Keywords
Supply chain selection, market segments, price-sensitive, lead-time-sensitive and service-level-sensitive market, profit maximization.

1. Introduction
Achieving maximum profit is the primary goal for any business organizations or industries. This profit is mainly related to the classical demand-supply principle i.e. sustainable demand and reliable supply of a product or service. There are different factors that influence the demand of a product and also, selection of an effective reliable supply chain is critical to making that product. Shortest and on-time delivery, highest service level and minimum price can win customer satisfaction and stimulate sales, expand market share and generate high profit. In this digital marketing era, in addition to price, the market of a product can be segmented based on the delivery time and service level. Service level is the probability to deliver product at a specified lead time and price. The demand of a product in different market segments varies with the degree of aversion of customer to wait and inclination towards price and service level. The same product or service can be offered in different lead times and service level with varying price. For
instance, international mail service of USPS (www.usps.com) can be the classical example for integrated market segments where price, delivery time and service level are considered together. A supply chain is a network of retailers, distributors, suppliers, manufactures and storage facilities that participates in production, delivery, marketing and sales of a product. The final product manufacturer in the supply chain relies on its suppliers of raw materials or components and, delay of one supplier in the chain may propagate to other members across the chain [1]. In manufacturing and marketing of a product or service, managers have to have in-depth knowledge of price, lead time and service level sensitive demand. With this knowledge, the winning strategy can be made in different markets to maximize profit. In this paper, two mathematical models are developed for a firm that wants to maximize profit by serving different groups of customers in various market segments. This detailed research will provide managerial insight to make business strategies and selection of optimal supply chain from various competitive options.

2. Literature Review

In conventional marketing strategy and economic models, revenue is a function of price and demand, and most of the time; it ignores the impact of lead time and service level on the product pricing and demand. Therefore, the profit maximizing firms concentrate solely on the price and price dependent demand. However, in the last few decades, the evolution of different manufacturing philosophies and technological innovations have brought significant value driven impact of service level and lead time to the product pricing and profit maximization of a firm. In this competitive globalized marketplace, the lower cost, faster response and perfect service level are considered as strategic weapons for the sustainable competitive advantage [2]. Palaka et al. [3] considered the lead time and price together to model the pricing decisions under lead time
dependent demand for a profit maximizing firm. The model was based on the M/M/1 queuing theory where customers were delay sensitive and the firm incurred congestion costs and lateness penalties. Service level was not included in decision variables. Banker and Karmarkar [4] considered cost due to the variability in processing and set up times and suggested a trade-off between capacity costs and inventory costs. Ray et al. [5] developed a demand model for profit maximization similar to Palaka’s work but included the effect of switchover due to lead time sensitivity. Switchover is the transition to supplementary products for better lead time and price. So and Song [6] and Palaka et al.[3] both had the objective to maximize profit by finding optimum decision variables i.e, length of guaranteed lead time, price and capacity with different cost structures. Yang et al [7] considered lead-time-sensitive demand in make-to-stock system and studied the impact of procurement lead time and sales lead time on demand and cost. Sales lead time is the number of days elapsed between customer order and recipient by the customer. Procurement lead time is the time between initiation of procurement action and recipient to the last stage of supply chain. Longer procurement lead time requires higher level of finished product stocks and increases inventory cost. The longer sales lead-time provides more flexibility to the suppliers and offer lower supply chain costs. Boyaci and Ray [8] showed the optimal solution for delivery time and price for two substitutable products in different market segments. Chen [9] provided a profit maximization model in time dependent market that has different customers with varying degrees of aversion to wait. He integrated market segments with advanced demand information and supply chain performance. Webster et al. [10] presented a model for dynamic marketing mix policies for between lead-time and price in make-to-order systems. Donohue [11] analyzed two-mode production environment- longer lead time with lower price and express lead time with higher price. Song et al. [12] studied the effect of longer
stochastic lead time and variability on the stochastic demand in single-item dynamic-control inventory systems. The shorter lead times require higher optimal base-stock level and, more variability leads to a higher average cost. A shorter lead time does not necessarily bring the smaller optimal system cost [13]. Hsu et al. [14] developed an optimization model for optimal stocking quantities for components of an assemble-to-order product where price and cost of components were determined by delivery lead time.

Gong et al. [15] showed mathematically that the optimal vector of planned lead times for different stages in serial production system can be obtained efficiently using a serial inventory model. In a multi-stage production system, the lead time variability and uncertainty are worse because unavailability in one stage causes delay to the subsequent stages and hence, the system [16]. So production system should be reduced to minimal production stages. Price is the most important factor in practice in supply chain configuration. Suppliers are chosen largely based on cost, although quality, price, flexibility and delivery performance are important to supply managers [17]. These selection criteria are mainly determined by the nature of market. In this paper, we propose that the supply chain selection should be made on an integrated basis considering market segments.

3. Model Frame Work

**Notation:**

- \( a \): market size;
- \( b \): maximum price that product can be achieved by providing minimum lead time;
- \( c \): total cost associated with the supply chain selection per product;
- \( D \): demand for the product based on the price, lead time and service level;
- \( i \): number of supply stages;
- \( j \): number of supply options in each stages;
- \( l \): targeted lead time;
- \( p \): selling price of a product;
- \( R \): the total profit;
- \( s \): service level, we have \( s = \frac{P(t \leq l)}{t} \);
- \( t \): actual lead/delivery time;
- \( \alpha \): minimum service level limit set by the manufacturer;
- \( \beta \): price sensitivity
coefficient of the demand; $\beta_l$: lead time sensitivity coefficient of demand; $\beta_s$: service level sensitivity coefficient of demand; $\theta_s$: rate of switch over due to the lead time in different markets; $\mu$: mean delivery time of a supplier; $\sigma$: standard deviation for the delivery time of a supplier.

Optimum supply chain is selected based on maximum profit which is a function of price, lead-time and service level dependent demand. Delivery time of each supplier in the supply chain follows general distribution (normal and exponential). The product is delivered based on the make-to-order principal. Demand is increasing with the decreasing of price and delivery lead time, and increasing with service level. The linear demand model is given as

$$D = a - \beta_p p - \beta_l l + \beta_s s.$$ 

**Model-1/2:** The model is formulated as:

Maximize 

$$R = (p - c)(a - \beta_p p - \beta_l l + \beta_s s)$$

subject to $\alpha \leq s \leq 1$; $c = \sum c_q$; $p > c$, $l > 0$, $a, b > 0$, $\theta, l > b$, $\beta_p, \beta_l, \beta_s > 0$

$$p = g(l)$$ for Model 2

The first part $(p - c)$ is used to calculate the profit per unit. The cost, $c = \sum c_q$, is the total cost, which is dependent on the supply chain configuration.

**Model 3/4:** If the product could not deliver on time (the rate is $l - s$), the price could be reduced from $p_0$ to $p$ as the punishment to the firm or the discount to the customer due to delay. The model is modified as

Maximize 

$$R = (p_0 - c)(a - \beta_p p_0 - \beta_l l + \beta_s s) + (a - \beta_p p_0 - \beta_l l + \beta_s s)(p - c)(1 - s).$$
\[ \text{subject to } \alpha \leq s \leq 1; \quad c = \sum_{c_g} p > c, \quad l > 0; \quad a, b > 0, \theta_l l > b \cdot \beta_p, \beta_s, \beta_t > 0 \]

\[ p = g(l) \quad \text{for Model 4} \]

In Model 2 and model 4, the lead-time dependent price function, \( p = g(l) \), is used to address customers’ delivery time sensitivity with price discount. The specific price equation is assumed to be linear, i.e. \( g(l) = b - \theta_l l \quad a, b > 0, \theta_l l > b \) (Chen 2001, Hsu et al. 2006, Ray and Jewkes 2004).

3. Some analytical results

**Model-1 with constant cost:** The cost is independent of mean value and variance of real delivery time. The optimal price value is

\[ \left\{ \frac{1}{2 \theta} (a + c \beta_p - l \beta_1 + s \beta_s) \right\} \]

The maximum revenue \( R \) is

\[ - \left( c - \frac{1}{2 \theta} (a + c \beta_p - l \beta_1 + s \beta_s) \right) \left( \frac{1}{2} a - \frac{1}{2} c \beta_p - \frac{1}{2} l \beta_1 + \frac{1}{2} s \beta_s \right) \]

**Model-2 with constant cost:** We add \( g(l) = b - \theta_l l \) for various prices at different targeted delivery times. The optimal price value is

\[ \left\{ \frac{1}{2 \theta} (a \theta_1 + b \beta_1 - c \beta_1 - 2 b \theta_1 \beta_p + c \beta_1 \beta_p + s \theta_1 \beta_s) \right\} \]

The optimal lead time is expressed as

\[ \frac{1}{\theta} \left( b - \frac{1}{2 \theta} \left( a \theta_1 + b \beta_1 - c \beta_1 - 2 b \theta_1 \beta_p + c \beta_1 \beta_p + s \theta_1 \beta_s \right) \right) \]
Model-1 with variable cost associated with performance in real delivery time: Here, we assume the revenue is given by

\[ R = (p - c)(a - \beta_p \rho - \beta_i \lambda + \beta_s \sigma) = (p - c')(a - \beta_p \rho - \beta_i \lambda + \beta_s \sigma) - A \]

where, \( A \) is fixed cost not related to the supplier’s performance in delivery time. The variable unit cost \( c' \) is expressed as

\[ c' = (b_1 + \theta \mu \mu + \theta \sigma / \sigma^2) / d + c. \]

Same as the model with constant cost, the optimal price value is

\[ \left\{ \frac{1}{2\sigma} (a + c \beta_p - \beta_1 + \beta_2) \right\} \]

but the maximum profit is

\[ -\left( c - \frac{1}{2\sigma} (a + c \beta_p - \beta_1 + \beta_2) \right) \left( \frac{1}{2} a - \frac{1}{2} c \beta_p - \frac{1}{2} \beta_1 + \frac{1}{2} \beta_2 \right) - b_1 - \frac{1}{\sigma^2} \theta \sigma - \frac{1}{\sigma} \theta \mu - A \]

Model-3 with constant cost

The cost is independent of mean value and variance of real delivery time. The optimal price value

\[ \frac{1}{2\sigma} (c \beta_p - p \beta_p + s^2 \beta_s + \alpha s - is \beta_1 + ps \beta_p) \]

The maximum revenue \( R \)

\[ (c - p)(a - \beta_1 + \sigma_1 - \frac{1}{2}(c \beta_p - p \beta_p + \sigma^2 \beta_s + \alpha s - is \beta_1 + ps \beta_p)) - \alpha (c - \frac{1}{2\sigma} (c \beta_p - p \beta_p + \sigma^2 \beta_s + \alpha s - is \beta_1 + ps \beta_p)) \]

\[ (a - \beta_1 + \sigma_1 - \frac{1}{2}(c \beta_p - p \beta_p + \sigma^2 \beta_s + \alpha s - is \beta_1 + ps \beta_p)) \]

Model-4 with constant cost

The cost is independent of mean value and variance of real delivery time. The optimal price value

\[ \frac{1}{\beta_1 + \beta_2 - \alpha \beta_1} (a \beta_1 + c \beta_2 - a s \beta_1 + L \theta_1 \beta_1 - 2 \theta_1 \beta_1 + s \theta_1 \beta_2 - s^2 \theta_1 \beta_2 - L s \theta_1 \beta_1 + 2 L s \theta_1 \beta_1) \]

Here, we assume,

\[ p = p_0 - \theta_1 (L - 1), \] where \( L \) is based on very high \( \alpha_1 \), such as 99%. 
4. Numerical results with one supplier for model 1

Table 1: Parameters for four cases

<table>
<thead>
<tr>
<th>cases</th>
<th>$\beta_p$</th>
<th>$\beta_i$</th>
<th>$B_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price-sensitive</td>
<td>50</td>
<td>25</td>
<td>500</td>
</tr>
<tr>
<td>Leadtime sensitive</td>
<td>25</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>Service and price sensitive</td>
<td>50</td>
<td>25</td>
<td>2000</td>
</tr>
<tr>
<td>Service and lead time sensitive</td>
<td>25</td>
<td>50</td>
<td>2000</td>
</tr>
</tbody>
</table>

Table 1 shows parameters used for numerical analysis addressing four different market segmentations. The product markets are characterized as price sensitive, lead-time sensitive and service level sensitive. Performances in delivery time for one supplier are represented by the mean $\mu$ and standard deviation $\sigma$. Results for model 1 are shown in Figure 1. Some managerial insights include: for one supplier with its specific performance in delivery time, there is one optimal lead time, service level, price, and profit existed; optimal values are widely different for suppliers with different performances; with different targeted lead times and/or service levels, the supplier should be chosen differently; for different markets, optimal profit and price are different, but there is not much difference in optimal lead time, and service level with one specific supplier; shorter mean delivery time $\mu$ and less variance $\sigma$ are the rule (the common sense) in choosing one supplier. But, in real world, smaller $\mu$ may go with larger $\sigma$, the supplier selection will be different for different market segments, which have different sensitiveness on price, lead time and service level; if one firm tries to address two or more market segmentations, the supplier could be changed or several suppliers could be chosen instead of one supplier.
5. Analysis with various supply chain structures for model 1

Serial and parallel (convergent) supply chain structures are evaluated numerically with the proposed models. Figure 2 shows these two supply chain structures with stochastic delivery time.

**Input Data:** Supply options for both chains are given in Table-2. Market related demand coefficients are chosen based on previous research and literature [5]. These parameters are very important to simulate the exact market segments. In our numerical analysis, the market is
segmented as follows: a) price sensitive market, $\beta_p = 50, \beta_l = 25, \beta_s = 250$, b) lead time sensitive market, $\beta_p = 25, \beta_l = 50, \beta_s = 250$, c) service level sensitive market. $\beta_p = \beta_l = 25, \beta_s = 1000$. Other input data include $a = 5000, b = 400, \tau = $20.00 per unit of product, $k = 10^6$ and $\theta_L = 8$ or 10.

Table 2: Supplier parameters for model-1

<table>
<thead>
<tr>
<th>Supply chain stages</th>
<th>Lead time of supplier 1 $\mu$</th>
<th>Lead time of supplier 1 $\sigma$</th>
<th>Lead time of supplier 2 $\mu$</th>
<th>Lead time of supplier 2 $\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>12</td>
<td>5</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Stage 2</td>
<td>16</td>
<td>4</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>

Serial Supply Chain: For serial supply chain and in a price and lead time sensitive market, the nature of price, service level and profit variations with lead time are shown in Figure 3 and Figure 4. The profit increases with the lead time to a certain limit and then starts falling down. The optimum lead time is 43 days and corresponding optimum price, service level and supply chain selection are $56, 96.95\%$ and (2, 1) respectively. The service level as the function of lead time for different supply options is shown in Figure 4. The figure indicates that the service level for supply option (2, 1) is the lowest among all four supply options while it offers the maximum profit. The figure also illustrates that profit decreases with the increase of service level after a certain point. Therefore, the manufacturer has to make a tradeoff between the service level and lead time for maximum profit. With the same set of data, service level and profit varies with different supply chain options. In lead time sensitive market, the optimized profit is achieved at the optimum lead time 40 days, which is 3 days earlier than that in the price sensitive market. The profit is $67.22k$ and is 57.6\% higher than that in price sensitive market.

In service level sensitive market, the optimum lead time is found at 36 days, which is the lowest lead time in comparison with price sensitive and lead time sensitive market. That means, the lead time is also critical in service level sensitive market. Perfect service level with longer lead
time does not satisfy customers. Customers tend to pay more for the desire service level within a short delivery time and which in turn increase profit for the company. The optimum decision variables and maximized profits in different market segments are shown in the Table 3. The switchover rate $\theta_L$ has direct impact on all decision variables and hence maximum profit and supply options. Higher switchover rate lowers the product price in price and service level sensitive market.

![Profit Vs Lead time](image1)

![Service Level Vs Lead time](image2)

Figure 3: Profit as a function of lead time  
Figure 4: Service level as a function of lead time

**Parallel Supply Chain:** Results for parallel supply chain are shown in the Table 4. At optimum lead time of 40 days in lead time sensitive market, supply options has significant effect on the maximum profit, especially supply option between (1,1) and (1, 2) and between (2,1) and (2,2). The overall service level improves and service level at optimum lead time of 40 days is close to 100% for each supply options. In serial supply chain, the service level for lead time sensitive market is about 62% but the value is improved to 100% for parallel supply chain. For each supply combination, service level reaches close to 100% after lead time of 34 days. The optimum lead time is 40 days as it was in serial supply chain.

Table 3: Results for serial supply chain in different market segments
<table>
<thead>
<tr>
<th>Market Characteristics</th>
<th>Maximum Profit ($K)</th>
<th>Optimum Lead Time (days)</th>
<th>Optimum Price ($)</th>
<th>Optimum Service Level (%)</th>
<th>Supply Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>42.65</td>
<td>43</td>
<td>56</td>
<td>96.95</td>
<td>2 1</td>
</tr>
<tr>
<td></td>
<td>47.81</td>
<td>35</td>
<td>50</td>
<td>82.56</td>
<td>2 2</td>
</tr>
<tr>
<td>Lead time Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>67.22</td>
<td>40</td>
<td>80</td>
<td>92.01</td>
<td>2 1</td>
</tr>
<tr>
<td></td>
<td>87.76</td>
<td>31</td>
<td>90</td>
<td>62.26</td>
<td>2 2</td>
</tr>
<tr>
<td>Service Level Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>195.78</td>
<td>36</td>
<td>112</td>
<td>97.72</td>
<td>1 2</td>
</tr>
<tr>
<td></td>
<td>189.32</td>
<td>30</td>
<td>100</td>
<td>78.81</td>
<td>1 2</td>
</tr>
</tbody>
</table>

Table 4: Results for parallel supply chain in different market segments

<table>
<thead>
<tr>
<th>Market Characteristics</th>
<th>Maximum Profit ($K)</th>
<th>Optimum Lead Time (days)</th>
<th>Optimum Price ($)</th>
<th>Optimum Service Level (%)</th>
<th>Supply Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>42.92</td>
<td>43</td>
<td>56</td>
<td>100</td>
<td>2 1</td>
</tr>
<tr>
<td></td>
<td>49.47</td>
<td>35</td>
<td>50</td>
<td>100</td>
<td>2 1</td>
</tr>
<tr>
<td>Lead time Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>68.42</td>
<td>40</td>
<td>80</td>
<td>100</td>
<td>2 1</td>
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<td></td>
<td>94.91</td>
<td>31</td>
<td>90</td>
<td>99.92</td>
<td>2 1</td>
</tr>
<tr>
<td>Service Level Sensitive $\theta_L=8$ $\theta_L=10$</td>
<td>205.92</td>
<td>35</td>
<td>120</td>
<td>100</td>
<td>2 1</td>
</tr>
<tr>
<td></td>
<td>222.82</td>
<td>28</td>
<td>120</td>
<td>99.40</td>
<td>2 1</td>
</tr>
</tbody>
</table>

**Serial Vs Parallel Supply chain:** The service level in parallel supply chain increases significantly compared to the serial supply chain for any market situations. The optimum lead time and optimum price of the product remain same as in PSC except a little change in service level sensitive market. For SSC, the maximum profit for lead time sensitive and service level sensitive market increases and it is same for price sensitive market. In comparison to SSC, the optimum supply chain configurations change in PSC. In parallel supply chain, both service level and profit increase with increasing switchover rate $\theta_L$. So, in a market segment where the switchover rate to the supplementary product due to delivery time is high, the operational process should be designed such a way that it takes minimum lead time.

**5. Conclusions**

The successful implementation of models depends on the proper selection of different market parameters and supply inputs. This research did not go through the sensitivity analysis of the parameters though it is important to simulate the exact market picture. Imprecise estimation of
market parameters may lead to wrong selection of supply chain and profit maximization. This research can be extended by developing non-linear demand models, make-to-stock system with dynamic inventory model, robust cost structure and sensitivity analysis of market and supply chain parameters.

References


