with daily maxima to eventually get the probability that successive daily maxima exceed a given level. Working with daily maxima increases the level of difficulty significantly as we now have to recognize, and allow for, not only time-trends, but seasonality in the mean and in the variability, as well as serial correlation.

Results show that while heat waves have become significantly more intense and more frequent in the four cities studied, the 50-year evolution is not the same in the four cases.

In this paper, we implement a preprocessing approach and introduce new modeling tools to ensure a proper implementation on our extreme temperature data. Traditional preprocessing is used to account for trends and seasonality in the mean, seasonality in the variance and serial correlation in daily maximum temperatures. The additional modeling, which includes the estimation of *seasons* over the year using change-point analysis and, then for each season, the estimation of *blocks* over time during which extreme daily maximum temperature exhibits similar tail behavior. In-sample and out-of-sample goodness-of-fit measures show that the proposed model is an excellent fit to the data. We then simulate long series of daily maximum temperatures to assess the change in the recurrence probabilities of heat waves over the fifty-year period studied. Results show that while heat waves have become significantly more intense and more frequent in the four cities studied, the 50-year evolution is not the same in the four cases. Furthermore, we show that changes are not uniform throughout the year, e.g. in Tucson, we see that while intense 5-day heat waves in the early fall are more than five times more likely in 2005 than 50 years prior, the likelihood of very intense 2 to 5-day heat waves in the early spring in the city has less than doubled over the 50 years. To our knowledge, no other published model allows inferences and comparisons for such year-round extreme events. ■

To appear in *Journal of the American Statistical Association*

Original title
*Modeling waves of extreme temperature: The changing tails of four cities*

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# Supply Side Story: Risks, Guarantees, Competition and Information Asymmetry

Mehmet Gümüş , Saibal Ray and Haresh Gurnani

The fragmentation of supply chains also reduced the end-to-end visibility across the chain, which exacerbates the detrimental effect of supply risk. In this context, the need for effective risk management in the presence of information asymmetry has emerged as an issue of concern for top management.

The information revolution flattened the world by leveling the field for the companies around the globe and enabling them to create more efficient supply chains. However, as supply chains expand to new geographies to seek for lower cost solutions; it inevitably exposed them to the risk of disruptions such as natural disasters, financial breakdowns, etc. The fragmentation of supply chains also reduced the end-to-end visibility across the chain, which exacerbates the detrimental effect of supply risk. In this context, the need for effective risk management in the presence of information asymmetry has emerged as an issue of concern for top management. Among the strategies used to deal with this concern, a popular one is called "Price and Quantity (P&Q) Guarantees". In other words, P&Q guarantees are contractual assurances from suppliers to provide a certain minimum quantity/capacity at a fixed price for the buyer.

In this paper, we study the role of such P&Q guarantees in managing supply disruption risk and the associated information asymmetry. Specifically, we study the following research questions:

- What motivates an unproven supplier to offer a P&Q guarantee? Under what conditions will she do so?
- How effective are P&Q guarantees in dealing with information asymmetry and supply risk? Especially, when and how do they provide the buyer visibility into the supply system?
- Finally, is the buyer always better off with this type of guarantee?

To answer the above questions, we develop a stylized two-layer supply chain model. At the downstream, there is a buyer (consider a Canadian producer) who has two suppliers. One of them is more expensive, and less risky (consider a "supplier $S_R$" in North America). The other one is cheaper, and more risky (consider a "supplier $S_U$" in Asia). Moreover, the $S_U$'s level of risk is unknown to the buyer. Building on this model, we create two different scenarios depending on whether $S_U$ offers P&Q guarantees or not.

First, we show that, in no-guarantee scenario, there is always incentive for the supplier $S_U$ to distort her private information regarding the true risk level; hence, she cannot credibly signal it to the buyer. However, a P&Q guarantee may allow her to do so by differentiating between the two risk levels through the guaranteed price. The buyer can then make the allocation decision between his two suppliers based on perfect visibility into the supply

## *Supply Side Story: Risks, Guarantees, Competition and Information Asymmetry* (continued)

system. So, P&Q contracts then act both as a supply assurance as well as a signaling device. We also analyzed the precise circumstances under which credible information sharing across supply chain is sustainable in equilibrium.

> Interestingly, it depends on the degree of information asymmetry at the supplier level [...] Consequently, guarantees can then increase costs for the buyer.

Next, we studied how such signaling device affects the buyer. Interestingly, it depends on the degree of information asymmetry at the supplier level. If it is not very high, it increases the intensity of competition between two suppliers, which in turn leads to lower costs for the buyer. But, when the degree of information asymmetry is very high, P&Q guarantee contract enables unproven suppliers to prove themselves, which in turn allow them to charge the buyer a premium price. Consequently, guarantees can then increase costs for the buyer.

Our paper is among the first in the literature to consider supplier-led initiatives to signal their capability to buyers in order to gain market share. In this context, our results suggest that even though supply guarantees can be used as an effective tool in the early stages of procurement relations when visibility into supplier reliability is likely to be low, buyers may need to be wary about such guarantees due to the cost associated with information rent. ■

To appear in *Management Science*

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# Energy Security:
## A Robust Optimization Approach to Design a Robust European Energy Supply via TIAM-WORLD

Frédéric Babonneau, Amit Kanudia, Maryse Labriet, Richard Loulou and Jean-Philippe Vial

The security of energy supply is a very important issue in most developed countries, in particular Europe, Japan, and the USA. In this article, we formulate the problem as one of long term reliability of the energy supply corridors of a particular region. Each such corridors (pipeline or sea route) is apt to become partly or fully unavailable (for any reason whatever) with a certain probability that depends upon the source of the corridor or the corridor itself. We assume that this probability is known and we seek a global configuration of the available corridors that is robust under the assumed uncertainties.

It consists in guaranteeing a given probability of satisfying the energy requirements of the region, at extra minimal cost.

The approach used in this research is a hybrid of chance constrained programming and robust programming. It consists in guaranteeing a given probability of satisfying the energy requirements of the region, at extra minimal cost. The guaranty is obtained under very mild technical assumptions, which thus insure the applicability of the method. The approach uses the TIAM WORLD model, suitably modified to include one additional constraint that "robustifies" the entire set of energy supply constraints for the region.

The method is applied to the energy supply of Europe, by considering a set of 67 potential corridors. The results show that a 95% reliability may be obtained at an additional cost of less than 0.7%, by suitably choosing the capacities of 29 corridors among the 67 available corridors. Several indexes of diversification are calculated, such as the coefficient of variation, or the diversification measures of Shannon and of Hirschmann–Herfindahl. The robust configuration found by the method increases these indexes in a dramatic manner compared to the reference scenario. Moreover, the solution significantly decreases European energy imports, while preserving in a large measure the energy mix within Europe. This is good, as the recommended solution has a very minor impact on the European technological mix. ■

To appear in *Environmental Modeling & Assessment*

Original title
*Energy Security: A Robust Optimization Approach to Design a Robust European Energy Supply via TIAM-WORLD*

**Frédéric Babonneau**
*Economics and Environmental Management Laboratory and ORDECSYS Scientific Consulting, Switzerland*

**Amit Kanudia**
*KANORS Consultants, India*

**Maryse Labriet**
*ENERIS, Spain*

**Richard Loulou**
*KANLO Consultants, France, and GERAD*

**Jean-Philippe Vial**
*ORDECSYS Scientific Consulting, Switzerland, and GERAD*

# Solving Optimization Problems with Complementarity Constraints Using an Interior-Point Method

Zoumana Coulibaly and Dominique Orban

The distinctive feature of optimization problems with complementarity (or "equilibrium") constraints is the presence of two subsets of variables, say $x$ and $y$, subjected to the constraint $\min\{x,y\} = 0$, where the minimum occurs componentwise. This condition is reminiscent of that satisfied by primal and dual variables in the classic optimality conditions of bound-constrained problems.

Problems with complementarity constraints can be traced back to the concept of Stackelberg (1952) games in economy but they also appear in the operations research literature from the 1970s in the context of bilevel optimization. If the lower-level problem of a bilevel program is convex and satisfies a qualification condition, replacing it with its optimality conditions leaves us with an equivalent problem with complementarity constraints. Nowadays, those problems occur in economy (Nash equilibrium problems in game theory), operations research (traffic equilibrium and pricing in transportation networks), engineering (contact, optimal structure design and semiconductor design problems), and of course, multilevel optimization, to name a few. Several such problems are focal points at GERAD and today, problems with complementarity constraints transcend all of the above applications.

Several such problems are focal points at GERAD and today, problems with complementarity constraints transcend all of the above applications.

The peculiar geometry of such problems makes it challenging to solve them efficiently. The set $\min\{x,y\} = 0$ can be visualized as two orthogonal half axes. This set has an empty strict interior and this type of geometry can defeat the classical optimality conditions. The expression of this constraint is also nonsmooth. These two observations seem to preclude efficient methods for continuous optimization such as interior-point methods—the state of the art—from being used. In addition, we now know that problems with complementarity constraints have their own sets of optimality conditions and those differ from the classical conditions.

We first need to reformulate the nonsmooth constraint. For instance, $x \geq 0$, $y \geq 0$, $x \cdot y = 0$ is an equivalent smooth formulation, where $x \cdot y$ is the usual dot product. A second formulation imposes $x \geq 0$, $y \geq 0$ and $x \cdot y \leq 0$. Other forms, some based on the Fischer-Burmeister function, appear in the literature. With a smooth constraint in hand, the first numerical approaches consisted in enlarging the feasible set using an empirical parameter $\varepsilon > 0$ by changing $x \cdot y \leq 0$ to $x \cdot y \leq \varepsilon$. The perturbed problem could then be solved using a classical method. This is only partly satisfactory because the solution of the perturbed problem depends on the perturbation. A solution of the original problem is recovered if we select a sequence $\{\varepsilon_k\}$ of enlargements that converges to zero. Unfortunately, the precise choice of $\varepsilon_k$ determines the convergence properties of this algorithm. In our opinion, the major disadvantage of this approach is that it requires advance knowledge of the presence of complementarity constraints and of where they are in the model—indeed only they must be enlarged. The consequence is that the method has a "complementarity mode" which should be activated when complementarity constraints are present. Other types of approaches

## *Solving Optimization Problems with Complementarity Constraints Using an Interior-Point Method* (continued)

in the literature have similar aspects specific to such constraints.

In this article, we were in search of a generic method that does not place the burden of managing enlargements on the user. In our approach, new actual variables of the problem play the role of $\varepsilon_k$. This is made possible by the classical $\ell_1$-penalty function—a tool from the 1960s!—which solves the original problem by solving a sequence of unconstrained problems. The added difficulty is that nonsmooth terms creep into the objective function! Fortunately it is possible to recover a smooth objective via the introduction of new variables, termed *elastic*. The price to pay this time is that the resulting subproblems have constraints again. They are however all inequality constraints that enlarge the feasible set. It is then realistic to consider interior-point methods! By carefully managing various parameters, it is possible to solve the original problem efficiently by solving the subproblems inexactly, and therefore cheaply. This elastic approach was initially proposed by Gould et al. (2010) for general continuous problems. Its strength is not only its numerical performance but its generality. It applies indeed beyond problems with complementarity constraints by construction—all constraints are relaxed, whether or not they express complementarity. This has several consequences. Firstly, there is no "complementarity mode" in this approach. Moreover, we can attack any problem with a (locally or globally) empty strictly feasible set—those are said to be *degenerate*. They occur in optimal structure design but also in other contexts where models are built automatically from functional data such as (partial) differential equations. We have already mentioned that problems with complementarity constraints have their own specific sets of optimality conditions. The same holds for other classes of degenerate problems. The magic of the $\ell_1$ penalty is that by approximately satisfying the classical optimality conditions of the subproblems, we asymptotically satisfy the specific optimality conditions of the original problem! This is counter-intuitive. Even more so when you realize that this holds for various classes of degenerate problems, each with their own specific sets of optimality conditions. In a sense, the algorithm "knows" which optimality conditions to aim for, without prior knowledge of the structure of the problem. ■

This is made possible by the classical $\ell_1$-penalty function—a tool from the 1960s!—which solves the original problem by solving a sequence of unconstrained problems.

*Z. Coulibaly and D. Orban. An $\ell_1$ elastic interior-point method for mathematical programs with complementarity constraints. Les Cahiers du GERAD G-2009-74, GERAD, Montréal, Canada, 2009. To appear in SIAM Journal on Optimization.*

*N. I. M. Gould, D. Orban, and Ph. L. Toint. An Interior-Point $\ell_1$-Penalty Method for Nonlinear Optimization. Les Cahiers du GERAD G-2010-38, GERAD, Montréal, Canada, 2010. From the original 2003 Rutherford Appleton Laboratory report.*

*H. Van Stackelberg. The Theory of Market Economy. Oxford University Press, Oxford, 1952.*

To appear in *SIAM Journal on Optimization*

Original title
*An $\ell_1$ elastic interior-point method for mathematical programs with complementarity constraints*

**Zoumana Coulibaly**
**Dominique Orban**
*Department of Mathematics and Industrial Engineering*
*École Polytechnique de Montréal and GERAD*

# Conflict vs Cooperation in a Two-Stage Production System: Complexity Analysis

U. V. Manoj, Chelliah Sriskandarajah and Edouard Wagneur

This article studies conflict and cooperation issues in a two-stage production system with $n$ jobs when the objectives of the two stages do not coincide: the objective of the first stage is to minimize the sum of the completion times of all the $n$ jobs, while the second stage's objective is to minimize the number of tardy jobs. The first and second stages are interconnected by an intermediate buffer.

Such situations occur for instance in the automotive industry.

Resequencing of the jobs at the buffer is always possible to enhance the performance of the system. However, there is a cost associated with the re-sequencing of jobs at this buffer. The performance of the system is measured by a convex combination of the costs at each stage, and the cost of re-sequencing of the jobs at the intermediate buffer. Separate optimization at each production stage yields an optimal schedule for this stage determined by its cost considerations. We show that when a stage solves its scheduling problem under the constraints imposed on it by the other stage, the resulting system will be suboptimal. Therefore, there is a need for coordination of the schedules. We show that although each individual problem can be solved in polynomial time, the coordination problem is NP-hard in the strong sense. Then, we design a Genetic Algorithm based on the idea of non dominated sorting for solving the system problem. The GA provided ideal solutions quickly, and numerical studies reveal that the cost saving provided by the coordinated schedule between both stages is usually significant. Coordination is possible between stages due to this cost saving. Finally, we briefly discuss the implications on our work for how both stages negotiate, coordinate, and implement their supply chain schedules in practice. ■

... the objective of the first stage is to minimize the sum of the completion times of all the $n$ jobs, while the second stage's objective is to minimize the number of tardy jobs. The first and second stages are interconnected by an intermediate buffer.

*This research was supported in part by the NRC grant RGPIN-143068-05*

To appear in
*Computers & Operations Research*, 39, 2012,12451256

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**Edouard Wagneur**
*Department of Mathematics and Industrial Engineering*
*École Polytechnique de Montréal and GERAD*

# Les Cahiers du GERAD – GERAD Technical Reports

## *Mathematical methods in support of decision making*

G-2011-18 On the Weber Facility Location Problem with Limited Distances and Side Constraints
**Fernandes, I.F., Aloise, D., Aloise D.J., Hansen, P., Liberti, L.**

G-2011-21 A Vertex Cut Algorithm for Model Order Reduction of Electronic Circuits
**Kitanov, P., Marcotte, O., Schilders, W., Shontz, S.M.**

G-2011-26 Gaussian Variable Neighborhood Search for Continuous Optimization
**Carrizosa, E., Drazic, M., Drazic, Z., Mladenovic, N.**

G-2011-27 Variable Neighborhood Search for Metric Dimension and Minimal Doubly Resolving Set Problems
**Mladenovic, N., Kratica, J., Kovacevic-Vujcic, V., Cangalovic, M.**

G-2011-28 A Parametric Simplex Search for Unconstrained Optimization Problem
**Zhao, Q., Mladenovic, N., Urosevic, D.**

G-2011-29 Multistart Branch and Bound for Asymmetric Distance-Constrained Vehicle Routing Problem
**Almoustafa, S., Hanafi, S. Mladenovic, N.**

G-2011-30 Templating and Automatic Code Generation for Performance with Python
**Orban, D.**

G-2011-31 Fitting Censored Quantile Regression by Variable Neighbourhood Search
**Rajab, R.S., Drazic, M., Mladenovic, N., Yu, K.**

G-2011-32 Maximizing Edge-Ratio Is NP-Complete
**Noble, S.D., Hansen, P., Mladenovic, N.**

G-2011-34 Global Approaches for Facility Layout and VLSI Floorplanning juin 2011, 26 pages.
**Anjos, M.F., Liers, F.**

G-2011-35 Semidefinite Resolution and Exactness of Semidefinite Relaxations for Satisfiability
**Anjos, M.F., Vieira, M.V.C.**

G-2011-36 Degeneracy of Harmonic Means Clustering
**Carrizosa, E., Al-Guwaizani, A., Hansen, P., Mladenovic, N.**

G-2011-37 The Mesh Adaptive Direct Search Algorithm with Treed Gaussian Process Surrogates
**Gramacy, R.B., Le Digabel, S.**

G-2011-38 The Poisson Maximum Entropy Model for Homogeneous Poisson Processes
**Khribi, L., Fredette, M., MacGibbon, B.**

G-2011-39 Centrality and Betweenness: Vertex and Edge Decomposition of the Wiener Index
**Caporossi,G., Paiva, M., Vukicevic, D., Segatto, M.**

G-2011-40 On r-Equitable Colorings of Trees and Forests
**Hertz, A., Ries, B.**

G-2011-43 A Review of Survival Trees
**Bou-Hamad, I., Larocque, D., Ben-Ameur, H.**

G-2011-44 A Primal-Dual Interior-Point Algorithm for Linear Programming with Selective Addition of Inequalities
**Engau, A., Anjos, M.F.**

G-2011-45 On the Maximum Orders of an Induced Forest, an Induced Tree, and a Stable Set
**Marcotte, O., Hertz, A., Schindl, D.**

G-2011-48 On Figures of Merit for Randomly-Shifted Lattice Rules
**L'Ecuyer, P., Munger, D.**

G-2011-49 Variable Neighborhood Search for the Travelling Deliveryman Problem
**Mladenovic, N., Urosevic, D., Hanafi, S.**

G-2011-50 Trajectory-Following Methods for Large-Scale Degenerate Convex Quadratic Programming
**Gould, N.I.M., Orban, D., Robinson, D.P.**

G-2011-51 Network Descriptors Based on Betweenness Centrality and Transmission and their Extremal Values
**Vukicevic, D., Caporossi, G.**

G-2011-53 Using Predictive Risk for Process Control
**Plante, J.-F., Bjorg Windfeldt, G.**

G-2011-54 The Normalized Revised Szeged Index
**Aouchiche, M., Hansen, P.**

G-2011-56 Stabilized Dynamic Constraint Aggregation for Solving Set Partitioning Problems
**Benchimol, P., Desaulniers, G., Desrosiers, J.**

G-2011-58 Robust VIF Regression
**Dupuis, D.J., Victoria-Feser, M.-P.**

# Les Cahiers du GERAD – GERAD Technical Reports *(continued)*

*Applications development in large scale technological, commercial and economic systems*

G-2011-19 Improving QoS of all-IP Generation of Pre-WiMax Networks Using Delay-Jitter Model
**Dahmouni, H., El Ghazi, H., Bonacci, D., Sansò, B., Girard, A.**

G-2011-22 Trade-Off Between Robust Risk Measurement and Market Principals
**Assa, H.**

G-2011-25 Game Theoretic Analysis of Negotiations Under Bankruptcy
**Annabi, A., Breton, M., François, P.**

*Mathematical methods in support of decision making* ***and***
*Applications development in large scale technological, commercial and economic systems*

G-2011-20 Integer Linear Programming Models for a Cement Delivery Problem
**Hertz, A., Uldry, M., Widmer, M.**

G-2011-23 Two-Phase Mathematical-Programming Heuristic for Flexible Assignment of Activities and Tasks to Work Shifts
**Elahipanah, M., Desaulniers, G., Lacasse-Guay, E.**

G-2011-24 A Simulation-and-Regression Approach for Stochastic Dynamic Programs with Endogenous State Variables
**M. Denault, M., Simonato, J-G., Stentoft, L.**

G-2011-41 Algorithm for Qualifying Eye Movements During Handwriting
**Alamargot, D., Caporossi, G., Chesnet, D.**

G-2011-42 Strategic Effects of a Border Tax Adjustment
**Eyland, T., Zaccour, G.**

G-2011-46 Learning Under Partial Cooperation and Uncertainty
**Breton, M., Sbragia, L.**

G-2011-52 Optimization-Based Adaptive Large Neighborhood Search for the Production Routing Problem
**Adulyasak, Y., Cordeau, J.-F., Jans, R.**

G-2011-57 A Branch-Price-and-Cut Method for a Ship Routing and Scheduling Problem with Split Loads
**Stalhane, M., Andersson, H., Christiansen, M., Cordeau, J.-F., Desaulniers, G.**

# Scholarships

- FQRNT – Doctoral fellowship for international students: **Nahid Masoudi**, Management Sciences specialization, directed by Georges Zaccour.
- FQRNT – Quebec-Mexico postdoctoral fellowship: **María Angélica Salazar-Aguilar**, co-directed by Gilbert Laporte and André Langevin.
- NSERC – Research scholarship: **Erik Frenette**, summer internship of 16 weeks, directed by Olivier Bahn.
- NSERC – Research scholarship: **Laetitia Wong**, summer internship of 16 weeks, directed by Michèle Breton.

# Awards, honours and contributions

- **Gerardo Berbeglia** has won the 2010 Mercure Award for the best doctoral dissertation. His dissertation, entitled *Complexity Analyses and Algorithms for Pickup and Delivery Problems*, was co-directed by Jean-François Cordeau and Gilbert Laporte.
- The 2011 Journées de la finance mathématique, organized by the Institut de finance mathématique de Montréal (IFM2), rewarded the three best M.Sc. theses of 2010. Mourad El-Hila, of HEC Montréal, took first place. His thesis, entitled *Estimation et calibrage du processus GARCH : une étude empirique*, was directed by Michèle Breton and Lars Stentoft (Finance).
- During the annual conference of the Association québécoise de pédagogie collégiale (AQPC), Alain Hertz was honored on June 8 at the Minister's Awards ceremony for the creation of his pedagogical work *L'Agrapheur - Intrigues policières à saveur mathématique.*
- With 30 years' experience in operational research, **François Soumis**, a professor in the Department of Mathematics and Industrial Engineering of École Polytechnique de Montréal, the holder of the Canada Research Chair in Large Transportation Network Organization and a member of the GERAD, has received a prestigious $40,000 grant from IBM.
- **Pierre Duchesne**, professor in the Department of mathematics and statistics of the Université de Montréal, has been nominated full professor.
- **Dominique Orban**, associate professor in the Department of Mathematical and Industrial Engineering at École Polytechnique de Montréal, has received the award for the best article of 2010 from Computational Management Science journal, for his article entitled *DrAmpl: a meta solver for optimization problem analysis.*
- The Canada Research Chair in Logistics and Transportation, hold by **Jean-François Cordeau**, will continue its activities over the next five years through the renewal of its grant, which amounts to $ 500 000, by the Chairs Canada Research Program.

# Thesis Defences

- **Rémi Pacqueau**, supervised by François Soumis
  Doctoral Thesis: *Optimisation stochastique d'horaires de personnel*

- **Lotfi Khribi**, co-supervised by Marc Fredette and Brenda MacGibbon
  Doctoral Thesis: *Application du principe de maximum d'entropie dans la prédiction des évènements récurrents dans le cas des processus de Poisson*

# Trainees

November 2, 2011 to February 2, 2012
Romain Absil (Université de Mons, Belgium)

October 21 to December 13, 2011
Alberto Costa (École Polytechnique de Palaiseau, France)

September 13 to December 31, 2011
Thibault Lehouillier (Grenoble INP-Ensimag, Université de Grenoble, France)

September 6, 2011 to September 1, 2012
Fabien Ngendakuriyo (Université catholique de Louvain, Belgium)

July 25 to September 2, 2011
Zaki Dernaoui (École Polytechnique de Paris, France)

July 18 to September 2, 2011
Benjamin Heymann (École Polytechnique ParisTech, France)

July 4 to September 1, 2011
Seyed Reza Mirnezami (HEC Montréal, Canada)

June 20 to August 29, 2011
Emmanuel Bigeon (ENSEEIHT, Toulouse, France)

June 14 to October 14, 2011
Andre Ianni (Dipartimento di Informatica e Sistemistica, Università di Roma, Italia)

May 16 to August 15, 2011
Mathieu Bayonne (ENSTA Paris-Tech, Paris, France)

May 9 to August 26, 2011
Erik Frenette (Concordia University, Montréal, Canada)

May 6 to August 26, 2011
Zeyneb Brika (École Polytechnique de Montréal, Canada)

April 4 to September 2, 2011
Antoine Mesnard (ISIMA, France)

April 1 to July 13, 2011
Berit Lofstedt (Technical University of Denmark, Denmark)

February 11, 2011 to February 11, 2012
Marcia Helena Moreira Paiva (Universidade Federal do Espirito Santo, Brazil)

January 11, 2011 to January 11, 2012
Camille Fertel (UQÀM, Canada)

October 4, 2010 to August 29, 2011
Nicolas Grebille (ENSTA Paris-Tech, Paris, France)

# Visitors

October 30 to November 2, 2011
Coralia Cartis (University of Edinburgh, UK)

October 12-16, 2011
Vito Fragnelli (Università del Piemonte Orientale, Italy)

October 7-16, 2011
Snježana Majstorović (University of Osijek, Croatia)

October 4 to December 15, 2011
Jordan Ninin (Institut de recherche en informatique de Toulouse, IRIT, France)

September 29-30, 2011
Nawel Amrouche (Long Island University, New York, USA)

September 28 to October 5, 2011
Damir Vukičević (University of Split, Croatia)

September 13-19, 2011
Andrea Bettinelli (Università Degli Studi Di Milano, Italia)

August 18 to September 30, 2011
Philipp Hungerländer (Alpen-Adria Universität Klagenfurt, Austria)

August 16 to October 7, 2011
Manuel Vieira (University Nova de Lisboa, Portugal)

August 15-29, 2011
David Schindl (Haute école de gestion de Genève, Switzerland)

July 10-17, 2011
Julien Thénié (ORDECSYS, Switzerland)

June 5-12, 2011
Bernard Ries (LAMSADE, Université Paris Dauphine, France)

June 2-6, 2011
Peter Kort (Tilburg University, The Netherlands)

June 1 to August 1, 2011
Alexander Engau (University of Colorado-Denver, USA)

June 1-12, 2011
Rajasekhar Sappidi (University of Waterloo, Ontario, Canada)

May 18-19, 2011
Antonio Antunes (Universidade de Coimbra, Portugal)

May 9-26, 2011
Mabel Tidball (LAMETA, INRA, Montpellier, France)

May 9-12, 2011
Katrin Erdlenbrach (LAMETA, France)

April 28 to May 6, 2011
Giuliana Carello (Politecnico di Milano, Italia)

April 27 to May 5, 2011
Jørgen Glomvik Rakke (Norwegian University of Science and Technology, Norway)

April 25 to May 6, 2011
Bernardetta Addis (Politecnico di Milano, Italia)

January 25, 2011 to January 1, 2012
Nabil Channouf (Sultan Qaboos University, Sultanate of Oman)

# Activities

## Workshops

November 25-26, 2011
**Third Workshop on Dynamic Games in Management Science**

July 18-20, 2011
**2011 INFORMS Simulation Society Research Workshop - Simulation in Complex Service Systems**

May 31 to June 1, 2011
**Mathematical Finance Workshop**

## GERAD contributes to

September 19-23, 2011
**AFG'11: 15th Austrian-French-German Optimization Meeting**

August 15-19, 2011
**Fourth Montreal Industrial Problem Solving Workshop – CRM-Mprime**

July 21-23, 2011
**Eighth International ISDG Workshop**

## CRM-ISM-GERAD Statistics Colloquiums

October 14, 2011
Debbie Dupuis (HEC Montréal and GERAD)
**Modeling Non-Stationary Extremes: The Case of Heat Waves**

October 14, 2011
Richard A. Davis (Columbia University)
**Estimating Extremal Dependence in Time Series via the Extremogram**

September 9, 2011
Aurélie Labbe (McGill University, Canada)
**An Integrated Hierarchical Bayesian Model for Multivariate Expression-Quantitative Trait Locus (eQTL) Genetic Mapping**

September 9, 2011
Edward Susko (CRM-SSC 2011 Prize Recipient) (Dalhousie University, Canada)
**Properties of Bayesian Posteriors and Bootstrap Support in Phylogenetic Inference**

## Séminaire pas ordinaire

May 19, 2011
Lê Nguyên Hoang (GERAD, École Polytechnique de Montréal)
**Introduction to Computational Complexity Theory**

# Activities

## GERAD Seminars

October 31, 2011
Coralia Cartis (School of Mathematics, University of Edinburgh, Edinburgh, UK)
**Optimal Newton-Type Methods for Nonconvex Smooth Optimization**

October 12, 2011
Snježana Majstorović, (Department of mathematics, University of Osijek, Croatia)
**Types of Domination on *m*-ary Chain Cacti**

September 21, 2011
A. Ridha Mahjoub (LAMSADE, Université Paris-Dauphine, France)
**Survivable Network Design Problems and Polyhedra**

August 24, 2011
David Schindl (Geneva School of Business Administration, Switzerland)
**Tabu Search and Network Flows for Tank Refueling**

June 17, 2011
Silvio De Araujo (Universidade Estadual Paulista, Brazil)
**Primal and Dual Bounds for the Capacity Constrained Lot Size Problem with Setup Times**

June 7, 2011
Bernard Ries (Université Paris Dauphine, France)
**On Intersection Graphs of Paths in a Grid**

May 18, 2011
Antonio Antunes (Universidade de Coimbra, Portugal)
**Integrated Public Facility Location**

## "Meet a GERAD researcher!" Seminars

November 3, 2011
Karim Samoura (Groupe d'études interdisciplinaires en géographie et environnement régional (GEIGER, UQAM))
**Approche participative de l'aide multicritère à la décision : enseignements tirés l'application à l'évaluation comparative des options d'exploitation du potentiel hydroélectrique du bassin du Konkouré en Guinée**

October 27, 2011
Jean-Philippe Waaub (Groupe d'études interdisciplinaires en géographie et environnement régional (GEIGER, UQAM) et équipe)
**L'aide multicritère à la décision en contexte multi acteurs : processus et outils pour les problèmes sociétaux complexes**

September 15, 2011
Elif Fidan Acar (McGill University, Canada)
**Inference and Model Selection for Pair-Copula Constructions**

September 8, 2011
Christian Genest (McGill University, Canada)
**Faire de la régression logistique multivariée à l'aide de copules**

# Activities

## "Meet a GERAD researcher!" Seminars *(continued)*

May 26, 2011
Adrian Vetta (McGill University, Canada)
**Thinking Ahead: An Approach to Game Playing**

April 21, 2011
Abdessamad Dine (HEC Montréal, Canada)
**Multivariate Trees and Forests for Mixed Outcomes**

April 14, 2011
François Bellavance (HEC Montréal, Canada)
**Estimation du risque d'avoir une collision lorsque le conducteur utilise un téléphone cellulaire en conduisant**

## GERAD Seminar cofunded by Fondation HEC and the Data Mining Chair

September 29, 2011
Damir Vukicevic (Department of Mathematics, University of Split, Croatia)
**Complex Networks and Community Detection**

Fondation HEC MONTRÉAL

HEC MONTRÉAL
DATA MINING CHAIR

## GERAD Seminars cofunded by Fondation HEC and the Chair in Game Theory and Management

October 13, 2011
Vito Fragnelli (Università del Piemonte Orientale, Italia)
**Operations Research Games**

October 6, 2011
Bruno Nkuiya (Université Laval, Canada)
**International Emission Strategies Under the Threat of a Sudden Jump in the Damages**

May 31, 2011
Arnaud Z. Dragicevic (CIRANO, Canada)
**Dynamics of Provision of Threshold Public Goods**

May 16, 2011
Alain Jean-Marie (INRIA, Montpellier, France)
**Optimality of Impulse Harvesting Policies**

Fondation HEC MONTRÉAL

HEC MONTRÉAL
CHAIR IN GAME THEORY AND MANAGEMENT

# Activities

## GERAD/Mprime Seminars

November 3, 2011
Joaquim R.M.M. Martins (University of Michigan, USA)
**Multidisciplinary Design Optimization: An Introduction for Applied Mathematicians**

October 27, 2011
Elizabeth M. Jewkes (University of Waterloo, Canada)
**Optimal Ambulance Location with Tiered Response Time Standards: a Case Study for the Region of Waterloo**

October 20, 2011
Willem-Jan Van Hoeve (Carnegie Mellon University, Tepper School of Business, USA)
**Decision Diagrams for Discrete Optimization**

October 6, 2011
John E. Mitchell (Rensselaer Polytechnic Institute, USA)
**Finding Global Optima of Convex Quadratic Programs with Complementarity Constraints**

September 22, 2011
Jeffrey T. Linderoth (University of Wisconsin-Madison, USA)
**Multi-Term Relaxations for Multi-Linear Programs**

September 15, 2011
Franz Rendl (Alpen-Adria Universität Klagenfurt, Austria)
**Matrix Relaxations for Graph Optimization Problems**

September 8, 2011
Philipp Hungerländer (Alpen-Adria Universität Klagenfurt, Austria)
**Semidefinite Approaches to Ordering Problems**