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# Ordering Strategies for Short Product Life Cycle Made-To-Stock Products

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**ABSTRACT**

To take advantage of economies of scale, vendors and transporters often use quantity discounts to influence the firms to order in larger quantities. Also, as the firms use delivery windows to procure and transport short life cycle products, it becomes important to simultaneously decide the best possible procurement and transportation plan over the product life cycle. Similarly, there is growing recognition amongst both practitioners and researchers to decide the end of the season markdowns by studying the sales pattern. In this paper, we propose a stochastic programming with recourse formulation to study this problem with the objective of maximizing the retailer's expected product life cycle profit keeping the initial business promised, subsequent lifecycle replenishment orders, transportation batch sizes and markdowns as recourse variables. We propose a solution procedure that efficiently solves this stochastic nonlinear problem. Our computational experiments suggest that it is always not necessary to select the most complex action plan. Under some business environments, the conventional strategy of placing and transporting a single large order is a better option. We then identify situations where decisions such as markdowns and use of quick response suppliers can be useful.

**KEYWORDS**

Economies of Scale, Inventory Control, JIT, Made-To-Stock (MTS), Ordering Strategies, Retail Supply Chain, Short Product Life Cycle, Supply Chain Management

## 1. Introduction

As consumers, our daily lives are associated with many short lifecycle Made-To-Stock (MTS) products. These are products that we often buy on impulse during visits to the supermarket. Examples of such products are electronic products (including mobile handsets and digital camera among others), garments, household goods, jewellery and toys. The product lifecycle for such products is generally in the range of three months to six months. For example, in the USA, the fashion and seasonal products have lifecycle of around 10 and 20 weeks respectively (US Office of Technology Assessment 1987). They are typically characterised by high demand volatility and it is difficult to predict the total lifecycle demand before the launch of the product. Fisher (1997) describes such products as innovative products and explains that planning of supply chain activities for such products is more complex as their supply chains need to more responsive without sacrificing on efficiency.

Owing to short lifespan (quick obsolescence), the difficulties in repeated negotiations and procurement, long procurement lead-time and the lower unit cost of acquisition in committing to a larger business volume, retailers would for such products prefer to commit to their supplier the entire product demand that they expect during the product lifecycle at the time of launching itself. However, depending on how the product performs vis-à-vis the retailer's original forecast, the retailer could end up in economic losses due to either short or surplus supply. The retailer would have to negotiate with the supplier, in the former case for further business and in the latter case for the salvage of the end of the season unsold units. In addition, the retailer would also have to decide whether the negotiated business volume should be received in single or multiple lots. The former case would be beneficial from the view-point of saving on fixed costs in ordering and transportation, while the latter would be beneficial from the view-point of quick response and low inventory costs. Initial business volume can be between 60 and 100 % of the total anticipated order (Subramanian 2000). For example, suit buyers procure 80 % before season while keeps remaining 20 % of the budget after the season starts (Daily New Record 1993). In J.C. Penny, the initial business volume could be 50-75 % of the anticipated sales (Sen 2008). These products also are generally subject to a planned phase-out that coincides with the launch or establishment in market of a successor brand. The various trade-off involved in ordering of a short product life cycle Made-To-Stock products is as shown in the ordering continuum below:

**Diagram 1: The Ordering Continuum**

| **Order Variable** | **Ordering Continuum** | | |
|---|---|---|---|
| Initial business volume (before product launch) | 100% of total volume | | less than total volume |
| Second business volume (during product lifecycle) | No | ←--------------→ | Yes |
| Shipments | Single | | Multiple |
| Price markdown (during product lifecycle) | No | | Yes |
| Impact on metrics → | Lower ← | material cost<br>shipping cost<br>responsiveness | → Higher |
| | Higher ← | inventory cost<br>stock outs<br>clearance sales<br>(atend of product lifecycle) | → Lower |

In this paper, we consider the situation where the firm gets discounts on larger purchase and transportation quantities. Motivated by JIT transportation practice, we also incorporate the initial order splitting situation. This allows us to explicitly study the tradeoffs between cost and responsiveness dimensions of the supply chain. We propose a nonlinear stochastic programming with recourse formulation to model this problem with the objective of maximizing the retailer's expected product life cycle profit keeping the initial business promised, and subsequent replenishment orders and markdowns as recourse decision variables.

The rest of the paper is organised as follows. In the next section, we discuss the literature review and motivation for the studied problem. In the section 3, the stochastic programming with recourse model and the proposed algorithm is presented. Section 4 discusses the results of the numerical study and managerial implications. The final section reports the conclusions and directions for future research.

## 2. Motivation and Literature Review

The sourcing problem for a new product facing stochastic demand has been investigated from different viewpoints. Earlier research work assumed that the procurement decision had to be made before the realization of demand. An example of this research could be the classical newsboy problem where the entire demand for a style product occurs in a single period. Bitran et al. (1986) and Matsuo (1990) proposed enhancements to this problem and computed production sequence and production volume of the style products over the multi period horizon in order to meet entire demand that occurred in the final period.

Cantamessa and Valentini (2000) developed a "deterministic" mathematical model to decide production plans for new products and investigated the benefits associated with implementing reactive backorder and lost sales strategies. However, the demand for the new product is highly uncertain and unpredictable at its launch; but, it becomes more predictable after analyzing an early demand pattern (Raman 1999). Quick response research stream used this more refined demand information and suggested some sophisticated sourcing options (Fisher and Raman, 1996; Bradford and Sugrue, 1990; Fisher *et. al.*, 2004; Choi, 2007).

This prior work that decides ordering quantities for such short life cycle products assume that the unit product cost and unit transportation does not change with the ordered or transported quantity. However, it is a common knowledge that a customer can receive a price discount after placing large orders (Silver, Pyke and Peterson, 1998; Yang and Zhou, 2006).

Vendors offer discounts to get economies of scale in purchasing, manufacturing and transportation (Munson and Rosenblatt, 1998). Particularly, in the fashion industry, the vendors are increasingly using monetary support such as quantity discounts to attract retailers under intense competition (Kincade *et. al.*, 2002). In shipping business, fixed costs such as custom fees, container charges etc are incurred for a shipment. This can be considered to be quantity discounts because average shipping cost per unit decreases with increase in the shipped quantity (Popken, 1994). In the road and rail transportation, transporters often provide discounts on full truckload and full wagon load (Munson and Rosenblatt, 1998).

Though the traditional practice is to receive all merchandise before the season, nowadays, retailers are using different delivery windows in the season. For example, suit retailers use two to three delivery windows in a season (Daily News Record, 1993). Because the retail shelf space is increasingly becoming costly (Sen, 2008), it is necessary to decide on a optimal delivery schedule for the procured products.

Also, given that the demand for new products is stochastic in nature, instead of offering a predefined markdown prices that may make customers strategic buyers, the markdowns offered at the end of the season needs to be rational determined by the unsold quantity at the end of the season (Sen 2008). As a result, it should depend upon the number of unsold units at the end of the product lifecycle.

Clearly, under quantity discounts situations, unit sourcing and transportation cost should decrease with increase in the ordered quantity. The monetary risk is lower here compared to the no quantity discount situations. Also, scenario dependent markdowns can reduce the risk of unsold inventory at the end of the season. As a result, we believe that both initial and replenishments order quantities can be substantially different. Also, we believe that deciding the optimal transportation plan can be equally important. This has motivated us to investigate the sourcing and transportation problem of the new products when sourcing and transportation costs decrease with the ordered quantity.

## 3. Model Formulation

### 3.1 Stochastic Programming with Recourse Model

The right ordering of short lifecycle MTS products is a challenging problem for the retailer owing to the high volatility in demand (volatility across markets and over the product life-cycle), and, hence, the inability to accurately forecast the total lifecycle demand before the launch of the product (at the time of initial negotiation with the supplier). For such products, there is evidence that the accuracy of demand forecasting improves considerably by the time the maturity phase of the product life-cycle is reached. Raman (1999) report that the product life-cycle demand (demand up to the product phase-out time) can be forecasted pretty accurately at about the end of the first quarter of the time between launch and phase-out. We describe this time point as Accurate Response Review Point (ARRP). Table 1 below describes the tactical and operational decision-making involved at the ARRP. It is followed by the notations used and the model formulation.

**Table 1: Possible ARRP Decisions**

<table>
<tr><th>Product launch scenario</th><th>Tactical</th><th>Operational</th></tr>
<tr><td>1. more successful than expected</td><td>– maintain launch price<br>– negotiate with quick response supplier for increasing overall purchases</td><td rowspan="3">Determine the optimal number of replenishments and replenishment quantities based on trade-off between inventory carrying cost, and fixed costs in ordering and transportation.</td></tr>
<tr><td>2. more or less as expected</td><td>– maintain launch price</td></tr>
<tr><td>3. less successful than expected</td><td>– reduce launch price<br>– plan for clearance sale</td></tr>
</table>

We assume a general quantity discount policy for both procurement and transportation. Thus, our model can incorporate the commonly used discount models such as all units, incremental and fixed fees. Nonetheless, Lal and Staelin (1984) suggested the idea of using continuous quantity discount policy to approximate discrete discount schedule having multiple breakpoints. Yang and Zhou (2006) found that this type of policy was useful in improving both channel and manufacturer's profit compared to single break point discount policy.

**Notations Used**

Model Parameters

$T$ = $\{t|t = 1,\ldots,T\}$; set of planning time periods over product life cycle, where end of Period 1 is the Accurate Response Review Point (ARRP).

$K$ = $\{k|k = 0, 1\}$; set of business volume decision time points (DTPs) (0 – initial and before product launch; 1 – at end of Period 1 or ARRP)

$S$ = $\{s|s=1,\ldots,S\}$; set of demand scenarios.

$\phi_s$ probability of occurrence of Scenario $s$.

$D_s$ total demand of the product at unit retail price $p$ under Scenario $s$.

$d_{ts}$ demand of the product in Period $t$ at unit retail price $p$ under Scenario $s$.

$d'_{Ts}$ demand of the product in Period $T$ at markdown price $q_s$ such that $d'_{Ts}$ = $d_{Ts}$ $(1+\varepsilon(p-q_s)/p)$, where $\varepsilon$ is the price elasticity.

$p$ unit retail price planned at launch of the SKU.

$q$ unit clearance price at end of Period $T$; $q$ such that $0 < q < p$.

$w_t$ backorder cost per unit in Period $t$.

$h_t$ inventory holding cost per unit in Period $t$.

$c_k(x)$ procurement quantity discount function that computes per unit procurement cost of the product for business volume $x$ negotiated in DTP $k$. The discount function can take several commonly used shapes such as fixed fee, nonlinear, multiple breaks etc. we assume that $c_k(x)\,x$ is a non-decreasing function of $x$.

$u_k(x)$ transportation quantity discount function that computes per unit transportation cost of the product for a batch size $x$ for volume negotiated in DTP $k$. The discount function can take several commonly used shapes such as fixed fee, nonlinear, multiple breaks etc. we assume that $u_k(x)\,x$ is a non-decreasing function of $x$.

$b_{ts}$ backorder at the end of Period $t$ under Scenario $s$.

$i_{ts}$ inventory at the end of Period $t$ under Scenario $s$.

Decision Variables

$x_0$ business volume in units confirmed by retailer in DTP 0

$x_{0t}$ quantity shipped in Period $t$ of the business volume confirmed in DTP 0

$x_{1s}$ business volume in units confirmed by retailer in DTP 1 under Scenario $s$.

$x_{1st}$ quantity shipped in Period $t$ of the business volume confirmed in DTP 1 under Scenario $s$, where $t > 1$.

$q_s$ Unit markdown price in period T under scenarios s; $q_s$ such that $0<q_s< p$

*Maximize*

$$\sum_{s=1}^{S}\phi_s\left(p\sum_{t=1}^{T-1}d_{ts}+q_s d'_{Ts}\right)-c_0(x_0)x_0-\sum_{s=1}^{S}\phi_s c_1(x_{1s})x_{1s}-\sum_t u_o(x_{ot})x_{0t}$$
$$-\sum_{s=1}^{S}\phi_s\left\{\sum_{t=2}^{T}u_1(x_{1st})x_{1st}+\sum_{t=1}^{T-1}\left(h_t i_{ts}+w_t b_{ts}\right)-h_T i_{Ts}+w_T b_{Ts}\right\} \quad (1)$$

*Subject to*

$$x_0=\sum_t x_{0t} \quad \ldots \quad \ldots\ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2A)$$

$$x_{1s}=\sum_{t=2}^{T}x_{1st} \quad \forall s \quad \text{-- ------- ---- ---- ---- ----}(2B)$$

$$x_{01}-i_{1s}+b_{1s}=d_{1s} \quad \forall s \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$$x_{0t} + x_{1st} + i_{(t-1)s} - b_{(t-1)1s} - i_{ts} + b_{ts} = d_{ts} \quad \forall s \quad \forall t > 1 \qquad \ldots \qquad (4)$$

$$\left(D_s - \sum_{t=1}^{T-1} d_{ts}\right)\left(1 + \varepsilon\left[p - q_s\right]/p\right) = d'_{Ts} \quad \forall s \qquad \ldots \qquad \ldots \qquad (5)$$

$x_0$, $x_{0t}$, $x_{2s}$, $q_s$ non-negative constraints

The above model has a stochastic (non smooth for discrete discount function)nonlinear objective function (equation 1) that maximizes expected profit by subtracting expected sourcing, transportation, inventory, backorder and lost sales costs from expected revenue. Equation 2A and 2B ensures that the quantity shipped in all periods is equal to the initial and quick response business volume committed. Equation 3 and 4 are inventory balance equations for period 1 and remaining all periods respectively. Equation 5 captures the impact of markdown in the last period on demand. The unit backorder cost in the period *T* is the unit lost sales cost. The unit inventory holding cost in the final period *T*, $h_T$, denotes the salvage value per unit. The salvage value is zero if the firm has to dispose the unsold units at the end of the season. In some situations, where the firm can sell the unsold units using other channels, the salvage value would be positive.

Using the series of lemmas and corollaries, we develop a solution procedure that efficiently solves the mathematical problem to optimality. Let $S^p$ be the partial solution vector that includes all initial and recourse procurement decisions except markdown decisions. Each $S^p$ can be used to calculate the number of units available for sale '$Z^{Ts}$' in period *T* under each scenario *s*. The following lemma shows how to calculate the optimal markdown price under each scenario using these unsold units available for sale in period *T*.

### 3.2 Proposed Solution Procedure

**Lemma 1**: *When* $\left(\frac{1}{\left(1-\frac{h_T}{p}\right)}\right) < \varepsilon$, markdown is never an optimal policy under all scenarios.

Otherwise, the optimal markdown can be calculated under each scenario as follows:

$$q_s^* = \left(\frac{p}{2\varepsilon}\right)\left(1+\varepsilon+\varepsilon\frac{h_T}{p}\right) \qquad when\ Z^{Ts} \geq D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right) \tag{6}$$

otherwise, it obeys the following condition

$$Z^{Ts} = D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right)$$

**Proof:** In the final period, when all the procurement decisions are taken, we have the following revenue optimization problem.

$$\text{Maximize } q_s^* D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right)+\left(Z^{Ts}-D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right)\right)h_T \tag{7}$$

$$\text{Subject to } Z^{Ts} \geq D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right) \tag{8}$$

Differentiating Equation 7 with respect to $q_s$ and setting the result to 0, we get the optimal markdown price:

$$q_s^* = \left(\frac{p}{2\varepsilon}\right)\left(1+\varepsilon+\varepsilon\frac{h_T}{p}\right)$$

Rearranging the terms and doing some algebraic processing, the markdown is meaningful when $\left(\frac{1}{\left(1-\frac{h_T}{p}\right)}\right) < \varepsilon$.

Note that if optimal markdown price violates constraint 8, then because the objective function is strictly decreasing in the markdown price, it is optimal for the firm to set the markdown price such that the constraint 8 becomes active. Hence, the optimal markdown price obeys the following equality.

$$Z^{Ts} = D_{Ts}\left(1+\varepsilon\left(\frac{p-q_s^*}{p}\right)\right)$$

Lemma 1 allows us to calculate the optimal markdown prices for each scenario for a given procurement decisions vector. Now, we propose few corollaries to strengthen both the lower and upper bounds for the procurement decisions.

Let,

D|max = maximum possible total product demand in the product life cycle

D|min = minimum possible total product demand in the product life cycle

$D_s$ | max = maximum possible total product demand under scenario s

$d_{Ts}$ = demand during time period T without markdown under scenario s.

$d_T^l$ | max =maximum possible demand during T with markdown

From Equation 5,

$$d_{Ts}^l = d_{Ts}\,(1+\varepsilon[p-q_s]/p)$$

Maximum possible demand occurs in period T under scenario s when $q_s$ =0.

$$d_{Ts}^l|\text{max} = d_{Ts}\,(1+\varepsilon)$$

$$d_T^l|\text{ max} = Max_s\,(d_{Ts}^l\,|max)$$

*So,* D| max = $\sum_{t=1}^{T-1} d_{tS} + d_T^l|\text{max}$ and $D_s|\text{ max} = \sum_{t=1}^{T-1} d_{ts} + d_{Ts}^l|\text{max}$

D|min = min s ( $D_s$)

Let, $u_0(0)$ and $c_0(0)$ denote the maximum per unit transportation and procurement cost that the firm pays to low cost supplier and slower transport mode in DTP 0. $u_0(0)+ c_0(0) < p$ so that low response supplier and slower transport mode are feasible alternatives.

**Corollary 1: D|min $\leq x_0^* \leq$ D|max**

**Proof:** Lower bound simply follows from the observation that when $x_0$<**D**|min, the firm can always increase profits by increasing $x_0$ upto **D**|min under all scenarios because $u_0(0)+ c_0(0) < p$ . Upper bound exists because $x_0 > D|\max$, the firm only increases costs without increasing revenue thereby decreasing profits.

Now, we assume that the $x_0$ is constant. Also, Let, $X_s = \sum_{t=2}^{T} x_s$ denote the total recourse procurement under scenario s. Then for the reduced problem,

Let, $u_1(0)$ and $c_1(0)$ denote the maximum per unit transportation and procurement cost that the firm pays to quick response supplier and faster transport mode. $u_1(0)+ c_1(0) < p$ so that quick response supplier and transport mode are feasible alternatives.

**Corollary 2 :** $(D_s - x_0)^+ \leq X_s^* \leq (D_s \mid \max - x_0)^+$

**Proof:** Given that the firm has committed an initial business volume of $x_0$ , if $(D_s - x_0)^+ > X_s^*$, under scenario s, the firm can always increase $X_s$ up to $(D_s - x_0)^+$ and increase the profits because $c_1(0) + u_1(0) \leq p$ . The upper bound comes from the simple observation that under scenario s, when $X_s^* > (D_s \mid \max - x_0)^+$, procurement and transportation cost increase and revenue remains constant. As a result, the profits strictly decrease.

When $T = 3$, when $x_{03} = x_0 - x_{01} - x_{02}$, constraint 2 is satisfied. Similarly, both implicit inventory and backorder variables for each scenario can be calculated using constraints 3 and 4 for a given partial procurement decisions vector $S^P$. Lemma 1 allows us to calculate optimal markdown prices under each scenario for a given $S^P$. This ensures that all the constraints are satisfied. As a result, the problem can be solved to optimality by doing an explicit search over only free procurement decision variables. Note that Corollaries 1 and 2 significantly reduce the search space for procurement variables. Suitable increment depending upon the transfer and procurement batch size (such as single product, cartoon, and pallet) can be used in the search process.

## 4. Results and Discussion

In the numerical experiments, we investigate the role of markdowns, recourse procurement and the implications of splitting the initial order. We assume three demand scenarios (low, medium, high) with probability of occurrence (0.3, 0.3, 0.4), respectively. The first, second and third period demand forecasts are (50, 70, 100), (100, 140, 200) and (100, 140, 200), respectively, at the launch price which is set to 20. Backorder costs for first two periods are kept at 1.5 per unit per period. Third period backorder is lost sales which is equal to 20 per unit. Salvage value is assumed as zero. Inventory holding rate per unit per period is kept at two levels, 1 and 3. Price elasticity of demand ($\varepsilon$) is kept at two levels, 0.25 and 2.0. Third period demand can be changed by reducing the retail price. We used linear quantity discount functions for procurement and transportation in our experiments as follows. $c_k(\mathrm{x}) = a_{0k} - a_{1k}x$ where $a_{1k}$ such that $c_k(x)x$ is a non-decreasing function of $x$. $a_{00} \leq a_{01}$. $u_k(\mathrm{x}) = e_{0k} - e_{1k}x$ where $e_{1k}$ such that $u_k(x)$ is a non-decreasing function of $x$. $e_{00} \leq e_{01}$

DTP 0 procurement cost structure can be described using the following $a_{01}, a_{11}$ values (4, 8) and (0.002, 0.004). DTP1 procurement cost structure is represented as $8 - 0.002x$.

Transportation cost structures for DTP 0 and DTP 1 can be represented as $(1 - 0.001x)$ and $(2 - 0.002x)$, respectively. We implemented the algorithm discussed in the previous section in Microsoft-Excel using VBA programming language to compute the optimal decisions.

Typically, the firm can use the following four strategies to manage the supply chain of the new products.

1. Only initial business volume, no order splitting, no recourse procurement, and no markdown.
2. Initial business volume, order splitting, no recourse procurement, and no markdown.
3. Initial Business volume, order splitting, recourse procurement, and no markdown.
4. Initial business volume, order splitting, recourse procurement, and markdown.

The first strategy is a traditional method which is easier to execute. Second strategy needs efforts to manage just in time transportation. The third strategy further requires identification of quick responsive supplier and faster transportation mode. The fourth strategy additionally requires efforts to plan and execute markdowns. The implementations of the third and fourth strategies involve forecast updating at ARRP based on actual sales data. Hence, an investment in an information technology system is required to collect necessary retail level data in a real time basis. In general, efforts and expenses increase as the complexity associated with the strategy increases. We also test the benefits associated with these supply chain planning strategies in our experiments. Using such analysis, managers can study the tradeoffs and take final decisions. We first carry out base experiments with Strategy 1 to evaluate relative value associated with other tactical and operational strategies (Strategies 2, 3 and 4).

Table 2 shows the optimal supply chain planning decisions under different situations under Strategy 4. In last column, we compare improvement in profitability with Strategy 4 compared to profitability obtained in base case (Strategy 1) and report the profits with the

Strategy 1 in bracket. Use of tactical and operational responses has resulted in improvement ranging from 8.1% to 74.4%. Given that profits in an apparel industry are about 3% of total sales (Fisher and Raman 1999), such an improvement would of great value to firms operating in these markets.

**Table 2: Simulation Results**

| Exp. No. | Business Environment | | | | Optimal Supply Chain Decisions | | | Increase in profit (%) on Strategy 1 |
|---|---|---|---|---|---|---|---|---|
| | $\varepsilon$ | $a_{01}$ | $h_{t=1,2}$ | $a_{11}$ | Order Split ($t$ = 1, 2, 3) | Second Order ($s$ = 1, 2, 3) | Markdown ($s$ = 1, 2, 3) | |
| 1 | 0.25 | 8 | 3 | 0.002 | (70,40,140) | (0,100,250) | N | 73.4 (2429) |
| 2 | 0.25 | 8 | 3 | 0.004 | (70,80,200) | (0,0,150) | N | 63.2 (2674) |
| 3 | 0.25 | 8 | 1 | 0.002 | (100,10,140) | (0,100,250) | N | 30.7 (3221) |
| 4 | 0.25 | 8 | 1 | 0.004 | (70,140,290) | N | N | 19.9 (3654) |
| 5 | 0.25 | 4 | 3 | 0.002 | (70,80,350) | N | N | 45.7 (3829) |
| 6 | 0.25 | 4 | 3 | 0.004 | (70,80,350) | N | N | 42.7 (4262) |
| 7 | 0.25 | 4 | 1 | 0.002 | (70,140,290) | N | N | 8.9 (5154) |
| 8 | 0.25 | 4 | 1 | 0.004 | (70,140,290) | N | N | 8.1 (5654) |
| 9 | 2 | 8 | 3 | 0.002 | (70,80,150) | (0,50,200) | (15, 20, 20) | 74.4 (2429) |
| 10 | 2 | 8 | 3 | 0.004 | (70,80,200) | (0,0,150) | (15, 20, 20) | 66.2 (2674) |
| 11 | 2 | 8 | 1 | 0.002 | (100,50,150) | (100,50,200) | (15, 20, 20) | 31.9 (3221) |
| 12 | 2 | 8 | 1 | 0.004 | (70,140,290) | N | (15, 15, 20) | 31.1 (3654) |
| 13 | 2 | 4 | 3 | 0.002 | (70,80,350) | N | (15, 15, 20) | 50.4 (3829) |
| 14 | 2 | 4 | 3 | 0.004 | (70,80,350) | N | (15, 15, 20) | 46.9 (4262) |
| 15 | 2 | 4 | 1 | 0.002 | (70,140,290) | N | (15,15, 20) | 12.4 (5154) |
| 16 | 2 | 4 | 1 | 0.004 | (70,140,290) | N | (15, 15, 20) | 11.3 (5654) |

Figure in parentheses in last column indicates Strategy 1 Profit

Depending upon the business environment, optimal solutions differ in terms of use of combination of recourse actions. When the procurement cost at DTP 0 is low, then it is optimal to place a single order at DTP 0 and firm does not benefit by using other recourse actions. This suggests that the conventional practice of placing a single large order has merits if low cost suppliers are available. However, though a single large order is placed, despite the discounts available with bulk shipping, it is optimal to transport in small batches across periods. Also, the optimal batch sizes depend upon the inventory holding rates. As inventory holding rate increase, the firm transports smaller batches in the initial periods followed by larger batches in the latter periods.

When the low cost supplier is not available and purchase discounts are not high, it is optimal for the firm to order as per the scenario. The firm places an initial order at DTP 0 to meet the some demand. The firm places another order at DTP 1 under high and medium demand scenario to meet the extra demand (Experiment 3). But, when the vendor offers a steep discount, the firm chooses to place a single large order in DTP 0 when inventory holding costs are low (Experiment 4). Though, this strategy results in excess stock under low and medium demand scenarios, the benefits obtained from the discounts are enough to justify a single large order in DTP 0.

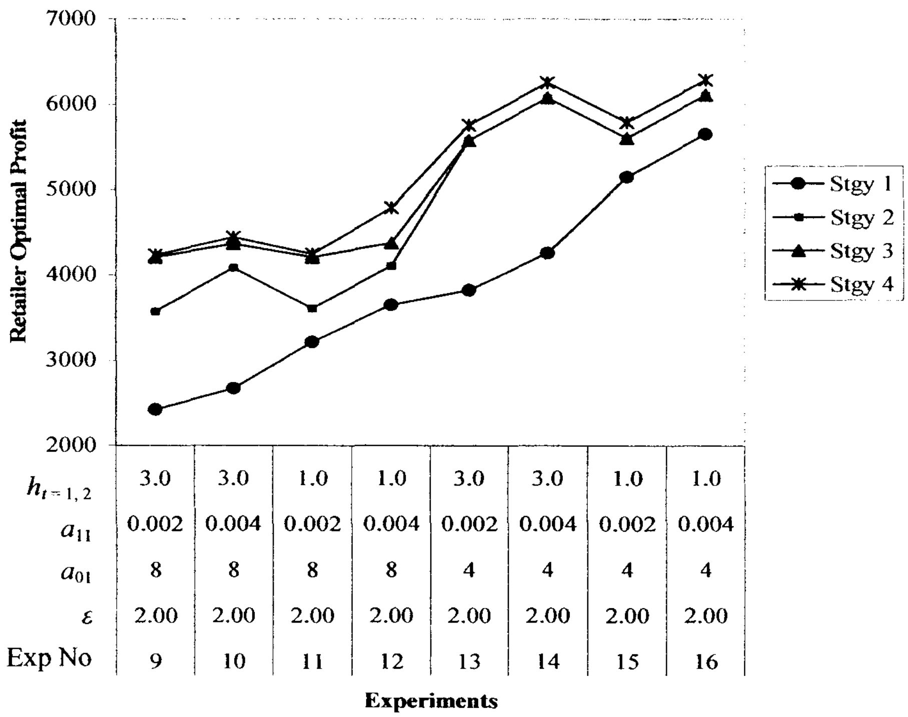
As the price elasticity of demand increases, the firm chooses to markdown prices under low and medium demand scenarios. Markdown under low demand case is more than medium demand situation. Thus, the optimal markdown price depends upon the unsold units in the final period. It should be noted that markdown is not always an optimal strategy. Under low price elasticity situation, though the firm has excess inventory, it is not optimal for the firm to reduce prices to clear the inventory.

Table 3 shows the percent increase in profits with the use of Strategies 2, 3 and 4 over Strategy 1. This is also depicted graphically in Diagram 2. As it does not make sense for firm to use markdown option under low demand elasticity, we have restricted out focus on Experiment 9 to 16. As we had discussed earlier, as we move from Strategy 2 to 4, costs and complexity of implementation increases. So based on nature of cost structure firm may choose only that combination of levers which provide sufficient benefits. For example, when premium paid to responsive supplier is high (Experiments 13 to 16 respectively) using recourse option of placing second order at ARRP has not been exercised but recourse action of markdown is exercised in all the four experiments though value of markdown differs across experiments. But in a situation where premium paid to responsive supply is relatively low in magnitude, profitability improves significantly by using appropriate combinations of recourse actions. Clearly, the manager should understand the business environment and then choose the optimal strategy instead of always choosing the complex strategies. Even though it is possible to understand how each of the individual parameters affects optimal mix of strategies individually, it is difficult for firm to work out intuitive solutions for various combinations of the relevant parameters. The model in this paper provides comprehensive framework for determining optimal decisions.

**Table 3: Performance of the Studied Supply Chain Strategies**

| Exp. No. | Profit increase (%) over Strategy 1 with | | |
|---|---|---|---|
| | Strategy 2 | Strategy 3 | Strategy 4 |
| 9 | 47.4 | 73.4 | 74.4 |
| 10 | 52.6 | 63.2 | 66.2 |
| 11 | 12.1 | 30.7 | 31.9 |
| 12 | 12.5 | 19.9 | 31.1 |
| 13 | 45.7 | 45.7 | 50.4 |
| 14 | 42.7 | 42.7 | 46.9 |
| 15 | 8.9 | 8.9 | 12.4 |
| 16 | 8.1 | 8.1 | 11.3 |

**Diagram 2: Comparison of Strategies**



## 5. Conclusion, Modelling Extensions and Future Scope

In this paper, we developed a mathematical model to decide procurement, transportation and markdown decisions for new short life cycle products by considering the discounts associated with larger purchases and transports. The solution procedure proposed to solve this problem to optimality in reasonable amount of time can handle all kinds of procurement and transportation discount structures.

The numerical experiments suggest that the conventional strategy of placing a single large order becomes dominant when low cost sourcing option is available and when higher discounts are offered for additional purchases. Thus, quantity discounts can play an important role of the procurement decisions even for short life cycle products. Also, the profits increase when the firm ships products in smaller batches despite the discounts available with larger shipments when inventory holding costs increase. From operations perspective, instead of only focusing on procurement decisions, managers should simultaneously decide both the procurement and transportation plan for short life cycle products.

Experiments also suggest that it is not always necessary to identify and place orders with quick response suppliers. Surprisingly, it is not always necessary to markdown in the final period to clear the excess inventory. Moreover, the markdown prices depend upon the excess inventory available in the final period. Therefore, managers should carefully understand their business environment before expending efforts on tactical and operational decisions such as identifying quick response supplier and planning for the markdowns.

**Computational extensions:**

We used linear quantity discount functions for both procurement and transportation in the numerical experiments. Other discount functions can be used in the computational experiments to further understand the tradeoffs between cost efficiency and responsiveness.

Similar to Cantamessa and Valentini (2000), the Bass diffusion model (Bass 1969) can be used to estimate the demand in different periods in our formulation to understand the influence of diffusion on the procurement decisions under uncertain environment.

Modeling Extensions:

Several pricing and advertising models have been proposed in the context of new products (Mahajan et al. 2000). It is possible to incorporate such models. The inclusion of such functions would result in a non smooth nonlinear model where it is difficult to obtain and verify the optimal solutions. A novel approach can be used to convert this non linear program into integer linear program to solve the problem to optimality (Shah and Patil 2008).

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