A Non-linear Procurement Model with Quantity Discounts

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This paper presents a procurement model for a multinational oil company with affiliate plants located worldwide. The proposed model uses a quantity discount relationship to reduce the total procurement cost. We use a non-linear programming method to solve the model and make comparisons with the current approach used by the oil company. The proposed approach has several distinct advantages: assured minimum cost, ease of data management, flexibility in design, and accuracy in results.

Key words: procurement, optimization, non-linear programming

INTRODUCTION

International procurement programmes represent complex allocation and distribution problems. The balance of supply and demand, combined with purchasing constraints serve as major obstacles to negotiations. In addition, subjective factors such as security of supply, product quality, and satisfactory customer service must be considered without losing sight of the primary objective—cost minimization.

The procurement of materials has been studied extensively. The majority of the procurement approaches have focused on the study of purchasing and its behavioural aspects. For example, Monczka and Giunipero$^1$ compare procurement of materials from national versus international sources and present a strategy for determining the best approach. DeRijcke et al.$^2$ present a diagrammatic flow method for integrating the design stages of the purchasing decision process with the choice stage. Other studies involving the purchasing function of procurement involve measuring and evaluating purchasing effectiveness (Croell$^3$ and van Weele$^4$), improving the productivity of personnel involved in procurement (Adams and Niebuhr$^5$), and the organizational level of the purchasing and procurement functions (Bloom and Nardone$^6$ and Moore et al.$^7$).

For quantitative procurement decision making, two distinct approaches have been employed by researchers. On one hand, comprehensive procurement methods have been developed for specific problem environments: e.g. Anderson and Chen$^8$ designed a decision support system for the procurement of military equipment; Narasimhan and Stoynoff$^9$ developed an integer programming model for optimizing aggregate procurement allocation decisions of a large manufacturing firm; Zierer et al.$^{10}$ presented a linear programming formulation of Shell Oil's distribution and procurement problem; and Silver$^{11}$ proposed a model for procurement and logistics decision making in large-scale projects in the oil and gas industry. On the other hand, models have been introduced to study the specific elements of the procurement problem. Biggs et al.$^{12}$ evaluated the use of material requirements planning for purchasing; Ansari and Modarress$^{13}$ made recommendations regarding the use of just-in-time in purchasing and procurement functions; Jordan$^{14,15}$ considered the problems of demand variability and purchasing decisions involving future price increases. In other related research, Monahan$^{16}$ proposed a quantity discount pricing model to increase vendor profits, and Badinelli and Schwarz$^{17}$ examined the backorders optimization in a one-warehouse N-retailer distribution system.

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The objective of this paper is to determine an optimal procurement strategy for a major oil company (MOC). The MOC is a multinational manufacturer of petroleum lubricants with seven manufacturing plants worldwide. The plants are located in Europe, in the Pacific, and in the United States. These plants blend chemical additives with base stocks to provide petroleum lubricants. Methacrylate polymer is one such additive. Although the foreign affiliates (plants) operate semi-autonomously they still maintain MOC's name and participate in its procurement programmes.

A wide range of chemical additives are used in blending lubricants. Those which are chemically similar and used for the same family of lubricant blends, such as methacrylate polymer, are purchased together in a programme. MOC's purchasing department coordinates these programmes by negotiating prices with, and awarding volumes to, suppliers. The combined demand of all seven plants provides maximum purchasing leverage in negotiations, and the centralized procurement function ensures coordinated supply security. For additives which are in short supply world-wide, this can be extremely important. Thus, the additive requirements for each affiliate are satisfied while the overall cost to the corporation is minimized.

Current approach

The current methodology for developing and analysing programmes falls short of fulfilling managerial requirements. The current method relies heavily on non-optimizing heuristics. It selects suppliers for each affiliate by determining the lowest total cost offered by these suppliers, then it determines whether this total cost is feasible given the suppliers' volume limitations. The process is iterative and sub-optimal at best; selections and adjustments are made until a feasible solution is obtained. Decisions are the product of intensive human analysis and spreadsheet tabulation. Spreadsheets calculate the delivered cost of an additive through basic addition and multiplication. A feasible solution is then chosen by manually comparing alternative sourcing for each affiliate. Management is deeply involved in the analysis as well as decision making under the current methodology. In times of limited supply and rising prices, the final solution is often more difficult to determine.

The current approach has several weaknesses. First, this method is prone to error because of its high dependence on human interaction. Change is inevitable during contract negotiations. Given the large amount of data involved, caution must be exercised in making all related changes to avoid generating erroneous output. Second, the current approach is quite slow. Although spreadsheets speed up the selection process, a great deal of time is still required manually to develop alternatives and evaluate their impact. It is up to management to sift through the calculations to determine the feasible selection of suppliers.

THE MODEL

The purpose of the model (MOCP) presented below is to determine the most cost effective procurement award plan. Cost is of primary concern in evaluating a procurement programme, although there may be times when the lowest cost alternative is not selected for reasons such as a supplier's reputation. However, the lowest cost alternative must still be identified in order to determine the trade-offs of other alternatives.

The broad scope of each procurement programme encompasses numerous prices and additive volumes. Each additive has unique data associated with it. Further complicating calculations, some data may be volume dependent. A typical example is a sliding price schedule where an increase in purchase volume decreases the unit price. A method is needed to handle all relevant data and calculations in an efficient manner.

For suppliers offering quantity discount, their pricing is essentially a step function. In order to eliminate the problem of performing non-linear optimization over intervals, one can use linear approximation between the two extremes of a supplier's pricing schedule. One such simple approximation rule is: 

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