DEVELOPMENT OF SPREAD SHEET SIMULATION MODEL FOR \((R,Q)\) INVENTORY REPLENISHMENT POLICY IN SUPPLY CHAIN

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Abstract
Inventory control is a critical problem in the supply chain. The purpose of this paper is to minimize the total inventory cost without forfeiting the service level. A spreadsheet simulation model is developed for packaging-material inventory control in a real-case study. An attempt has been made to investigate the responses of spreadsheet simulation on the \((R,Q)\) inventory replenishment policy with variable order sizes and reorder points. We examine the existing inventory policy by means of a spreadsheet simulation. The simulation results reveal that the proposed policy yields better performance.

Key words: Inventory control, \((R,Q)\) inventory replenishment policy, spreadsheet simulation, supply chain, size of order, reorder point

1. INTRODUCTION
Nowadays effective and competitive company operations can be improved through incorporating the concepts of supply chain operation into company management. Inventory control plays an important role in supply chain. It is concerned with how much to order and when to order. The rounding order to achieve a batch size is recognized as source of bullwhip effect (Potter et al 2004). Poor order sizing will decrease the efficiency of the supply chain. In this case study we have observed the similar problem. Currently \((R,Q)\) policy is applied to replenish inventory. The ordering quantity is not optimized with ordering cost and carrying cost. There are many models and policies are developed to manage the inventory for deterministic and stochastic demand (Merkuryev et al 2002 and Pethova et al2002). The supply chain optimization software like Arena, Supply chain Guru, promodel and supply chain builder can be used for complex supply chain problems. However it is much more difficult to understand the optimization models as the complexity of the problem increases (Sezen et al 2007). At the same time the spreadsheets can be developed easily with available resources (MS Excel, Quattro Pro and Lotus 123). Spreadsheets have powerful function for performing sophisticated computation and excellent graphing features for displaying the results. They can be used for data analysis, selective inventory control technique computation (ABC analysis, FSN analysis, XYZ analysis, and HML analysis), demand forecasting, MRP, aggregate planning, and scheduling. Some free downloadable spreadsheets are available at www.terry.uga.edu\/~selia\/spreadsheetsim and www.inventoryspreadsheetdownloads.portal.com.

2. LITERATURE REVIEW
Lee et al (1997) summarized the major causes of bullwhip effect: demand signal processing, order sizing, price fluctuation and shortage games. In this current paper we are investigating the impact of order sizing on inventory policy. In this section we are going to review the some of the literature on order sizing as well as the spreadsheet simulation in supply-chain activities. Potter .A.T and Disney et al (2004) studied the how varying the batch size, can affect the level of the bullwhip effect generated by the replenishment policy of a soft- drink firm. Pujawan et al (2003) investigated the impact of two different lot-sizing rules with non-integer values for time between the orders. Kleijnen et al (2005) outlined four simulation methods for SCM, namely spreadsheet simulation, system dynamics simulation, discrete event simulation and business games. These simulation guides to explain bullwhip effect and predict the inventory levels. Lebel and Carruth et al (1997) developed an inventory control model under different capacities using a Quattro Pro spreadsheet. They demonstrated the spreadsheet simulation with \((R,S)\) inventory replenishment policy. Leonardo Chwif et al (2002) implemented a spreadsheet simulation for an entire supply chain network. He validated spreadsheet simulation with real- time data from aluminum processing industry through \((T,S)\) inventory replenishment policy. There is no deviation when compared with the discrete event simulation results. Boute et al (2005) presented a spreadsheet application which explored a series of replenishment policies and forecasting technique under different demand patterns. He illustrated how tuning the parameters of the replenishment induces or reduces the bullwhip effect. He also demonstrated how the bullwhip reduction has an adverse impact on inventory holdings, ordering and customer service. Selia et al (2006) developed a spreadsheet simulation model, which included a basic inventory model, an inventory model with replication, an inventory model with data analysis and an order quantity evaluation by using the Excel menu and features. Mahamani et al(2006) demonstrated a spreadsheet simulation for warehouse management for optimizing inventory policy. In this work \((R,Q,k,t)\) replenishment policy is proposed with the real- time data from a mineral water plant warehouse. The stock is reviewed \(R\) units of time, if inventory to consumption ratio \((k)\) or the inventory to demand forecast ratio \((t)\) reaches some pre determined value, an order with \(Q\) is placed. This practice is evaluated with different values of \(k\) and \(t\). The simulation results from the \((T,S)\) replenishment policy shows that inventory level is almost equal but a small deviation is observed in the number of stock-outs when compared with \((R,Q,k,t)\) replenishment policy. Sezen et al (2007) implemented spreadsheet simulation model for inventory control in a single distributor three retailer network. \((r,Q)\) inventory replenishment was considered his study, and used variable demand as a control factor. Re order point, economic order quantity and initial inventory were taken as inputs. He
evaluated total inventory cost and percentage of shortage risk. As a further contribution, the current paper presents a spreadsheet simulation model for packaging-material inventory control in a fruit-juice manufacturing firm. It is a single buyer-multiple supplier network. We considered (r, Q) inventory replenishment policy with the control factors of order size and reorder point. The summary of related works were displayed in Table 1.

![Figure 1](image-url)

Table 1-Summary of the Literatures

<table>
<thead>
<tr>
<th>Name of the Author(S)</th>
<th>Specific Area of Application</th>
<th>Replenishment Policy</th>
<th>Name of Spreadsheet</th>
<th>Control Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lebel and Carruth(1997)</td>
<td>Inventory Control</td>
<td>(T, S)</td>
<td>Quattro Pro</td>
<td>Capacity</td>
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<tr>
<td>Boute (2005)</td>
<td>Bullwhip Effect Quantification</td>
<td>(T, S) &amp; (r, Q)</td>
<td>M.S Excel</td>
<td>Demand</td>
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<tr>
<td>Selia (2006)</td>
<td>Inventory Management</td>
<td>(T, S) &amp; (r, Q)</td>
<td>M.S Excel</td>
<td>Replication, Order quantity</td>
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<tr>
<td>Mahamani (2006)</td>
<td>Warehouse Management</td>
<td>(T, S) &amp; (R, Q, k, t)</td>
<td>M.S Excel</td>
<td>Inventory to consumption ratio &amp; Inventory to Demand forecast ratio</td>
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<tr>
<td>Sezen (2007)</td>
<td>Warehouse Management</td>
<td>(T, S)</td>
<td>M.S Excel</td>
<td>Demand</td>
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</table>

Table 2 Details of Consumption, Order Size, ROP, and LT

<table>
<thead>
<tr>
<th>Items</th>
<th>Annual Consumption</th>
<th>Existing Order Size</th>
<th>Existing Reorder Level</th>
<th>Lead Time (Weeks)</th>
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<td>12480</td>
<td>3744</td>
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<tr>
<td>116XX</td>
<td>3453</td>
<td>4500</td>
<td>1350</td>
<td>2</td>
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<td>1400</td>
<td>457</td>
<td>2</td>
</tr>
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<td>132XX</td>
<td>16616</td>
<td>1400</td>
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<td>2</td>
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</tbody>
</table>

3. CASE STUDY
The case study we are going to present here is from one of the famous fruit-juice manufacturing firm in India. It is a single-buyer multiple-supplier network. Managing the stock of packaging material is a very big challenge. The contribution of inventory value of the packaging material is 73% of the total inventory value, out of which 20% of packaging-material has a higher unit cost as well as a longer lead time. Therefore, we need a proper policy to manage the inventory of packaging materials.

4. COLLECTION AND ANALYSIS
They purchased 60 items for packaging store, including 17% of imported items. We used the multidimensional selective inventory control technique (Janadhanraju et al 2005) for selecting the key items to be controlled. The data regarding the weekly consumption, existing order size, existing reorder level and lead time of each item are collected and tabulated in Table 2. The statistical analysis of weekly demand shows that the standard deviation of demand is relatively high (Figure 1).

![Figure 1](image-url)

Therefore, the low ordering quantity and low safety stock make the product subject to frequent stock outs.

5. METHODOLOGY
We used the multidimensional selective inventory control technique (Janadhanraju et al 2005) for selecting the key items to be controlled. This is the combination of ABC, XYZ, SDE, FSN, and HML analysis. The proposed policy is developed with an optimal value of inventory parameters such as optimum ordering quantities and reorder point and given as an input on the Excel spread sheet. We examine the existing policy by means of spread sheet simulation, (r, Q) inventory replenishment policy is followed by both existing and proposed inventory systems. Theoretical total inventory cost is calculated for both the existing and proposed inventory systems by using traditional equation (Gopalan Krishnan et al 1997). The total inventory cost obtained from simulation results are compared with theoretical total inventory cost.

6. DEVELOPMENT OF SPREAD SHEET INVENTORY SIMULATION MODEL
The goal of the inventory simulation model is to find the total inventory cost and number of stock out. In (r, Q) inventory replenishment is used if the inventory on hand reached to the reorder level ‘r’ and then an order with quantity ‘Q’ is placed. Then the order will be received with in the lead time. The inventory on hand for the current period is inventory on hand in the previous period minus the demand of the previous period.
This is formulated in the spreadsheet in cell C (C2=C1-D1). The number of orders and number of stock out are either zero or one. If the inventory on hand reaches negative value, that is the indication of a stock out, the same quantity is fulfilled through back order. A reorder point indicator is provided in the Cell F (F1=C1-ROP). If the reorder point indicator value reaches zero or is negative, an order with Q is placed. By using this work sheet we can also quantify inventory quantity out to the horizon, number of order placed, number of stock out and stock out quantity. The screenshot for the work sheet is shown in figure 3.

Fig -2 Spread Simulation Model for Inventory Control

7. EXPERIMENTING WITH DIFFERENT LOT SIZE AND REORDER POINT

Input Parameters
- D - Annual Demand
- C₀ - Ordering Cost
- Cᵢ - Carrying Cost
- Cᵢᵢ Back order Cost
- Q - Order size
- LT - Lead Time
- ROP - Reorder Point
- σ - Standard Deviation
- Z - Service Level
- λ - Probability of Delay
- dₘₚ - Maximum delay
- I - Initial inventory

a) Obtaining the Model Parameters for Proposed System

EOQ = \( \sqrt{\frac{2 \times D \times C₀}{Cᵢ}} \)

b) Obtaining the Model Parameters for Existing System

In the existing system ordering quantity (q) and reorder point (r) of each item is directly given in table 2.

c) Evaluation of Theoretical Total Inventory Cost

By using the above parameters ordering cost, carrying cost and total inventory cost are derived for both existing and proposed system and tabulated in table 3.

Total Inventory Cost for proposed system = D/EOQ*C₀ + EOQ/2*Cᵢ

Total Inventory Cost for existing system = D/q*Cᵢ + q/2*Cᵢ
Theoretical Results of Proposed System | Theoretical Results of Existing System
--- | ---
**INPUT** | **OUTPUT** | **INPUT** | **OUTPUT**

<table>
<thead>
<tr>
<th>Item code</th>
<th>Proposed Order size</th>
<th>ROP</th>
<th>Total Inventory Cost ($)</th>
<th>Existing Order Size</th>
<th>ROP</th>
<th>Total Inventory Cost ($)</th>
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<tbody>
<tr>
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<td>457</td>
<td>237439.9</td>
</tr>
</tbody>
</table>

TIC of the Proposed system ( $) 58113.65
TIC of the Existing system ( $) 90378.602

**SAVINGS** ( $) 32264.94
**% REDUCTION** 35.6997605%

Table 3. Theoretical Total Inventory Cost

d) Evaluation of Simulated Total Inventory Cost
By using spreadsheet simulation ordering costs, carrying cost and total inventory cost, number of stock outs, number of orders and stock out quantities are evaluated for both existing and proposed systems and tabulated in table-4

<table>
<thead>
<tr>
<th>Item code</th>
<th>Proposed Order size</th>
<th>ROP</th>
<th>Total Inventory Cost ($)</th>
<th>No of stock out</th>
<th>stock out Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>85XX</td>
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</tr>
</tbody>
</table>

Simulated TIC of the proposed system ( $) 64694.58
Simulated TIC of the proposed system ( $) 79272.38

**SAVINGS** ( $) 14577.79641
**% REDUCTION** 18.3895025%

Table 4 Simulated Results
8. RESULTS AND DISCUSSION

From the experimentation the following results were obtained. The graphs were plotted between simulated results versus theoretical results as well as results from existing inventory policy and proposed inventory policy.

a) Comparison of Theoretical Total Inventory Cost

![Comparison of Theoretical TIC](image)

Figure 4. Comparison of Total Inventory Cost for Existing and Proposed System

b) Comparison of Simulated Results

![Comparison Simulated Total Inventory cost](image)

Figure 5. Comparison of Total Inventory Cost for Existing and Proposed System
c) Comparison of Proposed System and Existing System

Figure 6 confirmed that the poor order size and low re order point can strongly affect inventory performance. Therefore the proposed inventory policy yields better results by the way of an 18.36% reduction in total inventory cost with 100% service level (figure 5). The results from the theoretical evaluation also shows the same results (Figure 4). The existing inventory policy many stock outs are experienced (Table 4). This situation will create inconvenience to supplier as well as material manager. By using theoretical evaluation we can quantify the inventory reduction but it is impossible to predict the service level. Moreover in the theoretical calculations, the numbers of orders are expressed in decimal form but in real-time situation this never occurs. For this reason, theoretical total inventory cost is less than simulated total inventory cost.

9. CONCLUSION

In this case study the impact of poor order size and low reorder point in the inventory system is studied. The Spreadsheet simulation is successfully applied to the inventory control in supply. The simulation results reveals that the proposed inventory policy yields better performance. We observed that simulated total inventory cost for the proposed policy is lower than the existing inventory policy. Theoretical evaluation of total inventory cost also shows the same results since the order size and low re order point impacted hugely on profit. There may be more evidence after the implementation of spreadsheet sheet for inventory control with demand variation (Sezen 2007). The future contribution of research will be to validate the spreadsheet simulation against the dynamic reorder policies (r, Q) and (r, Q) (Babai 2005). Commercial supply-chain optimization software has high cost, relatively high installation time, supporting packages and complex programming method when compared with spreadsheet simulation. However the major drawback of the spreadsheet its limited option for generating random numbers and lack of facility in implementing a “while loop” or “for loop”.

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