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Market-based supplier selection with price, delivery time, and service level dependent demand

Li Qian*

4961 W Dauber DR., Ottawa Hills, OH 43615, United States

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ABSTRACT

A market-based strategy is proposed for joint decisions on price, delivery time, service level, and supplier selection or investment. Product or service demand is modeled as a linear function of attributes including price, guaranteed delivery time, service level, or other quality-like performances and the profit is maximized as the objective. For different market segments or markets, market characteristics, namely customer sensitivity on attributes, differ. A supplier could be characterized by operation performance terms of cost, delivery time, service level, or quality. Results denote that operation characteristics of the supplier chosen should match market characteristics. Results show that, with stochastic delivery time, the service level is not always binding at the minimal value reserved by the manager or the market, which is assumed in the literature. There exists a limit on performance improvement due to cost increase, and there is a limit on cost reduction with decreased performance. Specifically, the less costly supplier must be chosen if the cost difference is more than one value, while the supplier with better performance must be chosen if the performance difference is more than another value. Those values are determined by current performance characteristics and market characteristics. The model is also applied in investment decision on cost reduction and delivery time reduction. There is a maximum value in spending to reduce delivery time and improve service level and quality. The model suggests that one firm could focus more on cost reduction or quality-like performance improvement based on market characteristics. The best market segment may exist for a firm with fixed operation performance. In one word, a firm′s operation characteristics and market characteristics must be matched for better profitability. Furthermore, concepts of lean manufacturing, emphasizing more on cost reduction, and flexible or agile manufacturing, emphasizing more on less delivery time or better service level, should be combined accordingly based on market characteristics.

1. Introduction

A product or service could be characterized by a vector of attributes, such as sale price, guaranteed delivery time or lead time, services level, and quality. In different markets, customers behave differently, and the demand for a product or service in diverse markets varies with the degree of aversion of a customer to wait and inclinations towards price and service level. For example, some customers are sensitive to the delivery time, some are highly sensitive to the service level, and some are more sensitive to the sale price. In a make-to-order system, the service level is defined as the percentage of orders that could be delivered or implemented before the guaranteed delivery time. Under the circumstances, price, guaranteed delivery time, service level, and quality are crucial market decisions to be made by a firm.

To address different market segments, the same product or service can be offered at different lead times with varying prices. For instance, the photography center at Wal-Mart has different express services, including one-hour delivery and one-day delivery as well as some regular services such as one-day or three-day services for different types of photography development with varying charges. Along with the lead time and price, the market could also be segmented based on service level. The United States Postal Service (USPS) serves as a classic example, where price, delivery time, and service level are considered together. The options for international mail service through USPS are given in Table 1. On the other hand, actual operation performances in cost, delivery time, service level, and quality for a firm depend on the firm′s supplier selection. A supplier or a supply chain could be characterized by performance. For this reason, decisions regarding product attributes and supplier selection should be made jointly for better profitability of a product or service.

Some research has explored joint decisions on price, lead time, and capacity. So and Song (1998), for example, provide a model based on the queuing system to understand interrelations among price, guaranteed delivery time, and capacity expansion decisions in a make-to-order manufacturing environment. Their capacity expansion cost is linear to the capacity expansion level and the

* Tel.: +1 419 862 4543.
E-mail addresses: li.qian@materion.com, qianli@gmail.com

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Table 1
International mail service options in USPS (www.usps.com).

Service	Delivery time	Price	Service level
Global express guaranteed	1–3 days	$29.95	100%
Express mail	3–5 days	$23.95	Close to 100%
Priority mail	6–9 days	$9.95	Above USPS standard
First class	Varies	$0.72	USPS standard

current operating level, and their unit production cost is a constant for all operating levels. They study the relationship between price and delivery time with a fixed capacity and the relationship between delivery time guarantee and investment in capacity expansion with a fixed price. Then they combine these two sub-problems for optimal solutions on price, delivery time guarantee, and capacity expansion level. Their delivery reliability is approximated by an exponential function with a high and given service level.

Ray and Jewkes (2004) develop a model similar to So and Song′s (1998) work, but instead consider that the price itself is linearly determined by the length of delivery time and employ linear price and lead-time sensitive demand models. Again, a pre-specified service level is assumed in the model. They argue that a manager would understand customer characteristics for decisions on price and delivery time. Palaka et al. (1998) model the demand to be linear in price and the lead time quoted. Direct variable costs, congestion cost or work-in-process inventory holding cost, and lateness penalty costs are considered in their analysis for one make-to-order system. They note that the service level should be the maximal value of the industrial service level and one critical value, which is determined by the price and lead time sensitivity of demand and the penalty per job per unit lateness. Their analysis shows that capacity utilization should be lower with more lead-time sensitive customer demand.

In another study, Webster (2002) presents a model for examining dynamic marketing mix policies between lead time and price. Interplay among price, capacity, lead time, and profit is considered with different policies in setting prices and capacity over time. Linear production cost and linear demand functions are used for analysis. Similar to linear demand functions, Zhao et al. (2006), Zhao et al. (2012) model customers′ different preferences on lead time and price by using a linear utility/surplus function. Two different M/M/1 queues are used for lead-time sensitive and price-sensitive segments. They compare the uniform and the differentiated quotation model considering customer characteristics and production characteristics. The lead-time reliability or service level in the model is binding at optimality. In their work, the service level is defined as the number of customers served per unit time and the capacity cost is linear to the service level.

Further, some researchers investigate the use of price and delivery time to compete in the marketplace. For example, Boyaci and Ray (2003) show the optimal solution of price and delivery time for two substitutable products in different market segments. Differences in price and delivery time are considered in their linear price and time dependent demand models. They also assume that delivery reliability constraints or service levels are binding at the predetermined internal delivery time reliability target and that the capacity cost is linear to the process rate. They conclude that decisions on product differentiation and prices are influenced by capacity costs and the market characteristics. For service delivery, So (2000) studies the equilibrium solution under price and time competition by multiple firms. He illustrates that the characteristics of a firm and the market would affect the competition, stating that "high capacity firms provide better time guarantees while firms with lower operating costs offer lower prices and the differentiation becomes more acute as demands become more time-sensitive." Hong et al. (2012) study the equilibrium pricing and lead time decisions in the industry consisting of two firms with competition. As a final example, Liu et al. (2007) construct a Stackelberg game between one retailer and one supplier with linear demand models of price and lead time. They assume that the capacity cost rate is increasing convex in the process rate of the supplier. Although some research efforts envisage price and service sensitive demand (Bernstein and Federgruen, 2007), no research to date addresses price, delivery time, and service level as decision variables simultaneously. Regarding the effect of service level on sale volume or demand, consumers could obtain reputation information on the service level when they make purchase decisions.

Fisher (1997) suggests a firm to consider the product demand before creating the supply chain. Furthermore, Verma and Pullman (1998) note that actual supplier selection is largely based on price or cost, although quality and delivery performance of a supplier are notable to buyers. They argue that price and performance are prominent factors in the supplier selection process, and those performances should be evaluated in an integrated manner. Moreover, Min et al. (2007) state that few attempts exist to investigate market orientation in supply chain contexts. Christopher and Towill (2002) suggest to use three dimensions, including product characteristics, demand characteristics and replenishment lead-time, to develop appropriate supply chain strategies upon market characteristics. Green et al. (2012) conduct empirical studies to assess the relationships among marketing strategy alignment, supply chain performance, and organizational performance. Their findings indicate that the alignment of marketing strategies throughout the supply chain helps supply chain performance and organizational performance. However, no formal method is available for market-based supplier selection considering cost and other operation performance measures conjointly. Other operation performances include delivery time, service level, and other quality-like performances.

Accordingly, this paper provides a profit maximization model for joint decisions on market variables (price, guaranteed lead time, service level, and other quality-like attributes) and supplier selection in a make-to-order system. The total customer demand in a long term could be modeled as a deterministic and linear function of price, guaranteed lead time or delivery time, service level, and/or quality of a product or service. The actual delivery time is equal to the procedure time of a firm or a supplier, and it could be deterministic or stochastic. With the analytical model proposed, the paper attempts to address the following problems:

- How does a firm evaluate cost, quality, and performances in delivery time and service level in an integrated manner for supplier or supply chain selection under different market segments? It is well known that less cost, shorter mean delivery time, and less variance with respect to delivery time are general principles for increasing demand and profits. However, how does a firm balance operation performance to choose the best supplier based on customer characteristics of the market or market segment?
- How does a firm makes decisions on price, guaranteed delivery time, and service level with deterministic and stochastic procedure time under different market segments?
- Similarly, how can a firm select an appropriate supplier to improve operation performances for more profit? What is the maximum spending in increasing quality, service level, and performance in delivery time while keeping profit stable or increasing?

The paper has several main contributions. First, an approach to supplier selection is proposed for profit maximization based on

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