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Lateral Transshipment for Controlling Inventory – A Case Study

[1]Dharamvir Mangal, [2]Pankaj Chandna
[1]Mechanical Engineering Department,
The Technological Institute of Textile and Sciences,
Bhiwani (127021), Haryana, India
[2]Mechanical Engineering Department,
National Institute of Technology, Kurukshetra, Haryana, India

ABSTRACT

One of the major trends facing organizations today is the demands for ever-higher levels of responsiveness and shorter defined cycle times for deliveries of goods and services. The distribution system for new automobiles has remained unchanged for many years, with more emphasis on supplying customers from stock held at retailers. Despite high stocks, the performance of the supply chain has failed to meet customer expectations in terms of delivering the exact specification desired within an acceptable timescale. To overcome the uncertainties and to manage inventory in a supply chain, in this work emergency lateral transshipments are allowed as alternative actions in order to reduce the cost of shortage and surplus inventory after demands are realized and we present a simple and intuitive model that enables to characterize optimal inventory and transshipment policy for n number of locations with λ products outfit by a single warehouse where stock is held to meet customers' demands. An analytical approach is urbanized on an Indian automobile manufacturing company for estimating the total expected costs (carrying, transshipments and lost sales) of the two policies i.e. with transshipment and without transshipment and the results have been compared with existing one. This provides a mechanism for choosing between the two policies for any given set of problem characteristics. It has been observed that the notion of lateral transshipments appears to have substantial appeal and the benefits of avoiding retail level shortages outweigh the additional delivery costs resulting from transshipments, customer service may be enhanced significantly, associated inventory cost reduces, without the burden of additional safety stocks.

Key words: *Supply chain, Uncertainties, Inventory management, Lateral transshipment*

1. INTRODUCTION

In this competitive era of 'LPG' i.e. Liberalization, Privatization and Globalization, modern marketing systems, introduction of products with short life cycles, and the discriminating expectations of customers have enforced business enterprises to invest in and focus attention on their Supply Chains (SCs) in order to meet out the level of customer's satisfaction and to survive in the competitive market (Ansari and Modarress, 1990). Traditional functioning of marketing, distribution, planning, manufacturing, and the purchasing units of organizations along the supply chain were highly segregated and they used to function in an independent manner in order to meet out their own specific objectives which were often highly contradictory to the overall organizational goals. The result of these factors is that there is not a single integrated plan for the organization rather there were as many tactics as businesses. Given that, there was an intense need for the emergence of some mechanism through which these different functions can be integrated together with the objective to function as a unified whole (Rhonda and Robert, 1999). Here comes the role of Supply Chain Management (SCM) strategies through which such amalgamation can be achieved and the past shortcomings of the system may be overcome (Eric Sucky, 2005). The purpose of supply chain management is to improve trust and collaboration among supply chain partners, thus improving inventory visibility and the velocity of inventory movement (Choi and Hong, 2002; Huang et al., 2003; Quinn, 1997). In twenty first century era where organizations enter into the new business environment which deals with the idea of maximizing efficiencies, they face significant business risks associated with the increased dependence on business partners to shorten cycle times and deliver materials and supplies on increasingly shorter notice. High level competitiveness and ensuring major share of benefits to their own departments and units, stakeholders compete among each other and this generates an atmosphere of distrust and wariness among players in the supply chain (Zelbst et al., 2009). Hence this unhealthy supply chain relationship that exists usually falls in between arms lengths negotiation to full collaboration or integration. Other such development is the power considerations which were exerted by certain players in a supply chain. This type of relationship is especially prevalent in the automobile industry. Successful supply chain management requires cross-functional integration within the firm and across the network of firms that comprise the supply chain (Chandra and Kumar, 2001). In order to ensure smooth functioning among all the stake holders the process of automating connections with trading partners, organizations are increasingly dependent on upstream and downstream business partners and here technology plays a pivotal role in not only making things transparent but in maintaining relationships in the environment of faith and integrity. For the establishment of an ideal professional environment organizations should

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focus on supply chain relationship management (SCRM), improvements in performance that result from better management of key relationships and inventory control parameters (Guillen et al., 2005).

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. The most significantly affecting factor of supply chain is the inventory plans which are to be structured in such a way that they accommodate variability in demand, lead time and other uncertainties especially when the company is dealing with multiple and varying products (Axsäter, 2005; Musalem and Dekker, 2005). Towards the end of twentieth century, the disadvantages of holding huge inventories have been increasingly identified, particularly because of its adverse impacts on supply chain and on collaborative responsiveness. Figure 1 represents the uncertainties that affect the inventory control policies.

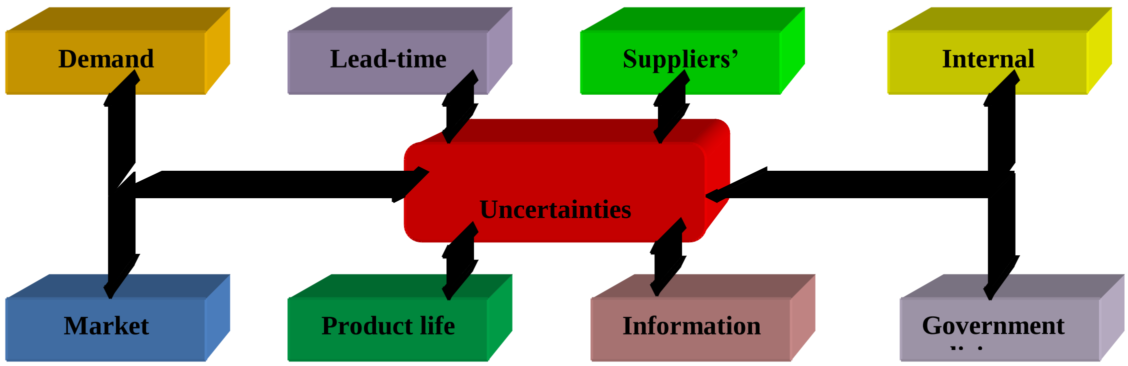

Figure 1: Uncertainties affecting inventory control

To reduce the impact of these inventory uncertainties, supply chain managers must first understand their sources, the targeted market size, researched feasibility outcomes and the magnitude of their impact (Tsiakis et al. 2001).

In a competitive and collaborative supply chain, number of risks exist that must be managed among the participants. Risks of unforeseen demands, lead-time, market trends, product life cycles, internal conflicts and even government policies etc. are to be compensated and managed effectively in order to ensure the customers' satisfaction e.g. suppose many retailers are selling identical products but at the time of shortage they share their product to each other. By doing so they not only overcome the uncertainties but at the same time they also minimize the risks as the transshipment costs generally remain lower than both the shortage cost and the cost of an emergency delivery from the central warehouse in the situations where transshipment time is shorter than the regular replenishment lead-time. Thus mutual collaboration mostly takes the form of lateral inventory transshipment from an outlet with a surplus of on-hand inventory to an outlet that faces a stock out (Krishnan and Rao, 1965). Professional adoption of lateral transshipment simultaneously reduces the total system cost and ensures the better services at the retailers' outlets in meeting out the best possible level of customers' satisfaction. These service levels cover the satisfied demand or the periods during which the products were delivered to the customers. The stocking locations that share their inventory in this manner are said to form a pooling group, since they effectively pool their resources to reduce the risk of shortages and provide better service at lower cost (Herer et al., 2002). A commonly used strategy to introduce this type of flexibility in the system need to be established and known as emergency lateral transshipment (ELT). Lateral transshipments are used to satisfy a demand at a location that is out of stock from another location with a surplus of on-hand inventory (Fredrik Olsson, 2008).

Auto manufacturers in India and all tiers of the supply chain have immense opportunities to enhance their entire supply chain process with the successful implementation of SCM solution. Total turnover of the Indian automobile industry is expected to grow from USD 34 Billion in 2006 to USD 122 Billion in 2016 (Ministry of heavy industries and public enterprises Government of India, 2006). The automotive industry is today a key sector of the Indian economy and a major foreign exchange earner for the country. By analyzing the Indian auto sector it has been found that the distribution system for new automobiles has remained unchanged for many years, with more emphasis on supplying customers from stock held at retailers. Despite high stocks, the performance of the supply chain has failed to meet customer expectations in terms of delivering the exact specification desired within an acceptable timescale. Vast scope exists for Indian automobile and auto component manufacturers to reduce their logistics costs with the implementation of SCM solutions. SCM solution market has been making inroads in India and it is being established widely by many automobile industries in the country, particularly manufacturing ones where inventory carrying cost is very high (Kamala and Doreswamy, 2007).

Considering the above, a model that enables to characterize optimal inventory and transshipment policy

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for n number of locations with λ products outfit by a single warehouse where stock is held to meet customers' demands is formulated. ELT technique with variable costs (holding, stock-out and effective transshipment) has been used to overcome the uncertainties of demand and lead-time. Based on this model an in-house program has been formulated and run on the actual data of an Indian based automobile manufacturing company and the results have been compared with the existing one. It has been observed that comparison indicators like stock-out quantities, surplus quantities and total associated cost have been decreased and it may also be concluded that lateral transshipment is an effective technique to strengthen the whole supply chain, to achieve better customer satisfaction and in terms of improving the service levels.

Further the paper is organized as follows. In the next section, supply chain scenario in Indian auto sector is illustrated. Section 2 covers the model assumptions, model formulation etc. while in section 3 the case study and its results has been describe. Finally, in section 4, some conclusions have been drawn.

2. MODEL FORMULATION

2.1 Assumptions used

Following assumptions have been used in the formulation of the model:

- Fixed numbers of units have been supplied to n number of retailers from central warehouse.
- λ numbers of products have been assumed at retailers' end.
- No additional quantities are transshipped from warehouse to retailers in case of stock-out.
- Emergency transshipments are only made to satisfy actual current demand and not to made build-up inventory and are assumed to be based on distance amongst retailers.
- Emergency Transshipment takes place on the same day.
- Any demand that is not satisfied after transshipment is considered as stock-out.
- Model allows complete pooling between retail outlets for λ numbers of products.
- The retailers have variable holding, stock-out and effective transshipment costs per unit amongst them.
- Holding and shortage costs are based on a retailers' ending day inventory level.
- Model assumes periodic review inventory control policy.
- Normally distributed random demand and lead-time have been assumed.
- Demand and lead-time at every retail outlet are independent of other's demand and lead-time.

Based upon the above mentioned assumptions the model has been formulated as under:

2.2 Mathematical Description

We shall be interested primarily in the control of supply chain-inventory system for manufacturing industries. A more restricted objective of the control of inventory is to satisfy the customer by meeting the schedule for deliveries. Failure of deliver order on time is one principal cause of loss of business and customers. Inventories are thus a necessary part of the contemporary manufacturing environment, and they must be managed if profits are to accrue.

The required mathematical relations for calculating the inventory levels are as follows:

a) Maximum level of inventory is given as:

$$I_{max} = (T_r + T_{Lmax})\mu_{dmean}$$

This equation is for longer lead-times and moderate demand fluctuations (more than 6 days) and if the span of lead-time is short (1-2 days) then maximum level of inventory may be calculated as:

$$I_{max} = (T_r + T_{Lmin})\mu_{dmean}$$

Similarly for the cases when demand is highly fluctuating then maximum level of inventory may be calculated as:

$$I_{max} = (T_r + T_{Lmax})\mu_{dmax}$$

Where T_r ,T_{Lmax}, T_{Lmin}, $\mu_{dmean}$and μ_{dmax} represent review period, maximum lead-time, minimum lead-time, mean demand and maximum demand respectively (Armah, http://www.warmah.com).

If different products are represented by λ then the maximum level of inventory for λ products is given as:

$$I_{max_\lambda} =(T_{r_\lambda} + T_{Lmax_\lambda})\mu_{dmean_\lambda} \text{where } \lambda = 1, 2, 3 \ldots \ldots . m$$

b) Mean demand may be calculated as:

$$\mu_{dmean} = Total\ demand/No.of\ days\ or\ periods$$

c) Demand variation of i^{th} retailer for λ products, which is based on normal distribution, may be calculated as follows:

$$\mu_{dmax}{}^{i}{}_{\lambda} = \mu_{dmean}{}^{i}{}_{\lambda} + 3\sigma_{i_\lambda} \text{and} \quad \mu_{dmin}{}^{i}{}_{\lambda} = \mu_{dmean}{}^{i}{}_{\lambda} - 3\sigma^{i}{}_{\lambda}$$

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Here i can vary from $1, 2, 3, \ldots \ldots \ldots \ldots . n$ retailers.
Where $\mu_{dmax}{}^{i}{}_{\lambda}$, $\mu_{dmin}{}^{i}{}_{\lambda}$, $\mu_{dmean}{}^{i}{}_{\lambda}$ and $\sigma^{i}{}_{\lambda}$ represents maximum, minimum, mean demand and their standard deviation of i^{th} retailer for λ products.

d) Where σ is the standard deviation and may be calculated as square root of the mean of the squares of the differences of the variate values from their mean and may be shown as:

$$\sigma = \sqrt{\sum \frac{(\mu^{i} - \mu_{dmean}{}^{i})^2}{N_T{}^{i}}}$$

e) Mean lead-time may be calculated as:

$$T_{Lmean} = Total\ lead - time/No.\ of\ days\ or\ periods$$

f) Similarly the span of lead-time of i^{th} retailer for λ products may be calculated as:

$$T_{Lmax}{}^{i}{}_{\lambda} = T_{Lmean}{}^{i}{}_{\lambda} + 3\sigma^{i}{}_{\lambda} \text{ and } T_{Lmin}{}^{i}{}_{\lambda} = T_{Lmean}{}^{i}{}_{\lambda} - 3\sigma^{i}{}_{\lambda}$$

g) Different retailers are having different capacity to hold maximum inventory due to individual constraints. So

$$I^{i}_{max_\lambda} = (T^{i}_{r\lambda} + T_{Lmax}{}^{i}{}_{\lambda})\mu_{dmean}{}^{i}{}_{\lambda}$$

h) When inventory level touches or falls below reorder level i.e. $I^{i} \leq Q_R{}^{i}$, then an order is placed. Reorder level is used as a trigger or flag to set up a new order. To calculate the reorder level, the firm will need to know how much time it takes for its supplier to deliver a new order. So, reorder level may be calculated as:

$$Q_{R}{}^{i}_{\lambda} = T_{Lmean}{}^{i}{}_{\lambda}\, \mu_{dmean}{}^{i}{}_{\lambda}$$

Sometimes when lead-time is very short in that case reorder level may also be considered as safety stock which is equal to:

$$Q_{S}{}^{i}_{\lambda} = T_{Lmin}{}^{i}{}_{\lambda} \mu_{dmin}{}^{i}{}_{\lambda}$$

And for highly fluctuating demands it is:

$$Q_{R}{}^{i}_{\lambda} = T_{Lmean}{}^{i}{}_{\lambda}\, \mu_{dmax}{}^{i}{}_{\lambda}$$

i) To calculate the quantity ordered by the retailer i, in-transit inventory is also considered. Therefore ordered quantity may be calculated as:

$$Q_{o\lambda}{}^{i} = I^{i}_{max_\lambda} - (Q_{t\lambda}{}^{i} + Q_{h\lambda}{}^{i})$$

Where $Q_{t\lambda}{}^{i}$, $Q_{h\lambda}{}^{i}$ represents the in-transit and surplus inventory respectively of i^{th} retailer for λ products.
Inventory may include three main types of costs. These are the costs to carry standard inventories and safety stock i.e. holding cost, shortfall or stock-out cost and emergency transshipment cost. In general total cost also consists of the transportation cost from the central warehouse and the same is used in the present model to calculate the effective transshipment cost amongst n retailers.

j) Expected holding cost is given as:

$$C^{i}_{h_\lambda} = \sum_{i=1}^{n} \sum_{\lambda=1}^{m} c^{i}_{h_\lambda} Q_{h_\lambda}{}^{i}$$

Where $C^{i}_{h_\lambda}$, $c^{i}_{h_\lambda}$ and $Q_{h_\lambda}{}^{i}$ represents the total holding cost of retailer i for λ products, unit holding cost and total no. of holding or surplus units respectively.

k) Stock-out cost is given as: (5)

$$C^{i}_{st_\lambda} = \sum_{i=1}^{n} \sum_{\lambda=1}^{m} c^{i}_{st_\lambda} Q_{st_\lambda}{}^{i} \qquad (6)$$

Where $C^{i}_{st_\lambda}$, $c^{i}_{st_\lambda}$ and $Q_{st_\lambda}{}^{i}$ represents the total stock-out cost of retailer i for λ products, unit penalty cost and stock-out quantities respectively.

l) Expected cost of lateral transshipment is given by:

(7)

$$C^{ij}_{ts_\lambda} = c^{i}_{ts_\lambda} d_{\lambda}{}^{ij} Q^{ij}{}_{(LTS)_\lambda}$$

(Transshipment with d_{ij} minimum will be preferred)
$C^{ij}_{ts_\lambda}$, $c^{i}_{ts_\lambda}$, $d_{\lambda}{}^{ij}$ and $Q^{ij}{}_{(LTS)_\lambda}$ represents the total transshipment cost of retailer i for λ products, transshipment cost per unit per unit distance, distance between i^{th} and j^{th} retailer and lateral transshipment quantities respectively. (2a)
If C^{i} is the replenishment cost per unit for retailer i from central warehouse then effective transshipment cost between retailers i and j is given as (Herer et al., 2006):

(8)

$$\hat{C}^{ij}_{ts_\lambda} = (C^{i}{}_{\lambda} + C^{ij}_{ts_\lambda} - C^{j}{}_{\lambda})$$

So total transshipment cost from retailer i to j is

$$C^{ij}_{TS_\lambda} = \sum_{i=1}^{n} \sum_{j=1, i\neq j}^{k} \sum_{\lambda=1}^{m} \hat{C}^{ij}_{ts_\lambda}\; Q^{ij}{}_{(LTS)_\lambda} \qquad (9)$$

(15)

m) Total cost without transshipment is taken as the sum of holding and stock-out cost (Quesada-Pineda, 2010) described below:

(9a)

$$C_2 = \sum_{i=1}^{n} \sum_{\lambda=1}^{m} c^{i}_{h_\lambda} Q_{h_\lambda}{}^{i} + \sum_{i=1}^{n} \sum_{\lambda=1}^{m} c^{i}_{st_\lambda} Q_{st_\lambda}{}^{i}$$

C_2, represents the total cost without transshipment.

n) Total cost per period, with transshipment can be represented as the sum of holding, shortage and effective lateral transshipment cost (Herer et al., 2006). It can be given by the following relationship: (10)

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$$C_1 = \sum_{i=1}^{n}\sum_{\lambda=1}^{m} c_{h_\lambda}^{i}\, {Q_{h_\lambda}}^{i} + \sum_{i=1}^{n}\sum_{\lambda=1}^{m} c_{st_\lambda}^{i}\, {Q_{st_\lambda}}^{i} + \sum_{i=1}^{n}\sum_{j=1,i\neq j}^{n}\sum_{\lambda=1}^{m} \hat{C}_{ts_\lambda}^{ij}\, {Q^{ij}}_{(LTS)_\lambda} \qquad (17)$$

In this work the two costs C_1 and C_2 given by equations (16) and (17) are to be compared for every period including the whole system. Here the ordering cost measurement is excluded to make high frequency ordering feasible.

The performance of the system is analyzed on the basis of aforementioned costs and service levels which are the performance measurements set by the management closely linking the customer services. Service levels can be described in two ways demonstrated by demand service level and period service level depicting the contended customers (Thomopoulos, 2004).

Demand service level can be mathematically written as:

$$D_{SL} = \frac{\sum_{i=1}^{n} {\mu_{ds\lambda}}^{i}}{\sum_{i=1}^{n} {\mu_{T\lambda}}^{i}} \qquad (18)$$

Where $\sum_{i=1}^{n} {\mu_{ds\lambda}}^{i}$, $\sum_{i=1}^{n} {\mu_{T\lambda}}^{i}$ represents the demand satisfied by retailer i for λ products and total demand arrived respectively.

o) Period service level can be written as follows

$$P_{SL} = {N_{D\lambda}}^{i} / {N_{T\lambda}}^{i}$$

${N_{D\lambda}}^{i}$ and ${N_{T\lambda}}^{i}$ are the delivery periods and total periods for retailer i for λ products.

Above mentioned formulated model is used to develop an in-house program in C++. Programming is done in such a way that if a retailer faces shortage, will transship the material from the nearest retailer having surplus and so on. Inputs to the program are, in-hand inventory, demand faced by the retailers, respective lead-times, holding, stock-out and effective transshipment costs. Outputs are received in terms of inventory reached at particular day, surplus quantities, stock-out quantities, service levels and respective costs faced by each retailer.

3. CASE STUDY

3.1 Maruti Suzuki India Limited (MSIL)

Maruti Suzuki India Limited (formerly Maruti Udyog Limited), a subsidiary of Suzuki Motor Corporation of Japan, is India's largest passenger car company, accounting for over 50 per cent of the domestic car market. Maruti Udyog Limited (MUL), established in 1981, had a prime objective to meet the growing demand of a personal mode of transport, which is caused due to lack of efficient public transport system. As on 31st March, 2011, the company has a sales network of 933 outlets in 666 towns and cities and provides maintenance support to customers at 2946 workshops in over 1395 towns and cities in the country having inventory of items at a distribution center (DC) located in North India (http://www.marutisuzuki.com). SC practices are implemented in MSIL at higher echelons as shown in figure 2 but there is no flow of information and material amongst the lower ends (retailers' level) and retailers are not clubbed with each other through any type of transshipments. If a demand occurs at a location and there is no stock on hand, the demand is assumed to be backordered or lost. In the pull type of inventory management system that is proposed in this work, where a demand is being generated by the retailers having zero inventory, lateral transshipment between the retailers may be allowed. Also in the present distribution structure the retailers are apart by moderate distances, so transshipment may done by road and by the car itself and the cars can be delivered on the same day.

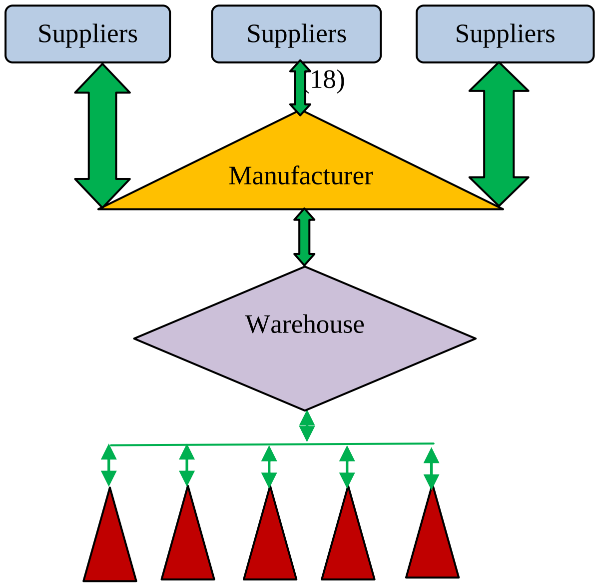

Figure 2: Investigated supply chain structure

3.2 Data used

Data has been collected from three retailers [Retailer-1-Bhiwani (B), retailer-2-Rohtak (R), retailer- 3-Sonepat (S)] spanning the months of January-April, 2009 for a particular brand, Wagon – R Duo, covering 360 demand periods deliberated as 120/ retailer. Collected data accommodates the day wise demand confronted by the retailers, daily opening stock at retailers' end and lead-time in getting the products from central warehouse. Holding cost/car/day is Rs. 118/-, stock-out cost/car is Rs. 7500/- individually for the three retailers and transportation cost/car between first and second retailer is Rs. 200/-, between second and third is Rs. 300/- and between first and third is Rs. 500/-. Transshipment cost/car from central warehouse to I, II and III retailer is Rs. 2600/-, 2500/- and 2500/- respectively.

Since retail outlets have variable demand and lead-time, they may face the problem of shortage or surplus of cars.

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However it has been observed that with lateral transshipment both holding and shortage quantity decreases thereby reducing the total expected cost. If the retail outlets do not go for lateral transshipment, they have to pay the holding cost for surplus inventory once the individual demand is satisfied, or have to pay for shortage cost if stock-out takes place. Figure 3 represents the proposed structure in which retailers are grouped together for the sharing of information and material by adopting emergency lateral transshipment policy. The difference in lateral transshipment cost between retailers is due to the variability in their mutual travelling distances. Appendix - C represents the collected data in terms of daily opening stock (In-hand inventory) and their respective demand.

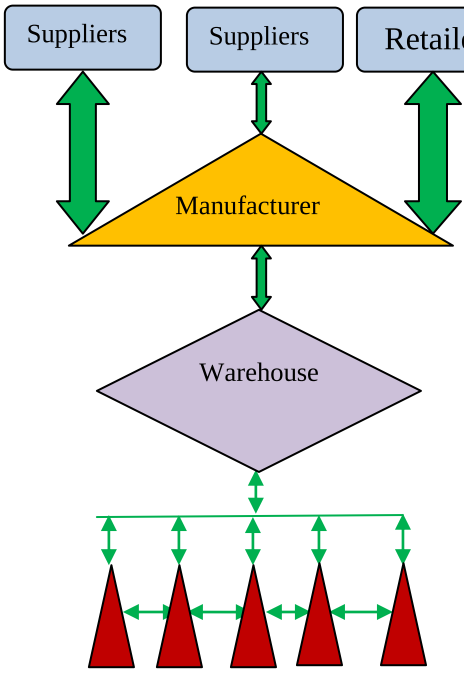

Figure 3: Proposed Supply Chain Structure

3.3 Results and discussions

Risk pooling effect, in considered supply chain is evaluated, as per mentioned relationships and mythology in earlier chapters. This supply chain is studied for inventory and related costs. To measure the performance of supply chain, demand service level and period service level are considered. For discussing the different aspects the related graphs have been generated ahead. Various facets of inventory (inventory available per period, surplus quantities and stock out quantities) will be considered, for both the cases, i.e. with transshipment and without transshipment and these aspects are analyzed for individual retailer as well as for the whole system.
Table 1 gives the observations for related parameters calculated for different inventory aspects by using formulated model. Appendix-A and table 2 represent the available inventory without transshipment and with transshipment respectively. After analyzing the response resulting from the two different strategies, with transshipment as well as without transshipment, it has been concluded that after adopting lateral transshipment, the level of surplus quantities has been affected in the form of reduction by an amount of 30, 62, 80 and 50 for the months of Jan., Feb., Mar. and Apr., 09 respectively in case of first retailer. Similar reducing effects, in surplus quantities, have been observed when this strategy was extended for the remaining retailers during same months as shown in figure 4. After having been calculated the data, for holding cost, in effect of the earlier obtained surplus quantities, significant cost reduction was found following the lateral transshipment as given in figure 5. Figure 6 shows the stock-out quantities of three retailers which have now been reduced in case of lateral transshipment, meeting the demands of more and more customers; moreover the retailers are having lesser inventories in hand, minimizing the holding cost. As the stock-out quantities are reduced, discussed earlier, this effect can be analyzed in terms of decreased stock-out cost which is given in figure 7. In figure 8 the sum of holding and stock-out cost, and the sum of holding, stock-out and effective transshipment cost have been compared for without and with transshipment respectively, as well as these costs are also shown individually and it has been found that with the incorporation of lateral transshipment, even though the effective transshipment cost is increasing yet the total cost as well as individual costs are reducing.
Also with lateral transshipment demand service level and period service level have been enhanced to a considerable amount as shown in table 3.

Table 1: Observations for related parameters (MSIL)

Calculations	Product (Wagon-R Duo)		
Retailers	**B**	**R**	**S**
Mean demand	1	1	1
Mean lead-time	4	4	4
Standard deviation for demand	1	1	1
Standard deviation for lead-time	1	1	1
Demand variation	0-4	0-4	0-4
Lead-time variation	1-7	1-7	1-7
Max. level of inventory	6	6	6
Reorder level	4	4	4

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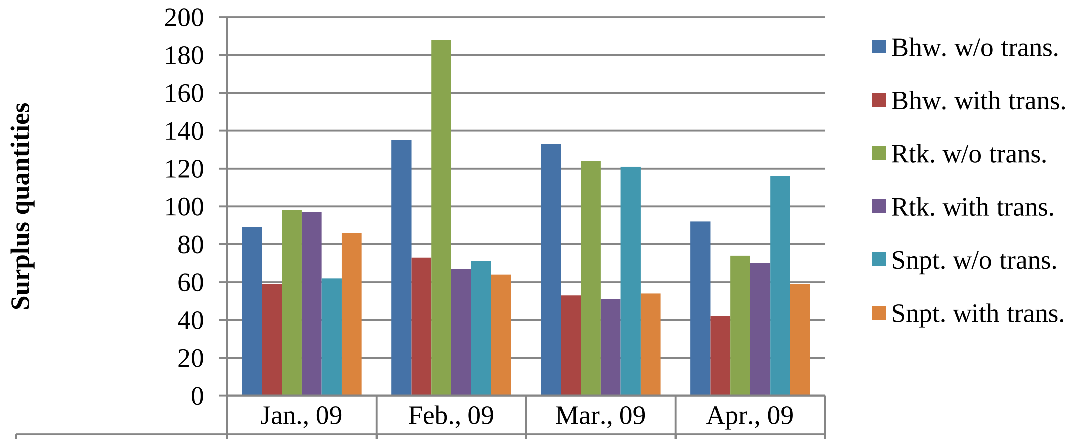
Table 2: Total inventory available with transshipment (MSIL)

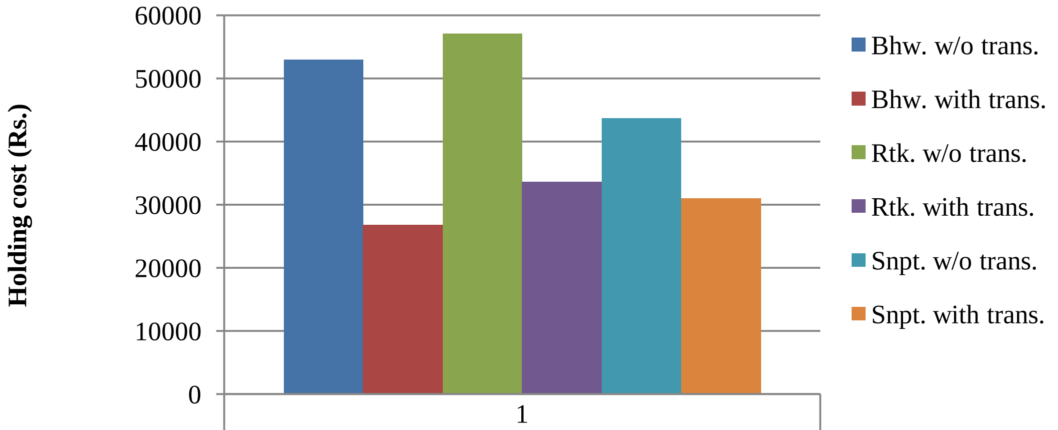
In-hand Inventory	January, 09			February, 09			March, 09			April, 09		
Day	B	R	S	B	R	S	B	R	S	B	R	S
1	4	0	0	4	3	3	3	5	5	3	4	3
2	3	0	0	4	3	2	1	4	4	2	5	5
3	1	0	6	3	6	3	0	4	3	4	3	4
4	1	6	6	3	6	1	2	4	1	2	2	4
5	1	6	5	3	6	1	2	3	0	0	0	4
6	3	5	5	4	3	0	1	0	0	0	0	3
7	2	4	5	4	3	0	3	2	2	2	0	2
8	2	6	5	4	1	3	1	2	2	0	3	3
9	1	6	4	4	1	3	1	0	4	2	2	2
10	1	5	4	4	1	3	0	0	3	3	4	1
11	1	5	3	5	4	3	2	4	0	1	4	1
12	3	5	3	4	4	3	1	3	0	1	4	3
13	4	4	2	2	5	3	4	2	0	3	4	2
14	4	4	3	2	2	6	3	3	0	2	3	2
15	3	4	1	1	2	5	1	2	3	2	4	2
16	1	4	1	1	0	5	0	2	6	3	4	2
17	1	4	1	2	0	3	2	0	3	1	2	2
18	3	5	3	4	0	1	2	2	1	1	2	2
19	3	5	2	1	4	1	1	2	1	0	2	1
20	1	4	4	1	4	1	4	3	1	0	4	3
21	3	2	4	0	5	1	4	1	0	3	2	2
22	3	2	4	2	4	3	3	2	3	4	3	2
23	2	2	2	2	3	4	3	0	4	4	2	3
24	0	0	2	5	2	4	5	0	4	3	2	2
25	2	2	4	5	2	4	4	0	3	3	2	2
26	2	4	4	5	2	4	4	3	3	2	3	4
27	2	4	3	4	4	4	3	3	3	4	3	2
28	4	3	5	4	3	6	3	4	4	3	5	2
29	6	3	3				2	4	4	3	5	3
30	6	3	3				4	4	4	2	5	2
31	6	3	3				3	4	3			



	Jan., 09	Feb., 09	Mar., 09	Apr., 09
Bhw. w/o trans.	89	135	133	92
Bhw. with trans.	59	73	53	42
Rtk. w/o trans.	98	188	124	74
Rtk. with trans.	97	67	51	70
Snpt. w/o trans.	62	71	121	116
Snpt. with trans.	86	64	54	59

Retailers

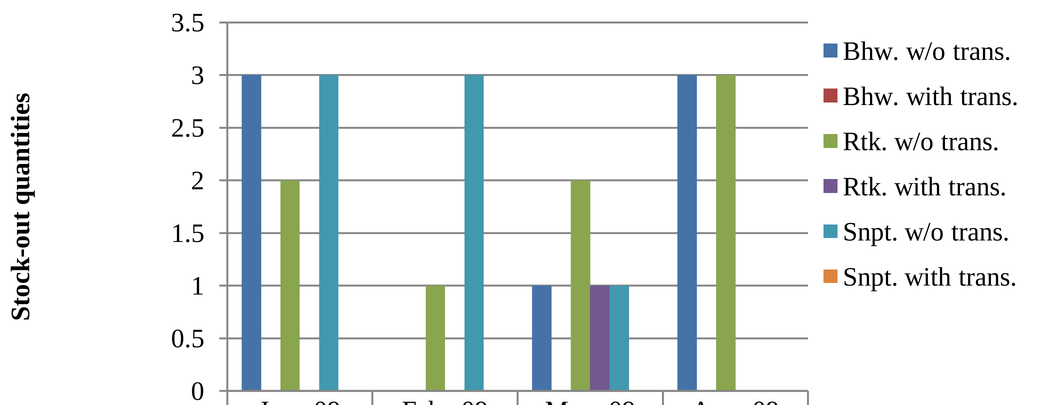
Figure 4: Surplus quantities with and without transshipment (MSIL)



	1
Bhw. w/o trans.	52982
Bhw. with trans.	26786
Rtk. w/o trans.	57112
Rtk. with trans.	33630
Snpt. w/o trans.	43660
Snpt. with trans.	31034

Retailers

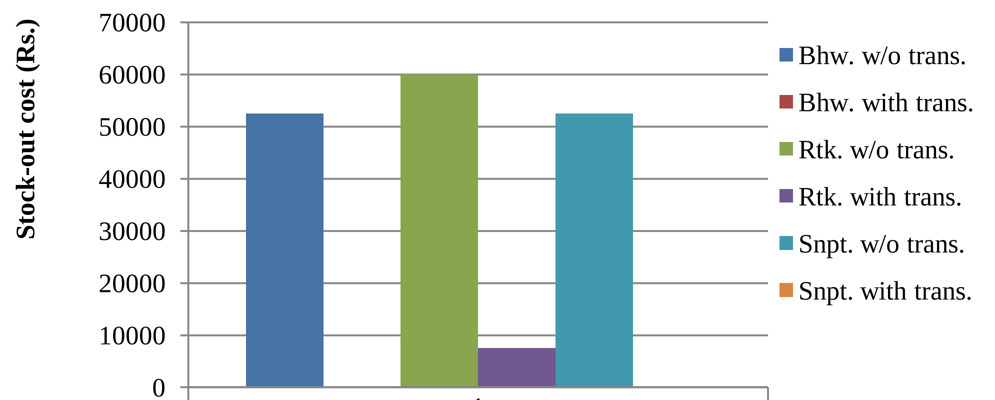
Figure 5: Holding cost with and without transshipment (MSIL)



	Jan., 09	Feb., 09	Mar., 09	Apr., 09
Bhw. w/o trans.	3	0	1	3
Bhw. with trans.	0	0	0	0
Rtk. w/o trans.	2	1	2	3
Rtk. with trans.	0	0	1	0
Snpt. w/o trans.	3	3	1	0
Snpt. with trans.	0	0	0	0

Retailers

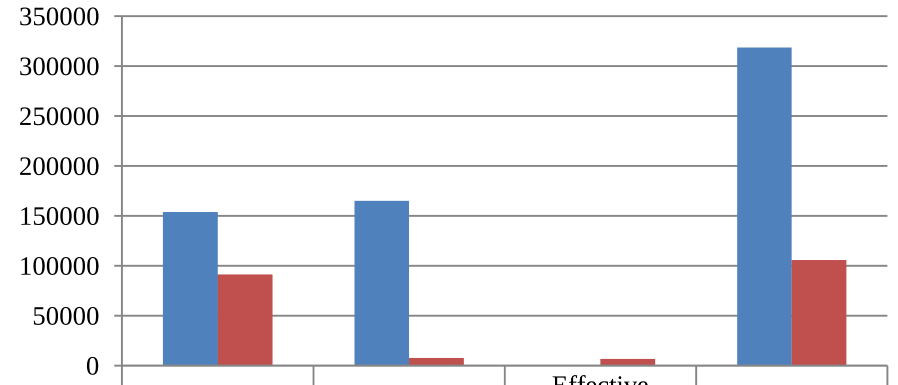
Figure 6: Stock-out quantities with and without transshipment (MSIL)



	1
Bhw. w/o trans.	52500
Bhw. with trans.	0
Rtk. w/o trans.	60000
Rtk. with trans.	7500
Snpt. w/o trans.	52500
Snpt. with trans.	0

Retailers

Figure 7: Stock-out cost with and without transshipment (MSIL)



	Holding cost (Rs.)	Stock-out cost (Rs.)	Effective transship ment cost (Rs.)	Total cost (Rs.)
Without transshipment	153754	165000	0	318754
With transshipment	91450	7500	6800	105750

Figure 8: Comparison of holding, stock-out, effective transshipment and total cost with and without transshipment (MSIL)

Table 3: Service levels with and without transshipment (MSIL)

Retailers	Demand service level		Period service level	
	Without transshipment (%)	With transshipment (%)	Without transshipment (%)	With transshipment (%)
Bhiwani	90	100	94	100
Rohtak	89	99	93	99
Sonepat	89	100	94	100

4. CONCLUSIONS

In this work, a multi-location inventory system has been considered where transshipments are allowed as recourse actions in order to reduce the costs of surplus or shortage inventory once demand is realized. Uncertainties like demand and lead-time have direct impact on managing inventories and managers are facing great difficulties while controlling these parameters. Emergency lateral transshipment technique with variable transshipment cost is used to overcome these uncertainties.

The results indicate that, from a managerial standpoint, the notion of lateral transshipments appears to have substantial appeal. If the benefits of avoiding retail level shortages outweigh the additional delivery costs resulting from transshipments, customer service may be enhanced significantly, without the burden of additional safety stocks. The future work in this area may include supply sources from two or more than two resources, lateral transshipment may be done up to reorder level, unidirectional transshipment may be done and suppliers with finite inventories may be explored. So it may be concluded that by using lateral transshipment transportation cost is increased, yet it is a better approach than a policy of no transshipments because total cost associated is less and better customer satisfaction may be achieved with available inventory by overcoming the uncertainties of demand and lead-time.

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REFERENCES

[1] Ansari, A., Modarress, B., 1990. Just-in-Time Purchasing. Free Press, New York.

[2] Armah William. Efficient management of inventory. http://www.warmah.com

[3] Axsäter Sevn, 2005. A simple decision rule for decentralized two-echelon inventory control. International Journal of Production Economics 93-94, 53-59.

[4] Chandra Charu, Kumar sameer, 2001. Enterprise architectural framework for supply-chain integration. Industrial Management and Data Systems 101 (6), 290-303.

[5] Choi, T.Y., Hong, Y., 2002. Unveiling the structure of supply network: Case studies in Honda, Acura, and DaimlerChrysler. Journal of Operations Management 20, 469-493.

[6] Eric Sucky, 2005. Inventory problem in supply chains: A bargaining problem. International Journal of Production Economics 93-94, 253-262.

[7] Fredrik Olsson, 2008. Optimal policies for inventory systems with lateral transshipments. International Journal of Production Economics, 1-10.

[8] Guillen, G., Mele, F.D., Bagajewicz, M.J., Espuna, A., Puigjaner, L., 2005. Multiobjective supply chain design under uncertainty. Chemical Engineering Science 60, 1535-1553.

[9] Herer Yale T., Tzur Michal, Yucesan Enver, 2002. Transshipments: emerging inventory recourse to achieve supply chain leagility. International Journal of Production Economics 80, 201-212.

[10] Herer Yale T., Tzur Michal, Yucesan Enver, 2006. The multilocation transshipment problem. IIE transactions 38, 185-200.

[11] Huang, G.Q., Lau, J.S.K., Mak, K.L., 2003. The impacts of sharing production information on supply chain dynamics: A review of the literature. International Journal of Production Research 41, 1483-1517.

[12] Kamala, T.N., Doreswamy, A.G., 2007. Strategies for Enhancing Competitiveness of Indian Auto Component Industries. Indian Institute of Management Kozhikode.space.iimk.ac.in/bitstream/2259/478/1/215-220+.pdf

[13] Krishnan, K., Rao,V., 1965. Inventory control in N warehouses. Journal of Industrial Engineering 16, 212-215.

[14] "Maruti Suzuki's Network". Marutisuzuki.com. http://www.marutisuzuki.com/ Maruti-Suzuki-sales-in-March-011.aspx. Retrieved 2011-04-22.

[15] Ministry of Heavy Industries & Public Enterprises Government of India, (2006). Draft automotive mission plan. dhi.nic.in. http://www.dhi.nic.in/ draft automotive_ mission_plan.pdf (retrieved 26.11.2009).

[16] Musalem Eric Porras, Dekker Rommert, 2005. Controlling inventories in a supply chain: A case study. International Journal of Production Economics 93-94, 179-188.

[17] Quesada-Pineda Henry, 2010. Lean inventory management in the wood product industry: Examples and applications. Virginia Tech (www.ext.vt.edu) 1-8.

[18] Quinn, F.J., 1997. Team up for supply chain success. Logistics Management 36, 39-41.

[19] Rhonda, R. Lummus, Robert, Vokurka, J., 1999. Defining supply chain management: a historical perspective and practical guidelines. Industrial Management and Data Systems 99 (1), 11-17.

[20] Thomopoulos, Nick T., 2004. Demands, backorders, service levels, lost sales and effective service level. International applied business research, annual conference proceedings, Puerto Rico, 1-5.

[21] Tsiakis, P., Shah, N., Pantelides, C. C., 2001. Design of multi-echelon supply chain networks under demand uncertainty. Industrial Engineering in Chemical Research 40, 3585.

[22] Zelbst Pamela J., Green Jr Kenneth W., Sower Victor E., Reyes Pedro, 2009. Impact of supply chain linkages on supply chain performance. Industrial Management and Data Systems 109 (5), 665-682.

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APPENDIX – A

Total Inventory Available and Demand without Transshipment (Maruti Suzuki India Limited)

Day	In-hand Inventory			Demand				In-hand Inventory			Demand				In-hand Inventory			Demand				In-hand Inventory			Demand		
Jan., 09	B	R	S	B	R	S	Feb., 09	B	R	S	B	R	S	Mar., 09	B	R	S	B	R	S	Apr., 09	B	1.1.1.1 R	S	B	R	S
1	4	0	0	0	1	0	1	4	7	4	0	0	1	1	6	10	6	2	1	1	1	4	5	5	1	1	0
2	4	0	0	1	0	1	2	4	7	3	1	0	2	2	4	9	5	1	0	1	2	3	4	5	0	2	1
3	4	0	2	0	0	0	3	3	8	1	0	0	2	3	3	9	4	0	0	2	3	3	2	4	2	1	0
4	4	1	2	0	0	1	4	3	8	0	0	0	0	4	7	9	2	0	1	1	4	1	1	4	2	2	0
5	4	1	1	1	1	0	5	3	8	2	1	2	0	5	7	8	1	1	1	2	5	3	2	4	0	0	1
6	3	0	3	1	1	0	6	5	9	2	0	0	0	6	6	7	3	0	2	0	6	3	2	3	0	1	0
7	2	1	3	2	0	0	7	9	9	2	0	1	1	7	6	5	3	2	0	0	7	3	1	5	0	2	1
8	0	1	3	1	0	1	8	9	9	1	0	0	2	8	4	5	5	0	2	1	8	3	4	4	1	0	1
9	3	2	2	0	1	0	9	9	10	0	0	0	0	9	7	3	4	1	1	0	9	2	4	3	1	1	1
10	3	2	4	0	0	1	10	9	10	0	1	0	0	10	6	2	4	0	2	1	10	1	3	2	2	0	0
11	3	2	3	0	0	0	11	8	10	2	1	0	0	11	6	0	3	1	1	0	11	4	3	4	0	0	0
12	3	2	3	1	1	1	12	7	11	2	2	1	0	12	5	4	5	0	0	1	12	4	3	4	0	0	1
13	2	1	2	0	0	1	13	5	10	3	0	3	0	13	5	4	4	1	0	1	13	4	5	3	1	1	0
14	2	4	1	1	0	1	14	5	7	3	1	0	1	14	4	4	6	2	1	0	14	3	4	5	0	1	0
15	1	4	3	2	0	0	15	4	7	2	0	2	0	15	2	5	6	1	0	0	15	3	3	5	2	0	0
16	0	5	3	0	0	0	16	5	5	2	2	0	1	16	1	5	6	2	2	1	16	1	3	5	2	2	0
17	6	5	3	0	1	0	17	3	5	1	0	0	2	17	4	3	6	0	0	2	17	6	3	5	0	0	2
18	6	4	4	0	0	1	18	3	5	4	1	2	0	18	4	3	4	1	0	0	18	6	3	3	1	0	1
19	6	4	3	2	1	1	19	2	3	4	0	0	0	19	3	5	4	0	1	0	19	5	3	4	0	0	0
20	4	3	2	2	1	0	20	2	3	4	1	1	0	20	3	4	4	0	2	1	20	5	3	4	0	2	1
21	2	6	3	0	0	0	21	3	2	4	0	1	1	21	7	2	5	1	1	0	21	5	1	3	1	1	0
22	2	6	3	1	0	2	22	3	1	3	0	1	1	22	6	1	5	0	2	1	22	4	0	3	0	1	1
23	1	6	1	2	2	0	23	6	0	5	0	1	0	23	6	3	4	0	0	0	23	3	2	6	1	0	1
24	0	4	2	0	0	0	24	7	6	5	0	0	0	24	6	3	4	1	0	1	24	4	2	5	0	0	0
25	0	7	2	0	0	0	25	7	11	5	0	0	0	25	5	5	3	0	0	0	25	4	5	5	1	1	0
26	6	7	2	0	0	1	26	7	11	5	1	0	0	26	5	5	6	1	0	0	26	3	4	5	0	0	2
27	6	7	1	0	1	0	27	6	11	7	0	1	0	27	4	5	6	0	2	1	27	3	4	5	1	0	0
28	6	6	1	0	2	2	28	7	10	7	1	0	1	28	6	3	5	1	0	0	28	6	4	5	0	0	0
29	6	4	4	0	0	0								29	5	3	5	0	0	0	29	6	4	7	1	0	1
30	6	7	4	0	0	0								30	5	5	6	1	0	1	30	5	4	6	0	1	0
31	6	7	4	2	0	0								31	4	5	5	0	0	0							