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LATERAL TRANSHIPMENT-A TECHNIQUE FOR INVENTORY CONTROL IN MULTI RETAILER SUPPLY CHAIN SYSTEM

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Utilizing emergency lateral transshipments between retailers to meet customer demand can be an effective means for companies to improve service levels and/or reduce costs in a supply chain. In this work, with the help of a model developed we examine the cost effects of lateral transshipment approaches in a supply chain network, with a single supply source and multiple retail locations. The retailers, who possibly differ in their lead time and demand parameters, may be coordinated through emergency lateral transshipments, that is, movement of a product among the locations at the same echelon level due to shortage of material. 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. However, in this work, lateral transshipments serve as an emergency supply in case of stock out. The transshipment rule is to always transship when there is a shortage at one location and stock on hand at the other. An important finding is that lateral transshipment approach is considerably superior to a policy of no such transshipments in terms of cost reduction albeit at the expense of increased transportation activity. Furthermore, with the help of model developed and by solving the example problem, finally we observed the benefits of lateral transshipment in terms of improvement in customer service level and overcoming the uncertainty of demand and lead-time.

Keywords: Supply Chain Management; Inventory Management; Lateral Transshipment.

1. Introduction

The increasing competitive pressures in the global marketplace have brought supply chain into the forefront of the business practices. Supply chain management has increasingly become an inevitable challenge to most companies to be continuously survived and prospered in the global chain-based competitive environment. Supply chain management is concerned with the coordination and integration of key business activities undertaken by an enterprise, from the procurement of raw materials to the distribution of the final products to the customers. It is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed as the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements. Supply chain management covers the products and information flow between the supply chain members. These products are becoming more complex, have a greater variety of options and must be tailored to a greater number of shrinking market "niches". Many quantitative models have been constructed to prove decision support for the management of materials in supply chains and an excellent review of these models is given by [1]. One of the major issues in a supply chain is management of inventory. Supply chain inventory management is an integrated approach to the planning and control of inventory, throughout the entire network of cooperating organizations from the source of supply to the end user. Inventory usually represents from 20% to 60% of the total assets of a firm. Therefore, inventory management policies prove critical in determining the profit of such firms. For the success of supply chain, flow of material (inventory) and information should be managed properly. Besides these two, one more factor that is equally important is "relationships among supply chain members". This relationship affects all areas of the supply chain and has a dramatic impact on its performance. Moreover, the single most important ingredient for successful supply chain management may well be a trusting relationship between partners in the supply chain, where each party in the chain has mutual confidence in the other members' capabilities and actions. Relationship among supply chain members can be improved by using lateral transshipment technique. Lateral transshipment is a 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. Lateral transshipment is defined as the redistribution of stock from retailers with stock on hand to retailers that cannot meet customer demands or to retailers that expect significant losses due to high risk [2]. Lateral transshipment is a very effective tool to measure and improve service level of the entire supply

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chain or of an individual retailer [3].

Lateral transshipment can be divided into Emergency Lateral Transshipment (ELT) and Preventive Lateral Transshipment (PLT). ELT mandates emergency redistribution from a retailer with ample stock to a retailer that has reached stockout [4]. PLT reduces risk by redistributing stock between retailers that anticipate stockout before the realization of customer demands. In short, ELT responds to stockout while PLT reduces the risk of future stockout. One can think of at least six important features that should be taken into account when trying to present existing work systematically: (i) the number of locations in the pooling group, (ii) the replenishment lead time from the central warehouse, (iii) the demand process, (iv) the timing (before or after demand is observed) and consequent purpose of transshipment (preventive or emergency), (v) the reparability of stocked items, and (vi) the measure of performance (cost or service level) [2]. However, since the network of facilities that constitute the entire supply chain is typically too complex to analyze and optimize globally, it is often desirable to concentrate on smaller parts of the system so as to gain a full understanding of its characteristics, performance and tradeoffs involved. One such part that is attracting growing attention is the local distribution network, consisting of multiple retail outlets (stocking locations), which are supplied by a central warehouse or distribution center [2, 5, 6, 7]. A better distribution of available inventory among the stocking locations can be achieved by preventive transshipment that takes place before realization of the entire ordering cycle's demand [8, 9, 10]. [6] resorted to simulation in order to study the two-retailer inventory system with non-negligible replenishment lead times and unequal cost parameters. Their main finding is that complete pooling is still superior to partial pooling, i.e. transshipment policies using target and\or reserves stock levels. They also provided approximations for the expected on-hand inventories, backorders and transshipments, as well as a heuristic algorithm for determination of near-optimal order-up-to quantities complete pooling. The earliest contribution to the emergency lateral transshipment problem in which the optimal order-up-to quantities assuming that the replenishment lead-time is zero and all costs at each location are identical is derived [4, 11, 12, 13]. Earlier lot of work has been reported on PLT and now in this work ELT is used for the purpose of inventory control and for cost saving. Although not universal to all industries, there has been a general shift of power from manufacturers to retailers over the last two decades, which has resulted from a combination of factors [5]. In this work a model has been formulated considering one central warehouse catering to 'n' retailers. Model allows complete pooling between retailers. Initially mean demand, mean lead time and review period are taken as inputs to the software developed and the resulting outputs are maximum inventory level, reorder level, demand and lead time variation. Then by introducing the demand and lead time which are randomly generated for 'n' retailers for 'n' number of days in the software we are able to get in-hand inventory, surplus quantities, ordered quantities, in-transit inventory and inventory reached at a particular day for all the retailers and for all periods i.e. for complete 'n' number of days. Holding cost and backorder cost are calculated for the case when there is no transshipment and transshipment cost is added when there is emergency lateral transshipment of in-hand stock amongst the retailers for the calculation of total cost associated with 'n' retailers. Then a comparison is done for different aspects of inventory control using lateral transshipment.

By using example problem finally in this paper it has been found that by incorporating lateral transshipment transportation cost is increased, yet it is a better technique than a policy of no transshipments. Lateral transshipment is a viable approach for reducing total cost associated with all retailers and also the total inventory available, surplus inventory and stock out quantities for all retailers is less in case of lateral transhipment as compared to without transshipment as well as service levels are also improved.

2. The Model Formulation and Methodology

A model has been formulated for study and to solve the existing problem of minimizing inventory and also the total associated cost with 'n' retailers served by a central warehouse.

The model considers a supply chain inventory system having one central warehouse or distribution centre with a very large capacity, and 'n' numbers of 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.

Central warehouse supplies a fixed quantity of units to the retailers and not allow 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. In case of shortage at one retailer and availability of product at any other retailer, lateral transhipment occurs between them. Demand not satisfied after transshipment is considered as shortage. Model allows complete pooling between retail outlets. The three retailers have identical unit costs of shortage per period, holding and unit transshipment cost between any two retailers. Unit lateral transshipment cost among retailer is being very low as compared to ordering from central warehouse. Relationships of different costs and, different inventory policies are given as per following description. Relationships for service level are also discussed to measure the performance.

In this work periodic review inventory policy is considered. 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 M = (Review Period + Mean Lead Time)*Mean Demand or M = (R + l_m). Reorder level is amount of inventories such that, if inventory level touches it or fall below this an order is placed. Recorder level of inventory is given as per following relation. Rl = Mean Lead Time*Mean Demand or Rl = $l_m D_m$. 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. It is the inventory, which has, been ordered but yet could reach to retailer. Hence ordered quantity can be calculated as per following relation, Q_i = Maximum Level of Inventory – (In transit Inventory + Surplus Inventory) or Qi = M – (Q_{ti} + H_i). Surplus quantity of previous day is held by retailer. Thus total inventory for sale in particular period is given as, T_i = Surplus inventory of previous day + Inventory reached that day to retailer i or $T_i = S_i + Q_{ri}$. It is assumed that all retailers have maximum level of inventory at the start, for both the cases with transshipment and without transshipment.

Here expected cost is adopted, to measure the performance of the system. In general total cost consist of the transportation cost from the central warehouse, inventory holding cost, shortage cost and cost of emergency lateral transshipment. But transportation cost in long run, will not vary with demanded quantity and ordered quantity. Hence we take transportation cost constant for overall system. This will be independent of base stock and transshipment policy, and can be disregarded.

Thus applicable cost function include only holding, shortage and lateral transshipment cost terms, so expected cost for holding is given as, $E(CH) = \sum_{i=1}^{n}$ Unit holding cost * surplus quantity of retailer i or

$$E(CH) = \sum_{i=1}^{n} C_h H_i \tag{1}$$

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

$$E(CO) = \sum_{i=1}^{n} C_p O_i \tag{2}$$

and expected cost of lateral transshipment is given by $E(CT) = \sum_{i=1,\, j=1, i\neq j}^{i=n,\, j=n}$ Unit transshipment cost*transshipment quantity from retailer i to j or $E(CT) = \sum_{i=1,\, j=1, i\neq j}^{i=n,\, j=n} C_t X_{ij}$ (3)

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. E_1(C) = Expected Holding Cost + Expected Shortage Cost + Expected Lateral Transshipment Cost or E_1(C) = E(CH) + E(CO) + E(CT)

$$\text{or } E_1(C) = \sum_{i=1}^{n} C_h H_i + \sum_{i=1}^{n} C_p O_i + \sum_{i=1,\, j=1, i\neq j}^{i=n,\, j=n} C_t X_{ij} \tag{4}$$

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. E_2(C) = Expected Holding Cost + Expected Stock-Out Cost or E_2(C) = E(CH) + E(CO)

$$E_2(C) = \sum_{i=1}^{n} C_h H_i + \sum_{i=1}^{n} C_p O_i \tag{5}$$

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 (SL_1) 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 (SL_2) can be used to measure the performance.

Demand service level can be mathematically written as:

SL_1 = 1 – Total stock out quantity/Total demand

$$\text{or } SL_1 = 1 - \frac{\sum_{i=1}^{n} O_i}{\sum_{i=1}^{n} D_i} \tag{6}$$

Period service level can be written as follows:

SL_2 = 1 – Total No of Stock out Periods / Total No of Periods or $SL_2 = 1 - N_O/N_T$ (7)

One of the above relations can be used to measure the service level of system. Using these equations software has been developed to minimize those periods in which the suppliers are not in position to serve products to customers and it can be achieved by incorporating lateral transshipment in the model as well as in the software. The model is now implemented on an example problem as explained in section 3.

3. EXAMPLE PROBLEM

The software developed is application oriented and run on one example problem. The problem considers three retail outlets, with one central warehouse. Warehouse is far away from retail outlets, but retail outlets are very near to each other. There is variable lead time, which is according to normal distribution curve, it is considered that delay may be due to different reasons such as accidents, road blocks etc. Since retail outlets have variable demand and lead time, which are randomly generated, they face shortage or surplus. When there is no transshipment among retailers, the retailers have to pay for surplus or shortage. However with lateral transshipment both holding and shortage quantity decreases simultaneously shortage or surplus at one retail outlet is decreased or removed thereby reducing the total expected cost. If the retail outlets do not consider for lateral transshipment, they have to pay holding cost for surplus inventory that remains after the individual demand is satisfied and have to pay for shortage cost, if stock-out take place at some outlets. Here three outlets are considered to form a complete pooling group. Complete pooling means that outlet with surplus will transship, its entire surplus to fulfill the shortage at the other outlets if the surplus is less than or equal to the shortage. For each retailer constant holding cost, shortage cost and transshipment cost are assumed.

The demand for the three retailers is randomly generated for 60 demand periods of 20 each (retail outlet) cost parameters for all the retailers are assumed to be same for the entire group. Holding cost for each surplus unit is Rs. 4 per unit. Shortage at each retailer is charged with Rs. 3 per unit, and transshipment cost of the group is taken as Rs. 2 per unit. Mean demand is taken as 15 units and its standard deviation is 3, and mean of lead-time is taken 2 and its standard deviation is taken as 1. Example problem is solved for lateral transshipment as well as without lateral transshipment. Service level and total cost associated with all the retailers in both cases of transshipment and without transshipment are calculated. Now we have complete data with us and the solution is as per following steps.

4. Results and Discussions

Emergency lateral transshipment in multi retailer system has been studied. Different aspects for two cases, with transshipment and without transshipment have been compared. The comparison is made for different aspects of inventory, such as Total Inventory Available (Fig. 1), Customer Demand, Surplus Inventory, Total Cost (Fig. 2) and Stock out Quantity. To measure the performance of system as well as performance of individual retailer, the service level has also been covered.

Total inventory of all the 3 retailers for 20 days without transshipment is 1278 and with transshipment is 1231. Therefore by using lateral transshipment reduction in inventory is 47 pieces as shown in fig. 1. While comparing in cost it has been found that total cost without transshipment which is the sum of holding and shortage cost is Rs. 2771, and with transshipment that even include transshipment cost is Rs. 2489 as shown in fig. 2.

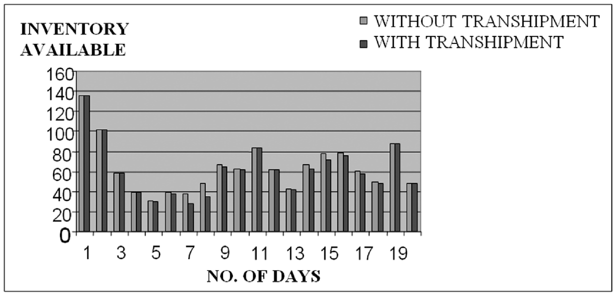

Fig. 1: Comparison of Inventory Available Per Day.

It clearly indicates that with lateral transshipment money saved within 20 days is Rs. 282. It has been found that stock out quantities with transshipment are 30 nos. less as compared to without transshipment that means 30 more customers were benefitted while adopting lateral transshipment in supply chain management. Shortage of items covered with transshipment in 20 days is 58 otherwise it would be 88 if there were no transshipment in between three retailers. Further it has been observed that surplus quantities with transshipment are 77nos. less otherwise in case of no transshipment we've to pay holding cost for these surplus quantities.

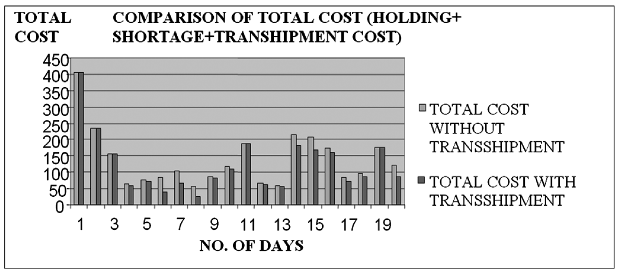

Fig. 2: Comparison of Total Cost (Holding + Shortage + Transshipment Cost)

Demand service level has been found 0.87 for without transshipment and 0.91 for with transshipment and period service level is 0.55 in the case of without transshipment and 0.8 with transshipment. So it's very much clear that lateral transshipment transportation cost is increased, yet it is a better approach than a policy of no transshipments because total cost associated is less.

5. Conclusions

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 is concluded that surplus quantities and stock-out quantities are less in case of lateral transshipment, so holding cost and back order cost are decreased. The total expected cost is less, in case of lateral transshipment than without transshipment. It is true for individual retailer, as well as group of retailers, participating in sharing of inventory in emergency. Therefore lateral transshipment is an effective tool to reduce the total system cost, as well as individual retailer's inventory cost. In case of lateral transshipment, more customers are satisfied, than without transshipment. Thus it is an effective way to satisfy the customers' demand. To make risk-pooling (lateral transshipment) strategy effective, there should be good relation among retailers. It is win-win situation to all the retailers.

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