Reinventing the Supplier Negotiation Process at Motorola

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As the world market for telecommunications underwent a massive downturn in the early 2000s, Motorola, Inc. needed to cut costs and increase productivity throughout its operations. It had to identify a method of reducing the time and effort required to prepare for and conduct negotiations with its suppliers, simplify their coordination, and optimize contract awards across sectors, to save costs. Motorola’s global procurement function selected Emptoris’s end-to-end Internet negotiations platform. Combining innovative bidding, online supplier negotiations, and scenario-based optimization analysis, it identifies the best procurement strategy while enhancing supplier relationships. Sourcing over $16 billion and saving more than $600 million, including $200 million specifically driven by the platform’s advanced capabilities, Motorola changed its supplier negotiation paradigm and moved to a truly global process.

Key words: analysis of algorithms; industries: computer, electronic.

As the world market for telecommunications underwent a massive downturn in the early 2000s, Motorola faced factors that together formed a business version of a perfect storm: reduced demand, products that did not have the right features and cost, and an unsustainable internal cost structure. Motorola needed to cut costs fast. The company aggressively attacked its internal costs and developed compelling new products, but it had to cut costs for purchases of goods and services as well to survive and succeed over the long term. Purchases, direct and indirect, make up over 50 percent of Motorola’s costs.

Motorola solved its dilemma by transforming its supplier negotiation processes. It implemented a complete, end-to-end, Internet-enabled supplier-negotiations software platform with advanced capabilities that would support the entire company. The company not only survived the perfect storm but came out of it leaner and stronger, more profitable, and with better long-term prospects.

With strong support and commitment from Motorola’s top executives, including its president, chief financial officer (CFO), and chief procurement officer (CPO), the company implemented Emptoris’s strategic sourcing platform in 2002. After implementation, nearly 600 Motorola users and over 1,000 supplier representatives adopted the platform. The company has since negotiated over $16 billion online, saving over $600 million. Motorola’s procurement community has used all aspects of the software platform to achieve these savings, employing such advanced technology as optimization and such capabilities as online requests for quotations (RFQs) and reverse auctions. These new capabilities prompted Motorola to transform its sourcing processes over the last two years. Motorola sourcing professionals now do business differently, relying heavily on the new software program.

Motorola has relied on the new software platform to make qualitative improvements as well, such as
quicker, more focused supplier negotiations than in past years. Both Motorola and its suppliers have benefited. The online process results in transparent negotiations that allow suppliers to be creative in their responses, which ultimately produces a win-win situation. Suppliers also gain market intelligence from the experience.

Motorola continues to expand its use of the Motorola Internet negotiation tool (MINT), with the goal of addressing 100 percent of its spending. The application has proved sustainable, saving costs in a variety of negotiation situations and market conditions.

Motorola Background
A well-known brand, Motorola turned 75 in 2003. Since 1928, the company has developed innovative technologies. Motorola was founded by Paul V. Galvin as the Galvin Manufacturing Corporation in Chicago, Illinois. Its first product was a “battery eliminator,” which allowed consumers to operate radios directly from household current instead of the batteries supplied with early models. In the 1930s, the company commercialized car radios under the brand name Motorola, a word suggesting sound in motion. The company name was changed to Motorola Inc. in 1947. By the time Paul Galvin died in 1959, Motorola had become a leader in military, space, and commercial communications, had built its first semiconductor facility, and was a growing manufacturer of consumer electronics.

Under the leadership of Robert W. Galvin, Paul Galvin’s son, Motorola expanded into international markets in the 1960s and began moving away from consumer electronics. By the end of the 1980s, it had become a worldwide supplier of cellular telephones, and in 1996, it produced the 3.1 ounce, pocket-sized StarTAC wearable cellular telephone. Following its merger with General Instrument Corporation, Motorola became a leader in cable modems and set-top terminals. Motorola’s 2003 revenue was $27.1 billion.

Motorola’s procurement function is well regarded in the industry, but its highly decentralized culture made centralizing the function difficult. It disbanded its limited corporate procurement function in 1998. Instead, the company’s business units (generally called groups and sectors, depending on size) each installed their own sourcing groups to negotiate and provide commodity management services to meet their own needs. Commodity managers from the various groups and sectors could opt to negotiate together, leveraging the corporation’s entire spending in a specific category or negotiate only on behalf of their own business units. The company lacked a CPO until early 2003, when Theresa Metty was promoted to the newly created CPO position from her previous role as the supply chain vice president of the personal communications sector.

Even with decentralized sourcing, Motorola made some progress. During the 1990s, procurement teams around the company began building a formal framework for sourcing. In the mid-1990s, Motorola implemented one of the first systems to provide electronic support for negotiation. The Motorola contract-information system (MCIS) automatically collected and aggregated forecasted demand information for thousands of unique line items within a given commodity from multiple business units and facilities across the corporation.

The negotiation process itself, however, remained stubbornly manual. Teams of Motorola commodity managers met with teams from all the potential suppliers for a particular commodity group, often over several weeks. Negotiations frequently entailed travel and its costs for Motorola and its suppliers. Once back in the office, the commodity manager created elaborate spreadsheets to model different award scenarios. There was no telling whether any particular scenario was the best or even close to the best except by patiently working through each alternative, which added weeks to the process.

The process was complex because the company used a large number of very similar parts (for example, different values of the same technology and size chip capacitor) in different applications and manufacturing environments. It generally approved parts from a particular set of suppliers for use on one business unit’s products or in a specific manufacturing facility (sometimes down to a specific production line) or on one customer’s product. Approving a new supplier required varying degrees of effort and cost,
depending on the application of the part as well as customer and regulatory requirements.

Motorola had been approached several times in the 1990s by companies offering reverse e-auction technology. Some procurement organizations in industry had begun to use the reverse e-auction process, in which suppliers bid against one another in real time, usually on the Internet. Reverse e-auctions speed up the price-discovery process and improve market transparency but have several potential drawbacks. Motorola had rejected the companies’ offers partly because their promises seemed unrealistic. Because Motorola had benefited from using corporate purchase agreements for nearly 20 years and strategic sourcing for nearly 15 years, it doubted that using reverse auctions would save 10 to 20 percent across all commodities. Also, the e-auctions would induce extreme levels of price-focused competition that could have damaged Motorola’s long-term relationships with suppliers.

Motorola sensed heavy weather ahead in the latter half of 2000. When the perfect storm hit the company in 2001, Motorola had to react quickly. It closed manufacturing facilities around the world and let thousands of people go.

In 2000, an e-business benchmarking program showed that some of Motorola’s peer companies were conducting negotiations online without harming their supplier relationships. Several groups within Motorola investigated Internet-based supplier negotiations and experimented with the concept in late 2000, conducting a couple of dozen reverse auctions with providers in Asia, Europe, and North America. The results were promising. By taking advantage of the new online tools, procurement might be able to do more with less to reduce its costs. Motorola began work to find a way to use Internet negotiations to save on material costs without adding personnel.

**Proof of Concept**

In March 2001, Motorola began a formal program within one sector. It formed a team of representatives from the supply chain, procurement, and IT functions. Using a structured approach to establishing Internet negotiation capabilities, the sector team ensured (1) that all team members and managers agreed on goals, and (2) that it followed rigorous project-management practices. After developing a training program and training many teams responsible for obtaining direct materials (parts in products on bills of materials (BOMs)) and indirect commodities, the team chose five indirect commodities for trial for the e-auction process. These commodities were in the categories of promotional merchandise, marketing-event management, and advertising. Using e-auctions, the firm saved typically 15 to 20 percent more than it would expect with traditional face-to-face negotiations. In addition, the final prices that approved suppliers offered averaged 40 to 60 percent lower than the current contracted prices. From that point on, the team members knew they were onto something very promising!

Direct material commodity managers then ran several Internet negotiations. One produced savings of 25 to 50 percent on specific line items for a commodity widely thought to offer minimal savings potential because the company had already reduced its costs. Even with these initial successes, the team had to sell the process internally. People resisted changing existing procedures, especially because they would have to abandon processes they viewed as a core competence. The team created awareness by publishing a monthly corporate Internet negotiations newsletter and appointing champions in various internal units, including the business unit CPOs and other leaders in procurement and commodity management. When these champions saw the initial results, they became convinced of the potential for the new process. The pilot program ended in 2001; the team had conducted 28 events representing $500 million in spending. By cherry-picking specific commodities, it obtained impressive savings. However, to extend the Internet negotiations process to manage all commodities, Motorola needed a more comprehensive, integrated, sustainable solution.

The team had identified shortcomings with the company’s pilot program. First, the e-auction software could not be integrated with the company’s internal demand aggregation systems. Second, the software was not user friendly, and users could not easily copy data from one e-auction event to another. Beyond these deficiencies, the software lacked the capability to issue e-RFQs or to support multistage (iterative)
supplier negotiations. The champions from the various business units had recognized early on that they could not use simple price-only e-auctions for most negotiations. E-auctions produced good results only under specific conditions. With the knowledge and experience it had gained from the pilot program, Motorola looked for technology that would meet its long-term requirements.

Motorola’s Requirements

Motorola’s supplier negotiation process has four steps: (1) develop a strategy, (2) aggregate requirements, (3) conduct negotiations, and (4) issue awards. Overall, the software would have to control or support the four steps. Commodity teams needed support for a variety of negotiation methods, ranging from straightforward e-quotations to complex iterative negotiations. Many criteria (for example, the competitive environment, detailed specifications, the size of the business, and cycle-time requirements) determine what type of e-quoting commodity teams choose.

Motorola sought a comprehensive, end-to-end, Internet-enabled negotiation capability. It wanted to allow, even encourage, suppliers to make innovative bids on various combinations of parts and to use expressive bids to offer lower total costs. The platform had to support as many as 1,000 purchasing professionals, managing the dozens of commodities and subcommodities on which Motorola spends $17+ billion per year. The platform had to automate negotiations for direct materials (such as resistors, stampings, cables, displays, semiconductors, and printed circuit boards) and indirect products and services (such as paper, printed materials, facilities maintenance, and freight). Equally difficult would be managing a heterogeneous supply base of over 1,000 vendors with different manufacturing locations, product portfolios, delivery capabilities, and language preferences.

The software had to determine which part numbers to award to which suppliers to support specific Motorola facilities, while taking advantage of suppliers’ special offers, often based on total volume of business. For the high-volume parts on which Motorola spends the most, it solicits bids on 500 to 1,000 line items from as many as several dozen suppliers for delivery to facilities around the world. To support this activity, some team members insisted that the software had to include true optimization capabilities (not the weighting and ranking methods some companies promoted) to eliminate manual awards. The team also wanted templates, or a template-building capability, to simplify setting up Internet negotiations. Finally, the software had to be easy to learn and use. The team knew that to adopt it, the general sourcing community would have to be able to use it. The firm could not have specialists on hand to conduct every negotiation.

Altogether the selection team defined over 100 requirements. They fell into eight areas, with each area assigned a weight. The team had not considered such criteria as flexible bidding formats, multistage negotiation capabilities, e-RFQs, constraint modeling, and optimization requirements in choosing the pilot vendor, but it now saw them as critical to e-sourcing. Because Motorola would be running the software itself, solution architecture, software technology, security, and event-management tools were important.

The team evaluated eight leaders in the e-sourcing market. The two-round evaluation process included a detailed RFQ, financial analysis, and demonstrations. In the second round, the team prepared scripts of case studies detailing actual Motorola practices. Relative to its competition, Emptoris satisfied or exceeded Motorola’s requirements, with an extremely strong, user-friendly core with advanced e-sourcing capabilities. Emptoris also had a strong development team willing to partner with Motorola to the develop superior functionality.

System Capabilities

Emptoris’s ePASS (electronic procurement application for strategic sourcing), which Motorola renamed MINT (Motorola Internet negotiation tool), provided the following functions:

—Integrated work flow that supports the buyer and the suppliers and reduces the workload during the multistage negotiation process, beginning with an e-RFQ, moving to an e-auction, and finishing with award analysis.

—Multiple online negotiation formats (reverse e-auction, online competitive bidding, multistage negotiation, and one-on-one negotiation).
—The ability to manage many line items (for example, over 10,000 items), hundreds of suppliers, and complex pricing formulas that factor in the costs of doing business with a supplier in a single negotiation.

—Expressive bidding, in which suppliers submit bids consisting of price and such other attributes as quantity, quality, discounts, and delivery requirements to give the buyer beneficial options.

—Online feedback to suppliers showing how competitive their offers are and what they need to do to win more business.

—Optimization-based bid analysis that is tightly integrated into the negotiation work flow, making it possible in any negotiation to identify the lowest total cost of ownership (all costs associated with procuring and using a material or service, including costs for parts, poor quality, logistics, inventory, resources, and ordering).

—Business-constraint modeling that enables trade-off analysis of different purchasing strategies based on such constraints as supplier count, capacity, delivery requirements, and performance requirements.

—Support for evaluating suppliers based on criteria using complex formulas for analyzing total cost of ownership and optimization-based bid analysis that factors in cost drivers, supplier capabilities, supplier capacity, supplier performance, and multiple forms of supplier discounts.

—User-friendliness, especially for suppliers, giving them bidding flexibility, smooth data importing and exporting, and improved reporting.

—The ability to integrate the software with existing internal systems to move data quickly into and out of the system.

Supporting Internet Negotiation

Motorola’s objective for its Internet negotiation program is to use the most appropriate tool for the situation. Whether to use e-auctions or Internet-supported, multistage, iterative negotiations for a commodity depends on such factors as overall demand in the marketplace versus growth (or decline) in total industry capacity, as well as Motorola’s own growth or decline in using that commodity. Motorola’s goal is to cut costs for purchases while maintaining supplier relationships.

The Internet negotiation process can be decomposed into six steps (Figure 1). In Step 1, for each

![Figure 1: The Internet negotiation process consists of six steps.](image-url)
item, the commodity team builds a model of the total cost of ownership (TCO), which includes price, shipping costs, and maintenance costs as well as non-price attributes, such as product specifications. Using MINT’s flexible data model, the commodity team can build the TCO formula rapidly. The model captures the data elements and the formulas that define their interrelationships. The commodity team communicates the requirements to the suppliers, who respond with initial bids based on TCO, which the system calculates and exposes to the suppliers.

In Step 2, the commodity team selects the best negotiation approach from the following options: an e-reverse auction (e-auction), an e-RFQ by sealed bid, or both. To hold an effective e-auction, the buyer must first issue an e-RFQ to confirm that prospective suppliers understand the requirements and to ensure that enough suppliers are competing for the business. Within a given direct-material-commodity area, Motorola sends close to 100 percent of its spending through e-RFQs to obtain preliminary quotes. The commodity team then evaluates the preliminary bids and market conditions to decide if an e-auction is appropriate. If Motorola cannot create a competitive e-auction (for example, because of constraints in switching suppliers), it uses other approaches. For example, the commodity team might rely solely on the outcome of an e-RFQ.

In Step 3, using embedded work flow and communication, the commodity team collaborates with suppliers, iteratively exploring options for how the suppliers can meet Motorola’s needs at the lowest TCO. These options may include modifications to quantities, to delivery requirements, to delivery dates, or to item specifications.

In Step 4, suppliers use MINT’s bidding function to offer innovative options for the commodity team to evaluate. This is important because suppliers often know many ways to meet the commodity team’s needs based on the supplier’s capabilities and costs. MINT allows each supplier to submit any number of bids that can include rebates, volume discounts, bundling, and substitutions, for example.

In Step 5, the commodity team builds and evaluates different purchasing scenarios to see the effects of various purchasing policies (that is, business constraints) on the TCO and the award distribution. A purchasing policy can split items between two suppliers to hedge risk. The team can run and compare an unlimited number of what-if scenarios against all bids in the system. The system optimizes all elements of the scenario, recommends line by line what supplier to buy from, and provides the analysis identifying the factors contributing to this decision. Because the optimization analysis is tightly integrated into the negotiation platform, the buyer can modify the requirements and reopen the negotiation.

In the final step of the process, Step 6, the commodity team chooses the scenario with the best balance between the TCO and the variation of the purchasing policies. It uses this scenario to award the business. While MINT offers sophisticated functionality, it provides an extremely easy-to-use environment. Members of the commodity team obtain the power of optimization without necessarily understanding how it works. Shielding users from the system’s underlying complexity encourages user adoption.

**Optimization in Strategic Sourcing**

The goal in strategic sourcing is to determine the best mix of suppliers that comply with purchasing policies and minimize the total cost of ownership (Figure 2, Table 1, Appendix). Often in purchasing situations, this problem can become quite complex because of a number of factors:

—The purchasing requirements can include thousands of items with different quantity and delivery considerations.

—Suppliers can submit multiple bids simultaneously employing complex pricing strategies.

—Supplier performance can also be incorporated. If the commodity team values long-term performance of strategic suppliers, it can factor into the analysis historical performance characteristics, such as quality, delivery, and service.

—Multiple business constraints create dependencies between items and can sometimes contradict each other, in which case, the team must identify an acceptable way to resolve the conflicts.

In standard combinatorial auctions (Hohner et al. 2003, Parkes 2001), the bundled bid is considered to cover a package containing the entire amount of each item, and the price bid is for the package. However,
unlike the combinatorial auction model, the Emptoris model allows and encourages split awards, which the standard model does not support. From the suppliers’ perspective, such bundled bids lowered their chances of winning because they did not have the flexibility to provide partial quantities. From the buyers’ perspective, such bundled bids did not allow them to determine individual prices for items. The buyers wanted prices for individual items so they could benchmark suppliers’ prices item by item. Therefore, Motorola needed a new method to handle bundling under split awards. Emptoris considered two ways to do this. The first was to combine different quantities of items into a package and offer multiple quantities of the package. Research showed that suppliers did not view bidding in this way. Suppliers tended not to think of bid packages as discrete units that buyers could purchase in multiple quantities. The second approach, which both buyers and suppliers preferred, allowed the suppliers to indicate prices and quantity ranges for each item in the bundle and to give discounts if the quantity of each item the buyer purchased was within that range. For example, the supplier might offer 10 to 20 units of item 1 at $10 per unit. It might also offer 50 to 100 units of item 2 at $5 per unit. However, if the buyer purchased any quantity between 10 and 20 of item 1 and any quantity between 50 and 100 of item 2 from the supplier, it would provide a 10 percent discount on both items. Modeling this behavior was one of many challenges facing us.

However, we faced two major problems in designing software to solve the company’s complex optimization problem. First, we had to develop an optimization approach that was fast and provided provably optimal solutions. The process had to be robust, scalable, and independent of the particular auction structure (bidding event). Second we had to make creating an optimization problem and analyzing the results easy and intuitive for users not familiar with optimization techniques. While many researchers have searched for ways to solve problems of determining auction winners (Eso et al. 2001, Sandholm 1999, Sandholm and Suri 2001, Park and Rothkopf 2001), most of them looked at much simpler auctions (such as single-item auctions or auctions without split awards) or suggested...
<table>
<thead>
<tr>
<th>Parameters and constraints</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum and maximum quantity or capacity</td>
<td>The amount the supplier will commit to at a given price or the amount the buyer requires from a supplier.</td>
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<tr>
<td>Per unit and fixed pricing</td>
<td>The item price and any fixed or one-time charges (e.g., setup charges).</td>
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<tr>
<td>Item-specific volume discounts</td>
<td>A bid on a single item whose price depends on the quantity purchased, for example, the supplier will charge $10 per unit for up to 1,000 units, $9 per unit for 1,000 to 2,000 units, and $8 per unit for over 2,000 units.</td>
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<tr>
<td>Cross-item bundling</td>
<td>Suppliers may offer price breaks for groups of items purchased together. Bundling is especially important to suppliers who can protect profit margins by grouping high-margin and low-margin items together at a special price. The model differs from conventional bundling approaches, and a more detailed explanation is given in the text.</td>
</tr>
<tr>
<td>Business volume discounts</td>
<td>Price reductions based on the total value of business awarded to a supplier for a given group of items, for example, a supplier may offer no discount for purchases under $500,000. However, it may offer a two percent discount or a $10,000 rebate on all purchases if the buyer purchases more than $500,000.</td>
</tr>
<tr>
<td>Delivery dates or times</td>
<td>The buyer's required time of delivery, either in terms of a specific date range or number of lead days. This may incorporate penalties for failing to meet the required delivery terms.</td>
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<tr>
<td>Item substitutions</td>
<td>Alternate goods or services suppliers provide at different prices, quantities, and delivery dates to meet buyer requirements.</td>
</tr>
<tr>
<td>Supplier performance</td>
<td>Nonprice performance factors that drive costs and are tied, for example, to quality, performance, service, or financial condition.</td>
</tr>
<tr>
<td>Supplier qualification status</td>
<td>Whether the supplier is qualified (or not) to meet the buyer's needs.</td>
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<tr>
<td>Supplier count limits</td>
<td>The minimum or maximum number of suppliers a buyer wants.</td>
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<tr>
<td>Split award</td>
<td>An award quantity split among suppliers to guarantee backup supply.</td>
</tr>
<tr>
<td>Supplier switching costs</td>
<td>The cost of adding a new supplier (such as costs to qualify a previously nonqualified supplier).</td>
</tr>
<tr>
<td>Preferred vendor allocation</td>
<td>The guaranteed allocation of some portion of the award to a preferred supplier.</td>
</tr>
<tr>
<td>Offset</td>
<td>The guaranteed allocation of some portion of the award to a vendor because of its geographic location or proximity to the point of use.</td>
</tr>
<tr>
<td>Supplier capacity limit</td>
<td>A limit on an award to a new supplier to reduce exposure.</td>
</tr>
<tr>
<td>Minority set-asides</td>
<td>The guaranteed allocation of a portion of the award to minority-owned suppliers.</td>
</tr>
<tr>
<td>Budgetary limits</td>
<td>The limit on an award to a certain total cost to avoid exceeding a budget.</td>
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Table 1: We considered and modeled many parameters for various Internet negotiation events.

heuristics or approximation schemes that were fast but did not guarantee optimal outcomes. The auction-optimization problem Emptoris needed to solve was far more complex than any problem considered in the literature. The two main requirements that made the problem complex were (1) to give the users a tool that was generic enough to capture their business needs, and (2) to create an efficient model that accurately reflected these needs. We first identified a set of rules that had major business importance. Some of these rules had straightforward linear formulations, while others, such as complex discount structures, were nonlinear and also required very large coefficients that in most cases introduced numerical instability. We had to reformulate them to make them tractable and still accurate. The resulting MIP formulation was very complex and in many cases, especially for large auctions, was not readily solvable by commercial optimizers. We then introduced heuristics that reduced some of the problem coefficients, guided the branch-and-cut strategy using knowledge of the specific problem structure, took advantage of the variable dependency, and iterated the solution to improve accuracy without increasing complexity. In addition, by using the appropriate settings of numerous CPLEX integer solver parameters, such as diving and probing, we further improved performance. Altogether these actions produced robust and scalable solutions, allowing the software to solve problems with hundreds of items and thousands of bids in a few minutes.

The following two case examples demonstrate how Motorola’s sourcing teams used the optimization capabilities of MINT to support Internet negotiations. MINT’s optimization capabilities can be used with e-reverse auctions and with online mul-
tistage or iterative negotiations. The examples highlight the use of business constraints (for example, supplier-qualification status, supplier-count limits, and various capacity constraints), supplier-performance factors, complex supplier-pricing strategies, and nonprice bidding attributes to accurately compare the total cost impact of various sourcing strategies.

Case Example 1
When buyers were sourcing process chemicals for Motorola’s semiconductor products sector, they used optimization bid analysis to ensure that they had enough qualified suppliers to meet production needs. In one case, six suppliers competed for 31 separate line items of business. Some suppliers had not yet been qualified to conduct business with Motorola. The resources required for qualification vary by sector and even by product group within a sector. For example, sectors that do business with the automotive industry typically have stringent qualification processes to comply with their customers’ requirements. Another factor that influences the resources required for qualification is the number of products that would be affected by using the new supplier. For example, it would be easier to qualify supplier A on part 123 if this part were used only in one cell phone than if the part were used in many cell phones. It can take Motorola up to six months to qualify a supplier. Because qualifying suppliers is time- and labor-intensive, Motorola identified and prioritized the nonqualified suppliers for qualification based on their ability to supply the process chemicals at the lowest total cost. In addition, for mission-critical process chemicals, Motorola wanted to ensure that it had adequate supplies, so buyers used optimization to model hedging strategies that ensured that a minimum of two suppliers received a set capacity for the critical line items.

Case Example 2
When sourcing transportation, commodity teams used optimization to identify the allocation to suppliers that obtained the lowest total cost that incorporated price and nonprice factors and business constraints designed to meet Motorola’s overall needs. In one case involving approximately $70 million in intercontinental heavy air transport (such as from Chicago O’Hare to Hong Kong), optimization identified the best allocation among seven suppliers across 205 transportation lanes (such as city-to-city flight routes). Motorola conducted similar analyses for a $17 million intracontinental (such as Singapore to Kuala Lumpur, Malaysia) heavy-air-transport negotiation. In this case, 16 suppliers competed across 105 transportation lanes. To calculate the total cost, buyers incorporated supplier prices, historical supplier-performance factors, and additional supplier-cost drivers. Suppliers bid on door-to-door (DTD) prices per transportation lane. Suppliers also submitted bundled bids that took advantage of scale pricing across multiple transportation lanes. To incorporate nonprice supplier cost information as part of the total cost of ownership, Motorola used suppliers’ historical performance scores on technology and quality. Finally, suppliers provided additional nonprice information, including minimum charges, transit times, and weekly consolidations. We included a variety of business constraints in the analysis, including awarding one lane to no more than one supplier, limiting the total award to two suppliers per lot, and limiting the award to the two preferred suppliers. We created scenarios so that we could better understand the cost implications of the various alternatives.

Motorola identified the following benefits of using optimization to support the negotiations:
—It obtained lower total costs by evaluating multiple supplier-driven creative discounting options simultaneously.
—It reduced the time it took to analyze awards by eliminating conventional spreadsheet analysis, which for a global direct material commodity involves tens of thousands of line items affecting 10 to 30 facilities.
—It improved supplier performance by enabling the commodity team to apply nonprice factors in a disciplined, objective manner. Doing so requires high data integrity, but suppliers can see a direct correlation between performance and new business.
—It increased employees buy-in by using what-if scenario analysis. Buyers can run many scenarios and see the impact of various strategies and business constraints on the total cost of ownership.

Encouraging User Adoption Throughout Motorola
MINT provides Motorola with five important capabilities. First, it reinforces the importance of Motorola’s
relationships with its suppliers. Using MINT, suppliers can offer innovative bids that include bundles, quantity-based discounts, business-volume discounts, and delivery and capacity alternatives that play to their strengths. Whereas previous approaches locked down all of the buyer’s requirements except price, making price the focus of competition, MINT encourages suppliers to bid on all parameters, not just on price. MINT exposes tremendous opportunities for incremental savings and enables Motorola and its suppliers to discover win-win agreements. Also, by providing suppliers with immediate feedback showing the competitiveness of their bids, MINT gives them valuable insight into the market. This information motivates them to seek further opportunities to reduce costs. Suppliers recognize MINT’s benefits; one company’s representative commented that the new process gave the firm time to work on its bids and to make better decisions.

Second, MINT identifies more opportunities for savings than traditional negotiation methods by motivating suppliers to compete in areas beyond just unit price. MINT’s analysis capability uncovers savings opportunities by identifying solutions with the lowest total cost of ownership, factoring in all the elements captured throughout the sourcing process. These elements include buyer requirements, business rules, and supplier-cost-reduction options around item quantities, delivery locations, delivery times, shipping options, capacity limits, substitutions, and pricing discounts (for example, packaged bundled deals and quantity discounts based on value).

Third, MINT offers many formats for negotiation, enabling Motorola to negotiate with its suppliers online for up to 100 percent of its spending. For commodities produced by many suppliers, Motorola can use MINT’s online reverse-auction capability to establish a dynamic bidding environment that drives out costs.

For commodities with few qualified suppliers and high costs for switching suppliers, Motorola can use MINT’s multistage negotiations to identify the best suppliers without harming supplier relationships. Further, the MINT software supports moving between formats; if necessary, the company can start a negotiation as a multistage negotiation and finish as an auction, or vice versa.

Fourth, MINT’s seamless data flow and support for the entire Internet negotiation process improves negotiations for both Motorola and its suppliers, reducing the time they devote annually to strategies and negotiations.

Finally, MINT’s Web-based user interface and integrated work flow enable all Motorola buyers to model complex purchasing strategies (such as sophisticated optimization problems) without a detailed understanding of how to use an optimization model to structure these problems. Buyers can construct an unlimited number of scenarios, incorporate multiple parameters and business constraints, compare the outcomes of different scenarios, and get an intuitive and detailed explanation of the factors that lead to the optimal award allocation. Suppliers can start using the system quickly with little training. Suppliers have commented that the online tool allows them to get an intuitive and detailed explanation of the factors that lead to optimal awards to increase the number of personnel participating in negotiations and to reduce their travel expenses.

In a typical case, MINT’s five capabilities helped Motorola and its suppliers to negotiate for capacitors using a series of e-RFQs and e-auctions. The MINT tool enabled suppliers to bundle families of capacitor parts easily, to build these families easily, and to bid online using a simple interface. Motorola commodity managers structured the bidding to accept variations in bundles so suppliers could bid to their strengths. Finally, all the suppliers viewed the prices of the best bid, motivating them to drop prices below Motorola’s expectations.

Awareness and Management Commitment

As we rolled the software out to users, we described its benefits at several internal procurement conferences. Through live demonstrations, we demonstrated how future users could run complicated scenarios through the robust optimization engine to reduce costs. We also invited top procurement executives to view live e-auctions so that they could see first hand the astounding savings we were achieving during early bidding events. These executives became enthusiastic sponsors of top-down goals that they incorporated in several of the sector scorecards. By 2003, the
company required most sourcing associates to include at least one e-negotiation goal in their annual personal commitment plans.

In addition, we established an aggressive training campaign for the entire global procurement community, running 11 training workshops in the US, seven in Asia, and two in Europe in 2002. We followed them with 15 train-the-trainer sessions. The newly certified trainers continued the training programs in 2003, holding local one-day workshops on specific subjects, such as requests for information, RFQs, auctions, and optimization. By the end of 2003, 376 individuals had participated in eight or more hours of training, and half of them became MINT superusers (Figure 3).

**Results**

We deployed MINT throughout Motorola in mid-2002 by training a critical mass of Motorola employees and supplier representatives (Figure 3). From June to December of 2002, Motorola used MINT to conduct 200 sourcing projects totaling nearly $7 billion (or 40 percent) of the company’s total spending on direct materials and indirect commodities. In 2003, Motorola trained a second wave of internal users and suppliers and increased the percentage of its spending that it sourced online. During that year (Figure 4), it sourced nearly $10 billion (about 56 percent of its total spending) online using MINT in over 450 events. MINT was the sole online system the company used to negotiate with suppliers and conduct optimization analyses of bids. The savings Motorola captured using MINT exceeded $600 million by the end of 2003.

We calculated, verified, and audited Motorola’s savings carefully. First, MINT automatically calculates the savings from the baselines for all quoting events. Baselines are independently verified by internal controllers prior to loading them into MINT. To determine whether MINT yielded above average savings, we tracked the firm’s prenegotiation expectations of savings for all e-auctions and compared the actual savings to the expected savings. During the first 50 auctions, we found that MINT saved five to 15 percent (an average of eight percent) more than our optimistic expectations. The main, and typically only, significant difference between past negotiations (such as without MINT) and the recent negotiations (with MINT) was the enhanced online process.

We attribute $600 million in savings to three main components. One is the ability to engage more suppliers during more negotiations and to help them to compete more effectively in bidding. This ability accounts for about 60 percent of the savings. Second is suppliers’ ability to make higher value-added bids, which reduces Motorola’s total cost (about 30 percent of recent savings). Third is reduction in time spent on negotiations and reduction in travel and other factors (about 10 percent of recent savings).

Motorola uses optimization for all events, usually in building scenarios, but for 20 percent of the e-auctions or RFQs, it uses MINT’s sophisticated optimization capabilities. From the beginning of its work, the MINT
program team focused on changing the way that Motorola’s global procurement community conducted sourcing and negotiations. The team implemented strong online capabilities rather than a point solution to ensure that MINT was fast, deep, and broad.

MINT’s capabilities have driven Motorola to transform its way of interacting with its suppliers. With its increasing deployment, MINT captures more of Motorola’s spending, and Motorola’s employees increase their use of the advanced analytical tools in MINT. The company expects to continue reducing costs in coming years. The use of MINT changed Motorola’s way of conducting negotiations with its suppliers and moved Motorola away from loosely coordinated efforts by individual sectors to conducting truly global negotiations with suppliers jointly across business units.

At the inception of the program, people often questioned whether MINT would simply boost the productivity of commodity managers and possibly cut travel expenses or if it would produce incremental savings. Early studies indicated that incremental savings would come from three sources:

—Negotiating for minor commodities for the entire firm, rather than by site or business unit.

—Commodity managers’ making lowest-total-cost decisions based on a clear understanding of the trade-offs between lower part costs and any switching costs required.

—The competitive forces produced by reverse auctions that generally reduce bids by four to seven percent.

The number of commodities covered by MINT has mushroomed over the life of the program. We attribute its wide adoption to (1) its capabilities, (2) our aggressive training of users, (3) documentation of the process, and (4) the goals set for the commodity teams. The company has run online bidding events for direct materials, such as semiconductors and passive electronic components, and indirect materials and services, such as advertising, office supplies, tooling, and transportation. Further, the company has run bidding events in every country where it has major operations, including Brazil, China, Germany, Malaysia, Mexico, Singapore, Taiwan, and the United States. Motorola has used MINT’s multilingual capabilities to conduct negotiations simultaneously in English and Mandarin Chinese. It has obtained bids on a long list of commodities (Table 2).

MINT allows Motorola to negotiate over 50 percent of its annual spending online, an order of magnitude higher than most companies have achieved. In 2003, Motorola used the online negotiation tool in bidding events from under $2,000 to over $2 billion. E-RFQs ranged from a single item to as many as 21,865 line items. As many as 48 suppliers participated in some events. Motorola received as many as 959 bids for auctions and over 100,000 for several multistage negotiations.

MINT has produced qualitative improvements as well. Motorola’s employees and suppliers’ employees find negotiations to be quicker and less stressful than in past years, with less travel required. As a

<table>
<thead>
<tr>
<th>Direct material commodities</th>
<th>Indirect material/services commodities</th>
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<tbody>
<tr>
<td>Accessories</td>
<td>Clean room supplies</td>
</tr>
<tr>
<td>Antennas</td>
<td>Construction</td>
</tr>
<tr>
<td>Burn-in boards</td>
<td>Consumables</td>
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<tr>
<td>Cabinets</td>
<td>Electricity</td>
</tr>
<tr>
<td>Cables</td>
<td>Facilities renovation</td>
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<tr>
<td>Castings</td>
<td>Information technology services</td>
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<td>Connectors</td>
<td>Models</td>
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<tr>
<td>Consumables</td>
<td>Natural gas</td>
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<tr>
<td>Crystals</td>
<td>Office relocation</td>
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<tr>
<td>Die cuts</td>
<td>Paper</td>
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<tr>
<td>Display phones</td>
<td>Peripherals</td>
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<tr>
<td>Displays</td>
<td>Printing marketing materials</td>
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<td>Etched lead frames</td>
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<td>Filters</td>
<td>Toner</td>
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<td>Fleet</td>
<td>Transmission lines</td>
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</tbody>
</table>

Table 2: Motorola negotiated for many commodities, both direct materials and indirect materials and services, using the MINT solution.
result, Motorola’s commodity managers can spend more time preparing for negotiations.

For example, Motorola’s stampings commodity team initially just dipped its toes in the water. When we first introduced the team to Internet negotiations, it put only 30 percent of its spending on e-RFQs and conducted only two e-auctions, which together were worth less than $20 million. By 2003, the team had put over 95 percent of its spending on MINT and conducted over 40 e-auctions.

Suppliers have benefited as well. One supplier commented, “Internet negotiation speeds up the process and allows it to be completed no matter the hour or weather without travel.” The online process makes the negotiation more transparent for the suppliers, giving them a fairer, more level playing field. They also gain market intelligence from the experience and opportunities to bid that they otherwise might not have had. A supplier said, “Having set up other users in my organization on the tool, they are now getting RFQs and messages that they would never have gotten before.”

The improvements MINT provided were of critical importance to Motorola; since 2001, cost control has been the number one priority for Motorola’s global procurement function and for Motorola (Figure 5).

Although Motorola already negotiates much of its spending online, it intends to use MINT for additional commodities. For example, Motorola still has several billion dollars in procurement spending that it has only partially leveraged with respect to aggregating demand, sourcing at the lowest possible total cost, or optimizing awards. MINT will enable the commodity managers to leverage that spending as well. By using a common, corporate tool, Motorola can consolidate and leverage spending that it otherwise could not. Motorola’s executive management believes that it must use MINT for all of its negotiated spending. Under CPO Theresa Metty, the firm’s global procurement organization has set ambitious targets for managing bidding events and spending using MINT for e-RFQs, e-auctions, and optimization.

Beyond that, the company has begun work to link the input and output of sourcing and negotiation to produce further efficiencies among the hundreds of people who work on sourcing. MINT will serve as the linchpin in the fully digitized sourcing process at Motorola, which the firm expects will greatly improve its competitiveness.

Online negotiations took hold at Motorola and grew during what was generally a buyer’s market. The market for electronic components is becoming a seller’s market. Motorola believes that MINT’s tools will become more important as conditions become less favorable for buyers. Auctions become less effective in a seller’s market, but e-RFQs, support for multistage negotiations, and optimization become more effective for buyers. Motorola sees MINT’s Internet negotiations and optimization capabilities playing a key role in the future.

**Appendix. Mathematical Formulation of the Auction Award Optimization Problem**

Emptoris identifies the following basic model variables and parameters:

- $S$—the set of all suppliers participating in the RFQ.
- $I$—the set of all items to be procured in the RFQ.
- $SB(s)$—the set of simple bids supplier $s \in S$ offers.

A simple bid is a bid on a single item in the RFQ. The bid includes price and the available amount of the item. In addition, these bids can include other information, such as quality of the product and color. Each supplier can make an unlimited number of different simple bids for the same item.
BB(s)—the set of all bundled bids supplier $s \in S$ offers. A bundled bid is an additional constraint enforced on top of a set of simple bids on distinct items that states that the supplier is willing to provide the corresponding items only as a package. Unlike combinatorial auctions, this approach does not permit the supplier to require the buyer to purchase the entire amount of any of the items in the bundle. In addition, the bundle is priced at the item level. This means that the price of the bundle is defined by the prices of the simple bids in it.

$VB(s)$—the set of all volume discount bids supplier $s \in S$ offers. A volume discount bid is a bid on a single item whose price depends on the quantity of the item purchased. The volume bid is represented by a set of simple bids within the set. The segments are enforced to be pairwise disjoint, and only one bid from this set can be awarded.

We describe bundled and volume-discount bids in more detail in the section headed Optimization in Strategic Sourcing.

$CB(b)$—the set of child simple bids of a bundled bid or a volume bid $b$. Child bids of a volume (bundled) bid are the simple bids within the set.

$B(s)$—the union of $SB(s)$ and $CB(b)$ for all $b \in VB(s), BB(s)$.

$B(i)$—the set of simple and child bids from all suppliers on item $i$.

$l_b$—minimum capacity associated with bid $b \in B(s)$. This is always positive. If the supplier does not provide this value, it can safely be assumed to be 1. This value indicates that the supplier will deliver the item only if the buyer orders a sufficiently large quantity.

$u_b$—maximum capacity associated with bid $b \in B(s)$. It may be positive or undefined. If positive, it is the maximum amount of the item the supplier can deliver.

$p_b^i$—price per unit associated with bid $b \in B(s)$.

$o_b^i$—one-time charge associated with bid $b \in B(s)$.

$QL_i$—lower bound on the quantity demanded of $i \in I$.

$QU_i$—upper bound on the quantity demanded of $i \in I$.

$x_b^i$—award quantity variable for bid $b \in B(s)$.

$xi_b^i$—indicator variable for bid $b \in B(s)$.

$xi_{bb}^i$—indicator variable for bundled bid $b \in BB(s)$. These variables are defined for the bundled bid itself and do not have prices associated with them. The variables are used to enforce the bundle constraint on the child bids of the bundle.

$a_i$—an auxiliary award variable for item $i \in I$, which is required to handle cases in which no bids exist to satisfy the requirement for item $i$.

$M$—big $M$, estimate based on the problem data. The value of this parameter can differ for different constraint types.

### Basic MIP Formulation

Minimize \( \sum_{b \in B(s), s \in S} (p_b^i x_b^i + o_b^i x_b^i) + \sum_{i \in I} M a_i \)

subject to

1. \( QL_i \leq \sum_{b \in B(i)} x_b^i + a_i \leq QU_i \quad \forall i \in I, \) (1)

2. \( l_b x_b^i \leq x_b^i \leq u_b x_b^i \quad \forall s \in S, \forall b \in B(s), \) (2)

3. \( \sum_{b \in CB(b)} x_b^i \leq 1 \quad \forall vb \in VB(s), \) (3)

4. \( x_b^i = x_{bb}^ib \quad \forall b \in CB(bb), \forall bb \in BB(s), \) (4)

5. \( x_b^i \) binary, \( x_b^i, a_i \geq 0, \) integer.

Constraints (1) ensure that the amount of each item purchased is within the required bounds. Constraints (2) provide the link between the award variable and the corresponding award indicator variable and ensure that the amount awarded to the bidder is within the specified bounds. Constraints (3) guarantee that at most one bid in the volume bid set is awarded. Constraints (4) ensure that all bids in the bundle have (or do not have) awards.

### Nonprice Attributes Affecting the Price

The buyer is permitted to introduce nonprice factors, such as supplier’s reputation and product quality. The buyer can introduce the desired factors with the specified weights to the bid prices, thus redefining the coefficients of the objective function. In addition, the buyer can introduce a per-day penalty for missing specified delivery dates.

Consider the following example: Suppliers A and B bid on the same item, supplier A has $p_a = 100$, supplier B has $p_b = 110$. Clearly, if price were the only
consideration, supplier A would get the award. However, the buyer knows that supplier A product is of lower quality, with a quality value of 4 on a scale of 1 to 10, with 10 being the highest quality. Supplier B has a quality value of 9. Suppose that the buyer considers price and quality equally important and puts weights of 50% on price and 50% on quality. Then, the weighted prices \( pw_a \) and \( pw_b \) are defined as follows. The quality rate is computed as \((10 - 4)/10 \times 100\% = 60\%\) for A and similarly as 10% for B. The final price is then

\[
\begin{align*}
pw_a &= 0.6 \times 0.5 \times p_a + 0.5 \times p_a = 80, \\
 pw_b &= 0.05 \times 0.5 \times p_b + 0.5 \times p_b = 60.5,
\end{align*}
\]

making supplier B more attractive.

Other Pricing Strategies

Suppliers can introduce a more complex bidding strategy, namely business volume discounts (BVDs). BVDs can be viewed as rebate policies, which reward the buyer if it procures over a certain dollar amount from the supplier.

The model supports two different BVD strategies. Fixed (percent) BVDs give the buyer a specified rebate amount (percent discount) if it procures a specified set of items within a certain currency range.

We introduced the following additional parameters and variables for BVDs:

- \( BVD(s) \) — set of all BVDs of supplier \( s \in S \).
- \( I(bvd) \) — set of items covered by a \( bvd \in BVD(s) \).
- \( B(bvd) \) — set of bids affected by a \( bvd \in BVD(s) \). This is the set of all bids on all items in \( I(bvd) \).
- \( L_{bvd}, U_{bvd} \) — lower and upper bounds of the currency range of a \( bvd \in BVD(s) \).
- \( r_{bvd} \) — rebate amount of a fixed \( bvd \in BVD(s) \).
- \( p_{bvd} \) — percent discount of a percent \( bvd \in BVD(s) \).
- \( s_{bvd} \) — variable for the total amount spent on the items in \( I(bvd) \).
- \( s_{i_{bvd}} \) — binary indicator variable, which is equal to 1 if the spending on the BVD items is within the currency range and 0 otherwise.

For the fixed BVDs, we use the following additional constraints:

\[
\begin{align*}
 s_{bvd} &= \sum_{b \in B(bvd)} (p_{b}^x x_b^s + q_{b}^x x_b^s), \\
 L_{bvd} s_{i_{bvd}} &\leq s_{bvd} \leq M - (M - U_{bvd}) s_{i_{bvd}}, \tag{5}
\end{align*}
\]

and a new term in the objective function \( -\sum r_{bvd} s_{i_{bvd}} \). Constraint (5) ensures that the indicator variable is set to 0 if spending on the BVD items is not within the currency range, and the objective term decreases the total spending by the rebate amount if the BVD is in effect.

We use a similar objective term and set of constraints for the percentage-type BVDs. In addition, we introduce a set of constraints to prevent double discounting when a bid contributes to more than one BVD. These constraints are straightforward but cumbersome.

Additional Business Rules

The buyer can also introduce a set of business rules, represented as additional constraints in the basic MIP formulations.

The following parameters are used for all constraints:

- \( I(c) \) — set of items selected for the constraint.
- \( S(c) \) — set of suppliers selected for the constraint.
- \( L(c), U(c) \) — constraint’s lower and upper bounds.
- \( B(s,c) \) — set of all bids from a supplier \( s \in S(c) \) on all items in \( I(c) \).

We distinguish three major categories of business rules. The buyer can specify any number of rules in each category, each having independent sets of items and suppliers, as well as upper and lower bounds. In what follows, we describe each category in detail.

The constraints limit the total number of suppliers awarded business over the selected set of items as well as the percentage of business awarded to each winning supplier. The corresponding business rule states that for the suppliers \( S(c) \) of items \( I(c) \), at least \( L(c) \) and at most \( U(c) \) suppliers can get awards. In addition, each supplier awarded business should receive at least a specified percent of the spending on items \( I(c) \).

Variables and Parameters

- \( mp(c) \) — minimum percent of business to award to each winning supplier.
- \( i_{c}^s \) — indicator for supplier \( s \in S(c) \), which is equal to 1 if the supplier has any award on any of the items \( I(c) \), and 0 otherwise.
- \( w_{c}^s \) — total award to supplier \( s \in S(c) \) on items \( I(c) \).
- \( w^c \) — total award to all suppliers on items \( I(c) \).
Constraints

\[ \sum_{b \in B(s,c)} x^s_b \leq M_i^c \quad \forall s \in S(c), \]  

(6)

\[ \sum_{b \in B(s,c)} x^s_b \geq i^c_s \quad \forall s \in S(c), \]  

(6')

\[ L(c) \leq \sum_{s \in S(c)} i^c_s \leq U(c), \]  

(7)

\[ w^c_s = \sum_{b \in B(s,c)} (p^s_b x^s_b + o^s_b x^s_b) \quad \forall s \in S(c), \]  

(8)

\[ w^c_s = \sum_{s \in S(c)} w^c_s, \]  

(9)

\[ w^c_s - mp(c)w^c \geq -M + M_i^c \quad \forall s \in S(c). \]  

(10)

Constraints (6) and (6') set the supplier indicator variable to 1 if the supplier receives any award. Constraint (7) ensures that the number of suppliers is within specified bounds. Constraint (8) defines the total spending for each supplier. Constraint (9) defines the total spending from all suppliers. Constraint (10) guarantees that if a supplier gets an award, the award is at least \(mp(c)\) percent of the total award.

The constraints limit the total number or percentage of units or currency awarded to selected suppliers over a selected set of items.

Variables and Parameters

\(w^c_s\)—total award to supplier \(s \in S(c)\) on items \(I(c)\).

\(w^c\)—total award to all suppliers on items \(I(c)\).

\(u^c_s\)—total number of units awarded to supplier \(s \in S(c)\) on items \(I(c)\).

\(u^c\)—total number of units awarded to all suppliers on items \(I(c)\).

Number of Units Constraints

\[ u^c_s = \sum_{b \in B(s,c)} x^s_b \quad \forall s \in S(c), \]  

\(L(c) \leq \sum_{s \in S(c)} u^c_s \leq U(c). \)

Percentage of Units Constraints

\[ u^c_s = \sum_{b \in B(s,c)} x^s_b \quad \forall s \in S(c), \]  

\(u^c = \sum_{s \in S(c)} u^c_s, \)  

\(L(c)u^c \leq \sum_{s \in S(c)} u^c_s \leq u^c U(c). \)

Currency Amount Constraints

\[ w^c_s = \sum_{b \in B(s,c)} (p^s_b x^s_b + o^s_b x^s_b) \quad \forall s \in S(c), \]  

\[ L(c) \leq \sum_{s \in S(c)} w^c_s \leq U(c). \]

Percentage of Currency Constraints

\[ w^c_s = \sum_{b \in B(s,c)} (p^s_b x^s_b + o^s_b x^s_b) \quad \forall s \in S(c), \]  

\[ w^c = \sum_{s \in S(c)} w^c_s, \]  

\[ L(c)w^c \leq \sum_{s \in S(c)} w^c_s \leq w^c U(c). \]

The constraints limit the weighted purchasing cost (the cost that includes nonprice attributes). The buyer can also impose the above constraints replacing pure price \(p^s_b\) and \(o^s_b\) with weighted price \(wp^s_b\) and \(wo^s_b\), thus creating constraints limiting weighted price that includes nonprice attributes instead of pure purchasing costs.

Emptoris has been extremely successful in optimizing auctions of different sizes and structures. The model proved to be very robust and scalable. It was applicable to a wide range of problems from events with just a dozen bids to events with tens of thousands of bids. Problem sizes and complexity varied considerably from customer to customer and from event to event for a single customer. Problems varied from instances producing just a few nodes in the branching tree and converging in a matter of seconds, to instances with tens of thousands nodes and taking several minutes to complete. For example, MINT optimized an auction with over 200 items, over 700 bids, and over a hundred constraints limiting the award to each winning supplier for each item category and limiting the number of suppliers, in less than a minute. A much larger problem with about 15,000 items, 75,000 bids, and a few dozens of constraints, most of which covered all the bids in the auction, took a little over 10 minutes. The problems were solved to optimality within CPLEX tolerance, which in most cases was the default solver tolerance. Overall, the extensive optimization experiments demonstrated the efficiency and scalability of the optimization process and clearly showed that this approach meets and exceeds the solution requirements.
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