Inventory Control In Supply Chain Through Lateral Transshipment – A Case Study In Indian Industry

Dharamvir Mangal mangaldharamvir1@rediffmail.com

Assistant Professor/ Mechanical Engineering Department
MD University Rohtak
TITS, Bhiwani, 127021
Haryana, India

Pankaj Chandna pchandna08@gmail.com

Associate Professor/ Mechanical Engineering department
NIT, Kurukshetra, 132119
Haryana, India

Abstract

Supply chain management emphasizes collaborative relationships between supply chain members. The purpose of this work is to examine the antecedents of retailer - retailer partnership and to explore its impact on the supply chain performance. We consider coordination among stocking locations through replenishment strategies that take explicitly into consideration transshipments, transfer of a product among locations at the same echelon level. A continuous review inventory system has been adopted, in which lateral transshipments are allowed. In general, if a demand occurs at a location and there is no stock on hand, the demand is assumed to be backordered or lost. Lateral transshipments serve as an emergency supply in case of stock out and the rule for lateral transshipments is to always transship when there is a shortage at one location and stock on hand at the other. The aim is to explore the role of lateral transshipment to control inventory and associated cost within supply chain and, from this, to develop an exploratory framework that assists understanding in the area. A simple and intuitive model is presented that enables us to characterize optimal inventory and transshipment policies for 'n' locations. The research is based on a case study of a bi-wheeler company in India by using its data and to strengthen its supply chain. This paper represents such an effort in that it integrates both inventory and transshipment components in the study of multi-location inventory systems. This work will enable the managers to overcome the uncertainties of demand and lead-time resulting into customer satisfaction and cost reduction.

Keywords: Inventory control 1, Supply chain management 2, Lateral transshipment 3

1. INTRODUCTION AND LITERATURE REVIEW

In the last couple of decades, the numbers of products offered to the market have generally exploded. At the same time, the product life-time has decreased drastically. The combination of these two trends leads to increased inaccuracy of the demand forecasts, leading to firms facing an increased demand uncertainty resulting the increase in inventory levels. The role of inventory as a buffer against uncertainty has been established for a long time. However, more recently, the disadvantages of holding inventory have been increasingly recognised, particularly with regard to the adverse impact that this may have on supply chain responsiveness. Increasing globalisation has tended to lead to longer supply lead-times, which, by conventional inventory control theory, result in greater levels of inventory to provide the same service levels (Waters, 2002) [1]. In lean supply chain thinking, inventory is regarded as one of the seven "wastes" and, therefore, it is considered as something to be reduced as much as possible (Womack and Jones, 1996) [2]. Similarly, in agile supply chains, inventory is held at few echelons, with goods passing through supply chains quickly so that companies can respond rapidly to exploit changes in market demand (Christopher and Towill, 2001) [3]. There have been various supply chain taxonomies based on these concepts and most stress the need for inventory reduction within each of the classifications. Biju Kr. Thapalia et al., 2009 [4], covered the geographical risks for inventory strategies and their impact on supply chain with the help of a case study. F.T.S. Chan and H.K. Chan, 2009 [5], proposed an information sharing approach in multi echelon supply chains to convey exact information regarding inventory to the upstream level and simulation approach is used to test the effectiveness of proposed work. However, there has been some concern about the true costs of inventory and whether companies do in fact recognise these fully. For example, Christopher, (2005) [6] highlighted costs such as storage, obsolescence, damage, deterioration, shrinkage, insurance and management costs, as well as the more traditional cost of capital. With an incorrect assessment of inventory costs, there is the danger that companies may make inaccurate supply chain trade-offs in this respect and, therefore, hold too much inventory (Lee and Billington, 1992) [7].

Interest in the concept of supply chain management has steadily increased since the 1980s when companies saw the benefits of collaborative relationships within and beyond their own organization. The concept of supply chain is about managing coordinated information and material flows, plant operations, and logistics. It provides flexibility and agility in responding to consumer demand shifts without cost overlays in resource utilization. The fundamental premise of this philosophy is; synchronization among multiple autonomous business entities represented in it. That is, improved coordination within and between various supply-chain members. Increased coordination can lead to reduction in lead times and costs, alignment of interdependent decision-making processes, and improvement in the overall performance of each member as well as the supply chain. Kishore K. Pochampally et.al., 2009 [8] evaluated the performance of a reversed closed loop supply chain with numerical example. Supply chain management (SCM), which is also known as a logistics network (Simchi-Levi et al., 2003) [9] has been extensively studied in recent years. The logistical network consists of facilities and distribution options that perform the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. SCM encompasses the management of all these (process) activities associated with moving goods from raw materials through to the end user. SCM coordinates and integrates all of these activities into a seamless process. It embraces and links all of the partners in the chain. For this reason, successful SCM is the process of optimizing a company's internal practices, as well as the company's interaction with suppliers and customers, in order to bring products to market more efficiently.

As we know that firms can no longer effectively compete in isolation of their suppliers and other entities in the supply chain. A typical structure of a divergent inventory system is number of locations which replenish from a central supplier. Due to demand uncertainty inventory investments can be very high in such supply chain systems. A commonly used strategy to introduce flexibility in the system is to establish transshipment links between locations at the same echelon. This means that locations at the same echelon in some sense share inventory. Transshipments, the monitored movement of material between locations at the same echelon, provide an effective mechanism for correcting discrepancies between the locations' observed demand and their available inventory. As a result, transshipments may lead to cost reductions and improved service without increasing system-wide inventories. Lateral transshipments between stocking locations are used to enhance cost efficiency and improve customer service in different ways. There are basically two main approaches to capture the impact of transshipments between stocking locations. Within the first approach, transshipments are used after the demand is observed but before it is satisfied. If there is excess demand at some of the stocking locations while some have surplus inventory, lateral transshipments between stocking locations can work as a correction mechanism. Moreover, pooling the stocks can be viewed as a secondary source of supply for inventory shortages, especially when transshipments between stocking locations are faster and less costly than emergency shipments from a central depot or backlogging of excess demand. An alternative way of analyzing the impact of transshipments between stocking locations is to consider it as a tool to balance inventory levels of stocking locations during order cycles. To guarantee a certain level of customer service in all stocking locations, it is desirable to keep the inventory position at each location in balance relative to each other.

In our current research, we focus on collaborative planning and replenishment policy via lateral transshipment between retailers as a way to improve both cost and service.By allowing transshipments among locations better customer service can be achieved with retained inventory levels. We have recently witnessed an increasing use of transshipment, mainly as a result of better integration of the retailers participating in a distribution network. Normally, in divergent inventory systems, installations at some lower echelon replenish stock from a central warehouse at some upper echelon. The main benefit often associated with transshipments is balancing inventory levels at the various locations through emergency stock transfers. One of the first papers which mentioned the transshipment problem was Clark and Scarf, (1960) [10]. However, they ignored the problem due to the mathematical complexity. In another early paper, Krishnan and Rao, (1965) [11] developed a periodic review, single-echelon model in which they allow transshipments between the lower echelon stock facilities. Gross, (1963) [12] considered a transshipment model where it is assumed that both ordering and transshipments are made before demand is realized. Some papers which present results on optimality are Das, (1975) [13], Robinson, (1990) [14], Archibald et al., (1997) [15], Herer and Rashit, (1999) [16]. Das, (1975) [13] considered a two-location, single-echelon, and single-period problem with periodic review. The main contribution of Das is the opportunity to transfer stock in the middle of a period. He derives optimal transfer and ordering rules by using stochastic dynamic programming, and shows that the so-called complete pooling policy is optimal. Robinson, (1990) [14] studied a multi-period and multi- location problem where transshipments between locations are possible. Under the assumptions of negligible transshipment and replenishment lead times, he demonstrates the optimality of the order-up-to policy. However, analytical results are only found in the two-location case. In the general case, Robinson suggests a heuristic solution method. Archibald et al., (1997) [15] examined an inventory system much related to Robinson, (1990). One difference is that in Archibald et al. Paper transshipments can be made at any time during the period. They formulate the problem as a Markov decision process, and allow emergency orders from the external supplier if transshipment from another location is not possible. Herer and Rashit, (1999) [16] studied transshipment with fixed and joint replenishment costs, but only with single period. Minner and Silver, (2005) [17] considered a distribution system with two identical locations, in which lateral transshipments are allowed. The rule for lateral transshipments is, however, not optimized. They assume that all unsatisfied demand after transshipments is lost, and develop heuristics in order to being able to evaluate costs.

In developing country like India, there has been a growing trend of realisation of supply chain optimisation. Rapid surge in global sourcing of auto components has also become a challenge for Indian manufacturers and suppliers although sourcing has reduced the cost of production substantially. 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. By exploring Indian automobile sector, it has been found that uncertainties like demand and lead time have direct impact on managing inventories and managers are facing great difficulties while controlling these parameters. Customer satisfaction and cost reduction are again the key issues to be handled effectively and efficiently. Retailers in the supply chain face great uncertainty regarding consumer demands. If retailers that require long replenishment lead times from suppliers are located closer to each other, a lateral transshipment policy can be used as an effective alternative to minimizing total cost. Although transportation cost is increased, lateral transshipment is known as a better approach than a policy of no transshipments. The contribution of this paper is twofold. Firstly, we formulate a model that is simpler and more intuitive. Secondly, due to the simplicity of the model we are able to gain analytical insight into problems of higher dimensions than has been achieved earlier, i.e., problems with ‘n’ locations and general cost parameters. In this work, emergency lateral transshipment technique with variable transshipment cost is used to overcome these uncertainties. Variable transshipment cost, amongst retailers, is due to difference of distances between the retailers. In India as the retailers are apart by moderate distances so no additional transportation facility is required rather transshipment is done by road and by the vehicle itself. Model allows complete pooling between retailers. Each retailer faces normally distributed random demand pattern, demand at every retail outlet is independent of other’s demand. Lead-time is also normally distributed and independent of other retailer’s lead-time. All retailers are following periodic review policy. Based on this model, the programme has been formulated in C++. A case study has been done on an Indian automobile (bi-wheeler) manufacturing company. The formulated programme is being run on company’s actual data and the response is compared with existing results of the company. Finally, it has been observed that comparison indicators like backorder quantity, surplus quantity and total associated cost have decreased drastically and it has been 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.

2. MODEL FORMULATION

We consider an inventory system of a bi-wheeler manufacturing company in India that operates multiple retailers for the sale of bi-wheelers. The system uses a periodic-review, centralized inventory control policy. Each day, the retailers order replenishment bikes based on the total inventory available and reorder point. The external demand at each retailer comes from independent customers for the bi-wheelers.

1. Model Assumptions

The model we study assumes that central warehouse supplies a fixed quantity of units to the retailers and not allows transshipping more quantity, in case of stock-out in a particular period. If surplus quantity is remained after fulfilling the demand, retailer will hold it. Transshipment will be applied to respond to spot shortages so that if a retailer experiences a stock-out, the same will be transshipped from a nearest retailer with an adequate supply. During this practice the replenishment time is assumed to be zero or it is assumed that transshipment takes place instantaneously. Any demand that is not satisfied after transshipment is backlogged. The sequence of events in any period is delivery, demand, review, transshipment, and order. For computational tractability, the system is approximated by aggregating demand daily and allowing for a single transshipment opportunity at the end of the day right after the daily inventory review. We note this may be a limiting assumption since in practice transshipments might be used anytime during the review cycle as opportunities arise. Model allows complete pooling between retail outlets. The retailers have identical unit costs of shortage per period, holding and variable transshipment cost between any two retailers. This variable transshipment cost is due to the difference of distance between adjacent retailers.The model we study assumes that holding and shortage costs are based on a retailers' ending inventory level.

2. General Model with Emergency Transshipments

To minimize cost and inventory in a supply chain, a model has been formulated which considers a supply chain inventory system having one central warehouse or distribution centre with a very large capacity, serving to 'n' numbers of retailers with variable transshipment cost amongst the retailers.. Each retailer faces normally distributed random demand pattern, demand at every retail outlet is independent of other's demand. Lead-time is also normally distributed and independent of other retailer's lead-time. All retailers are following periodic review policy. Using this model an in-house programme has been formulated in C++ to study and to solve the existing problem of minimizing inventory and also the total associated cost.

Relationships of different costs and, different inventory policies are given as per following description. Inventory is checked at the end of every single period and if inventory is less than or equal to reorder level quantity then an order is placed. Maximum level of inventory is given as $I =$ *(Review Period + Mean Lead*

*Time)*Mean Demand or* $I = (R_p + M_l)M_d$ and reorder level is given as per following relation. $R_o =$ *Mean Lead Time*Mean Demand or* $R_o = M_l\, M_d$. When inventory reaches at reorder level or below this level, an order is placed. Here in transit inventory is also included, to calculate the ordered quantity by retailer *i*. Hence ordered quantity can be calculated as per following relation, $O_{qi} =$ *Maximum Level of Inventory – (In transit Inventory + Surplus Inventory)* or $O_{qi} = I - (Q_{in} + O_{ri})$. Surplus quantity of previous day is held by retailer. Thus total inventory for sale in particular period is given as, $I_{ti} =$ *Surplus inventory of previous day + Inventory reached that day to retailer i* or $I_{ti} = P_i + O_{ri}$. In this work applicable cost function includes holding, shortage and lateral transshipment costs, so expected cost for holding or surplus is given as, $R(CS) = \sum_{i=1}^{n}$ *Unit holding cost * surplus quantity of retailer i* or

$$R(CS) = \sum_{i=1}^{n} U_s S_i \tag{1}$$

Expected cost of shortage is given as $R(CB) = \sum_{i=1}^{n}$ *Unit penalty cost * Stock out quantity of retailer i or*

$$R(CB) = \sum_{i=1}^{n} U_p S_{oi} \tag{2}$$

and expected cost of lateral transshipment is given by $R(CL) = \sum_{i=1, j=1, i\neq j}^{i=n, j=n}$ *Unit transshipment cost*transshipment quantity from retailer i to j* or

$$R(CL) = \sum_{i=1, j=1, i\neq j}^{i=n, j=n} U_t O_{ri} \tag{3}$$

$U_t = A_{ij}\, b$, where A_{ij} is the distance between retailers i and j and b is unit distance travelling cost. In case of, without transshipment expected cost will be sum of expected holding cost and expected stock out cost. It can be written as following. $R_2(C)$ = *Expected Holding Cost + Expected Stock-Out Cost* or $R_2(C) = R(CS) + R(CB)$ or

$$R_2(C) = \sum_{i=1}^{n} U_s S_i + \sum_{i=1}^{n} U_p S_{oi} \tag{4}$$

Now expected cost per period, with transshipment, will be sum of expected holding cost, expected shortage cost, expected lateral transshipment cost. It can be given by following relationship. $R_1(C)$ = *Expected Holding Cost + Expected Shortage Cost + Expected Lateral Transshipment Cost* or $R_1(C) = R(CS) + R(CB) + R(CL)$ or

$$R_1(C) = \sum_{i=1}^{n} U_s S_i + \sum_{i=1}^{n} U_b S_{oi} + \sum_{i=1, j=1, i \neq j}^{i=n, j=n} U_t Q_{ij} \qquad (5)$$

In this study, the ordering cost is not considered due to elimination of the effect of order batching. In this way, small batch sizes with high frequency ordering will be possible and, thus, effect of existence of large batch sizes arising from ordering costs is removed. The performance of system is measured by expected cost and service level. Service level can be shown in two ways. These are, demand service level and period service level. Demand service level (D_{SL}) gives better idea of satisfied customer. But when previous day's unsatisfied customer demand, does not affect next day's demand, then Period service level (P_{SL}) can be used to measure the performance.

Demand service level can be mathematically written as

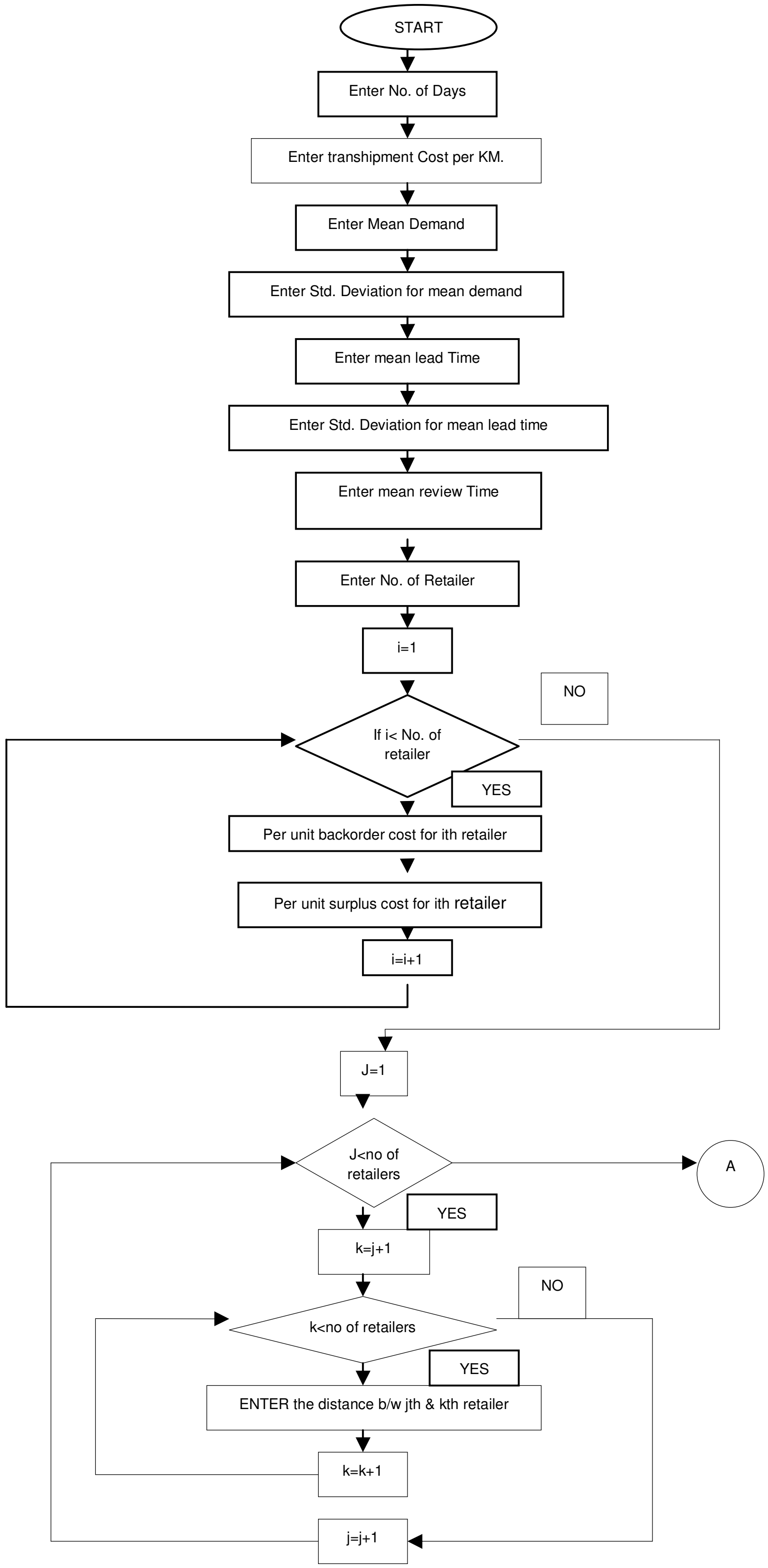
D_{SL} = 1 – Total stock out quantity/Total demand or

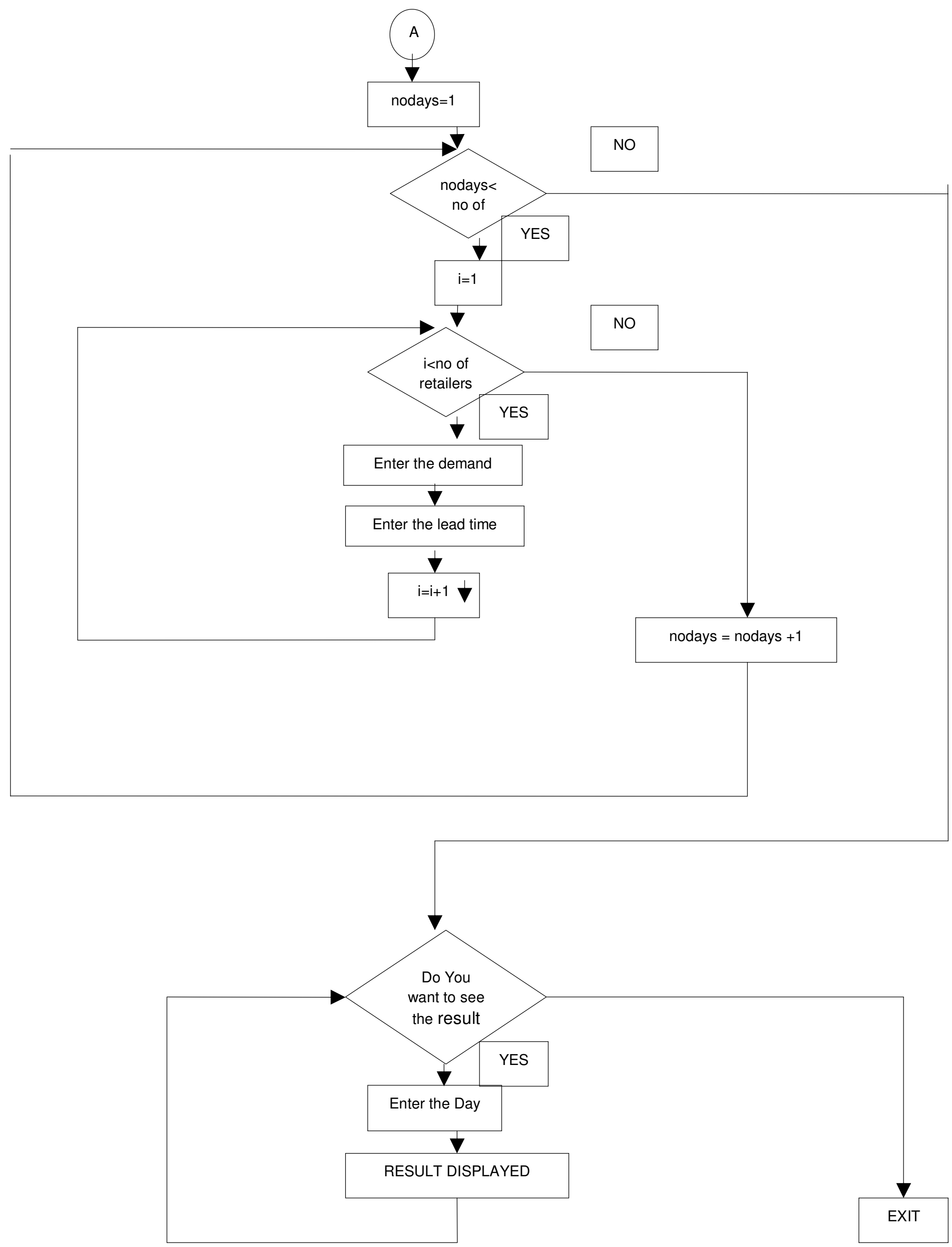
$$D_{SL} = 1 \quad \frac{\sum_{i=1}^{n} S_o}{\sum_{i=1}^{n} D_i} \qquad (6)$$

Period service level can be written as follows

P_{SL} = 1 - Total no. of stock out periods / Total no. of periods or $P_{SL} = 1 - {}^{N_o}/_{N_t}$ (7)

We can use these relations to measure the service level of the system. Above mentioned formulated model is used to develop an in-house programme in C++. The formulated programme is now implemented on a case study as explained in section 3. Flow chart of the algorithm is as under.


START
Enter No. of Days
Enter transhipment Cost per KM.
Enter Mean Demand
Enter Std. Deviation for mean demand
Enter mean lead Time
Enter Std. Deviation for mean lead time
Enter mean review Time
Enter No. of Retailer
i=1
If i< No. of retailer
NO
YES
Per unit backorder cost for ith retailer
Per unit surplus cost for ith retailer
i=i+1
J=1
J<no of retailers
A
YES
k=j+1
k<no of retailers
NO
YES
ENTER the distance b/w jth & kth retailer
k=k+1
j=j+1



3. CASE STUDY

Automobile sector is one of the emerging markets in India and presently lateral transshipment is being less exercised at retailers' level in their supply chain structure. As inventory management and customers' satisfaction are the key areas in modern industrial sector, the same problems are also being faced by the supply chain managers.

We consider a company that manufactures bi-wheelers in India. The company keeps inventory of items at a distribution centre (DC) located in North India. It has a sales network of 498 outlets, and provides maintenance support to customers at 1500 workshops. Beside this company has 1400 rural outlets in towns with population 0f 25000 and below. As shown in Figure 1 the company opts supply chain strategies at different echelons but not on the lower side i.e. at retailers end. Retailers are not grouped with each other through any type of transshipment. In the pull type of inventory management system that is proposed in this work, where a demand is being generated by the retailer when having zero inventories, 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 vehicle itself and it can be delivered on the same day.

This data collection has been made for the months of January, 2009 to June, 2009 by the authors. The data is collected for one brand for 900 demand periods (180 each) for 5 retailers. Collected data represents the day wise demand faced by the retailers, daily opening stock at retailers' end and following cost parameters. Holding cost per bike is Rs. 12/-per day, backorder cost is Rs. 900/- per bike and transportation cost per bike per kilometre is Rs. 0.80/-. Distance between retailers varies from 50 to 120 kilometres. Since retail outlets have variable demand and lead time, they face shortage or surplus. However with lateral transshipment both holding and shortage quantity decreases thereby reducing the total expected cost. If the retail outlets do not consider for lateral transshipment, they have to pay the holding cost for surplus inventory once the individual demand is satisfied and have to pay for shortage cost, if stock-out take place. Figure 2 represents the proposed structure in which retailers are grouped together for the sharing of information and material by adopting lateral transshipment. For each retailer constant holding cost, shortage cost and variable transshipment costs have been considered. The variability in transshipment cost is due to the differences of distances between retailers. Transshipment between retailers is made in such a way that if a retailer faces backorders he does transshipment from nearest retailer and onwards.

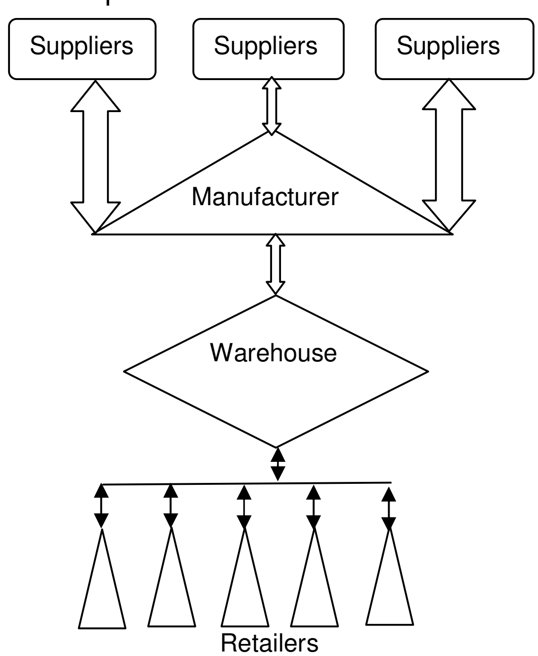


FIGURE 1: Investigated Supply Chain Structure

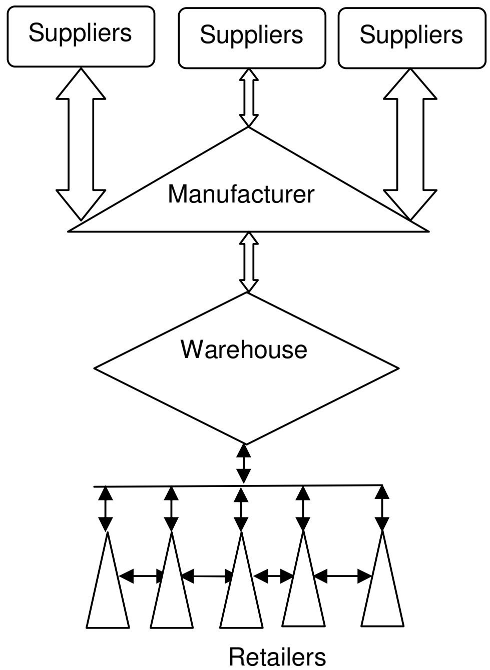


FIGURE 2: Proposed Supply Chain Structure

Ordering strategies and lead times are also taken into account. The developed programme is run on actual data of the bi-wheeler manufacturing company and the outcome has been compared with existing one.

4. RESULTS AND DISCUSSIONS

Emergency lateral transhipment technique, in considered supply chain structure is evaluated by making a comparison between the company's existing results and those which are obtained after the programme implementation. Figure 3 shows the comparison of surplus inventory at retailers' end without transshipment and with transshipment. It has been found that surplus stock without transshipment for 900 (Jan. 09 to Jun. 09) demand periods is 1545, 1312, 1374, 1624, 1488 and 1564 while with transshipment the stock is reduced to 788, 680, 808, 1152,1057 and 926 respectively.

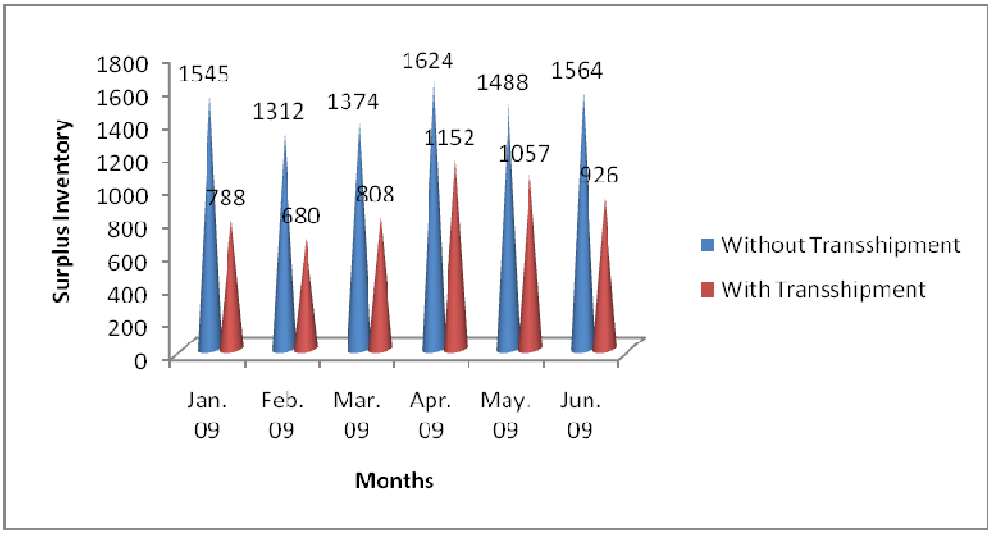


FIGURE 3: Comparison of surplus inventory with and without transshipment

Backorder quantities are also calculated in both the cases as shown in Figure 4 and it has been observed that with the use of lateral transshipment not even a single customer was backordered during the six months duration and without transshipment the numbers' of undelivered customers were 104 which reflects that by the use of lateral transshipment more customers are satisfied even with lesser inventories in hand.

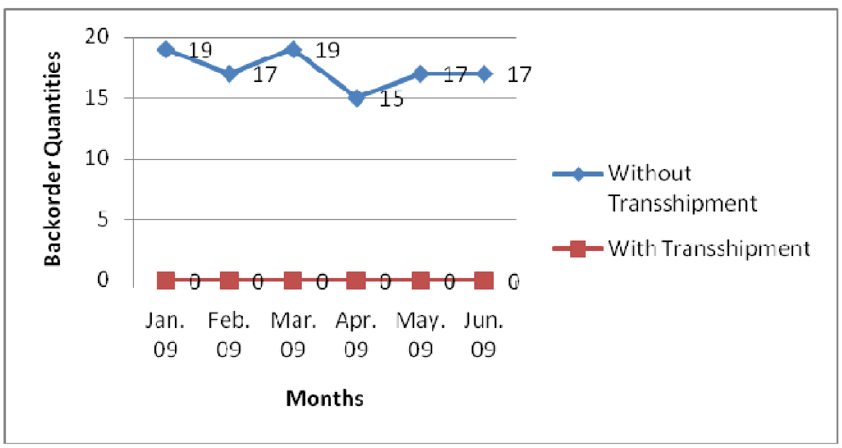


FIGURE 4: Comparison of backorder quantities with and without transshipment

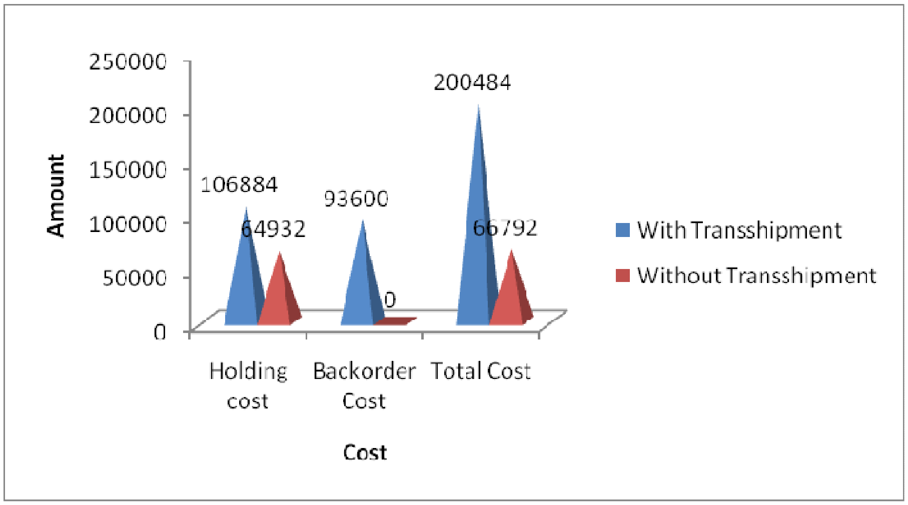


FIGURE 5: Comparison of holding, backorder and total costs with and without transshipments

As shown in Figure 5 similar effects have been obtained in regards to the holding and backorder costs. By using lateral transshipment holding cost has been reduced up to Rs. 64932/- and zero backorder cost as all the demands are fully satisfied. On the other hand these costs were found to be Rs. 106884/- and Rs. 93600/- when there is no lateral transshipment. Further total cost has been reduced to Rs. 66792/- from Rs. 200484/- even with the addition of transshipment cost of 104 bi-wheelers. Also with lateral transshipment demand service level and period service level has been enhanced from 0.9 and 0.75 to 1.0 and 1.0 respectively. Based on the results, this work has examined, from a cost-parametric perspective, the relative effectiveness of a transshipment approach in supply chain network, characterized by a single supply source at the higher echelon and multiple retail locations at the lower. Finally it has been observed that comparison indicators like backorder quantity, surplus quantity and total associated cost have decreased while using emergency lateral transshipment policy.

5. CONCLUSIONS

In this work, a multi-location inventory system is considered where transshipments are allowed as recourse actions in order to reduce the costs of surplus or shortage inventory after demands are realized. Based on the results, this work has examined, from a cost-parametric perspective, the relative effectiveness of a transshipment approach in supply chain network, characterized by a single supply source at the higher echelon and multiple retail locations at the lower. Our transportation network formulation has enabled us to gain analytical insight into problems of higher dimensions than has been achieved earlier.Furthermore, a number of simplifying assumptions such as zero lateral shipment lead-times, infinite supplier inventories, etc. are made here. In this paper a model has been formulated for one central warehouse serving to ‘n’ retailers. Emergency lateral transshipment technique is used for controlling inventories and associated costs for all the retailers and finally it has been found that surplus quantities and stock-out quantities are less in case of lateral transshipment, so holding cost and back order cost are decreased. For comparative purpose, a case study is solved by using their methodology and by implementing the collected data in the programme developed. Our 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. Finally, we suggest that the issue of emergency shipments from one or more other supply sources be examined in future work in this area.

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