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Influence of Lateral Transshipment Policy on Supply Chain Performance: Two Echelon Supply Chain System with Stochastic Demand Case

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Abstract

In the supply chain system we consider one supplier and two retailers which face stochastic demand (different random distribution) in the case of non-lateral transshipment (NLT) and bidirectional lateral transshipment (BLT). Model derived for measure the performance level of both NLT and BLT. By comparing the numerical result of these we conclude that lateral transshipment policy cannot effectively improve the performance of supply chain systems, even reduce system's customer demand satisfaction rate, and increase system inventory variation , in case of retailer face different random distribution demand .

Keywords: Supply chain system, Bidirectional lateral transshipment, Non-lateral transshipment.

Introduction

Lateral transshipment - *a local warehouse which provides stocked items to another local warehouse which is out of stock or to prevent out-of-stock occurrences. In other words, these local warehouses exchange their inventory on the same echelon level*. Different local warehouses can operate individually and rely on regular or emergency replenishments from the central warehouse when they are out of stock. It may however be more useful to have a quicker backup from other local warehouses as well. Lateral transshipments can be seen a form of pooling. Physically, there are multiple stock points, but they have access to each other's inventory when needed. Cost savings can be expected because of this pooling. In case a local warehouse is out of stock at the moment of a customer's request, it first tries to obtain the required parts from a neighboring local warehouse. This costs less time than an emergency delivery from the central warehouse. In many industries and service organizations, the reliance on two-echelon inventory systems for repairing and supplying recoverable items is becoming more and more prevalent. This paper focuses on discussing the two-echelon inventory system involving a central warehouse (or supplier) and multiple local warehouses (or retailers) with lateral transshipments as an option under the various inventory replenishment policies. Non-lateral transshipment and bidirectional lateral transshipment model have been derived in this paper and the better performance in both will be measured.

Model description of NLT

The relationship among the system operations describes the supply chain without lateral transshipment is follows. The system structure contains supplier and retailers. For the supplier inventory is decided by order rate of supplier (ORS) and shipment rate to retailer (SRTR). Order rate of supplier is determined commonly by order quantity of supplier (*OQS)* and order delay time of supplier (ODTS). Delivery rate of retailer (DRR) is determined by order quantity of retailer (OQR) and inventory of the supplier (IOS). Supplier adjust inventory level (SAIL) by setting desired inventory supplier (DIS) together with inventory of supplier determine inventory gap of supplier (IGS). Inventory gap of supplier and inventory adjustment rate of supplier (IARS) determine inventory gap of supplier, in turn, inventory gap of supplier has a direct impact on order quantity of supplier and an indirect impact on order rate of supplier (*ORS)*. For retailers, inventory is determined by order rate of retailer (*ORR)* and sales rate of retailer. Order rate of retailer is the delay of, shipment rate to retailer; delay time is order delay time of retailer (ODTR). Sales rate of retailer (SRR) is decided by inventory of retailer (IR) and customer demand of retailer. Average sales rate retailer is obtained from sales rate of retailer after the time of average sales rate smooth time of retailer (ASRSTR). Retailers also adjust inventory level by setting desired inventory of retailer (DIR) .Desired inventory of retailer is decided by average sales rate of retailer (ASRR) and desired inventory of retailer (DIR).DIR is decided by average sales rate of retailer (ASRR)and desired inventory cover time of supplier . DIR and inventory of retailer jointly determine inventory gap of retailer (IGR).IGR and inventory adjustment time of retailer (IATR) commonly determine (IARR). If IGR is greater than 0, retailer sent orders to suppliers, order quantity OQR is decided by average sales rate of retailer (ASRR). Inventory gap of retailer (IGR), IARR and AOQSTR determine AOQR. There are two performance variables, customer demand satisfaction rate CSRR and total inventory TI. CSRR is decided by inventory IR and customer demand CDR, TI is a accumulation sum of supplier inventory SI and IR.

Model description of NLT

The relationship among the system operations describes the supply chain with bilateral transshipment is follows.*LT21* means the transshipment from retailer 2 to retailer 1. It is a flow rate variable and means that when retailer 1 out of stock, retailer 2 will replenish retailer 1 by transshipment on condition that it has surplus stock. *LT21* is decided by *CDR* and *IR*, and influence *OQR*. *LT12* is a flow rate variable and means that when retailer 2 is out of stock, retailer 1 will replenish retailer 2 by transshipment on condition that it has surplus stock. *LT12* is decided by *CDR and IR*, and influence *OQR.*

Mathematical model formulation NLT case

The inventory dynamics equations of supplier i, is

SI (t)= SI(t-1)+dt x (ORS-SRTR1-SRTR2) ……..(1)

The inventory dynamics equation of retailer i,is

IR (t)=IR(t-1)+dt x (ORR-SRR) ……………….(2)

The average order quantity equation of retailer i

AOQR=SMOOTH (OQR, AOQSTR)…………(3)

The average sales rate equation of retailer i,is

ASRR=SMOOTH (SRR, ASRSTR)………..(4)

ORR=DELAY1 (SRTRi, ODTRi)…..(5)

ORS=DELAY1 (OQS, ODTS)………………(6)

Equation (5) and (6) are the order rate equation of suppliers and retailers, which are the delay function of the corresponding order quantities in a given period of time.

$$\mathrm{SRTR} = \begin{cases} 0 & \mathrm{SI} \le 0 \\ \mathrm{OQRi} & \mathrm{SI} > 0 \text{ and } \sum_1^2(\mathrm{OQRi}) \le \mathrm{SI} \\ \mathrm{SI}\ \mathrm{X}\left(\frac{\mathrm{OQRi}}{\sum \mathrm{OQRi}}\right) & \mathrm{SI} > 0 \text{ and } \sum \mathrm{OQRi} > \mathrm{SI} \end{cases} \quad …………….(7)$$

This equation is the supplier shipment rate to retailers.

$$\mathrm{SRRi} = \begin{cases} 0 & \mathrm{IRi} < 0 \\ \mathrm{IRi} & 0 \le \mathrm{IRi} \le \mathrm{CDRi} \\ \mathrm{CDRi} & \mathrm{IRi} > \mathrm{CDRi} \end{cases} \quad ………………………(8)$$

Equation (8) is the sales rate equation of retailer i.

Likewise an inventory equation of supplier DIS, order rate equation of supplier ORS, Inventory gap equation of supplier and retailer IGS & IGR, inventory adjustment rate equation of supplier and retailer IARS & IARR, Ordering quantity equation of supplier and retailer OQS & OQR can be derived.

The total inventory equation of the supply chain system is

$$TI=SI+\sum IRi \ldots\ldots\ldots\ldots(9)$$

Mathematical model formulation BLT case

The transshipment rate equation is

$$LT12 = \begin{cases} 0 & IR2 \geq CDR2 \text{ or } IR1 \leq CDR1 \\ CDR2 - IR2 & IR2 < CDR2 \text{ and } IR1 > CDR1 \text{ and } (IR1 - CDR1) \geq (CDR2 - IR2) \\ IR1 - CDR1 & IR2 < CDR2 \text{ and } IR1 > CDR1 \text{ and } (IR1 - CDR1) < (CDR2 - IR2) \end{cases} \ldots\ldots\ldots\ldots(10)$$

$$LT21 = \begin{cases} 0 & IR1 \leq CDR1 \text{ or } IR2 \geq CDR2 \\ CDR1 - IR1 & IR1 > CDR1 \text{ and } IR2 < CDR2 \text{ and } (IR2 - CDR2) \leq (CDR1 - IR1) \\ IR2 - CDR2 & IR1 > CDR1 \text{ and } IR2 < CDR2 \text{ and } (IR2 - CDR2) > (CDR1 - IR21) \end{cases} \ldots\ldots\ldots\ldots(11)$$

Inventory rate of retailer equation is

$$IR1\ (t)=IR1(t-1)+dt \times (ORR1-SRR1+LT21-LT12) \ldots\ldots\ldots\ldots(12)$$
$$IR2\ (t)=IR2(t-1)+dt \times (ORR2-SRR2-LT21+LT12) \ldots\ldots\ldots\ldots(13)$$

Order quantity of retailer equation is

$$OQR1=\begin{cases} 0 & IGR1 \leq 0 \text{ or } IARR1 + ASRR1 - LT21 + LT12 \leq 0 \\ IARR1 + ASRR1 - LT21 + LT12 & IGR1 > 0 \text{ and } IARR1 + ASRR1 - LT21 + LT12 > 0 \end{cases} \ldots\ldots\ldots(14)$$

$$OQR2=\begin{cases} 0 & IGR2 \leq 0 \text{ or } IARR2 + ASRR2 + LT21 - LT12 \leq 0 \\ IARR1 + ASRR1 - LT21 + LT12 & IGR1 > 0 \text{ and } IARR2 + ASRR2 + LT21 > 0 \end{cases} \ldots\ldots\ldots(15)$$

NUMERICAL EVALUATION OF NLT AND BLT

We assume the initial value of constants, AOQSTRi=1, ARSTRi=1, DICTRi=1, DICTRS=2, IATRi=1, IATS=2, ODTS=2,SI(0)=500,IR(i)=100,T=200 where T is the simulation time.

Table 1.System simulation results under different distribution of the needs

	NLT		BLT	
	Mean	Stdev	Mean	Stdev
CSRR1	0.633	0.426	0.552	0.447
CSRR2	0.618	0.442	0.557	0.450
TI	769.0258	229.2123	758.8274	240.3414

We assume retailer I face different distribution demand. Retailer 1 is subject to the Poisson distribution and retailer 2 is subject to normal distribution with the range from 50 units to 150 units. From Table1, Comparing with NLT situation, the system total inventory decreases in BLT, but slightly. By viewing the standard deviation of total inventory in two varieties of policies, we see that transshipment is not effective with the different distribution demand case. Lateral transshipment decreases the customer demand satisfaction rate in different levels, especially the BLT. In NLT and BLT mean of CSRRi are 0.633 and 0.552, respectively; mean of CSRR2 are 0.618 and 0.557, respectively. From this point, we deduce that lateral transshipment may be not compatible with the different distribution demand.

Conclusion

The two retailers are facing with the different distribution demand, even though lateral transshipment reduce total inventory of the system, but the extent is not obvious. However, it decreases the customer demand satisfaction rate of the supply chain system. The different distribution demand will make ordering and replacement becomes extremely complex. If the retailers still use a separate order-up-to policy, Lateral transshipments may becomes impossible and difficult to improve system performance.

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