This edition of Research highlights three problems related to uncertainty in manufacturing and supply chain design. The papers summarized below can be found in the November issue of IIE Transactions (Vol. 36, No. 11).

Inventory deployment in the steel industry

Industries in which products are customized tend to operate by a make-to-order (MTO) policy. However, to reduce customer order lead-times, it is frequently the case that some portion of production is planned according to a forecast of orders. Order lead-times are quoted based on the estimated cycle time, and when cycle times are long this carries the risk that forecasted orders may not materialize. In process industries, such as steel making, the degree of customization of finished products tends to be very high, so this risk is particularly important to manage.

The pressure to reduce delivery lead-times has motivated integrated steel manufacturers to change from a pure MTO production mode to a hybrid MTO/make-to-stock (MTS) mode in which strategic inventory is positioned throughout the supply chain. Placing inventory at the finished product stage results in lower cycle times but also lower demand pooling benefits. On the other hand, placing inventory upstream from the finished product stage results in greater pooling benefits at the expense of increased cycle times. In a process industry, there is a large (often continuous) range of possible semifinished product designs that can be carried in stock, which further complicates inventory placement decisions.

In “Strategic Inventory Deployment in the Steel Industry,” Brian Denton and Diwakar Gupta present a stochastic programming model that can be used to answer these important questions. The model formulation is consistent with integrated steel manufacturers’ management’s view of key decision variables, cost drivers, and uncertainties. The authors point out several important insights regarding the choice of semifinished inventory design types, the impact of various types of uncertainty (including yield, demand adjustments, and order cancellations), and a measure of the value associated with reducing uncertainty. The paper describes the model in the context of integrated steel manufacturing; however, it is also applicable to general problems involving the design and configuration of transportation networks given uncertainty in supply and demand.

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Robust scheduling

One challenge in managing manufacturing or service operations is to sustain a high performance level consistently, even under unplanned and uncertain conditions. Often, operation managers strive for a balance between system performance and robustness under uncertainty.

In “Improving Scheduling Robustness via Preprocessing and Dynamic Adaptation,” Erhan Kutanoglu and S. David Wu study the balance between performance and robustness in the context of scheduling with a due-date objective. They define robustness as the system performance realized under unexpected variations. They propose a procedure that preprocesses the scheduling data, carefully constructs a skeleton of the schedule (a partially defined schedule), while leaving the detailed
scheduling decisions to be made dynamically as events unfold in real time. The idea is to combine the global view provided by an optimization analysis with the dynamic view provided by local real-time adaptation.

By exploiting the scheduling data and the statistical characterization of the uncertainty, the authors propose a preprocessing model that pinpoints critical decisions that must be made to achieve global scheduling performance. This allows the non-critical decisions to be made later through dynamic adaptations, which provides a means of absorbing system disturbances. In this way, the authors develop a method that combines statistical analysis, mathematical modeling, and common sense in a structured manner. Through extensive experimental testing, they show that it is possible to achieve a performance level that can be sustained over an increasing amount of uncertainty. They show that both preprocessing and adaptation are necessary to achieve the right balance between performance and robustness. They also show that the benefit of the proposed scheme comes at a negligible computational expense.

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**International sourcing**

In "A Benders-based Heuristic for the Robust Capacitated International Sourcing Problem," José Luis González and Manuel Laguna deal with the problem of selecting suppliers for plants that are geographically dispersed around the world.

Balance between system performance and robustness under uncertainty is one element of achieving consistent high performance, according to Erhan Kutanoglu.
The economy in different regions where the plants are situated has an effect on exchange rates and ultimately on the demand that must be satisfied in each location. In addition to production and transportation costs, the sourcing problem also considers fixed costs associated with technology transfer, personnel training, and quality programs, such as ISO certifications. The problem in the real world is fraught with uncertainty regarding most, if not all, of these inputs.

González and Laguna approach this decision problem using robust optimization that transforms a stochastic problem into a deterministic one using scenarios to model the uncertainty in the data at the expense of making the problem larger. This transformation results in a very flexible framework for modeling risk. The complexity of the resulting model, however, is such that finding an exact solution becomes impractical. Therefore, González and Laguna focus on finding solutions of acceptable quality with the application of modern heuristic techniques that blend concepts from computer science, artificial intelligence, and operations research. Their approach is able to find near-optimal solutions for the nonlinear model they developed.

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