
# Operations Research



# In This Issue

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### Making a Capacity Planning Decision

Determining the capacity, location, and type of manufacturing facilities are important strategic decisions for a firm. These decisions have serious implications for stockholders, managers, workers, and the general community. In "A Scenario Approach to Capacity Planning," Gary Eppen, Kipp Martin and Linus Schrage describe a model developed for General Motors to aid in making decisions about capacity. The model incorporates elements of scenario planning, integer programming and risk analysis. Of particular interest is a method of finding capacity plans that yields histograms of returns for management that are consistent with their risk preference.

### When Human Lives are at Risk

If governmental decisions involve the risk of deaths among members of the public, the consideration of equity in risk sharing is important and complex. Consider the case where a decision entails a one-in-a-hundred chance that either Mr. X alone or everyone else will die. Although Mr. X faces the same probability of death as everyone else, he is clearly at a disadvantage. Equity, then, is not simply the equality of the probability of death. In "Ex Ante Equity in Public Risk," Jayavel Sounderpandian explains the complexities and suggests mathematical formulas to measure such equity.

### Designing Survivable Communication Networks

Recent work at Bellcore and the Regional Telephone Companies has focused on the impact of fiber optic technology on telephone network design. One conclusion is that survivability against network failures is a particularly important issue. *Two-connected* network topologies are needed to provide the necessary levels of survivability. In "Methods for Designing Communication Networks With Certain Two-Connected Survivability Constraints," Clyde Monma and David Shallcross describe fast and effective heuristic methods for designing near optimal, survivable fiber optic networks. These methods have been incorporated into a computer-based system that aids telephone company network planners.

### New Properties for Shortest Path Methods

Following the introduction of partitioning shortest path (PSP) algorithms, there has been interest in determining complexity bounds for this algorithmic class. This interest has been heightened because one PSP—using a special threshold strategy—uniformly dominated all competitors tested. In "New Sharpness Properties, Algorithms and Complexity Bounds for Partitioning Shortest Path Procedures," Fred Glover and Darwin Klingman introduce two new members of the PSP class, which they classify as *globally sharp* and *globally scan sharp*. These methods have complexity bounds that are superior to previous methods with corresponding properties.

### What Are the Options on How to Compete?

While on a plant tour, Gabriel Bitran and Devanath Tirupati were asked by a manager if his lead times were too long and his work-in-process was too high. They replied, "The amount of work-in-process and the length of your lead times depend on how you want to compete." The manager said, "What are my options on how to compete?" This question is not easy to answer. The authors considered the interaction of system design, technology choice and capacity planning to give a partial answer that deals with elements a plant manager can control. The resulting methodology ("Tradeoff Curves, Targeting and Balancing in Manufacturing") models discrete manufacturing environments as networks of queues and complements the analysis with tradeoff curves involving capacity, lead times and work-in-process. With these tools, the manager can choose how to position the facility by deciding how much effort to invest in reducing uncertainties, which plant and process design to choose, what technology and how much of each to have.

### Production With Setup Costs Eliminated

Encouraged by Japanese success stories, manufacturers have made considerable headway in reducing setup times and costs of production. In parallel, simple rules for production control (such as kanbans) exploit the reduced complexity of production planning. In "Optimal Inventory Policies for Assembly Systems Under Random Demands," Kaj Rosling addresses the simplified planning situation by making a rigorous extension to classical inventory theory. He suggests a modified order-up-to policy for assembly systems with no setup costs in production. He demonstrates how assembly systems may be interpreted as serial systems, and how the classical algorithm of A. J. Clark and H.

Scarf (1960) can be applied to find the long-run, optimal order-up-to levels easily.

### Dynamic Process Improvement

In "Dynamic Process Improvement," Charles Fine and Evan Porteus explore the economics of investing in gradual process improvement, typified by the Just-in-Time and Total Quality Control philosophies. They formulate a general model of investment where each period's returns are unknown at the time of investment, but are positively related to the magnitude of the period's investment. Two investment policies for the model are analyzed and compared: the optimal policy and the last chance policy, which is closely related to the former, but exhibits a more aggressive investment posture. They derive conditions for the optimality of investing forever in process improvement, toward zero defects or zero setup costs. The authors also examine how the degree of uncertainty in the return process influences the optimal investment policy.

### Scheduling Simultaneous Resources

Most of the scheduling literature concerns sequencing a set of jobs on a single resource: the machine in a job shop, the operating room in a hospital or the truck on a delivery route. In reality, jobs may require a variety of resources; for example, a tool, a machine, a fixture and an operator may all be required to complete the operation. Typically, the machinery is scheduled and an operator is needed. If one resource is substantially more expensive than the others, economic prudence suggests that a shop have the others available in abundant supply. This permits a reduction in the complexity of the problem by only scheduling the critical resource. But, if two or more resources are expensive, for example, hospital operating rooms and surgeons, the need to schedule them simultaneously arises. In "Simultaneous Resource Scheduling to Minimize Weighted Flow Times," G. Dobson and U. S. Karmarkar address the concurrent scheduling problem. They describe a decomposition of the jobs that places more *weight* on heavily demanded resources.

### Tandem Queues With Blocking

Tandem queues with finite intermediate buffers arise in a variety of situations, such as production systems, computer and communication systems. Buffers absorb disturbances that are due to randomness in the system. In "Approximate Analysis of Queues in Series With Phase-Type Service Time and Blocking," Tayfur Altiok considers general service times. He approximately decomposes a system into single queues with revised arrival and service processes and revised buffer capacities. These queues are analyzed by an iterative procedure that computes the stationary distribution of the number in each queue. Most of the performance measures, such as output rate, utilization, average number of units in each queue and blocking probabilities can be obtained easily from these distributions.

### Service Facilities for Holding Customers

Service facilities often respond to increased congestion by speeding up. For example, as the lines at check-out counters in a supermarket get longer, the manager might assign extra people to help bag the groceries, thus increasing the rate at which each counter can serve customers. In a communication system, it is plausible to use a faster rate of transmission when more messages are waiting in the buffer. In other queueing systems, the operator turns the server on when the number of customers reaches a threshold. These operating policies are monotonic: the service rate does not decrease as the congestion level increases. Knowing that an optimal policy is monotonic can dramatically accelerate its computation. For example, in the on/off problem, the search for an optimal policy is reduced to a one-dimensional search for the optimal threshold level. There is an extensive literature on models and algorithms for queueing control problems, focusing largely on finding conditions under which an optimal policy is monotonic. The complexity of the models and the difficulty of their analysis bely the plausibility of the intuition that an optimal policy is monotonic. Indeed, can one imagine a queueing system in which it would *not* be optimal to use a monotonic policy? As long as it costs more to have more customers present, one should *obviously* reserve a higher service rate for times when more customers are present. Shaler Stidham, Jr. and Richard Weber ("Monotonic and Insensitive Optimal Policies for Control of Queues With Undiscounted Costs") use this intuition as the basis for a rigorous proof that an optimal policy is monotonic in a variety of queueing models.

### Finding Average Cost Stationary Policies

Queueing control problems are of current interest. At various times, certain decisions may be made, for example, adjustment of the service rate, and certain costs incurred, such as the cost of an additional server. A policy specifies the optimal decision to make at each decision point so that some quantity, such as the expected discounted cost or long-run average cost per unit time, is minimized. Policies that make the same decision whenever the system is in a given state—

when five customers are waiting, always serve at rate two—are favored because they are easier to implement. The underlying model for many discrete time queueing control problems is a Markov decision process. In "Average Cost Optimal Stationary Policies in Infinite State Markov Decision Processes With Unbounded Costs" Linn Sennott gives readily verified conditions for the existence of an optimal average cost stationary policy and shows the versatility of the theory by applying it to two queueing control examples.

### Extensions of Little's Law

In 1961, J. D. C. Little gave a proof of the queueing formula $L = \lambda W$ in this journal. Little's Law, as $L = \lambda W$ has come be known, was firmly established as a fundamental principle of operations research in 1987 when it was printed on T-shirts honoring the 35th anniversary of ORSA. One might think that we had seen the last word on $L = \lambda W$, but Peter Glynn and Ward Whitt investigate it further in their paper, "Extensions of the Queueing Relations $L = \lambda W$ and $H = \lambda G$." They were motivated by examples not covered by previous extensions.

### Traffic Processes in Queueing Networks

Paul Burke (in 1956) and Edgar Reich (in 1957) showed that the departure process from an M/M/1 queue is Poisson in equilibrium. Throughout the 1970s and early 1980s, several authors found that many traffic processes in networks of quasireversible queues were not Poisson. Even though the input and output processes at a node are not Poisson they still may have the same probability law. In 1981, J. Labetoulle, G. Pujolle, and C. Soula showed that a Jackson network of single server queues and an interinput interval have the same distribution as an interoutput interval. This does not imply that the input and output processes at a node have the same probability law. In general, they do not. A simple example demonstrating this is the M/M/1 queue with instantaneous Bernoulli feedback. In "A Simple Proof of the Equivalence of Input and Output Intervals in Jackson Networks of Single Server Nodes," Peter Kiessler provides an intuitive proof of Labetoulle, Pujolle and Soula's result, which also applies to single server queues in more general networks.

### The Stochastic Queue Median Model

In "The Stochastic Queue Median Over a Finite Discrete Set," Rajan Batta examines the stochastic queue median model where potential facility locations are restricted to a finite set of discrete points. Such a restriction on available facility location sites often arises in the form of a natural constraint that is frequently specific to the application setting.

### Bounding Methods for Facilities Location

Multifacility location problems are often solved with iterative computational procedures. Although these procedures converge in practice, it is desirable to be able to compute a lower bound on the objective function at each iteration. This enables the user to stop the iterative process when the objective function is within a prespecified tolerance of the optimum value. In "A Generalized Bounding Method for Multifacility Location Models," Robert Love and Paul Dowling describe a new bounding method for multifacility problems. A proof is given that the new procedure is superior to other known methods.

### The GAP: Improved Bounds

Scheduling a set of tasks to be performed by a set of agents may be modeled as a generalized assignment problem (GAP). Each task is assigned to one agent subject to each agent's limited capacity. The objective is to minimize the cost of the assignments. The structure of the GAP is amenable to the design of efficient solution methods. In "An Improved Dual-Based Algorithm for the Generalized Assignment Problem," M. Guignard and M. B. Rosenwein solve a Lagrangian relaxation of the GAP model and obtain strong lower bounds on the objective function value. They combine an enhanced Lagrangian dual ascent scheme with a surrogate constraint to the relaxed model. The bounding technique is embedded within branch-and-bound which solves GAPs to optimality. The paper demonstrates that efficient solution of medium-sized, structured NP-hard models is feasible if clever algorithmic methods that exploit problem structure are designed.

### What Should OR Do in the Next Decade?

In the July–August 1988 issue, this journal published a report (pp. 619–637) from the Committee on the Next Decade in Operations Research that had been convened by NSF. Since the report was, of necessity, limited to certain topics, in "Comments on the CONDOR Report," four commentators suggest other matters that should also be of concern in the next decade. First, Harvey Wagner discusses several of the practical issues that must be faced when bringing the theoretical tools described in the report into use. He also describes the practical difficulties of obtaining industrial experience data for the committee's recommended MODELWORLD laboratory and the ed-

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