Operations Research

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

In This Issue

To cite this article:
(2009) In This Issue. Operations Research 57(1):ii-v. https://doi.org/10.1287/opre.1090.0691

OPERATIONS RESEARCH
Vol. 57, No. 1, January–February 2009, pp. ii–v
ISSN 0030-364X | EISSN 1526-5463 | 09 | 5701 | 00ii

informs

DOI 10.1287/opre.1090.0691

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Closed-Loop Supply Chain Research

Closed-loop supply chains and remanufacturing provide a foundation for sustainable industrial development. This article traces the evolution of research in closed-loop supply chains taking a business perspective (e.g., profit maximization). By taking a business process view of closed-loop supply chains, V. D. R. Guide Jr. and L. N. Van Wassenhove posit in "The Evolution of Closed-Loop Supply Chain Research" the most pressing industrial issues are not simply technical problems and that a holistic business approach is necessary. Based on their extensive experience partnering with companies and in academia, they present numerous opportunities and challenges for interdisciplinary research. The article is also intended to stimulate discussions in the OR/MS community about how we can best contribute to the growing need for the development of industrial systems that are ecologically and economically sustainable.

Better Demand Forecasting for Supply-Constrained Drugs

Forecasting demand based on historical sales data is of limited usefulness in markets where sales volumes have been limited by insufficient product supply. Biologic drugs often fall into this category due to the inherent difficulties and high expenses in manufacturing them, and underestimating demand for these drugs can have serious implications for patients. Rather than relying on sales-based forecasts, in "Modeling Potential Demand for Supply-Constrained Drugs: A New Hemophilia Drug at Bayer Biological Products," J. S. Stonebraker and D. L. Keefer use methods from decision analysis to model the variability in population-based epidemiological data together with the variability in treatment modalities to develop a probability distribution, for the potential demand for hemophilia A drugs. In doing so, they integrate data from the medical literature with judgmental probability data from medical experts. The resulting demand distribution was crucial in convincing senior Bayer management that the underlying demand for hemophilia drugs could be much higher than their intuitions or conventional forecasts suggested. This insight helped them make strategic decisions affecting the future of Bayer's hemophilia drugs. This approach is widely applicable for modeling demand for supply-constrained drugs and for brand-new drugs. Better demand models can help provide strategic direction for both the pharmaceutical industry and for health-care agencies, and thus create lifesaving therapeutic options for patients.

Satisfying Demand in Electricity Markets

The introduction of competition in the power generation business has changed the way in which power generating units are scheduled in many regions of the world. The problem is no longer defined as supplying the demand for power at the lowest cost. Generation companies are required to submit offers to some sort of auction, which yields a spot price for electricity and a production schedule. Each company must therefore decide the amount of energy to offer at each price and for each time period. Several elements complicate this decision, such as nonconvex production costs and operation constraints, uncertainty with respect to the behavior of the rest of agents, and nonconvex revenues. In "Stochastic Power Generation Unit Commitment in Electricity Markets: A Novel Formulation and a Comparison of Solution Methods," S. Cerisola, Á. Baíllo, J. M. Fernández-López, A. Ramos, and R. Gollmer formulate a stochastic unit commitment model that incorporates these elements and results in a large-scale mixed-integer programming problem. The authors solve a realistic numerical example using four different approaches, two of which are original variants of Benders decomposition algorithm for multistage stochastic integer programs.

Financial Hedging in a Competitive Supply Chain

The importance of supply chain modelling has grown considerably in recent years as the global economy has become increasingly inter-connected and as companies have understood the benefit of optimizing their manufacturing and distribution channels. Moreover, it is now routine for large corporates to hedge many of their financial and commodity exposures. These exposures include, for example, exposures to foreign exchange and interest rate fluctuations as well as fluctuations in the price of raw materials and energy costs. It makes sense then to consider the problem of jointly operating and hedging the supply chain. In "Supply Contracts with Financial Hedging," R. Caldentey and M. B. Haugh consider this problem in a competitive environment where a retailer and producer compete in a Stackelberg game. In their stylized model, the retailer purchases a single product from the producer and afterwards sells it in the retail market at a stochastic clearance price. The retailer, however, is budget-constrained and is therefore limited in the number of units that he may purchase from the producer. Moreover, they assume that the retailer's profit depends in part on outcomes in the financial markets. This

dependence motivates the introduction of flexible supply contracts where the producer offers to the retailer a menu of wholesale prices, one for each possible realization of the financial market. They also consider flexible contracts where the retailer is able to trade dynamically in the financial markets. After solving the resulting Stackelberg games, the authors characterize the circumstances under which the retailer and/or producer prefer the flexible contract (with or without dynamic trading) to the classical standard contract. They also compare the efficiency of these new contracts by comparing their performance to that of a central planner who can impose a globally optimal solution.

Delay Announcements: What Will the Customer Do?

In service systems with invisible queues, delay announcements provide prospective customers with an estimate of the time they will have to wait before they can start service. Making delay announcements is a relatively inexpensive way to improve the customer service experience. A maxim in the psychology of waiting is that "uncertain waits feel longer than known waits." But what is the impact of making delay announcements upon the system performance? In order to answer this question, one needs to consider what customers will do when they receive the delay announcement, and in particular how this information will affect their patience. In overloaded regimes, delay announcements can reduce delays experienced by served customers because more customers may elect to abandon, possibly deciding to return at another time. In the paper, "The Impact of Delay Announcements in Many-Server Queues with Abandonment," M. Armony, N. Shimkin, and W. Whitt develop mathematical models, which take into account customer response, that show the benefit of making delay announcements. They emphasize that the performance analysis of delay announcements involves an equilibrium concept.

Dynamic Capacity Expansion for a Service Firm

A service firm such as telecommunication service provider faces three important factors in its capacity planning: demand variability, (existing) capacity obsolescence and deterioration, and capacity supply uncertainty. Indeed, with random demands for its services the firm needs to strike a balance between under-capacity and over-capacity, taking into consideration natural deterioration, technology innovation, as well as supply uncertainty and risk. In "Dynamic Capacity Expansion for a Service Firm with Capacity Deterioration and Supply Uncertainty," X. Chao, H. Chen, and S. Zheng study a dynamic capacity expansion problem where the service firm faces random demand for its service and random supply limit for its capacity expansion; they also consider the potential benefit of future contracts. They show that the optimal capacity expansion policy is of a simple base-stock type, and that incorporating future contracts can substantially improve the firm's performance. The problem is studied under various scenarios including stochastically dependent supply limits and stochastically dependent demand processes, which establish the robustness of the optimal strategy in various market conditions.

Effective Control of a Make-to-Order System

While traditionally manufacturers keep inventory to fulfill demand, many are adapting the make-to-order strategy to better satisfy the varying needs of their customers. Unfortunately, although a make-to-order strategy allows manufacturers to offer greater variety of products, it also results in increased lead times. Therefore, a key challenge in operating make-to-order manufacturing systems is to optimize system performance while keeping lead times at acceptable levels. In "Dynamic Control of a Make-to-Order, Parallel-Server System with Cancellations," M. Rubino and B. Ata study the problem of dynamically controlling a make-to-order manufacturing facility with due-date lead times, and order cancellations and develop nongreedy dynamic policies for controlling such a system.

Determining Which Digits to Report from Your Monte Carlo Simulation Experiment

"Omitting Meaningless Digits in Point Estimates: The Probability Guarantee of Leading-Digit Rules," by W. T. Song and B. W. Schmeiser, determines which digits to report and analyzes what information is lost by truncating low-order digits in statistical estimates. Meaningless digits are defined by comparing their distributions to a uniform (completely random) distribution of the digits, which contains no information. An important special case of Leading-Digit Rules is the simple-to-implement rule that truncates estimates to the left-most nonzero digit of the standard error of the estimate. This particular rule guarantees that the first omitted digit has correctness probability of no more than 0.117, only a bit more than the one-in-ten probability of a completely random digit. This Leading-Digit Rule is designed to appeal to all levels of users; specifically, naive users are not misled, and sophisticated users have assurance that the truncation is consistent with the standard error.

Estimating Quantile Sensitivities

Quantiles have been used widely in financial and service industries as major measures of random performances. Quantile sensitivities provide valuable information on how quantile performances are affected by changes in parameters; they can be used to control and optimize quantile performances. In "Estimating Quantile Sensitivities," L. J. Hong proposes a pathwise quantile-sensitivity estimator that is easy to implement and has attractive mathematical properties.

Stable Coalitions in Supply Chains

Decentralized assembly systems have been the topic of several papers in the operations management literature. However, much of the existing literature (with very few exceptions) focuses on the contracting and coordination issues between suppliers and the assembler. Evidence from real-world assembly systems shows that complementary component-suppliers often form coalitions that sell kits (bundles) to the assembler. In "Coalition Stability in Assembly Models," M. Nagarajan and G. Sošić study the alliances that suppliers may possibly form in this supply chain and predict the structure of possible stable alliances, as a function of the power structure in the market, the number of suppliers, and the structure of the demand.

Cost Sharing in Supply Chain Collaboration

The concept of supply chain collaboration has been widely discussed, and successful case studies have been reported across many industry sectors. Collaborative efforts often lead to increased responsiveness and lower inventory levels, and thus improve supply chain profitability. One important issue in supply chain collaboration is keeping the different parties motivated to collaborate. The willingness to collaborate often depends on the existence of mechanisms that allocate the cost or gain (from the collaboration) in such a way that is considered advantageous by all the participants. The gain sharing or cost allocation issue can be analyzed by using notions from cooperative game theory. In "Cost Allocation for Joint Replenishment Models," J. Zhang discusses the cost allocation issue for a supply chain in which a group of retailers jointly replenish their inventories. Based on a duality result for the joint replenishment problem with submodular set-up cost, the author proposes a scheme to allocate the system-wide cost of the optimal power-of-two inventory policy. The proposed allocation is stable in the sense that it is in the core of a properly defined cooperative game.

The Role of Technological Dependence in the Adoption of Innovations

History attests to the slow pace at which innovations are adopted. The literature on technological innovation has attributed this slow pace mainly to uncertainties outside the firm such as the uncertain value of an exogenously developed innovation and/or uncertainty over future technological change. The models in this literature deal with the adoption of a single type of technology. In practice, however, there is ample evidence that a firm often makes an adoption decision of one technology depending on changes in other technologies. In "The Adoption of Multiple Dependent Technologies," S. Cho and K. F. McCardle show that dependence among multiple types of technologies can significantly influence the timing of adoption. They explore the impact of economic or stochastic dependence on the timing of adoption, and show that the dependence can either expedite or delay the adoption.

Redundant by Design

For today's networked economies and societies, from business process outsourcing and collaborative fulfillment to social networking and distance learning, infrastructure networks that carry materials, information, and energy are vitally important. So, even seemingly localized disruptions—a beaver chewing a fiber-optic cable, an interstate overpass collapsing, a tree falling over power transmission lines, or a strike by dockworkers—can endanger lives and cause enormous economic losses if traffic is not swiftly rerouted around the disrupted link. While real-time disruption management and network restoration capabilities are important, the resilience of a network rests fundamentally on its topological design. By judiciously installing redundant links, network planners can make the networks immune to disruptions by creating alternate paths for critical traffic. To address this important but computationally difficult problem, the paper "Connectivity Upgrade Models for Survivable Network Design" by A. Balakrishnan, P. Mirchandani, and H. P. Natarajan develops theoretical results to enhance the model formulation, and proposes a solution methodology combining a cutting plane procedure with an optimization-based heuristic. Extensive results, based on carefully designed computational experiments, demonstrate that the proposed algorithm generates near-optimal solutions, making it valuable for practical decision-support systems.

Nondominated Set Representation in Multiobjective Linear Programming

Generating all efficient faces or all efficient extreme points in multiobjective linear problems is computationally demanding. There would be just too many efficient extreme points in a moderate-size problem to make such an approach practical. Even when all efficient faces or all extreme points can be generated, selecting the most preferred solution remains a difficult problem. Hence, it is important to find a discrete set of points that are well dispersed over the nondominated set and represent all parts of the set. There has been limited research in the literature to sample a representative set of solutions from the nondominated set. Existing approaches either produce low quality representations or produce high quality representations but are computationally cumbersome. In "Generating a Representative Subset of the Nondominated Frontier in Multiple Criteria Decision Making," E. Karasakal and M. Köksalan propose the idea of fitting a surface to approximate the nondominated set in multiple objective linear problems. The authors obtain a set of approximately evenly spaced points from the fitted surface and project them on to the nondominated set. The authors show that their approach performs

well in terms of both the quality of the representation and the computation time.

Incentive Mechanisms to Motivate Demand Information Sharing

In many industries demand information sharing has proved to be a significant factor in reducing supply chain costs and achieving supply chain coordination. To entice all members in a supply chain to share demand-related information, a fair scheme must be devised to allocate the cost savings generated by information sharing among supply chain members. If the cost savings are not allocated fairly, some members of the supply chain may decide not to cooperate, thus hurting the supply chain's performance. In "Allocation of Cost Savings in a Three-Level Supply Chain with Demand Information Sharing: A Cooperative-Game Approach," M. Leng and M. Parlar apply cooperative game theory to determine the allocation of cost savings resulting from demand information sharing in a three-echelon supply chain with a manufacturer, a distributor, and a retailer. After computing the expected costs for the three supply chain members, the authors develop a three-player cooperative game in characteristic-function form, solve the game to find various allocation schemes, perform numerical analyses, and discuss managerial insights that are drawn from this research.

Reoptimized Vehicle Routing with Stochastic Demands

The vehicle-routing problem with stochastic demands is a classical abstraction of the efficient distribution of products to customers whose demands are uncertain. In this stochastic environment, how should a distribution manager dynamically update (reoptimize) his/her routing and replenishment decisions in response to the demand information that is revealed during real-time operations? Despite its practical relevance, this question is rarely considered in the literature on the vehicle-routing problem with stochastic demands. In "Reoptimization Approaches for the Vehicle-Routing Problem with Stochastic Demands," N. Secomandi and F. Margot propose and analyze an exact Markov decision process model for the reoptimization version of this problem, and present a novel and effective solution methodology, called partial reoptimization, which allows them to approximately solve large problem instances in a computationally efficient fashion. Partial reoptimization outperforms an existing heuristic and compares favorably against a lower bound, computed by simulation and integer programming methods, on the expected cost of an optimal policy.

Improving Airline Fleet Assignment

Several major airlines operate large fleets of varying aircraft sizes, each serving over 1,000 daily flights. Operations research models have had significant impact on the way airlines manage their fleet assignment decisions. In "Airline Fleet Assignment with Enhanced Revenue Modeling," C. Barnhart, A. Farahat, and M. Lohatepanont argue that while existing models have adequately captured the operational constraints of the problem, they have not accurately captured the revenue side. The authors explore a model where fleet types are assigned to subnetworks of flights rather than to individual flights. The motivation of this approach is its ability to better capture network effects where a capacity decision for one flight impacts the revenue from other flights. They present a solution approach and computational results that suggest the approach is computationally tractable and can yield significant profit improvements over comparable models.

Joint Pricing and Inventory Control Strategies in the Retail Industry

As the title indicates, the technical note "Optimal Dynamic Joint Inventory-Pricing Control for Multiplicative Demand with Fixed Order Costs and Lost Sales" by Y. Song, S. Ray, and T. Boyaci studies the optimal pricing and inventory control problem for a retailer in a price-sensitive, multiplicative demand framework. The model incorporates issues like lost sales, holding cost, fixed and variable procurement costs, as well as salvage value. Establishing the optimal pricing and inventory ordering policy in such a framework is known to be a difficult problem and has not been addressed in the literature.

Predicting the Performance of Ambulance Systems Quickly and Reliably

Emergency Medical Services (EMS) operators face a difficult task. Their duty is to provide high quality medical care and transport to hospital. Their task is made difficult by growing demand (because of population increase and aging), constant or shrinking inflation-adjusted budgets, and the operational complexities of managing a system where demand occurs randomly in time and space and the "servers" (the ambulances) are constantly moving. In "Approximating Vehicle Dispatch Probabilities for Emergency Service Systems with Location-Specific Service Times and Multiple Units per Location," S. Budge, A. Ingolfsson, and E. Erkut describe a project sponsored by an EMS operator whose volume of high priority calls has been growing by 10% per year over the last several years. The authors extend previous models that capture the dynamics of such systems to allow for multiple ambulances per station. This is important in practice, because the high cost of building ambulance stations often makes is too costly to have a single ambulance at each station. They have used the model in several applied research projects with various EMS operators. The model serves as a basic building block to help decide how to allocate ambulances between stations and how to schedule ambulance crews over time.