Preface

In our rapidly changing economy, businesses face the challenges of increasing their responsiveness and resiliency to varying market forces while minimizing business costs. Decisions that involve these challenges may catapult a business to success in the marketplace or cause a business to fail. Many examples exist of even a single poor business decision having a devastating impact on a business. Naturally, businesses are using the vast computation power of modern computers to help make crucial decisions. This computational power helps businesses study a large number of scenarios and possibilities in order to reach favorable outcomes, given a particular set of circumstances.

Inspired by market needs, research in business analytics and optimization is thriving. This special issue of the *IBM Journal of Research and Development* presents a sampling of this diverse research in such areas as workforce management, risk management, transportation scheduling, production planning, resource allocation, inventory management, marketing optimization, and fraud detection. The research is interdisciplinary, as it involves statistics, mathematical programming, machine learning, simulation, and other disciplines.

The first three papers focus on the topic of workforce management. Gresh et al. describe the Resource Capacity Planning Optimizer, developed for workforce capacity planning in the IBM Global Services organization in order to support the growing services business of this division. The authors' approach demonstrates the effectiveness of applying supply chain methodology and tools to workforce management. Their work also makes use of tools that were originally developed for supply chain optimization.

Naveh et al. present a novel approach to the problem of matching highly skilled human resources to available job positions, using a method that is scalable so that it can handle large pools of jobs and resources in a dynamic market. The approach deployed by the authors applies constraint programming in order to successfully manage the complex constraints encountered in the field and reach near-optimal assignments that take into account all resources and positions in the job pool. The constraints, which are applied at both the individual and team levels, concern job role, skill level, geographical location, languages, and many other factors.

The third paper on workforce management, by Hu et al., describes a methodology, developed for the consulting arm of IBM Global Services, that enables automatic generation of job staffing plans for service engagements. The staffing plan generation is based on several key characteristics of a project as well as a project type selected from a project taxonomy that is obtained by statistical clustering of labor records from a large number of prior engagements.

Businesses, and, in particular, publicly traded businesses, face the daunting task of complying with an increasing number of intricate and evolving regulations. Müller and Supatgiat present a dynamic-programming-based approach to minimize the expected cost of regulatory compliance. Compliance cost is the sum of the cost of implementing a set of measures, the cost of carrying out periodic inspections, and the audit outcome cost for various compliance levels.

Yashchin presents a new approach for modeling certain kinds of risks. This approach is appealing in the early phases of risk modeling, when reliable data is difficult to obtain and the existing data sources are known to be biased and incomplete. In this paper, Yashchin considers the exposure of a financial institution to operational risk given size-biased loss data. The bias in the data results from the assumption that the probability of a loss to be discovered increases with its magnitude.

Vaidyanathan et al. study the crew-scheduling problem of North American railroads. Specifically, the authors consider the problem of minimizing the cost of assigning train operators to scheduled trains while honoring several operational and contractual requirements. The authors develop a multi-commodity flow-based crew optimization approach that models the assignment of crews to trains by mapping the flow of crews on an underlying network. Next, they formulate the crew assignment problem as an integer programming problem on this network, and develop several highly efficient algorithms using decomposition and relaxation techniques. The algorithms make use of the special structure of the underlying network model in order to provide rapid crew assignments.

The next two papers concern steel production planning. Dash et al. describe an optimization tool for designing steel-plate products. The problem is modeled as a hierarchical bin-design problem that involves the design of casts by sequencing slabs, followed by the specification of mother plates that are rolled from each slab, and the order and surplus slabs produced from each mother plate. The optimization tool uses mathematical programming combined with heuristic search techniques. In another paper, Yanagisawa considers the material allocation problem that arises in the initial stage of steel production planning. Here, the problem is to determine the best matching of orders and materials with respect to an objective function that takes into account the due dates of orders, preferences for matches, allocated weights, surplus weights of materials, and other factors. Yanagisawa applies a local search technique to obtain a solution that results in substantial cost reduction.

Parija et al. develop an optimization model for determining budgets necessary for managing wildland fires during the initial firefighting response period. For a given budget, the model uses a mixed-integer linear optimization approach to maximize the amount of land protected from fire damage as a result of the initial response. The model is solved iteratively to establish a function that maps the best achievable effectiveness, in terms of acres managed, at different budget levels. To ensure the scalability of the optimizer, the authors employ a heuristic-based approach and a reformulation of the original model.

Barahona et al. describe a prototype inventory-placement and transportation-scheduling solution developed in support of the emerging military doctrine of Network-Centric Operations (NCO). The objective of NCO is to collect, disseminate, and react to real-time information in order to improve the performance of the army as a fighting force. The authors consider the problem of maintaining combat vehicles, and, in particular, maximizing the operational availability of vehicles by exploiting accurate information on the status of available repair-parts inventory, the current locations of mobile supply points, and the demand for parts. Simulations indicate that the Network-Centric Logistics prototype can significantly improve the availability of combat vehicles in comparison to current practice.

The next two papers concern marketing optimization. Selby considers the problem of multi-channel marketing event optimization. The need for such optimization is growing, as increasing numbers of firms use multiple channels—such as e-mail, call centers, and direct mail—to contact customers with marketing events. Selby presents a fast algorithm based on an advanced greedy heuristic. This algorithm determines the optimal set of marketing events to present to an individual customer given a set of marketing events by channel, a set of individuals, some additional constraints, and the concepts of saturation and cannibalization.

Labbi and Berrospi present computational models of customer buying behavior in order to determine and leverage the value generated by a customer within a given time frame. The tool developed by the authors helps determine long-term customer value by using dynamic programming algorithms in order to identify which marketing actions are the most effective in improving customer loyalty and hence increasing revenue. This tool was used in a pilot project with a leading European airline to optimize its frequent flyer program.

The subject of the next two papers is inventory management. Businesses that wish to deploy optimization tools often face the challenge of the relatively high cost of such tools. This is especially relevant in the case of small and medium-sized businesses with limited budgets. Motivated by this challenge, Katircioglu et al. present an inventory optimization solution that can be implemented in a cost-effective way on a platform that is commonly used by small and medium-sized businesses. The tool collects demand statistics and generates optimal inventory policies, such as those involving safety stocks and lot sizes.

Korevaar et al. describe an inventory budget optimizer for a two-echelon delivery structure that involves a central warehouse, regional warehouses, and customers. The optimizer may either minimize the total replenishment costs under the constraint of reaching global target service levels, or maximize the target service levels given an available replenishment budget. In a first optimization step, the optimal order quantity and optimal pack size are determined for each unit; in a second step, the optimizer determines whether to stock each unit at the regional warehouse and, if so, what the safety stock level and rush order reorder point will be. The optimizer has been implemented successfully in an automotive spare parts planning environment.

The paper by Anderson et al. describes a system for detecting attacks from company insiders. The system is based on behavior anomalies, and it uses peer-group profiling, composite feature modeling, and statistical data in real time to monitor insider attacks. One of the special features of the described system is its ability to self-tune as part of its operation.

Better et al. consider the general problem of the design of accurate and effective business simulation models used to determine optimal policies or scenarios. Simulation provides a powerful decision support tool, especially in highly complex and uncertain situations. In such situations, a realistic simulator can be used to test scenarios and to assess the outcomes of various decisions. However, because of the prohibitively large numbers of different system configurations and variables, it is not always obvious which configurations and variables require the most attention. The authors propose an approach based on enhanced data-mining methodology and state-of-the-art optimization technology to search for optimal values of input parameters to a simulation model, and for optimizing the underlying simulation model.

In the final paper, Lee examines various aspects of modeling and solution via mixed-integer nonlinear programming. Mixed-integer nonlinear programming provides a powerful modeling tool that is not currently in wide use because of the lack of effective solver technology. Recently, significant advances have been made in solver technology for mixed-integer nonlinear programming. This paper discusses such new techniques, some of which are based on methods designed for mixed-integer linear programming and nonlinear programming, and some that are specific to mixed-integer nonlinear

programming. The paper concentrates on the classical uncapacitated facility location problem with a nonlinear objective function.

Looking to the future, we envision a vast potential for research in business optimization—both in modeling and solving business problems and in finding better and more cost-effective ways to incorporate and deploy such advanced tools with business processes.

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Guest Editor