1. INTRODUCTION
Managing the inventory is the major issue in supply chain management. It is the right area to be focused to increase the profit margin. In this study a (R, Q, k, t) replenishment policy is developed to reduce inventory in warehouse. This policy is evaluated with real time data from consumer goods industry (saravani et.al). B.Ramirez et.al successfully implemented a (R, s, Q, c) replenishment policy in a cardboard box marketing firm. This policy is evaluated by means of discrete event simulation and accurate ordering policy is identified. Several ordering options were analyzed and compared to find the policy that best accomplishes the firm's organizational objectives. M.Z.Babai et.al proposed a couple of forecast based inventory management policies for single stage; single item inventory system, namely (R, Q) dynamic re order policy and (T,S) dynamic order up to the policy. The inventory parameters like protection interval, reorder point, replenishment level, order quantity and safety stock are compared with standard inventory policies (T,S) and (R, Q). Kleijnen et.al outlined four simulation types for SCM, namely spread sheet simulation, system dynamics simulation, discrete event simulation and business games. These simulation guides to explain the bullwhip effect and predict the inventory values. Leonardo chwil et.al demonstrated a supply chain case study in aluminum processing industry. He analyzed the supply chain with excel spread sheet simulation. The results from spread sheets simulation compared with discrete event simulation. Robert N. Boute et.al presented a typical spread sheet application which explores a series of replenishment policies and forecasting techniques under different demand patterns. Spread sheet application gains a clear insight into the use or abuse of inventory control policies in relation to the bullwhip effect and customer service. Changrui Ren et.al developed comprehensive methodology; strategic objectives are translated into performance metrics by quality strategy map. Then quantitative techniques such as system dynamic simulation and optimization are adopted to take managers through the stages of strategy mapping, action and decision making. Balan et.al analyzed the global supply chain with system dynamics model. The sensitivity analysis of system dynamics model reveals that in a developed country the information delay is of lower order in nature. This approach reduces the level inventory at every stage.

2. PROBLEM DESCRIPTION
This consumer product manufacturing network consists of one manufacturing unit, four warehouses, twenty seven retailers and eighteen suppliers. The transportation mode for this network is truck; the frequency of replenishment will be one week and different lot size. The distance between the warehouse and industry is 400 KM. This warehouse the manager experienced some overstocking.

3. DATA COLLECTION AND ANALYSIS
The data regarding the actual stock supplied to the warehouse and retailer demand up to 52 weeks are collected. The winter forecasting model is followed for estimating retailer demand. The statistical analysis has been made for retailer demand data.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Statistical parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean</td>
<td>38016.84</td>
</tr>
<tr>
<td>2</td>
<td>Standard deviation</td>
<td>11038.48</td>
</tr>
<tr>
<td>3</td>
<td>Variance</td>
<td>963387543</td>
</tr>
</tbody>
</table>

Table-1 Statistical Analysis of Retailer Demand Values

The graph and statistical analysis shows that the retailer demand fluctuates with respect to time. So the traditional inventory control techniques like P-system and Q system does not yield better results.

4. METHODOLOGY
The methodology of the proposed work includes Development...
of metric network for warehouse inventory management, development of a (R, Q, k, t) Replenishment policy, Spread Sheet Simulation, Inventory and Stock out Screening, optimizing the adequate ordering policy, sensitivity analysis of the optimum policy and comparing the optimum policy with standard inventory replenishment policy.

5. DEVELOPMENT OF METRIC NETWORK MODEL FOR WAREHOUSE MANAGEMENT
The Supply Chain Operation Reference Model (SCOR) is a process reference model that was introduced in 1996 through the supply chain council and supported by more than 1000 academic and industrial organizations to become an industrial standard for supply chain management. SCOR model describes the business activities, operations and task corresponding to all levels of supply chain. Based on SCOR model, a typical metric network model is developed for warehouse inventory management. (Fig-2)

6. REORDERING POLICY DEVELOPMENT
The problem can be described as follows
- Single item
- Single warehouse
- One supplying source
- Fixed ordering lots
- Fixed unit cost, No quantity discount
- Shortage cost and back ordering is not considered

6.1 A (R, Q, k, t) Replenishment Model
In general the (R, Q, k, t) model can be stated as

\[ R \] - Review Period
\[ Q \] - Economic Replenishment Quantity
\[ k \] - Inventory to Retailer Demand Ratio
\[ t \] - Inventory to Retailer Demand Forecast Ratio

Review the inventory level every \( R \) units of time; If the \( k \) or \( t \) value is less than or equal to some value we must order \( Q \).

This policy is evaluated with different values (2 to 4) of \( k \) and \( t \) then optimum policy is identified.

6.2 Notation
\[ R \] - Units of time between the inventory revisions
\[ Q \] - Lot size of the item
\[ k \] - Inventory to Retailer Demand Ratio
\[ t \] - Inventory to Retailer Demand Forecast Ratio
\[ I_{o} \] - Old inventory level
\[ I_{n} \] - New inventory level
\[ D_{r} \] - Retailer demand
\[ F_{t} \] - Retailer Demand Forecast
\[ x \] - Periods of time
\[ X \] - Value of the \( k \)
\[ Y \] - Value of the \( t \)

(\( k = t = 2 \) to 4 is selected for this problem)

6.3 Replenishment Algorithm
The proposed algorithm for replenishment of stocks consists of the following steps

Step-1
Assume \( I_{i} = 0 \) (Initial Inventory Level is Zero)
\[ I_{i} = I_{i} + Q_{i} \]
Review the \( k \) and \( t \) values
If \( I_{i}/D_{r} = k_{i} \geq X \)
\[ I_{i} = I_{i} + Q_{i} \]
or
If \( I_{i}/F_{t} = t_{i} \geq Y \) (X=Y=2 to 4 for our proposed problem)
New order with quantity of \( Q_{i} \) is placed
\( Q_{i} = Q_{i} = Q_{i} \)
Else go to step-2

Step-2
If \( I_{i}/D_{r} = k_{1} > 1 \), \( I_{o} = 0 \) (if stock out happens \( I_{o} \) become zero)

6.4 Obtaining the Model Parameters Parameter R
Depends on the specific problem addressed considering the revision policy of the firm. In this problem the stock reviewed every week.

Parameter Q
Economic lot size of the items which can be derived from the following equation

\[ I_{o} = I_{i} + Q_{i} - D_{i} \]
\[ I_{o} = I_{o} + Q_{i} \]

Review the \( k \) and \( t \) values
If \( I_{o}/D_{o} = k_{2} \geq X \)
or
If \( I_{o}/F_{t} = t_{2} \geq Y \) (X=Y=2 to 4 for our proposed problem)
New order with quantity of \( Q_{i} \) is placed
\( Q_{i} = Q_{i} = Q_{i} \)
Else go to step-3
Repeat the steps up to 52 weeks

6.5 Obtaining the Model Parameters Parameter Q
Economic lot size of the items which can be derived from the following equation

\[ I_{o} = I_{i} + Q_{i} - D_{i} \]
\[ I_{i} = I_{i} + Q_{i} \]

Fig 2 - Metric Network Model for warehouse Inventory Management
\[ Q = \sqrt{\frac{2 \times D \times C}{C}} \]

\( D \) - Average Retailer Demand  
\( C \) - Ordering Cost  
\( C \) - Carrying Cost  

**Parameters** \( k \) & \( t \)  
\( k \) - New Inventory to Retailer Demand Ratio  
\( t \) - New Inventory to Retailer Demand Forecast Ratio

In this problem the replenishment policy is evaluated with different values of \( k \) & \( t \) given in table-2

<table>
<thead>
<tr>
<th>Replenishment Policy</th>
<th>values of ( k ) &amp; ( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy - A</td>
<td></td>
</tr>
<tr>
<td>Policy - B</td>
<td>( k \geq 3 ), ( t \geq 3 )</td>
</tr>
<tr>
<td>Policy - C</td>
<td>( k \geq 4 ), ( t \geq 4 )</td>
</tr>
</tbody>
</table>

**Table-2 Replenishment Policies to Be Evaluated**

7. SPREAD SHEET SIMULATION

This policy could not be evaluated by means of theoretical models due to complexity of real system. In this sense simulation can provide a powerful tool for evaluating the performance of the proposed system and choosing the right alternative before actual implementation. It is a simple equation which is easy to program through spread sheet by using Microsoft excel software 2003. It is very simple and realistic nature. The replenishment algorithm is formulated in excel formula bar.

**New Inventory** = Old Inventory + Stock Replenishment – Retailer Demand  
**Old Inventory** = New Inventory from previous period - Stock Replenishment

The spread sheet is developed with the following data namely Retailer Demand Forecasting, Retailer demand for current Period, Old Inventory, Stock Replenishment, New Inventory, New Inventory to Retailer Demand Forecast and New Inventory to Retailer Demand for current period. The replenishment policies are evaluated by using the input given in table-1. The warehouse management performance metrics calculated from each policy and the corresponding values are tabulated.

<table>
<thead>
<tr>
<th>Inventory Parameters</th>
<th>Policy - A</th>
<th>Policy - B</th>
<th>Policy - C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Inventory Quantity</td>
<td>5478696</td>
<td>7933688</td>
<td>9078832</td>
</tr>
<tr>
<td>Inventory Reduction</td>
<td>51.7 %</td>
<td>30 %</td>
<td>20 %</td>
</tr>
<tr>
<td>No of orders</td>
<td>14</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>No of Stock Out</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Reduction in TIC</td>
<td>50.3 %</td>
<td>31.2 %</td>
<td>23.6 %</td>
</tr>
<tr>
<td>Mean</td>
<td>105359.53</td>
<td>152570.92</td>
<td>174592.92</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>30311.46</td>
<td>41996.45</td>
<td>43529.93</td>
</tr>
<tr>
<td>Variance</td>
<td>9318784617</td>
<td>1763701844</td>
<td>1894854806</td>
</tr>
</tbody>
</table>

**Table -3 Comparisons of Policies with Inventory Parameters**

8. ANALYSIS OF RESULTS

8.1 Inventory levels screening

By focusing the inventory level of Policy A, more inventory reduction is possible, but number of stock outs is more. In Policy B the level of inventory reduction is moderate and numbers of stock outs are quite comfortable. The Policy C does not have stock out risk but level of inventory reduction is low. By considering the total inventory cost we can say that Policy B yields better performance. Inventory level comparisons of policies are displayed in the figure-3

8.2 Stock-out Screening

For running smooth business the number of stock out should be with in limit rather than the inventory reduction. In Policy C no stock out is experienced, but numbers of replenishments are equal with Policy B. The Inventory to Retailer Demand Ratio and Inventory to Retailer Demand Forecast Ratio are compared for all policies and displayed in figure-4 and figure 5. In Policy B only one stock out is observed in the week-4 which is displayed in figure-6. The Inventory to Retailer Demand Ratio values for the Policy B is given in figure-7, which reveals that most of values are not near the stock out region. The Policy B yields better performance in the view of inventory reduction and less stock out.

**Fig-3 Comparisons of Inventory Level**

**Fig-4- Inventory to Retailer Demand Ratio**

**Fig-5- Inventory to Retailer Demand Forecast**
9. SENSITIVITY ANALYSIS

The sensitivity analysis of the Policy B is carried out with +30%, +20%, +10%, -10%, -20% and -30% values of Retailer demand and corresponding number of stock out and number of replenishment values which are tabulated. In +30% levels sensitivity analysis reveals that only one stock is experienced in week 9 which is shown in figure -7.

<table>
<thead>
<tr>
<th>Inventory parameters</th>
<th>+30%</th>
<th>+20%</th>
<th>+10%</th>
<th>-10%</th>
<th>-20%</th>
<th>-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of stock out</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No of orders</td>
<td>22</td>
<td>20</td>
<td>18</td>
<td>15</td>
<td>14</td>
<td>13</td>
</tr>
</tbody>
</table>

Table-4 Sensitivity Analysis of Policy B
The performance of standard inventory replenishment policy (T, S) is also evaluated by means of excel spread sheet simulation for the same data. The level of inventory of the (T, S) policy is more than the actual level of the inventory maintained by the firm. The total inventory cost reduction value of the (T, S) policy is in negative.

### Table-5 comparison of (R, Q, k, t) & (T, S) Policies

<table>
<thead>
<tr>
<th>Inventory Parameter</th>
<th>P-system (T, S)</th>
<th>Policy A</th>
<th>Policy B</th>
<th>Policy C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in TIC</td>
<td>-15.6%</td>
<td>50.3%</td>
<td>31.2%</td>
<td>23.61%</td>
</tr>
<tr>
<td>No of stock out</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

### REFERENCES

16) Seetherama L. Narasimhan, W. Mcleavey and Peter J. Billington (2002). Production Planning and Inventory Control, Prentice Hall of India Private Limited, New Delhi

AUTHORS
A. Mahamani, Assistant Professor, Mechanical Engineering Dept., Sri Venkateswara College of Engineering and Technology, R.V.S Nagar, Chittoor-517127 (A.P), India
E-mail: mahamani_sudhan@yahoo.co.in

Dr. K. Prahlada Rao, Professor, Mechanical Engineering Dept., JNTU College of Engineering, Anantapur-515002 (A.P), India

Dr. V. Pandurangadu, Director, JNTU-OTR, College of Engineering, Anantapur-515002 (A.P), India.