

Editor's note: This is another in a series of articles profiling members of the INFORMS Roundtable.

DECISION SCIENCES :

A Story of Excellence at Hewlett-Packard



BY SHAIENDRA JAIN

Hewlett-Packard is a technology company that operates in more than 170 countries around the world. We explore how technology and services can help people and companies address their problems and challenges, and realize their possibilities, aspirations and dreams.

No other company offers as complete a technology product portfolio as HP. We provide infrastructure and business offerings that span from handheld devices to some of the world's most powerful supercomputer installations. We offer consumers a wide range of products and services from digital photography to digital entertainment and from computing to home printing.

Founded in 1939 and headquartered in Palo Alto, Calif., HP is among the world's largest IT companies, with revenue totaling \$104.3 billion for the fiscal year ended Oct. 31, 2007.

HP's three business groups drive industry leadership in core technology areas:

- Personal Systems Group: business and consumer PCs, mobile computing devices and workstations
- Imaging & Printing Group: Inkjet, LaserJet and commercial printing, printing supplies, digital photography and entertainment
- Technology Solutions Group: business products including storage and servers, managed services and software

Decision Sciences at Hewlett-Packard

HP'S DEEP ROOTS in technologies and very competitive business environment provide a rich set of opportunities for applied research and applications of decision sciences. This applied research is directed toward new product and service creations, as well as toward operational processes innovation.

Targeted growth, cost efficiency and capital strategy are the key elements of our operating framework. Operational excellence is at the heart of cost efficiency framework. Decision Sciences has one of the central roles in addressing HP's needs in operational excellence. There are literally hundreds of people practicing O.R./decision sciences in HP. Most of them are part of the three business groups mentioned above. Other O.R. and decision science practitioners and consultants can be found throughout HP's global organization focusing on different projects, including long-term applied research to address problems of theoretical and practical interest. This article focuses on the work of HP's Decision Technology team, which is part of Business Optimization Labs within HP Labs.

All About the Roundtable

HP Laboratories

AT ITS HEART, HP is a technology company, fueled by progress and innovation. As Hewlett-Packard's central research organization, HP Labs' job is to invent for the company's future. The majority of HP's research is conducted in our business groups, which develop the products and services we offer to customers.

HP Labs' function is to deliver breakthrough technologies and technology advancements that provide a competitive advantage for HP and to create business opportunities that go beyond HP's current strategies. The lab also helps shape HP strategy, and it invests in fundamental science and technology in areas of interest to HP.

A very high percentage of HP Labs research is focused on technologies for next-generation products and services. A small team of about 25 people conducts applied research focused on business processes. This team invents new processes that change the way HP operates in terms of marketing, manufacturing and procurement. In other cases, the team develops efficient processes to deliver services to our customers. In a few instances, the team has created brand new services for HP's customers or directly contributed to new product technologies.

About 90 percent of Decision Technology team members have Ph.D.s. The typical major is O.R., IE, economics/game theory, statistics or computer science (data mining/machine learning). The group is funded through internal research and development dollars targeted for both medium- to long-term applied research.

The HPL team exploits opportunities to build upon existing methodologies and creates decision sciences models and solutions for a comprehensive array of business contexts. The applied thrust of this work can be classified in few areas: marketing/customer operations, supply chain management/back-end operations, enter-

INFORMS has two types of members: individual and institutional. The latter (usually a company) joins by joining the INFORMS Roundtable and appointing as its representative the person in overall charge of O.R.

The Roundtable has been very active since its founding in 1982, with three meetings each year and much communication in between. Its member institutions and its member representatives take a strong interest in how INFORMS serves the needs of practitioners, and have undertaken many initiatives and provided many services toward this end. These involve, for example, public awareness of O.R., both of the annual INFORMS conferences, continuing professional education, one of the prizes and various committees.

In addition, the Roundtable has an advisory responsibility to INFORMS. One bylaw states that it "... shall regularly share with INFORMS leadership its views, its suggested initiatives and its implementation plans on the important problems and opportunities facing operations research and the management sciences as a profession and on the ways in which INFORMS can deal proactively with those problems and opportunities ..." By tradition, it meets with the newly elected INFORMS president-elect each spring to discuss practice-related topics of interest to him or her, and with the entire INFORMS Board each fall to discuss topics of mutual concern.

The Roundtable membership comprises about 50 organizations. Further information is available at <http://roundtable.informs.org>.

This series of articles aims to share with the INFORMS membership at large some information and insights into how O.R. is carried on in practice today.

In measuring a product's importance, it is not enough to consider its individual revenue or sales volume, since neither fully reveals its importance in enabling sales of other products. Given a set of historical orders, RCO computes a nested series of product portfolios along the efficient frontier of order revenue coverage and portfolio size. The core technology for this tool is driven by large-scale combinatorial optimization. RCO is used today in several HP business units to hone product offerings and drive focus toward the most critical products.

HP's deep roots in technologies and very competitive business environment provide a rich set of opportunities for applied research and applications of decision sciences.

prise-wide risk management, service operations and new service creation with a foundations in decision sciences. The following examples will illustrate the breadth of application areas, applied research contributions and skills/methodologies represented by the organization.

Product portfolio management. One challenge the HPL team has helped to address is the complexity of HP's product portfolio. Variety in a product offering can help capture market share, but excessive variety can lead to confusion among customers and sales people, high product management costs, high inventory-related costs, low sales productivity and poor order fulfillment performance.

A revenue coverage optimization (RCO) tool developed by HPL enables businesses to intelligently hone a product portfolio by determining the relative importance of products based on order history.

Marketing mix modeling. The impact of marketing as an instrument to generate revenue is well studied in the consumer goods industry. In the B2B space where portfolios include products and services along with indirect selling, measuring marketing effectiveness is more difficult. In an era of shrinking marketing budgets with ever-rising revenue goals, measuring marketing effectiveness and modifying strategy is a business imperative. Our return on marketing investment solution, known as RoMI, is implemented across many regions worldwide.

The marketing mix problem is complex and its solution depends on a variety of disciplines spanning marketing, econometrics, optimization and psychology. Econometrics is used to determine the effect of marketing vehicles on revenue. Subject matter expertise and analysis of the business outlook and environment is blended into the econometric equation to improve the predictive capacity of

the model. Finally optimization is invoked to find a mix of marketing investments to yield the highest revenues and profit given a budget. The benefits due to this program were approximately \$50 million in 2007 with a potential for \$500 million in increased revenues by end of fiscal year 2008.

Behavioral research in supply chain operations. There's growing interest in using economic experiments to understand behavioral issues in decision-making. HP Labs established the first industrial experimental economics research program in 1994. This program has resulted in significant contributions to science and important business benefits to HP, and also generated significant external visibility.

HP Labs has pioneered the application of experimental economics methodology to supply-chain contracting issues. Over the past years, this technology has transferred into multiple HP business organizations including the Consumer Business Organization and HP's Printing business. All of these projects have resulted into either significant contract/process changes. This work of HP Labs has provided new insight and guided the design of contracts between HP and its resellers. These contracts address various business policies including product return, price protection, minimum advertised price, forecast sharing and others. In a recent project, economics experiments, with human subjects in roles of distributors, were used to study mechanisms designed to solicit forecast commitments.

HP's entire supply chains are optimized to drive costs out of the system via outsourcing, vendor-managed inventory and other lean supply chain management techniques.

Auction technologies and procurement. Online bidding processes have come to occupy a central place in procurement and sales operations for many enterprises. Recognizing the challenge and the opportunity, HP's eSourcing (part of the corporation's Procurement organization) and HP Labs teams have formed a close partnership to develop a portfolio of advanced analytical tools to support the key decisions in setting up online bidding processes for allocating procurement contracts.

The methodology that underlies the technology spans several disciplines – from game theory, microeconomics, econometrics and decision analysis to mathematical programming – to identify the optimal decision tradeoffs based on formal modeling of risks and uncertainties, as well as private information and incentive issues that arise in bidding environments. During the last five years of collaboration, HP has used online bidding processes to purchase more than \$21 billion worth of materials with significant cost savings.

Enterprise risk management. HP's extended supply chain network is very complex. HP's businesses are extremely competitive;

their entire supply chains are optimized to drive costs out of the system via strategies such as outsourcing, vendor-managed inventory and other lean supply chain management techniques. While this ensures that HP is competitive under normal business conditions, HP recognizes that an assortment of high impact, low probability risk events or risk drivers could disrupt HP's revenue stream quite dramatically. These events, both internal and external, include operational risk drivers such as changes in strategic CM partnerships and disruptions to key facilities, financial risk drivers such as currency fluctuation, external drivers such as natural hazards and terrorist activity, and strategic risk drivers such as theft of intellectual property, reduced innovation and aggressive competitor pricing actions. Should these triggering events occur, they may disrupt the normal operation of business functions, leading to potentially catastrophic impacts on many measures of financial performance such as production, cost of service, revenue and customer experience.

The purpose of the Enterprise Risk Review Process is to 1) identify and document this constellation of risks across the enterprise, 2) quantify and profile their impact on performance, and 3) assess and/or recommend mitigation strategies that either reduce their probability of occurrence or diminish their impact should they occur.

HP Labs has been responsible for research and development of underlying models that quantify and profile the risks. The models draw upon research from different disciplines including risk and portfolio management, simulation, statistics and optimization.

Personalized marketing campaign at Snapfish. Snapfish conducts regular e-mail campaigns that reach more than 40 million registered members. The recipient list for each campaign is created by the marketing manager, based on "gut-feel" and experience, using a number of marketing and transaction-based criteria.

The HP Labs team, leading the campaign modeling work, is applying statistical modeling techniques on the customer transaction data to identify criteria that can more accurately predict customer response to an e-mail campaign. The HPL team extended standard discrete-choice and decision tree models to develop new learning algorithms that address the unique characteristics of the training data, such as the very large sent lists and the very low response rates. It draws from previous work in the marketing science and econometrics literature. The result of the modeling is a scored list of all the Snapfish members, where the score indicates the propensity to respond to an e-mail campaign. This has been used to design a targeted campaign for the top 20 percent of members and for dropping the bottom ranked 10 percent from the list.

IT consolidation – HP CAT (Consolidation Analysis Tool). HP is one of the largest hardware vendors in the enterprise IT market. Driven by the business focus on total cost of ownership (TCO) and return on investment (ROI) on IT assets, and fueled by the rapid advancement in hardware technology (which has resulted in more powerful servers and storage systems at lower costs) and enabled by the emergence of virtualization software, many of HP’s enterprise customers have seen a current technology trend for IT consolidation.

The HPL team developed HP CAT, a data analysis and decision support tool, for helping IT consultants, administrators and planners manage their IT infrastructure assets (servers and storage) more efficiently. The core algorithm of HP CAT is a high-dimensional, bin-packing algorithm for optimizing workload placements. HP CAT was used in more than 100 enterprise customers (tens of thousands of servers) in its first year of release, resulting in significant business benefits for HP with enhanced revenue opportunities and better utilization of IT resources for its customers.

Collaborations and Conclusion

FOR DEVELOPMENT and deployment of decision sciences solutions, the HPL team works very closely with business unit teams. In addition, in most cases HP-IT has a very significant role in the success of the projects. The HP Labs team takes ownership of the development of underlying algorithms and core algorithmic software engine development, while HP-IT is generally responsible

for the integration of the core analytical “engine” with back-end IT systems, database design and development, system architecture, deployment and support of complete system.

Over the years, HP Labs team has built strong research collaborations with leading faculty members in several areas of interests to HP and the academic community. The experimental economics/game theory program at HP Labs started with collaboration with CalTech. In auction technologies, HPL has collaborations with MIT, USC and Bilkent University. In the contract design area, the HPL team has closely worked with Stanford University and jointly received an NSF research grant. In personalization technologies and in 1-1 marketing analytics, the HPL team has partnered with UCLA faculty. More recently, in warranty policy design and pricing area, the HPL team is collaborating with Columbia University.

While it is difficult to discuss all of the decision sciences projects of HPLabs, let alone of HP, it is safe to say that the application of rigorous mathematical models is well established throughout HP. Applied researchers and practitioners are making contributions that directly impact the top and bottom line. **IORMS**

Shaileendra Jain is director of the Decision Technology Department at Hewlett-Packard Laboratories, Palo Alto, Calif. While this article summarizes the work of the entire HP Labs team, the author acknowledges Julie Ward, Lakshminarayan Choudur, Kay-Yut Chen, Kemal Guler, Krishna Venkatraman, Hsiu-Khuern Tang and Alex Zhang for providing content of their respective projects.



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