SOURCING PARTNER SELECTION FOR MANUFACTURER IN A MAKE-TO-ORDER SUPPLY CHAIN

Jinfeng Yue, Yu Xia, Thuhang Tran
Department of Management and Marketing, Jennings Jones College of Business, Middle Tennessee State University, MTSU Box 75, Murfreesboro, TN 37132

Bintong Chen
Washington State University, College of Business and Economics, Department of Management and Operations, Todd 337D, Pullman, WA 99164-4736

ABSTRACT

This research provides a decision supporting system for the make-to-order supply chain to facilitate the sourcing process using information about their sourcing partners' cost and processing time. The portfolio allows the manufacturer to make trade-offs between cost and probability to finish the job on time. Additionally, the portfolio can be obtained for a given due date or for reduced due dates in a competitive bid situation. The portfolio approach allows the manufacturer to maintain control over the sourcing process by internalizing key sourcing partners to keep costs low without losing the needed flexibility to meet customer demands.

Keywords: Decision supporting systems, Sourcing partner selection, Supply chain management, and Manufacturing

INTRODUCTION

Today's competitive market and rapidly evolving technology are driving manufacturers to rethink their sourcing options in order to be more flexible while still controlling for costs. For a make-to-order manufacturer, multiple part suppliers and irregular delivery times from customers can complicate the supplier selection process. Nonetheless, manufacturers can meet their strategic goals more effectively and operate more efficiently by designing and managing their supply networks with system sourcing to find the best long-term sourcing solutions, regardless of the number of suppliers or whether the supplies are outsourced or in-sourced. Furthermore, as a recent analysis by the Gartner Group shows, manufacturers can enable capability building, global growth, increased agility and profitability by treating suppliers as partners (Anonymous, 2005). Through operational integration with its suppliers, a manufacturer can gain significant production efficiencies as evidenced by General Motors' (GM) Gravatai plant in Brazil (Burt, 2001). Moreover, Proctor & Gamble (P&G) has shown how the use of a sourcing system based on expressive competition generated 9.6% savings on $3 billion of sourcing (Sandholm, Levine, Concordia, & Martyn, 2006). This system goes beyond reverse auctions and combinatorial package bidding based on lowest-price, but it is a qualitative program that uses expressive language to define and match suppliers' and buyer's limits and preferences to reach an optimal sourcing allocation solution. Consequently, the optimal solution may be open to interpretation by the analyst.

Both GM and P&G have smooth production processes where considerable work has already been conducted thoroughly. However in other manufacturing sourcing structures, because of special parts related with each customer order, just-in-time (JIT) and regular inventory control systems are not feasible. One exemplar of this type of sourcing structure is Lucent (recently acquired by Alcatel). Its telephone switches are composed of thousands of components, and each customer order comes with special requirements resulting in special ordering for some key parts (Hoyt, 2001). In this make-to-order sourcing system, irregular ordering for key parts makes capacity difficult to schedule, leading to possible bottlenecks. Large orders may lead sourcing partners to subcontract the part orders creating reliability issues since the manufacturer may lose control over quantity, quality, and delivery time as well as the overall sourcing chain. Because the manufacturer cannot pre-order key parts, the cost varies with each order, and the delivery time is determined by the slowest key sourcing partner. In order to win the bid, the manufacturer must promise a competitive delivery date or risk losing the contract; although, an overly aggressive delivery date may lead to delivery schedule slippage, loss of reputation, and late penalties. In a worse case scenario, key component shortages caused by booming demand or insufficient raw materials may worsen the sourcing problem for the manufacturer.

The selection process proposed in this paper proposes an alternative to qualitative models by offering a strategy to help the make-to-order manufacturer prioritize and source from a menu of options that are quantitatively defined. However, like the qualitative models, our selection process does require close interaction and open exchange of information between the manufacturers and suppliers.

Given the complexity and idiosyncrasies of strategic sourcing in a make-to-order supply chain, information sharing, the type of information shared, and how the information is used are all critical components in managing the supplier sourcing process effectively (Kocabasoglu & Suresh, 2006). Several studies have developed theoretical models to highlight the benefits of information sharing which includes reduced inventory and variable costs (Lee, So, & Tang, 2000). Cost reductions can average around 50% even when the manufacturer has limited capacity (Gavirneni, Kapuscinski, & Tayur, 1999) or when the information is used to coordinate decision making among sourcing partners (Sahin & Robinson, 2005). The value of the information may depend on the number of stages, lead-time length, and order batch sizes (Chen, 1998; Cachon & Fisher, 2000).

The type of information shared among supply chain members is also significant. Manufacturers can use a number of characteristics to evaluate supplier suitability including: price, replenishment lead time and cost (Easton & Moodie, 1999); delivery timeliness, quality, and competition (Watanapa & Techanitisiwad, 2005); capacity (Webster, 2002); transportation and order processing costs (Hong & Hayya, 1992); reliability and maintenance cost (Ruiz-Torres & Mahmoodi, 2006); fixed costs and volume discounts (Murthy, Soni, & Ghosh, 2004), to name a few. However, the three factors in determining sourcing partners that have been consistently identified by previous researchers as being the most important are price, delivery time, and quality (Weber, Current, & Benton, 1991; Kannan & Tan, 2002). In this study, delivery time is assumed fixed; price is determined by cost, and service level is an alternative measure of quality that involves alleviating bottlenecks. As a result, this study will focus on using cost, and service level in choosing sourcing partners and allocating orders.

Numerous quantitative models have been proposed to aid the sourcing and allocation of strategic components among suppliers with the majority focused on addressing the question of sole versus dual-sourcing. Researchers have used mathematical programming to determine the optimal number of suppliers and related allocation decision to minimize ordering, holding, transportation, and inspection costs (Hong & Hayya, 1992). Those who recommend dual sourcing find that it can reduce inventory costs and provide lower overall costs if the mean lead times are significantly different (Lau & Zhao, 1993), and minimize stock outs when lead-time uncertainty cannot be reduced (Kelle & Miller, 2001). Some have examined the issue of uneven split orders with dual sourcing while considering demand conditions, lead times, and various costs such as transportation, holding, shortage, and expediting costs to determine when dual sourcing is superior to sole sourcing (Ramasesh, Ord, Hayya, & Pan, 1993; Tyworth & Ruiz-Torres, 2000; Ryu & Lee, 2003).

Various methodologies have been proposed to assist the manufacturer with the supplier sourcing and allocation decision. Researchers have examined the case when supplier reliability is an issue using decision trees (Berger, Gerstenfeld, & Zeng, 2004; Ruiz-Torres & Mahmoodi, 2006), greedy algorithm (Chen, Yao, & Zheng, 2001) and discrete-time Markov chain (Smith, Garza, & Hasenbein, 2006). One notable study by Linn, Tsung, and Ellis (2006) integrate two key characteristics (i.e., price and quality) into a capability index and price comparison chart (CPC) mapping the choices a manufacturer has, but the method does not incorporate split orders, and ultimately, it suggests an optimal single sourcing solution. Another notable study by Murthy et al. (2004) uses the Lagrangian relaxation technique to minimize sourcing and purchasing costs in a make-to-order supply chain where suppliers provide single sealed bids or open-bid dynamic auctions. Because of the bidding process, the allocation is, in effect, determined by the supplier.

The common thread running through the extant studies is the search for a singular optimal solution given the various demand conditions to meet and costs to minimize. The models presented are intended to help the manufacturer make a single best sourcing decision. In contrast, our research contributes to the sourcing literature by providing a decision supporter that will offer the manufacturer multiple sourcing options depending on its cost-reliability tolerances. Our approach is based on the following thinking. A single optimal solution may not be practical since there are too many issues to consider under real-world conditions. If the decision making support system can provide multiple options to support the decision, instead of making a single optimal solution for the practitioner, the decision maker will enjoy more flexibility and make decisions relevant to real-world demands.

Additionally, both the sourcing and allocation determination is made by the manufacturer using information shared by the suppliers. This research assumes the manufacturer makes the sourcing selection based on cost and processing time information of the certificated part suppliers. Our supply chain sourcing heuristic enables make-to-order manufacturers with multiple key parts and several certified suppliers for each part to improve service level as well as decrease costs and delivery times. The manufacturer can control the supply chain by vertically integrating its key parts sourcing process with our heuristic. Also, it can determine for each order a portfolio of supplier allotment options to alleviate bottlenecks. Our procedure can work equally well for cases when a due date is given or when the manufacturer must find the shortest due date for competitive bid. The portfolio enables the manufacturer to improve its flexibility and customer service. Moreover, this approach encourages the manufacturer to build a close, cooperative, and productive long-term relationship with its suppliers to meet the common goal of winning the customer's bid.

MODEL DESCRIPTION

This study examines the situation when a manufacturer receives (or decides to bid) a customer order. As we discussed before, each customer order is unique and comes with several make-to-order key parts that may vary in number. For each key part, the manufacturer has multiple certified sourcing partners (suppliers) with similar qualities. With the required (or bidding) due date and desired service level, the manufacturer needs to decide how to allocate the sourcing quantity to each certified supplier for each key part. To do so, the manufacturer needs to have each supplier's cost structure and stochastic processing time information for that particular part at that particular time. Although there are many other factors that may influence the sourcing portfolio selection, meeting the due date, reducing costs, and alleviating bottlenecks are the most important criteria. These are mainly determined by suppliers' processing time and cost structure which is the practical foundation for this study.

Our model starts with the assumption that one particular order contains m key parts; for each key part i (i=1,2, …, m), N_i items are needed, and k_i certified suppliers (denoted as S_{ij} , j =1,2,…, k_i) are available. We assume that the processing time of each item by supplier S_{ij} follows an independent normal distribution with mean μ_{ij} and variance σ^2_{ij}. The normal distribution for the processing time conveys a realistic picture and is widely used in operations management study. We assume this information is known to the manufacturer when it makes the sourcing decision. The sourcing cost from supplier S_{ij} includes both the variable cost, V_{ij} per unit, and a fixed cost F_{ij} if supplier S_{ij} is chosen.

We assume that if all the key parts are finished by required time T, then the manufacturer has no problem catching the order due date. For the desired service level SL (the probability of finishing all parts within time T), the manufacturer needs to decide a sourcing portfolio by ordering n_{ij} units (i=1,2,…, m; j =1,2,…, k_i) from supplier S_{ij}.
Since there are N_i items for part i for the order, we have

$$\sum_{j=1}^{ki} n_{ij} = N_i \ . \tag{1}$$

The cost from supplier S_{ij} is

$$C_{ij}(n_{ij}) = F_{ij} \times b_{ij} + V_{ij} \times n_{ij}, \qquad \text{where } b_{ij} = \begin{cases} 0 & \text{if } n_{ij} = 0; \\ 1 & \text{if } n_{ij} > 0. \end{cases} \tag{2}$$

The probability to finish n_{ij} items of part i from supplier S_{ij} within time T is

$$P_{ij}(n_{ij}) = \begin{cases} \Phi\left(\dfrac{T - n_{ij} \times \mu_{ij}}{\sqrt{n_{ij} \times \sigma_{ij}^2}} \right), & \text{if} \quad n_{ij} \neq 0 \\ 1, & \text{if} \quad n_{ij} = 0 \end{cases} \tag{3}$$

Theoretically, if more than one supplier is used for a key part, the longest finishing time among the sourcing suppliers (i.e., the part bottleneck) determines the finishing time for the part.

Therefore, for a given allocation of key part *i*, denoted as n_{ij} ($j = 1,2,\cdots,k_i$) called the *part portfolio* for part *i*, the probability of finishing part *i* by time *T* is calculated, by independent property, as the multiplication of all the probabilities of finishing the allocated units by time *T* of k_i certified suppliers.

$$P_i\left(n_{ij},\ j = 1,2,\cdots,k_i\right) = \prod_{j=1}^{k_i} P_{ij}\left(n_{ij}\right). \tag{4}$$

Similarly, the longest finishing time of all the parts (i.e., the order bottleneck) determines the finishing time for the order. The probability of no delays for an order is the probability of finishing all parts by a given part required time *T*, which equals the product of the probabilities of each individual part,

$$P\left(i = 1,2,\cdots,m; n_{ij},\ j = 1,2,\cdots,k_i\right) = \prod_{i=1}^{m} P_i\left(n_{ij},\ j = 1,2,\cdots,k_i\right). \tag{5}$$

If this probability is no less than the desired service level *SL*, the related portfolio, which is the allocation of all key parts to sourcing partners, denoted as n_{ij} (i = 1,2, …, m; j =1,2, …, k_i) called the *sourcing portfolio*, is valid for the given order. In addition, the associated cost function for sourcing part *i* is obtained by the sum of the cost functions of all k_i certified suppliers for part *i*

$$C_i\left(n_{ij},\ j = 1,2,\cdots,k_i\right) = \sum_{j=1}^{k_i} C_{ij}\left(n_{ij}\right). \tag{6}$$

The associated cost of sourcing all *m* key parts is the summation of the sourcing costs of all parts,

$$C\left(i = 1,2,\cdots,m; n_{ij},\ j = 1,2,\cdots,k_i\right) = \sum_{i=1}^{m} C_i\left(n_{ij},\ j = 1,2,\cdots,k_i\right). \tag{7}$$

Instead of finding an optimal part portfolio for each part and an optimal sourcing portfolio for an order, this research aims to support the manufacturers' sourcing decision by providing a group of superior choices of portfolios, called frontier sourcing portfolios, with consideration of cost and probability of finishing the order on time. The procedures to find the frontier sourcing portfolios are available by contacting authors.

DISCUSSION

Rather than finding an optimal sourcing plan, our method provides choices to manufacturers in terms of due date, service level and cost. The manufacturer can make its sourcing decision, whether a single supplier or combinations of suppliers, depending on the situation. When the due date is sufficiently long, a single supplier is most likely the best choice for each part so the manufacturer has fewer frontier portfolio options. In this instance, Deming's quality point of using a single supplier for each part is ideal. When the due date is shortened, a single supplier may not have sufficient capacity to finish the entire job by itself. Consequently, several supplier combinations are comparably capable of fulfilling the requirement for each part, and thus, the number of frontier portfolios increases so the manufacturer has more choices. When the due date is shortened further, the number of supplier combinations that can finish the job for each part varies. Most importantly, when the due date is shortened, the frontier contains only portfolios sourced from multiple suppliers. The number of sourcing suppliers is decided by the due date and the suppliers' capacities.

Furthermore, when the part required time is shortened, the part frontier portfolios change. As a result, the sourcing frontier portfolio may have different options as well. When the due date is reduced, some key parts have a higher probability to finish on time; however, some other parts may have lower probability to finish on time. The part that cannot be finished with the desired service level on time becomes the bottleneck. The manufacturer can easily use the methods proposed here to determine the bottleneck in their sourcing plan. To resolve the bottleneck problem and improve its performance, the manufacturer may want to build strategic relationships with its bottleneck part sourcing partner. Or, it may find more suppliers for the bottleneck part.

REFERENCES

Upon request.