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In This Issue

World's Largest Fast-Fashion Retailer Uses OR to Reengineer Its Global Distribution Process

With more than 1,500 stores in 68 countries and €6.26B in annual sales (2007), Zara is the flagship brand of the Inditex Group and the world's leading fast-fashion retailer. A key challenge in Zara's supply chain is to determine the exact number of units of each size (up to eight) of each article (up to 3,000 at any time) that should be included in each shipment to each store (more than 1,500) twice a week. This problem is critical because its solution determines the "blood stream" of Zara's merchandise to its stores, and it is challenging because: (i) the number of associated shipment decisions reaches several million, (ii) the amount of relevant data is enormous, (iii) the available warehouse inventory is often limited, (iv) most stores will only sell merchandise when the set of available sizes is complete enough (introducing complex dependencies across sizes), and (v) these decisions must be made in just a few hours. In 2005, the process used by Zara for determining those shipments involved the examination by a large team of warehouse employees of shipment requests sent by every store. Zara recognized that this process could be substantially improved and started collaborating with academic researchers to develop an alternative process involving formal forecasting techniques, stochastic analysis, and a large-scale MIP model. In the summer of 2006 the prototype of a tool implementing these models was tested as part of a controlled pilot field experiment which showed, with a high level of rigor, that the new process increased in-season sales by a conservative estimate of 3%–4%, reduced transshipments between stores, and increased the time articles spent on store displays. Zara completed the deployment of this new optimization-based process to all its stores in 2007. That year, the realized financial benefits from the model's impact on sales alone were estimated at about \$275M with \$34M in additional net income. Both measures are predicted to continue growing at a rate of 13% per annum in subsequent years. "Inventory Management of a Fast-Fashion Retail Network" by F. Caro and J. Gallien is the result of this collaboration.

Helping Cargo Logistics Service Provider to Increase Return from Their Vehicle Fleet

The diversity of customer expectations and the competitive pressure continue to increase across industries. Companies

are faced with the challenge to offer products and services tailored to the needs of their customers and to do so efficiently. To meet this challenge, many companies have started to introduce customer segmentation, an approach where customers of different classes are treated differently, e.g., by differentiating services and prices. In "Capacity Rationing in Stochastic Rental Systems with Advance Demand Information," F. Papier and U. Thonemann analyze customer segmentation motivated by the rail cargo operations of one of Europe's largest logistics service providers. The company owns more than 100 different fleets of cargo rail cars that are rented out to commercial customers. To improve efficiency, the company recently started to differentiate service by offering classic service and premium service. Although the premium service is priced above the classic service, it has become quite popular. Customers requiring high availability, such as customers from the automotive industry, and customers who cannot substitute rail cargo transportation by other transportation modes easily, such as the customers from the petrochemical industries, value the availability guarantee and accept the price premium. The challenge of the rail cargo company is to decide which demands to fill and which demands to reject. The authors build on two operations research approaches to analyze this decision: admission control in queuing and rental systems, and using advance demand information (ADI).

Pricing and Managing Inventory When There Is Competition and Data Uncertainty

It is well known that the pricing and production decisions of a firm over time have a significant impact on its profit. In order to determine an efficient strategy, it is important to take into account the presence of data uncertainty, even when little information is known about the structure of the uncertainty. Similarly, the presence of a competitor can greatly affect what the optimal decision should be. In "Dynamic Pricing and Inventory Control: Uncertainty and Competition," E. Adida and G. Perakis provide a method for addressing these issues. They show that while the Nash equilibrium that results from the competitive setting is not unique, a particular type of equilibrium, called normalized equilibrium, is unique, and they develop an algorithm that enables it to be determined.

Nonconvex Piecewise Linear Optimization

Piecewise linear functions are widely used to approximate nonlinear functions that describe complex physical processes and also to model cost functions that involve quantity discounts. Frequently, such functions are nasty in the sense that the associated optimization problem cannot be solved by standard convex programming methods. In “Mixed-Integer Models for Nonseparable Piecewise-Linear Optimization: Unifying Framework and Extensions,” J. P. Vielma, S. Ahmed, and G. Nemhauser study the modeling of nonconvex piecewise linear functions as mixed integer programming (MIP) problems. They review several new and existing MIP formulations for continuous piecewise linear functions with special attention to multivariate nonseparable functions, and they extend these formulations to lower semicontinuous piecewise linear functions. The formulations are compared with respect to their theoretical properties and their computational performances.

Staffing and Routing in Call Centers

One of the challenges in operating large-scale call centers is to find staffing and routing rules that will minimize the labor cost while maintaining prespecified service levels for different customer classes. A complicating feature is the heterogeneity of both the customer classes and the agent pools. In the paper “Service-Level Differentiation in Many-Server Service Systems via Queue-Ratio Routing,” I. Gurvich and W. Whitt propose staffing and routing rules that are designed to minimize total agent costs while meeting different kinds of class-dependent service-level constraints. Their solution is based on a proportion-based routing rule called *fixed-queue-ratio*; a newly available agent is assigned to serve the class for which a constant multiple of the ratio of its queue length to the total queue length is largest. By setting the parameters of the routing rule properly, the proposed solution can address several different kinds of service-level constraints, including constraints on (i) the proportion of customers that must wait more than a specified time, (ii) the proportion of abandoning customers, and (iii) the average waiting time. There may be different constraints on different classes and constraints that apply to more than one class.

Going After Insurgents: Whether, with What, and Why

In many current conflicts around the world, low-signature terrorists and/or insurgents pursue their political goals by deliberately attacking unarmed civilians or ambushing government troops. Offensive counterinsurgency operations can require government forces to attack insurgents directly in their own strongholds. In “Confronting Entrenched Insurgents,” E. H. Kaplan, M. Kress, and R. Szechtman develop models to address the key questions faced by

the government in such scenarios: Under what conditions should government forces attack insurgent strongholds? How should the government allocate its attacking force across different strongholds when the insurgents’ threat to the government’s civilian population must be taken into account? How should the government respond to “smart” insurgents who anticipate the government’s plan of attack and prepare accordingly? How do the results change when collateral civilian casualties resulting from government attacks on insurgent strongholds are taken into account? The authors address these questions via force allocation and game theory models applied to modified Lanchester combat equations that account for the asymmetries in intelligence and military capabilities that characterize counterinsurgency operations. When the government has perfect intelligence, in equilibrium the insurgents concentrate their force in a single stronghold, which the government either attacks or not, depending upon the resulting casualty count. Otherwise, under reasonable assumptions regarding the government’s behavior and intelligence capabilities, it is optimal for the insurgents to “spread out” in a way that maximizes the number of soldiers required to win all battles. The models show that the insurgents have a strong incentive to blend in with their civilian population. Such strategic insurgent behavior makes it harder for the government to protect its citizens from insurgent attacks. Whether in Lebanon, Gaza, Iraq, or Afghanistan, this is an observable tactic used by terrorists and insurgents the world over.

An Integrated Solver for Optimization Problems

Optimization problems come in different varieties that make them more amenable to one solution approach over another. For some of these problems, however, no single approach is capable of obtaining satisfactory results. In such cases, recent research suggests that the right combination (or integration) of different technologies can simplify modeling and speed up computation substantially. Unfortunately, integration often requires the development of special purpose computer code, which is time consuming and error prone. In “An Integrated Solver for Optimization Problems,” T. Yunes, I. D. Aron, and J. N. Hooker combine mixed-integer linear programming, constraint programming, and global optimization in a single system. They propose a general-purpose integrated modeling and solution framework called SIMPL, which views traditional approaches as special cases of a more general solution method. Their computational experiments involve a variety of problems such as production planning, product configuration, machine scheduling, and truss structure design. With concise models written in SIMPL’s high-level modeling language, they show that the results obtained with special purpose computer codes can be matched, and sometimes improved upon, with a fraction of the implementation effort.

Estimating Probability Sensitivities

Probabilities are importance measures of random performances, and probability sensitivities refer to the partial derivatives of the probability function with respect to certain input parameters. Probability sensitivities can be used to control and optimize the probability function. In “Pathwise Estimation of Probability Sensitivities Through Terminating or Steady-State Simulations,” L. J. Hong and G. Liu study the estimation of probability sensitivities in terminating or steady-state simulations and propose a pathwise sensitivity estimator for probability functions. The proposed estimator has good asymptotic properties, and its rate of convergence can be accelerated by using importance sampling.

Getting More and Better Use from Simulation

Stochastic simulation is useful in many applications because virtually any level of detail can be modeled and any performance measure can be estimated. On the other hand, simulation models often require significant time to run, particularly when there are many alternatives to evaluate, rendering them less useful when real-time or near-real-time judgments and decisions are required. A *metamodel* is an equation-based representation of the simulation as a function of design or decision variables which, critically, can be evaluated or explored as quickly as needed. In “Stochastic Kriging for Simulation Metamodeling,” B. Ankenman, B. L. Nelson, and J. Staum create a new method for generating simulation metamodels, a method that can account for both the experimenter’s uncertainty about the form of the equation-based model and the sampling uncertainty that is inherent in a stochastic simulation. The theory of stochastic kriging is developed, and methods for designing the simulation experiment and fitting the metamodel are provided. An example shows the benefits of stochastic kriging over the standard methods of regression and ordinary kriging.

Tuning the Inventory Level with the Right Lead-Time Quotes Is Key to Profit and Customer Satisfaction

Due to concerns about the loss of goodwill, firms almost never reject an arriving customer and feel pressure to quote short lead times. However, many real-life examples show that overloading the system with customer orders or quoting unrealistic due dates results in late deliveries to the customers and consequently leads to very high penalties that deteriorate the profits. The key is to dynamically control the system through order acceptance, to keep the right amount of stock to achieve responsiveness, and to quote reliable due dates. In “Dynamic Lead-Time Quotation for an M/M/1 Base-Stock Inventory Queue,” S. Savaşaneril, P. M. Griffin, and P. Keskinocak study the joint lead-time quotation, order

acceptance, and inventory management problem of a manufacturer or an after-sales service provider with the objective of maximizing profits. Analysis shows that if inventory is kept at the right level, the lead-time quotes are more “conservative,” i.e., it is more likely that the quoted lead times will be met. Higher or lower inventory levels may result in higher number of customers waiting in the system, leading to a lower “service level.” Depending on the customers’ characteristics, the benefit of inventory flexibility or the benefit of quoting lead times with a higher precision can be significant.

Managing Inventory with Unobserved Lost Sales

In most retail environments, when inventory runs out, the unmet demand is lost and not observed. The sales data are effectively censored by the inventory level. Factoring this censored data effect into demand estimation and inventory control decision makes the problem difficult to solve. In “Bounds and Heuristics for Optimal Bayesian Inventory Control with Unobserved Lost Sales,” L. Chen develops bounds and heuristics for this problem. He first derives a set of solution upper bounds that work for all prior and demand distributions. For a fairly general monotone likelihood-ratio distribution family, he derives relaxed but easily computable lower and upper bounds along an arbitrary sample path. He then proposes two heuristics. The first heuristic is derived from the solution bound results. The second heuristic is based on the approximation of the first-order condition. The numerical results indicate that both heuristics perform very well and outperform the myopic policies by a wide margin.

Optimization of Supply Chains with Periodic Batch Ordering

In production/distribution systems, materials often move in batches, such as containers, pallets, or cases, according to fixed schedules. In these environments, fixed costs are often incurred for each production/order batch and for each shipment. These fixed costs may include shipping costs, material handling costs, and insurance. For managers, it is important to know the right batch sizes and reorder intervals at different locations in order to minimize the supply chain cost. In “Optimal and Heuristic Echelon (r, nQ, T) Policies in Serial Inventory Systems with Fixed Costs,” K. H. Shang and S. X. Zhou consider an N -stage serial supply chain and model such periodic batch replenishments by echelon (r, nQ, T) policies. They provide an approach to obtain the optimal policy and suggest a simple and near-optimal heuristic. Their results provide qualitative insights on managing periodic batch-ordering systems.

Integrating Production and Transportation with Shipment Consolidation

An important objective in a collaborative supply system is to integrate production and transportation functions. It is well known that marginal production cost usually decreases as the scale of production increases. In transportation, cost reduction is realized by shipment consolidation programs that have the effect of merging frequent and small shipments into one large shipment. A cost-effective production and shipment schedule for the supply system is guaranteed only when the essential characteristics of production and transportation operations are incorporated at the same time into planning decisions. In “Economic Lot-Sizing for Integrated Production and Transportation,” H.-C. Hwang formulates problems with general concave production cost functions to model economies of scale in production and stepwise transportation cost functions, and develops optimal algorithms for economic lot-sizing problems with or without backlogging.

Competitive Mechanism for Selfish Jobs

Scheduling jobs that are arriving online on a set of parallel machines is a key issue both in business and engineering applications. But what if problem data is not centrally available but private to selfish job agents, and what if there is no central coordination to distribute jobs over machines? In “Mechanism Design for Decentralized Online Machine Scheduling,” B. Heydenreich, R. Müller, and M. Uetz formalize such a setting. They introduce the notion of a myopic best response equilibrium, relaxing the strict requirements of the classical dominant strategy equilibrium. They show that a surprisingly simple mechanism allows a myopic best response equilibrium in which jobs act truthfully, such that the resulting schedule achieves a constant competitive ratio with respect to the offline optimal social welfare. They also discuss the implications of requiring decentralization, as opposed to central coordination, in distributing the jobs over machines.

How to Compete for Limited Resources

Competitive agent scheduling models are used to model situations where different sets of jobs have to compete for the same processing resources. This class of scheduling models has numerous important applications in practice. For example, in computer networks, a server may have to process various different job classes (such as file downloading, voice messaging, and Web browsing) that are subject to different constraints and have different priority levels. A request to the server for voice messaging, file downloading, or Web browsing constitutes a job. In order to provide a satisfactory quality of service, it is necessary to keep on the

one hand the maximum penalty (e.g., the maximum lateness or the total completion time) of those jobs that correspond to the downloading of files less than or equal to some fixed value, while on the other hand meet the deadlines of the voice messaging packages. This problem can be modeled via competitive multiagent scheduling. In manufacturing settings, machines may have to undergo maintenance at regular intervals. The maintenance of the machines can be viewed as jobs that are the responsibility of, say, Agent B, while the actual jobs to be processed on the machines are the responsibility of Agent A. This problem is also an application of the competitive two-agent scheduling model. In “Competitive Two-Agent Scheduling and Its Applications,” J. Y.-T. Leung, M. Pinedo, and G. Wan study this new class of scheduling models. They enlarge the framework for the competitive two-agent scheduling problems and establish the relationships between two-agent scheduling problems and a class of rescheduling problems as well as a class of scheduling problems subject to availability constraints.

A New Approach for Solving Chance-Constrained Problems Robustly

Data uncertainty, which is prevalent in the real world, often plagues optimization problems by rendering them computationally intractable. In particular, under the influence of data uncertainty, it is computationally excruciating to obtain a solution that is jointly feasible with high probability in a set of linear constraints tainted with uncertain coefficients. Moreover, from a practical perspective, it is impossible to elicit the exact distribution of the uncertain data. In “From CVaR to Uncertainty Set: Implications in Joint Chance-Constrained Optimization,” W. Chen, M. Sim, J. Sun, and C.-P. Teo introduce a new computationally amiable technique for obtaining robust solutions to the joint chance-constrained linear optimization problem. The approach allows the modeler to consider uncertain parameters whose distributions are unknown but with the same descriptive statistics on the data such as known means, variances, and directional deviations, among others. The authors develop interesting approximation schemes, show their tractability, and provide numerical results of applying their techniques to a resource optimization problem.

Inventory Optimization

Optimizing the production and inventory decisions in a supply chain in the face of demand uncertainty is an important activity. When unmet demand at the downstream stage, i.e., customer-facing stage, leads to lost sales, there are no known computational algorithms that can solve this optimization problem efficiently. In “On the Optimal Policy Structure in Serial Inventory Systems with Lost Sales,” W. T. Huh and G. Janakiraman derive useful mathematical properties that describe how the optimal inventory decisions at various stages of the supply chain depend on the

current inventory status of the entire chain. These results are useful in providing both an intuitive and theoretical understanding of the optimal policy.

How to Manage a Multiechelon Stochastic Inventory System

It is recognized that the optimal policy for most multiechelon stochastic inventory systems is either unknown or extremely complicated; thus, it is difficult to implement the optimal policy in practice. In “A Power-of-Two Ordering Policy for One-Warehouse Multiretailer Systems with Stochastic Demand,” L. Y. Chu and Z.-J. M. Shen apply a power-of-two (POT) policy to one-warehouse multiretailer systems with stochastic demand. They develop a polynomial time algorithm to find a close-to-optimal power-of-two policy for arbitrary target service levels. The approach highlights the important role of the warehouse safety stock level, which, in addition to the length of the warehouse order interval, significantly affects the lengths of the retailers’ order intervals. To derive the close-to-optimal policy, the authors employ a plane partition method using information related to the warehouse’s order frequency and safety stock level. The long-run average cost of the proposed POT policy is guaranteed to be no more than 1.26 times the optimal periodic order policy cost under which the warehouse and retailers place synchronized orders periodically.

Workforce Revenue Management via Linear-Programming–Based Policies

As delineated in a recent study by the Pelorus Group, the worldwide market for workforce optimization products increased in 2006 by more than 20 and exceeded \$1 billion. It is anticipated that it will continue to grow at a similar pace in the coming years. Workforce revenue management is a primary emerging application segment. In many industries, an increasing part of the workforce is hired ad hoc to perform a specific project. Thus, professional manpower services is a growing market that brings up new challenges in workforce revenue management. One of the fundamental problems faced by manpower companies is how to manage their resources that usually consist of several limited pools of workers with different skills. Potential (nonhomogeneous) customers arrive over time according to some stochastic process, and the goal is to select which customers to serve so as to maximize the overall profit. In “Provably Near-Optimal LP-Based Policies for Revenue Management in Systems with Reusable Resources,” R. Levi and A. Radovanović develop a simple class of policies for an important model that captures various important workforce management applications. The policies are driven by the optimal solution of a simple linear program that guides the selection of the most profitable types of customers. Surprisingly, it can be shown analytically that these policies perform very close to optimal and are asymptotically optimal as the capacity of the system increases.