Operations Research

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Managing Utility Fuel Inventory

In the early 1970s, coal and oil inventories held by U.S. electric utilities amounted to $1.2 billion. By the early 1980s this value had increased to over $9 billion. In this changing environment, utility companies have become increasingly concerned with striking a balance between the advantages and disavantages of holding inventory. To address the situation, the Electric Power Research Institute (EPRI), working closely with 15 electrical utilities, developed the Utility Fuel Inventory Model. It allows the user to consider the effects of fluctuations in fuel supply and consumption as well as the variation in fuel costs over time, and also provides probabilistic information that is useful for monitoring and managing fuel purchases. In *A Utility Fuel Inventory Model*, Peter A. Morris, M. James Sandling, Richard B. Fancher, Michael A. Kohn, Hung-po Chao and Stephen W. Chapel describe the model and its use, including one of its initial applications. Over 50 utility companies currently use the model, and a recent survey of EPRI projects (*Public Utilities Fortnightly*, April 2, 1987) listed it among the "big winners with large payoffs."

In a complementary paper ("Inventory Policy in the Presence of Market Disruptions"), Hung-po Chao develops a dynamic model that has served as one component of the overall Utility Fuel Management Model; his model considers the effects of uncertain arrival times as well as the severity and duration of market disruptions.

Deriving the Demand for Primary Energy Resources

From 1985 to 1995 the total U.S. demand for electric power is expected to grow by over 30%, from 2.31 to 3.05 trillion kilowatt hours (*Annual Outlook for U.S. Electrical Power 1987*, Energy Information Administration, U.S. Department of Energy, May 1987). Since the actual growth is unknown, suppliers must decide, in the face of uncertainty, whether to expand capacity and/or to introduce new technologies, and in what quantities. Doing so requires that they convert the demand for end-use products into a derived demand for primary resources: coal, oil, natural gas, turbine, nuclear, hydroelectric and geothermal. In "Derived Demand and Capacity Planning under Uncertainty," Eduardo Marco Modiano studies this situation by using two alternative behavioral models for decision making: *here-and-now* and *wait-and-see*. He also presents an application to the U.S. energy sector's demand for coal and the related expansion of coal-fired and electricity generation plants.

Improving Your Bargaining Position

In bargaining and negotiation, a common threat of either party is to seek better offers elsewhere. This tactic adds to a party's bargaining strength, but is time consuming. Although this "threat of search" is a well-known element in real bargaining situations, it has never been explicitly modeled. Now, Shirish D. Chikte and Sudhakar D. Deshmukh ("The Role of External Search in Bilateral Bargaining") present such a model. Their game-theoretic analysis confirms the intuitive belief that the higher the individual's inherent capacity to search for competing offers, the stronger his or her bargaining position. They conclude that the "fair price" the negotiators settle upon represents optimal sharing of the savings accrued from not having to search.

Characterizing Utility Functions

Although the earliest practice of utility assessment dates back to Daniel Bernoulli in 1738, most modern methods of assessment are based on the theory developed by John von Neumann and Oskar Morgenstern in the 1940s. Over the past 45 years, the experience accrued from the thousands of utility functions assessed in various decision analyses has continually improved the assessment technology. Today, the widespread availability of computers has further fueled analysts' interest in refining and automating procedures for assessing decision makers' utility functions. Peter H. Farquhar and Yutaka Nakamura ("Constant Exchange Risk Properties") generalize John W. Pratt's seminal 1964 research on constant risk properties and obtain a new risk property that accurately determines the form of several different utility functions.

Divide and Rule

Dynamic programming reduces the computation time for solving sequential decision problems from an exponential to a linear function of the number of states. However, even the number of states can grow exponentially as a function of the natural problem parameters. For example, the number of states in a multi-item inventory planning problem grows exponentially in the number of different types of items. Aggregation is a technique that identifies "similar" states and thus reduces the number that needs to be considered, typically through a partitioning of the state space. In "Aggregation in Dynamic Programming," James C. Bean, John R. Birge and Robert L. Smith provide a simply computed bound on the error resulting from such a general aggregation procedure. They illustrate the method with an application to rolling horizon planning.

Helicopter Harvesting of Forests

Since its first use in 1971, helicopter logging—the practice of removing cut logs from forests by helicopter—has accounted for the harvest of over 3.5 billion board feet of timber, most of it from areas that could not otherwise have been harvested economically, due to small tree stands, difficult access, or environmental fragility. Recently, environmental concerns have led the U.S. Bureau of Land Management and the U.S. Forest Service to curtail harvesting on one-third of all commercial forest lands. As a consequence, the lumber industry can be expected to place even more emphasis on helicopter operations, which provide an environmentally sound alternative to expensive and ecologically damaging road construction: one group of researchers (D. P. Dykstra, D. E. Aulerich and J. R. Henshaw, "Prebunching to Reduce Helicopter Costs," *The Journal of Forestry*, Vol. 76, pp. 362–364) has estimated that towing logs from their felling locations by horse to "prebunching" helicopter harvesting sites can reduce costs by approximately 40%. In "The *P*-Centroid Problem on an Inclined Plane," M. John Hodgson, Richard T. Wong and John Honsaker develop a location-allocation model for minimizing the aggregate work in such prebunching helicopter operations, and for determining ideal shapes, numbers and locations of harvesting sites.

Allocating Costs in Locational Models

Efficiency and effectiveness ought not to be the only measures for evaluating the location of public service facilities; equity is another important criterion. Court cases in the United States (for example, *Hawkins* v. *the town of Shaw, Mississippi*, 1972) have ruled that inequity in the provision of local services amounts to racial discrimination. One simple condition of equity is equal payment for equal services received, a premise that naturally raises issues of cost allocation. Such costing issues often arise in equity considerations since, in principle, the allocation of the system's operating costs and the location of service facilities are very closely related. In "The Role of Cost Allocation in Locational Models," Daniel Granot suggests a game-theoretic approach for generating the location of a unique facility in a tree network, and offers a corresponding cost allocation scheme. His model determines a pairing of facility location and corresponding cost allocation that cannot be improved upon, unilaterally, by any subset of users, and that is consistent with the equity principle of equal payment for equal services received.

Expanding Telephone Network Capacity: Technology Choices

As of 1985, the telephone networks of AT&T and the 46 local exchanges (such as Pacific Bell, New England Telephone, and BellSouth) comprised 1,312,014,300 miles of wire and cable, much of it made of copper. (Source: U.S. Federal Communications Commission, Industry Analysis Department). The emerging technology of fiber optics offers significantly more transmission capacity and better transmission quality than the copper cable now in use. It also has broader transmission capability—for example, fiber optic cables can carry video signals. Currently, however, fiber optic materials are much more expensive than copper cable. Telephone companies can avoid construction of fiber optic transmission lines by adding more copper cable or by using message concentrators to enhance existing copper cable. The trade-offs between these technology choices, as well as the proper timing of investments, involve issues that are subtle and difficult to analyze. In "Multifacility-Type Capacity Expansion Planning: Algorithms and Complexities," Sang-bum Lee and Hanan Luss examine several variations of a broad class of capacity expansion models whose applications include the sizing and timing of copper cable investment, and might extend to include other technology choices as well.

Routing Vehicles When Your Customers Can't Wait

Many businesses must satisfy customers who impose early pickup time and/or delivery deadlines. These time windows also arise naturally in the service sector—for example, in bank or postal deliveries. Yet, until recently, organizations have handled this type of constraint in an ad hoc manner, mostly by manually adjusting routing-based schedules. As with most combinatorial optimization problems, this planning situation can be addressed using either a heuristic or an optimization approach. In "Algorithms for the Vehicle Routing and Scheduling Problems with Time Window Constraints," Marius M. Solomon describes a variety of route construction heuristics and conducts an extensive computational study of their behavior in a number of problem environments. He suggests a method that seems to be robust and flexible in accommodating both the temporal and spatial dimensions inherent in such problems. A. W. J. Kolen, A. H. G. Rinnooy Kan and H. W. J. M. Trienekens, in "Vehicle Routing with Time Windows," adopt an optimization approach. They develop an enumerative algorithm, and demonstrate its effectiveness with computational results on several test problems containing as many as 15 customers and 4 vehicles.

Solving Large-Scale Markov Chains

Many stochastic systems are formulated as Markov chains. Common examples of such systems include inventory planning systems, product brand-switching choices, and a plethora of queueing systems. Frequently, the number of states of the chain is so large that direct methods for finding the steady-state probabilities would require many hours (or even days) of computer time. In "A Method to Calculate Steady-State Disruptions of Large Markov Chains by Aggregating States," Brion N. Feinberg and Samuel S. Chiu describe an iterative method for determining these quantities that is an order of magnitude faster than Gaussian elimination.

Evaluating Automated Production Processes

Automatic transfer lines are manufacturing systems in which each part travels along a fixed sequence of machines, stopping at a storage area or buffer before entering the next machine. Most of these systems perform metal cutting operations, and are used chiefly by the auto industry to manufacture engine blocks, transmission cables, cylinders, connecting rods, and other internal parts of automobiles. The cost of such systems varies from $20–30 million for the largest to $100,000 for a small transfer line. In the past, researchers have modeled such tandem queueing systems as networks with infinite queues—that is, all storage areas can hold an unlimited number of parts. Now, Stanley B. Gershwin ("An Efficient Decomposition Method for the Approximate Evaluation of Tandem Queues with Finite Storage Space and Blocking") describes a method for analyzing a class of queueing systems that have finite buffers. His approach, which is based on an approximate decomposition and is computationally more efficient than simulation, provides both vendors and purchasers of automatic transfer lines with a method for evaluating proposed system designs.

Deploying Queues that Have Different Server Groups

Large-scale telephone systems often divide operators into groups who handle different services such as directory assistance and credit card calls. This practice can be expected to grow as telephone services to consumers become more widespread: for example, AT&T is currently developing telemarketing and other nontraditional operator services that will require personnel with specialized training to handle incoming calls. These systems can involve substantial costs: in 1983, before divestiture, the Bell System incurred operator wages in the neighborhood of $2 billion per year. In "Comparison of Policies for Routing Customers to Parallel Queueing Systems," D. J. Houck studies the effect of pooling servers rather than maintaining separate pools in which operators serve requests from a particular customer group. His results show that, in systems with two groups of servers, an optimal routing policy produces delays almost identical with those obtained for a system that combines the two groups. Moreover, in every case considered, the policy of routing customers to the queue with the smallest expected delay is nearly optimal.

Technical Note

For branch-and-bound methods to solve integer programs effectively, tight lower bounds are essential. In "An Improved Lower Bound for Minimizing Weighted Completion Times with Deadlines," Uttarayan Bagchi and Reza H. Ahmadi propose a new lower bound that improves upon those found in the literature.

Presidents' Symposium

In recognition of ORSA's 35th anniversary, the January–February issue of this Journal introduced a series of articles in which former presidents of ORSA consider our profession's past accomplishments and future challenges. In this issue, Hugh J. Miser, who is also a former Editor of *Operations Research* ("Science and Professionalism in Operations Research"), and Saul I. Gass ("A Perspective on the Future of Operations Research") draw lessons from past successes to suggest actions that may help to ensure that operations research will continue to grow in scope and influence. Their perspectives touch upon issues of professional identification and practice, and include such topics as outreach, standards of quality, and the craft of professional practice.