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DEVELOPMENT OF A (R,Q,k,t) SINGLE ITEM INVENTORY REPLENISHMENT POLICY FOR WAREHOUSE MANAGEMENT IN SUPPLY CHAIN -A CASE STUDY IN MINERAL WATER COMPANY

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Abstract

In this paper, the case of a mineral water company is studied and a (R, Q, k, t) single item inventory replenishment policy is proposed and evaluated by means of excel spread sheet simulation in warehouse. The alternative replenishment policies are compared by changing the inventory to retailer demand ratio and inventory to demand forecast ratio values. The performance of the selected ordering policy is evaluated by using sensitivity analysis and stock out screening. The results revealed that the implementation of this policy can reduce the total investment and maximize the customer service, while maintaining the business efficiency.

Keywords: supply chain, warehouse management, replenishment policy, Excel spread sheet simulation, inventory reduction

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 mineral water company B.Ramirez et.al (Ramirez, Espinnosa; 1997) successfully implemented a (R, s, Q, c) replenishment policy in a cardboard box marketing firm. This policy is evaluated by means of discrete event

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simulation and adequate 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 (2005) proposed a couple of forecast based inventory management policies for single stage; single item inventory system, namely (Rk,Q)dynamic re order policy and (T,Sk) 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 (2003 and 2005) 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 chwif et.al (2002) demonstrated a supply chain case study in aluminum processing industry. He analyzed the supply chain with excel spread sheet simulation. The results from spread sheet simulation compared with discrete event simulation. Robert N.Boute et.al (2006) 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 in to the use or abuse of inventory control policies in relation to the bullwhip effect and customer service. Changrui Ren et.al (2006) developed comprehensive methodology; strategic objectives are translated in to 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 (2006) 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 mineral water company consists of one manufacturing unit, two warehouses, ten retailers and twelve 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 200 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 1. Statistical Analysis of Retailer Demand Values

S.No	Statistical parameters	Values (in cases)
1	Mean	17775.4
2	Standard deviation	5906.424
3	Variance	34885847

The statistical analysis shows the retailer demand fluctuates with respect to time. So that the traditional inventory control techniques 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, S

ensitivity analysis of the optimum policy and Comparing the optimum policy with standard inventory replenishment policy.

5. DEVELOPMENT METRIC NETWORK MODEL FOR WAREHOUSE INVENTORY 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 and displayed in Fig. 1.

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
- Weekly review of inventory levels (Saturdays)
- Stock replenishment on Mondays

6.1 A (R, Q, k, t) Replenishment Model

In general the (R, Q, k, t) model can be stated as:

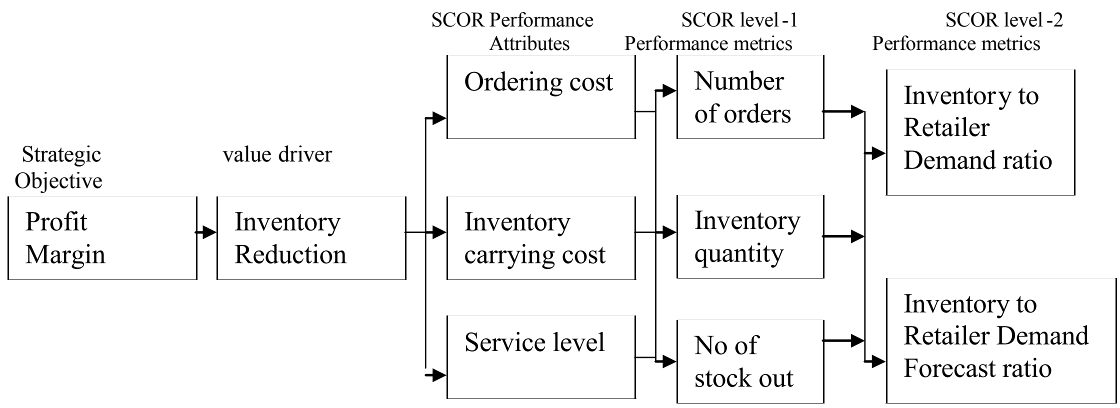


Figure 1. Metric Network Model for Warehouse Inventory Management

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 less than or equal to some value we must order Q.This policy is evaluated different values(1.5 to2) 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- Retailer Demand Forecast
x- Periods of time
X-Value of the k
Y-Value of the t
(k=t=1.5 to2 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_{o1}=0 (Initial Inventory Level is Zero)

$$I_{n1}=I_{o1}+Q1$$

Review the k1 and t1 values

If $I_{n1}/D_{r1}=\mathbf{k_1} \geq \mathbf{X}$

or

$I_{n1}/F_1=\mathbf{t_1} \geq \mathbf{Y}$ (X=Y= 1.5 to 2 for our proposed problem)

New order with quantity of Q_2 is placed

$(Q_1=Q_2=Q_n)$

Else go to step-2

Step-2

If $In_1/Dr_1=k_1 > 1$, $I_{o2}=0$ (if stock out happens I_{o2} become zero)

or

$$I_{o2}=I_{o1}+Q_1-D_{r1}$$
$$I_{n1}=I_{o2}+Q_2$$

Review the k_2 and t_2 values

If $I_{n2}/D_{r2}=k_2 \geq X$

or

$I_{n2}/F_2=t_2 \geq Y$ (X=Y=1.5 to 2 for our proposed problem)

New order with quantity of Q_3 is placed $(Q_1=Q_2=Q_n)$

Else go to step-3

Repeat the steps up to 52 weeks

6.4 Obtaining the Model Parameters Parameter R

Depends on the specific problem addressed considering the revision policy of the firm

Parameter Q

Economic lot size the items which can be derived from the following equation:

$$Q = \sqrt{\frac{2 * D_r * C_o}{C_c}}$$

D_r-average retailer demand

C_o-ordering cost

C_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 2. Replenishment Policies to be evaluated

Replenishment Policy	values of k & t
Policy-A	k ≥ 1.5, t≥ 1.5
Policy-B	k ≥2 , t≥ 2
Policy-C	k ≥ 2.5, t≥ 2.5

7. SPREAD SHEET SIMULATION

In this policy could not evaluate 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 actually implementation. 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 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-2 .The warehouse management performance metrics calculated from each policy and the corresponding values are tabulated.

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

Table 3. Comparisons of Policies with Inventory Parameters

Inventory Parameters	Policy -A	Policy -B	Policy -C
Total inventory quantity	2874271	3897143	4262384
Inventory reduction	47.58 %	28.93 %	22.27 %
No of orders	12	12	12
No of stock out	4	0	0
Reduction in TIC	32.49 %	22.61 %	19.09 %
Mean	55274.44	79945.05	81968.92
Standard deviation	24234.57	24872.87	26561.35
Variance	587314749	618659700	705505376

level of inventory reduction is moderate and number of stock out 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 Policy B yielding better performance. Inventory level comparisons of policies are displayed in the figure 2.

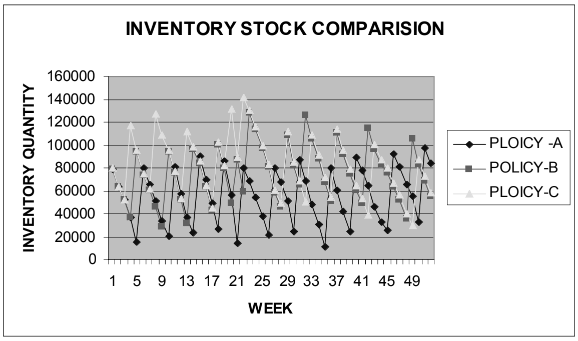


Figure 2. Comparisons of Inventory Level

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 B and C there is no stock out is experienced, but number of replenishments are also in equal. The Inventory to Retailer Demand Ratio and Inventory to Retailer Demand Forecast Ratio are compared for policies and displayed in figure 3 and figure 4. In Policy B no stock out is observed, which is displayed in figure-5. The Inventory to Retailer Demand Ratio values for the Policy B is given in figure 3, which reveals that most of values are not near the stock out region. The Policy B yielding better performance in the view of inventory reduction and less stock out.

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 two stock outs are experienced, which is shown in figure 6.

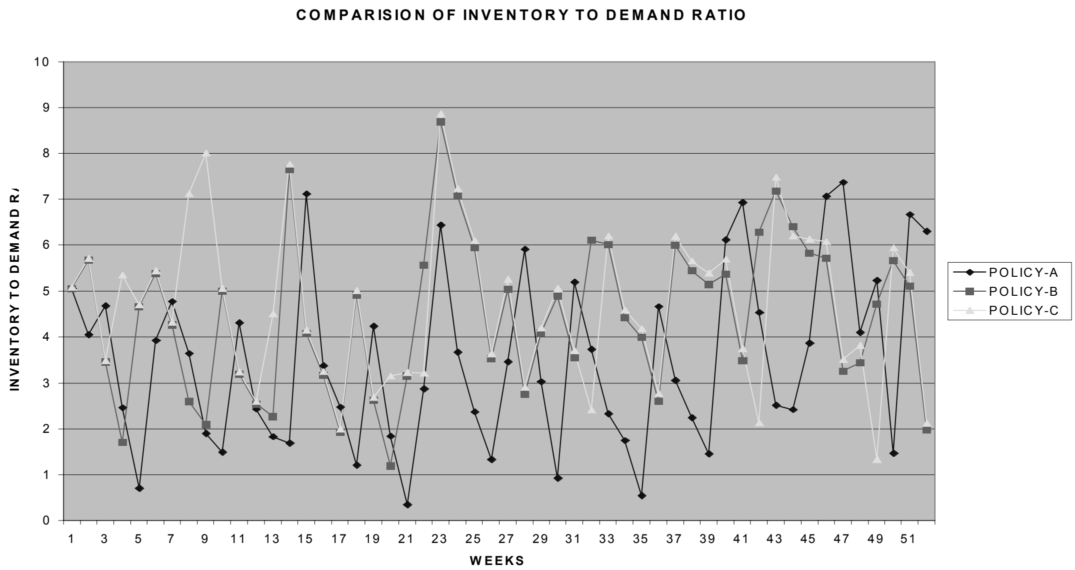


Figure 3. Inventory to Retailer Demand Ratio

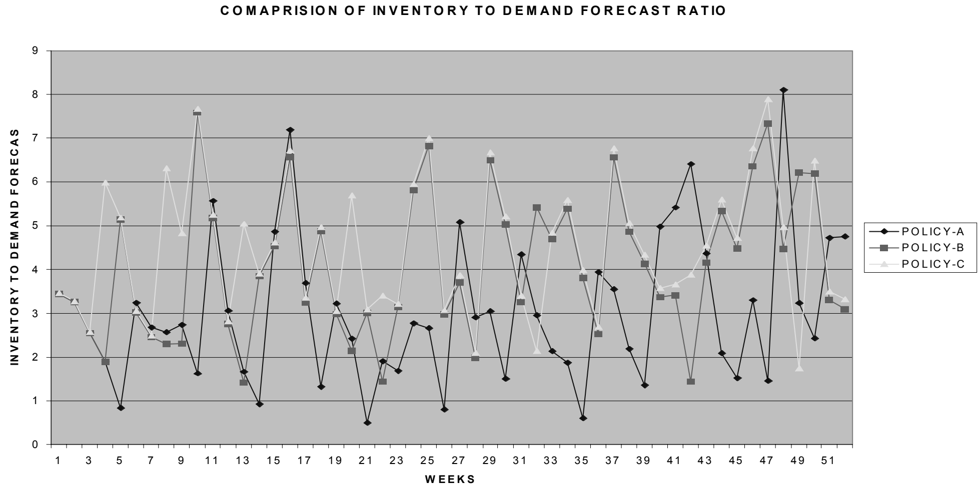


Figure 4. Inventory to Demand Forecast Ratio

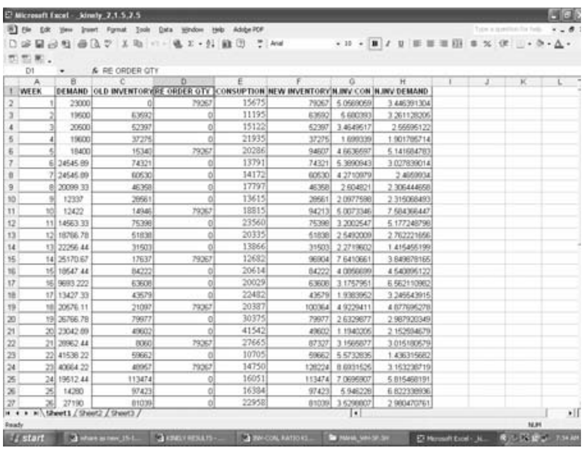


Figure 5. Simulation Screen Shot for Policy-B

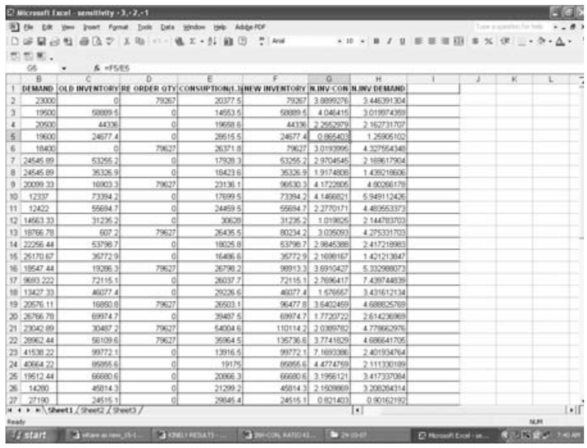


Figure 6. Simulation Screen shot for +30% levels

Table 4. Sensitivity Analysis of Policy B

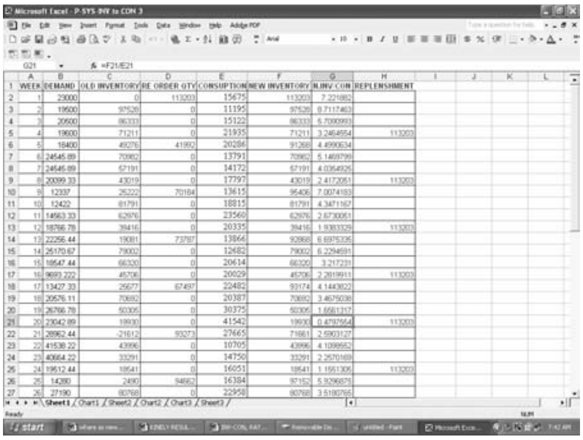
Inventory parameters	+ 30%	+ 20%	+ 10%	-10%	-20%	- 30%
No of stock out	15	14	13	12	10	9
No of orders	2	0	0	0	0	0

10. COMPARISION WITH STANDARD (T, S) INVENTORY REPLENSHMENT POLICY

The performance of standard inventory replenishment policy (T, S) also evaluated by means of excel spread sheet simulation for the same data. The level of inventory of the (T, S) policy is nearer to this policy. In customer service point of view a severe stock out is experienced in the 21 week, which is displayed in simulation screen shot as well as fig 8.

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

Inventory Parameter	P- system (T, S)	Policy A	Policy B	Policy C
Reduction in TIC	26.2 %	32.49 %	22.61 %	19.09 %
No of stock out	1	4	0	0



WEEK	DEMAND	OLD INVENTORY	RE ORDER QTY	CONSUPTION	NEW INVENTORY	N.INV CON	REPLENSHMENT
1	23000	0	113203	15675	113203	7.221882	
2	19600	97528	0	11195	97528	8.7117463	
3	20600	86333	0	15122	86333	5.7090993	
4	19600	71211	0	21935	71211	3.2464554	113203
5	18400	49276	41992	20286	91268	4.4990634	
6	24545.89	70982	0	13791	70982	5.1469799	
7	24545.89	57191	0	14172	57191	4.0354925	
8	20099.33	43019	0	17797	43019	2.4172051	113203
9	12337	25222	70184	13615	95406	7.0074183	
10	12422	81791	0	18815	81791	4.3471167	
11	14563.33	62976	0	23560	62976	2.6730051	
12	18766.78	39416	0	20335	39416	1.9383329	113203
13	22256.44	19081	73787	13864	92868	6.6975336	
14	25170.67	79002	0	12682	79002	6.2294591	
15	18547.44	66320	0	20614	66320	3.217231	
16	9693.222	45706	0	20029	45706	2.2819911	113203
17	13427.33	25677	67497	22482	93174	4.1443822	
18	20676.11	70692	0	20387	70692	3.4675038	
19	26766.78	50305	0	30375	50305	1.6561317	
20	23042.89	19930	0	41542	19930	0.4797554	113203
21	28962.44	-21612	93273	27665	71661	2.5903127	
22	41538.22	43996	0	10705	43996	4.1098552	
23	40664.22	33291	0	14750	33291	2.2570169	
24	19512.44	18541	0	16051	18541	1.1551306	113203
25	14280	2490	94662	16384	97152	5.9296875	
26	27190	80768	0	22958	80768	3.5180765	

Figure 7. Simulation screen shot for (T, S) Policy

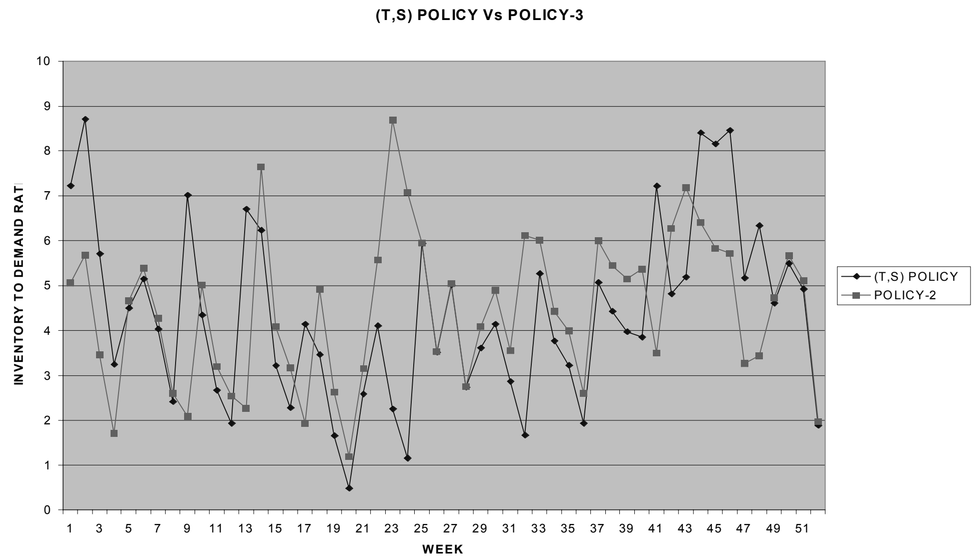


Figure 8. stock out screening for (R, Q, k, t) & (T, S) policies

11. CONCLUSION

The (R, Q, k, t) replenishment policy proved to an effective way of leveling the trade off involved in this complex real world situation. The sensitivity analysis reveals the flexibility of this policy. The stock out screening indicates most of values of inventory to demand ratio are not near stock region. As compared with (T, S) replenishment policy, the level inventory is nearer to this policy. In view of customer service the (T, S) replenishment policy a severe stock out is experienced. This work will support to increase the profit margin by the way of reduction in total inventory cost and improve the customer service without altering the resources. The future work will be to evaluate the (R, Q, k, t) Replenishment policy with the real time data from raw materials and spare parts inventory systems.

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