**Effect of transshipment on supply chain management performance: case of two-retailer system and mono-echelon**

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**ABSTRACT**

In our paper, we studied the problem of lateral transshipment as a mode of cooperation between retailers located on the same level, to improve supply chain management.

For this, a series of simulation experiments are carried out to estimate the effect of the transshipment application, in terms of maximizing the expected average profit and minimizing the shortage rate and by estimating in our work that demand follows the Poisson law distribution**.** Partial pooling is a very interesting transshipment policy and should be explored further in future research.

Keywords: Transshipment policies, complete-pooling, Simulation, Supply Chain Management, VMI.

**INTRODUCTION**

Supplier-managed inventory is a widely used strategy successfully practiced in supply chain management, aimed at reducing costs and adding value. Suppliers manage inventory for retailers, including replenishment, delivery, and inventory management decisions for supply chains implementing VMI. And for this, the effective solution to avoid the trade-off between inventory conservation and transport efficiency is to adopt a global vision of inventory levels throughout the supply chain, starting with the purchase of raw materials. through product sale ends by delegating control of all depots, including inter-echelon shipments, to a single point. Implementing VMI could effectively help reduce the inventory level of downstream companies in the supply chain. The application of VMI thus increasing the depth of suppliers facing risks and hazards.

In this paper, we consider a single-echelon centralized inventory system with multi-retailers selling single products and facing stochastic demand that follows the Poisson law. Given the large distance between supplier and retailers, and the corresponding high fixed transportation costs, long replenishment cycles are generally used. In such situations, transporting inventory between retailers is much easier and less expensive, and can be done more frequently. In this work, we therefore explore what the cost benefits are of allowing multiple shipments between retailers during a supplier's replenishment cycle. The application of transshipment between retailers of the same level obviously involves certain costs, in particular for the handling and movement of items but it can be used as a means to deal with out of stock at an instant of time.

1. **Literature review**

The problem studied in this paper concerned decisions regarding the transshipment problem and the location of warehouses. Inventory management with transshipment is currently a very important area in research work. The main role of transshipment is to pool stocks to overcome uncertainties relating to requests arriving at sites at the same level. However, transshipment allows a continuous presence and penetration of local markets with a quick response to customer requests.

According to the literature we mainly detect two approaches to lateral transshipment. The first is that of emergency transshipment; it corresponds to the transshipment carried out following an actual stock shortage at a retailer resulting from the arrival of a random demand. The work of (Khurana,2015; Dukkanci and Kara, 2017 and Giusti et al.,2021) has analyzed this approach. The second approach is that of preventive transshipments; these correspond to a balancing redistribution of stocks at the beginning or end of each supply cycle but before demand of customers is observed. The work of (Alumur et al., 2021; Gama, 2022 and Mirhedayatian et al., 2021) has dealt with this approach. Emergency transshipment resolves an actual situation of rupture. Preventive transshipment, for its part, aims to prevent future breakups.

Works that have studied emergency transshipment are the most frequent in the literature. In this paragraph, we summarize the policies adopted in this context.

- Transshipment policies

• The all-or-nothing policy: a retailer either fully satisfies the missing customer demand or delivers nothing (Qu et al., 2019).

• Complete pooling: the retailer agrees to transfer all its available stock if necessary; in other words, he agrees to pool all his stock, without restriction (Fathollahi-Fard, et al. 2022).

• Partial pooling: transshipment is carried out while preserving a targeted stock level. We find the following variants (Yu en al, 2022):

* The retailer accepts transshipment up to the excess stock at its order point;
* The retailer accepts transshipment up to the stock in excess of its safety stock;
* The retailer accepts transshipment up to the amount of excess stock at the estimated demand for the following period.
* The decision to transship at a retailer level depends on the current stock level and the time remaining before the next supply.

**Modeling Mathematical**

We use the periodic storage policy (T,si) for each retailer *i*.

According to the research work of Sun et *al*. (2022), and according to this supply policy which consists of controlling the system at the start of each monitoring period. If, at the beginning of the elementary forecast period k, the stock position is lower than the replenishment level Sk, a quantity Qk must be ordered to bring the stock position back to the level Sk.

**Parameter**s

The notations used in this paper are as follows:

***n****: Number of retailers;*

***i****: Retailer index (counter) with i = 1, 2;*

$D\_{iT}$*: Demand during the periodicity T at the retailer i (random variable) follows the normal law* ***(***$µ\_{i}$***,***$σ\_{i}$***).****These demands are independent and identically distributed (i. i. d);*

$Q\_{i} $***:*** *The quantity of supply for the retailer i;*

***T****: Inventory position revision period, which is divided into k intervals of time of periodicity T;*

$S\_{k}$***:*** *Maximum level of stock at retailer i at the start of the supply cycle;*

$PS\_{iT}$***:*** *Stock position at retailer i at each time period T;*

$\overbar{TDG\_{i}}$: *Average Global Desservice Rate for i retailers;*

$\overbar{Π\_{i}^{G}}$***(XG***$S\_{i ,}D\_{i}$***)***: *Average Global Profit for the two retailers i, with i = 1, 2.*

***Vi****: Unit selling price for each site i, with i = 1.2.*

$C=C\_{12}=C\_{21}$*: Unit cost of transshipment whatever the direction of lateral transfer,*

$C\_{pi}$***:*** *Unit cost of shortage for such a site i.*

 ***Mathematical Function of Average Global Profit***

In this paper I focus on the influence of Transshipment policy: "Complete-Pooling" on global profit maximization.

The function of Average Global Profit for our centralized system composed of two levels and two retailers, by integrating transshipment and applying the "Complete-Pooling" policy, can be formulated by the equation 3.

$\overbar{Π}\left(X\_{G}\right)=$ E (V1 ($X\_{1}$+$X\_{21}$) + V2 ($X\_{2}$+$X\_{12}$)-C ($X\_{12}$+$X\_{21}$) - $C\_{pi}$ ($\sum\_{i=1}^{2}I\_{i}^{-}))$ **(1)**

With $X\_{G}$=$X\_{1}+X\_{2}+X\_{12}+X\_{21}$

The modeling of this Transshipment policy with the use of ARENA 16.0 software can be presented in Figure 1.



*Figure 1*. The simulation model Supply Chain: Complete-Pooling

***Assumptions***

We consider the following assumptions:

* Retailer 1 confronts a random demand independent of demands from retailer 2;
* The transshipment time is zero;
* In the case where a retailer 1 faces a stock shortage, whereas, the retailer 2 has a surplus of inventory, a transshipment of the necessary quantity $(X\_{21}) $ will take place from 2 to 1 to avoid or minimize the shortage: this is the correct transshipment (also called reactive transshipment). Otherwise depot 1 may require an emergency order of size *Q1* at the distribution center;
* In the event of "Complete-Pooling", the retailer who is in the overstock position agrees to transfer all of his available stock if necessary.

***Objective function***

The objective is to identify the most economically profitable transshipment policy for a centralized system over a finite time horizon R, by seeking the lowest possible Average Global Desservice Rate.

For this, the objective function of the "Complete-Pooling" transshipment policy will be defined in the form of the equation (5).

Max (E (V1($X\_{1}$+$X\_{21}$) + V2($X\_{2}$+$X\_{12}$)-C ($X\_{12}$ +$X\_{21}$) – $C\_{pi}$ ($\sum\_{i=1}^{2}I\_{i}^{-}))$

S/C

$X\_{12}$$\sum\_{i\ne j}^{}X\_{ij}$≤$PS\_{1T}$ , With T= R/k et k=2, 3, 4,…,10.  **(5)**

$X\_{21}$$\sum\_{i\ne j}^{}X\_{ij}$≤$PS\_{2T}$ With T= R/k et k=2, 3, 4,…,10.

$ S\_{i}\geq 1 $Strictly positive integer, ∀ i=1, 2

With

$S\_{i}$ = ($µ\_{i}$\*k+$σ\_{i}\sqrt{k}$)  , ∀ i=1, 2 and k :being the number of periodicities, avec k=2, 3, 4,…,10.

And $X\_{i}\~$N ($µ\_{i},σ\_{i}$).

**SIMULATION RESULTS**

We recall that, according to (Sun et *al*. (2022)) the initial level of replenishment for a demand that follows the normal law of mean and standard deviation, will take the form of the equation and will be calculated by applying the equation 11.

$S\_{n}^{0}$= ($µ\_{n}$\*T+$σ\_{n}\sqrt{T}$)  **(11)**

With:

 *T*: number of periods

$ µ\_{i}: $average demand during the period *T* of retailer *i,* with *i=1, 2.*

    $σ\_{i}: $standard deviation of demand of retailer *i*, with *i=1, 2.*

Table 1 shows the different measures of initial stock level of replication and for n= 2, with N: number of retailers.

Recall that the network structure considered in this paper is made up of a distribution center and two retailers, who face random and non-identical demands on average and standard deviation. We assume that the simulation length is 10 years.

We have assumed that the demand$D\_{1}$ of the first retailer follows the law N (100, 20) and that of the second retailer, $D\_{2}$ follows the law N (200,50). These demands are Independent and identically distributed *(i.i.d*).

Also, we have considered in all the examples of our research that:

* The revision period R = 30 days, (Based on (Emel and Lena, 2017));
* The unit sale price for retailer 1 equal to 95 $ and that of retailer 2 is worth 125 $,
* The unit cost of rupture whatever the site is equal to 30 $,
* The unit cost of transshipment =3 $, 0.5 $, k = 2, 3, 4,…, 10.

Table ‎1.*Determination of different measures of the initial level of replenishment*

|  |  |  |
| --- | --- | --- |
| **K** | $$S\_{1}^{0}$$ | $$S\_{2}^{0}$$ |
| 2 | 229 | 470 |
| 3 | 335 | 687 |
| 4 | 440 | 900 |
| 5 | 545 | 1112 |
| 6 | 648 | 1322 |
| 7 | 753 | 1532 |
| 8 | 857 | 1741 |
| 9 | 960 | 1950 |
| 10 | 1063 | 2158 |

Table 2.*Determination of the values of the relative improvement percentage of the Average Global Profit for a unit cost of transshipment = 3 $*

|  |  |
| --- | --- |
| **K** | **Without-transshipment / Complete-Pooling** |
| 2 | 10% |
| 3 | 12% |
| 4 | 11% |

To calculate the different percentages of relative improvement in Average Global Profit indicated in Table 2, we apply the mathematical formula 2.

**[% of Relative Improvement=** $\overbar{Π\_{i}^{G}}$**(Complete-Pooling)**$-\overbar{Π\_{i}^{G}}$**(Without-transshipment)) /** $\overbar{Π\_{i}^{G}}$**(Without-transshipment))\*100] (2)**

(This for the first column of the table while for the two transshipment policies ("Complete-Pooling" and "Partial-Pooling") we apply this formula while looking for the percentage improvement value between them).

**CONCLUSIONS AND PERSPECTIVES**

This research work aims to study the effect of collaboration in the event of an emergency by applying the transshipment policies named "Complete Pooling" between two storage sites on the overall average profit of the centralized system and at the customer service level.

The most important findings can be summarized as follows:

* Sharing stocks between sites of the same level greatly optimizes the Average Overall Profit of the entire system;
* Collaboration between sites always improves the customer's Average Overall Service Rate, that is to say the probability of cycles without disruption and the probability of customer satisfaction;

Several particularly interesting extensions of this model can be considered in future research. For example, we can emphasize the positive effect of the collaboration of the “Partial-Pooling” policy with a modification of the transshipment threshold and the use of the wider network where the number of sites exceeds both, integrating the distance between the different storage sites located at the same level.

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