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Optimization of Inventory System: A Case Study of Haldiram Bread Industry

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ABSTRACT
Supply chain generally involves the transformation of products from supplier to manufacturer and from distributors to retailers & finally to customers. But by using the lateral transshipment the products from one location to another location in a same stage i.e. from retailers to retailers at emergency condition can be sent. This can optimize the inventory carrying at warehouse and transferred unit from warehouse to retailers and minimize the back order and inventory level at the retailers. Thus total supply chain cost can be minimized. In the present work single-echelon two stage optimization models is employed for inventory distribution from warehouse to three retailers in first stage. Optimal transshipment of product among three retailers due to interactive-lateral transshipment is identified in second stage. Model is validated by case study of Haldiram bread industry.
KEYWORDS: lateral transshipment, inventory, Supply chain

I. INTRODUCTION

Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements.

II. INVENTORY MANAGEMENT

The scope of inventory management also concerns the fine lines between replenishment lead-time, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods and demand forecasting.

III. ECHELON SYSTEM

Echelon system mainly two type's single–echelon and multi–echelon inventory optimization .A sequential single-echelon approach forecasts demand and determines required inventory for each echelon separately. Multi-echelon inventory optimization determines the correct levels of inventory across the network based on demand variability at the various nodes and the performance

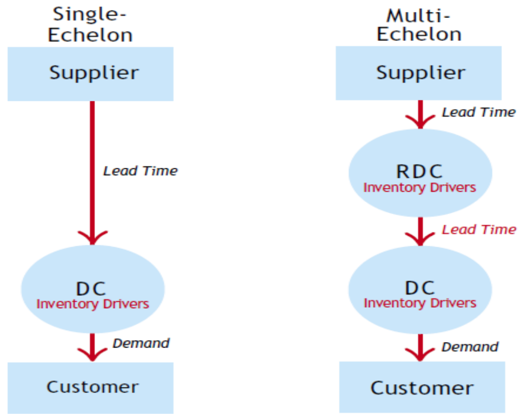


Fig. 1. Echelon System

Lateral transshipment is defined as a retailer use which provides stocked items to another retailer which is out of stock or to prevent out-of-stock occurrences

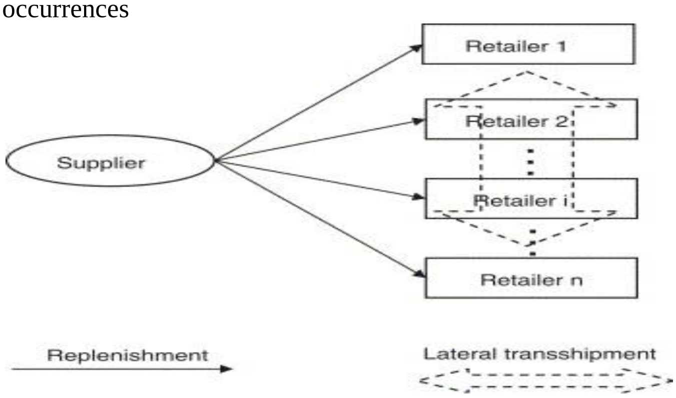


Fig.2. Lateral Transshipment in Inventory System.

IV. INVENTORY CARRYING COST

In almost any business analysis involving inventory, physical inventory levels must be converted to inventory costs. The more inventories you have, the higher your exposure to this sort of loss. Quality Cost - High levels of inventory usually increase the chance of product damage and creates lower feed-back loops between supply chains partners.

V. UNIT INVENTORY CARRYING COST AT WAREHOUSE

Unit inventory carrying cost at warehouse = Unit paper box cost + Unit labor cost + Unit electricity charges.
One paper box = Rs.3.25
Capacity of box = 40 unit
One unit cost = Rs.3.25/40=Rs.0.08125
One labor charge per day = Rs.300
One labor put 2000 unit per day or carry unit
One unit=300/2000 =Rs.0.15
Cooling charges, electricity charges Rs.18 for 24 hours or one day
Warehouse capacity =1200 unit
Rs.18 for 1200 units,one unit=Rs.18/1200=Rs.0.015
Unit inventory carrying cost at warehouse = 0.15+0.015+0.08125= **Rs.0.24625**

Similarly Inventory Carrying Cost at Retailers are 0.185/unit, 0.37/unit, 0.4625/unit respectively.

VI. INVENTORY TRANSPORTATION COST

A critical issue in the management of physical distribution activities is whether the organization should own transport facilities or hire them.

Unit Transportation cost from warehouse to retailers with the average of truck is 10 km. / liter and capacity 500 unit. Unit cost from warehouse to 1st , 2nd & 3rd retailers are **Rs.0.07456, Rs.0.082016 & Rs.0.096928.**

Unit transportation cost from retailer to retailer:
Assuming Two wheelers average 50km. / liter and Petrol cost Rs.74.56.
First retailer to second retailer unit transportation cost =0.5 km.*Rs.1.4912=**Rs.0.7456/unit**.
First retailer to third retailer unit transportation cost =1.5km.*Rs.1.4912=**Rs.2.2368/unit**.
Second retailer to third retailer unit transportation cost
=1.0km.*Rs.1.4912=**Rs.1.4912/unit**

VII. BACK ORDER COST

Backorder costs are important for companies to track, as the relationship between holding costs of inventory and backorder costs will determine whether a company should over- or under-produce. Back order cost is equal to profit per unit, as Rs.2.50 at every retailer.

VIII. LINEAR PROGRAMMING MODEL

Linear programming (LP or linear optimization) is a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships.

IX. MODEL DESCRIPTION

Generalized model is a single-echelon two stage distribution inventory model with N_w warehouses and N_r retailers with limited capacities. In this model considered more number of warehouses and all warehouses products transfer to all retailers. In this warehouses have a limited capacity for carry products. All retailers have limited number of product to carry. Model is optimizing for total supply chain cost. [8]

X. TWO STAGE CONSTRAINED OPTIMIZATION MODEL

The generalized model deals with optimizing the inventory levels of the supply Chain entities with consideration of single-echelon warehouse to retailers and among retailers. The diagrammatic representation of the proposed model for the period p is shown in Figure 3.1.
TC_p = Minimize TC_{p1} +Minimize TC_{p2}

TWO STAGES PROPOSED MODE

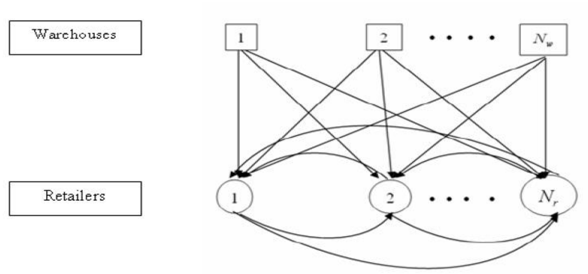


Figure3.1 Two stage constrained optimization model

In this we consider transshipment between one warehouse and three retailers in first stage and in second stage, lateral transshipment among three retailers. In this once stocks allocated from warehouse to these three retailers then in second stage if necessary then they can transfer among them to fulfill the demand of customers.

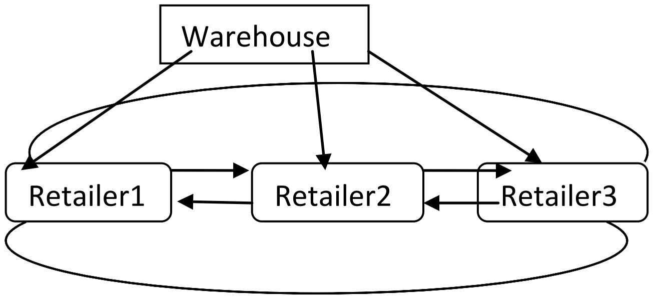


Figure 3.2 Two stage inventory distribution model

FIRST STAGE PROBLEM

Objective Function= Total transportation cost from warehouse to all retailers in period p. + Total inventory carrying cost at warehouse in period p.

Objective Function Minimization

$\mathbf{TC_{p1}= a_1*X_1+a_2*X_2 +a_3*X_3 + a *Z}$

In the first stage, we have the following constraints:

1. Inventory at the warehouse should be less than or equal to the warehouse capacity in period p.

$\mathbf{Z \;\square\; C_w}$

2. The total retailers forecasted demand for a period p should be less than or equal to warehouse inventory in that particular period p.

$\mathbf{Z \;\square\; (D_{f1}+D_{f2}+D_{f3})}$

3. The sum of units transferred from warehouse to a retailer should be greater than or equal to the forecasted demand of that particular retailer in period p.

$\mathbf{X_1 \;\square\; D_{f1},\ X_2 \;\square\; D_{f2} ,\ X_3 \;\square\; D_{f3}}$

4. The total number units transferred from warehouse to a particular retailer should be less than or equal to that retailer capacity in period p.

$\mathbf{X_1 \;\square\; C_{r1},\quad X_2 \;\square\; C_{r2},\quad X_3 \;\square\; C_{r3}}$

5. The sum of the units transferred from a warehouse to all retailers should be less than or equal to the warehouse inventory for a particular period p.

$\mathbf{X_1+X_2+X_3 \;\square\; Z}$

SECOND STAGE PROBLEM

Objective function=Total inventory carrying cost of all three retailers in period p. + Total back order cost of retailers in period p.

Objective function minimization

$TC_{p2} = (y_1*I_1+y_2*I_2+y_3*I_3) + (c_1*Ib_1+c_2*Ib_2+c_3*Ib_3)$

I=Inventory at retailer at the end of period=Stage Inventory at retailer at the end of stage 1-Unit transferred to retailer to retailers.

I b =Back order at retailer at the end of period p=Stage back order at retailer at the end of stage 1-Unit received by retailer from retailers.

INDUSTRY CASE STUDY:

The Sandwich Bread is made from wheat flour, Sugar, yeast, salt, milk, refined palmolein oil, flour improver and permitted preservatives. Haldiram one warehouse is located in Pardi road Nagpur. In this project consider three retailers who are selling Haldiram Bread. First retailer is located 5km to warehouse. First Retailer is located at Babu Lal ji Takmore Marg Itawari Nagpur. Second retailer is located at Nikolas Mandir sabji Mandi Itawari Nagpur and 5.5 km distance from warehouse. Third retailer is located at Bavsar chowk Mahal Nagpur and 6.5 km distance from warehouse.

XI. FORECASTED DEMAND

In this forecasted demand of products on retailers before starting the periods. Consider 10 intervals of four days time periods. Collected demand on retailers of products for 10 intervals

The equation for FORECAST is a+bx, where:

$a=\bar{y}\text{-}b\bar{x}$ $\quad$ $b=\frac{\sum(x-\bar{x})(y-\bar{y})}{(x-\bar{x})2}$

Where x and y are the sample means AVERAGE (known_x's) and AVERAGE (known y's).

B13 =FORECAST(A13,B3:B12,A3:A12)

	A	B	C
1			
2		Forecasting of 2jan. To 10 Feb. demand data at Retailer 1	
3	1	262	
4	2	303	
5	3	272	
6	4	265	
7	5	261	
8	6	276	
9	7	294	
10	8	312	
11	9	305	
12	10	325	
13	11	316.9333333	
14			

Forecasted Demand for Period 1 (11^{th} Interval) at Retailer 1.

Similarly Forecasted Demands are calculated for both the retailers and for two periods.

XII. INPUT DATA FOR WAREHOUSE AND RETAILERS

In this consider Haldiram bread industry that is situated in Nagpur (India). Consider one warehouse and three retailers who are selling bread of this industry. The following data is collected for validating the above proposed model.

	Warehouse
Inventory carrying cost per units in Rupees	0.24625
Warehouse Capacity in units	1200

Table 4.1 Input Data for warehouse.

Retailers Demand in Units						
	R_1		R_2		R_3	
	Forecasted	Actual	Forecasted	Actual	Forecasted	Actual
P_1	316	303	263	233	166	198
P_2	288	330	225	219	138	122

Table 4.2 Retailers Demand.

Similarly Inventory cost, transportation cost, and Back order cost are tabulated.

XIII. MS EXCEL SOLVER SOFTWARE

Excel has an add-in called the Solver which can be used to solve systems of equations or inequalities.

Step 1:
Formulate the linear programming problem.
1. Define the decision variables.
X_1, X_2, X_3, Z (For first stage first period)
2. Write the objective function.
Objective Function Minimization
$TC_{p1} = 0.07456*X_1 + 0.082016*X_2 + 0.096928*X_3 + 0.24625*Z$

3. Write each constraint so that all of the decision variables included in the constraint are written on the left side of the expression and so that the right side is a non-negative constant.

Step 2:
Open Excel and make sure that have Solver accessible

Step 3:
Enter information from the formulation into Excel.

	A	B	C	D	E	G	I
1	distribution problem						
2							
3		x1	x2	x3	z	rhs	formula
4	objective Function	0.0746	0.082	0.0969	0.2463		
5		0	0	0	1	1200	
6		0	0	0	1	745	
7		1	0	0	0	316	
8		0	1	0	0	263	
9		0	0	1	0	166	
10		1	0	0	0	400	
11		0	1	0	0	350	
12		0	0	1	0	300	
13		1	1	1	-1	0	
14	solution	0	0	0	0		
15							

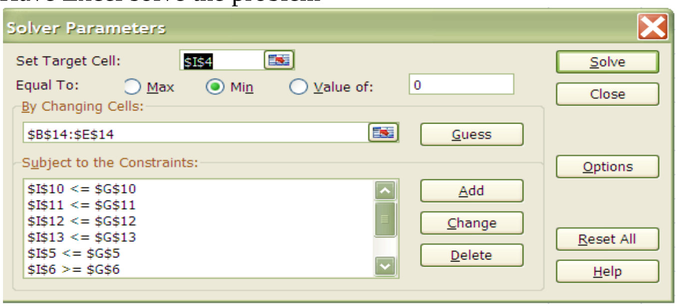
Information from the formulation into Excel

Step 4:
Enter formulas for Excel to use in calculations.
1. Need to enter a formula for the value of the objective function and a formula for each constraint.
2. Each formula set up using the sum product function. This function uses two ranges of cells, multiplies the values in the corresponding positions, and then adds the values. In this case sum product (B4:C4:D4:E4, B14:C14:D14:E14) will provide the same result as the formula
= B4*B14 + C4*C14 + D4*D14 + E4*E14.
In this case: $0.07456*X_1 + 0.082016*X_2 + 0.096928*X_3 + 0.24625*Z$
3. By using absolute references for the cells that will contain the decision variables. In this case = sum product (B4:C4:D4:E4,$B$14:$C$14:$D$14:$E$14)) this way enter the formula in the first cell and then copy that formula down the column.

	A	B	C	D	E	G	I
1	distribution problem						
2							
3		x1	x2	x3	z	rhs	formula
4	Objective Function	0.07456	0.08202	0.09693	0.24625		=SUMPRODUCT(B4:C4:D4:E4,$B$14:$C$14:$D$14:$E$14)
5		0	0	0	1	1200	=SUMPRODUCT(B5:C5:D5:E5,$B$14:$C$14:$D$14:$E$14)
6		0	0	0	1	745	=SUMPRODUCT(B6:C6:D6:E6,$B$14:$C$14:$D$14:$E$14)
7		1	0	0	0	316	=SUMPRODUCT(B7:C7:D7:E7,$B$14:$C$14:$D$14:$E$14)
8		0	1	0	0	263	=SUMPRODUCT(B8:C8:D8:E8,$B$14:$C$14:$D$14:$E$14)
9		0	0	1	0	166	=SUMPRODUCT(B9:C9:D9:E9,$B$14:$C$14:$D$14:$E$14)
10		1	0	0	0	400	=SUMPRODUCT(B10:C10:D10:E10,$B$14:$C$14:$D$14:$E$14)
11		0	1	0	0	350	=SUMPRODUCT(B11:C11:D11:E11,$B$14:$C$14:$D$14:$E$14)
12		0	0	1	0	300	=SUMPRODUCT(B12:C12:D12:E12,$B$14:$C$14:$D$14:$E$14)
13		1	1	1	-1	0	=SUMPRODUCT(B13:C13:D13:E13,$B$14:$C$14:$D$14:$E$14)
14	solution	0	0	0	0		

Formulas for Excel to use in calculations.

Step 5:
Have Excel solve the problem



Dialogue Box to solve Problem.

Select the Options button and select "Assume Linear Model" and "Assume Non-Negativity." Leave all other boxes at the default values.

	B	C	D	E	F	G	H	L	N
1		13	T13	30	T23	32	R31+R32		formula
2	objective	0.185	-0.185	0.37	-0.37	2.5	-2.5		2.035
3		1	0	0	0	0	0	13	13
4		0	0	1	0	0	0	30	30
5		0	0	0	0	1	0	32	32
6		-1	1	0	0	0	0	0	-11
7		0	0	-1	1	0	0	0	0
8		0	0	0	0	-1	1	0	0
9		0	1	0	1	0	-1	0	0
10	solution	13	2	30	30	32	32		

Excel Solver Solution for Second Stage, First Period Similarly for different stages and periods it is formulated on excel solver.

XIV. RESULTS AND DISCUSSIONS:

After solving the model for two stages, using MS Excel Solver Software, the optimal solutions and results for the case study are obtained. The problem is solved for 2 periods, by using the industry data by considering a single warehouse and three retailers. These results are tabulated, compared with the real time existing solution of the industry.

Period	Number of units at Warehouse	
	Proposed model	Existing (Industry)
P_1	745	800
P_2	651	750

Table 6.1 Optimal Warehouse Stocks in units.

Period	Retailer	Proposed model	Existing (Industry)
P_1	R_1	316	330
	R_2	263	270
	R_3	166	180
P_2	R_1	288	300
	R_2	225	210
	R_3	138	150

Optimal numbers of units transferred from warehouse to retailer.

Period		Proposed model			Existing (Industry)		
	Customer	R_1	R_2	R_3	R_1	R_2	R_3
P_1	R_1	-	0	2	0	0	0
	R_2	0	-	30	0	0	0
	R_3	0	0	-	0	0	0
P_2	R_1	-	0	0	0	0	0
	R_2	6	-	0	0	0	0
	R_3	16	0	-	0	0	0

Table 6.3 Optimal number of units transferred from retailer to retailer.

Period	Proposed model			Existing (Industry)		
	R_1	R_2	R_3	R_1	R_2	R_3
P_1	11	0	0	27	37	0
P_2	0	0	0	0	0	28

Table 6.4 Optimal numbers of Inventory at Retailers.

Period	Proposed model			Existing (Industry)		
	R_1	R_2	R_3	R_1	R_2	R_3
P_1	0	0	0	0	0	18
P_2	20	0	0	30	9	0

Table 6.5 Number of back ordered units at retailers.

XV. CALCULATION OF OPTIMAL TOTAL COST IN EXISTING (INDUSTRY)

Total supply chain cost in period one= First stage cost+ Second stage cost

First stage cost=330*0.07450+270*0.082016+180*0.096928+800*0.24625 =Rs.261.196

Second stage cost= 27*0.185+37*0.37+18*2.5 =Rs.63.685

Total supply chain cost=Rs.261.196+Rs.63.685
=Rs.324.881

Total supply chain cost in period second=First stage cost+ Second stage cost

First stage cost=300*0.07456+210*0.082016+150*0.096928+750*0.24625=Rs.238.81806

Second stage cost=28*0.4625+30*2.5+9*2.5=Rs.110.45

Total supply chain cost=Rs.238.81806+Rs.110.45
=Rs.349.26808

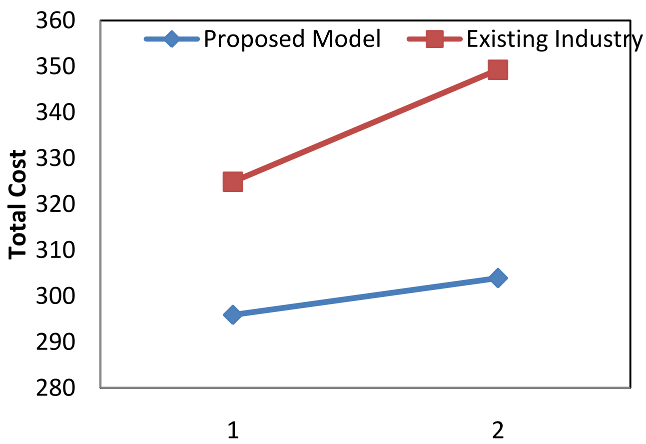


Fig.6.1Comparison of Proposed Methodology and Existing (Industry)

XVI. CONCLUSION AND FUTURE WORK

In this work, two stage inventory distribution systems has been considered where transshipment are allowed as resource action in order to reduce the inventory level, transferred unit and back orders. Warehouse supplied products to three retailers, who in turn serve a large number of customers. Model has taken the distribution and inventory carrying costs into account in the supply chain network at each period. Excess or low inventory at warehouse and retailers increases problems such as increase in inventory carrying cost and back order cost. By using lateral transshipment these problems can be minimized. This is indicated by the case study of bread industry where results are encouraging and reduced overall system costs. By making retailers to interact and taking a decision on lateral transshipment, the inventory level of different locations at the same echelon is balanced.

REFERENCES

[1] Dharamvir Mangal and Pankaj Chandna, Lateral transshipment –A technique for inventory control in multi retailer supply chain system, International Journal of Information Technology and Knowledge Management, July- December 2010, Volume 2,No.2, pp. 311-315.
[2] Supplychaininformation.blogspot.com
[3] Calvin B. Lee, Multi echelon Inventory Optimization, Evant Inc.2003.
[4] Min Chen, Lateral Transshipment in Inventory Models, Vrije University Amsterdam, 2008.
[5] Metin Turkay, Linear Programming Models, INDR 262 Optimization Models and Mathematical Programming.
[6] K. Balaji Reddy, S. Narayanan and P. Pandian, Single-Echelon supply chain two stage distribution inventory optimization models for the confectionery industry, applied mathematical Sciences, Vol. 5, 2011, no.50, 2491-2504.
[7] MS Excel 2007 forecasting function.
[8] www.msubillings.edu
[9] B. Fahimnia, L. Luong and R. Marian, an integrated model for the optimization of a two- echelon supply network, Journal of Achievements in Materials and Manufacturing Engineering, 2 December 2008 Volume 31 Issue.
[10] Avijit Banerjee, Jonathan Burton and Snehamay Banerjee, A simulation study of lateral