Reprint ISSN 0973-9424

International Journal Of Mathematical Sciences And Engineering Applications

(IJMSEA)

@ ASCENT
ASCENT PUBLICATION
PUNE, INDIA

www.ascent-journals.com

International J. of Math. Sci. & Engg. Appls. (IJMSEA)
ISSN 0973-9424, Vol. 17 No. I (June, 2023), pp. 9-19

ON OBLIQUE TRANSFER MECHANISM OF DYNAMIC (OPERATIONAL) COMPLEXITIES IN DELIVER CHAIN SYSTEM

ROHIT KUMAR VERMA[1] AND MAMITA[2]
[1] Associate Professor, Department of Mathematics,
Bharti Vishwavidyalaya, Durg, C.G., India
[2] Research Scholar Ph.D., Department of Mathematics,
Bharti Vishwavidyalaya, Durg, C.G., India.

Abstract

Because of horizontal connections between retailers, replenishment rules, and time delays, supply chain dynamics are very complicated. This article seeks to explore the impacts of oblique transference on stability, the bullwhip effect, and other performance characteristics in a two- tiered supply chain system with one supplier and two retailers. A hybrid discrete-time state space model was specifically developed by us to support two different order placement scenarios. Through the application of analytical stability data, we found that ineffective Oblique Transference tactics readily disrupt the supply chain system. The lead times of the Oblique Transference add to the stability problem. Theoretical conclusions are tested in simulation experiments, and the influence of system parameters on performance indicators is investigated through numerical analysis. According to numerical models, latitudinal transshipped items improve both stores' customer service ratings. It's also important to remember that the needs of the two shops may still be satisfied even if only one store places orders with the upstream provider.

Key Words and Phrases : *Placement scenarios, Numerical analysis, Supply chain System.*

1. Introduction

The dynamics of a supply chain system have become more complicated as a result of several factors, such as the global economic downturn, the rise of e-commerce, and disruptive events. These traits provide serious challenges to supply chain management in uncertain environments. Analytically optimal policies that maximize the advantages for the entire supply chain system over an extended period are often extremely challenging to determine in uncertain scenarios [1]. Understanding how different factors affect the dynamic complexity of supply chain systems will be extremely helpful in choosing the parameters. One strategy for addressing demand variability and reducing the risk of stock-out is to implement collaborative programs between supply chain participants using state-of-the-art information technologies, such as Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR) [2]. In contrast to cooperative programs where products are moved from upstream to downstream, members of the same echelon may redistribute or pool a portion of inventory to lower the risks connected with demand fulfillment. To adapt to variations in demand, software tools like Oblique Transference are used to transport goods and services among sources, storage locations, and destinations [3]. But by making the horizontal link between supply chain participants more difficult, oblique transference enhances the structure and functionality of supply chain systems. Due to the dynamic complexity of a supply chain system with an oblique transference between two stores, this research adopts a complex systems method [4].

The advantages of Oblique Transference have been thoroughly documented, including how they can lower inventory costs and boost customer satisfaction. Furthermore, Oblique Transference improves supply chain system resilience in the event of inventory pooling-related disturbances. Programs for collaboration with Oblique Transference have been put into action in a variety of industries, including retail, the energy sector, and the car industry [5].

To quickly finish fixing the automobiles of their customers, auto dealers sometimes swap parts. Oblique Transference might be restricted to happen only at specific times before the full amount of demand is satisfied or they can happen whenever there is a stock shortage. We speak of the first kind of Oblique Transference is referred to as proactive transshipment, whereas reactive transshipment is the second kind. In order to disperse goods among all stocking points with the least amount of handling, proactive Oblique Transference are planned in advance. Since the reactive transshipments only address the immediate shortage and disregard the possibility of future shortages, they may be expensive or too late to redistribute products in selling products. We concentrate on proactive Oblique Transference in this research [6]. Inferring optimal or suboptimal transshipment policies as well as replenishment decisions under particular assumptions has been the main focus of the majority of the literature on Oblique Transference to date. The methodologies described in the literature can primarily be divided into four classes: simulation experiments, game theory, queuing theory and mathematical programming. These modelfs rigid underlying assumptions could make it difficult to put them into practice. For instance, the majority of the results in the body of literature already in existence are based on certain demand models, such as a particular kind of probability distribution or time series process. However, realistic demand is extremely uncertain because of a variety of circumstances, such as marketing campaigns, the economic downturn, and political developments [7]. Analyzing and solving inventory models with more grounded assumptions is challenging. Dynamic system theories, on the other hand, concentrate on how system structure affects dynamic behaviors, which are strongly related to system performance. A supply chain system is actually a dynamical system by nature because of the changeable nature of its inventory and order. The bullwhip effect, stability, and chaos are a few examples of supply chain dynamics that have drawn a lot of attention in recent years [8].

Therefore, the effects of member interactions on supply chain dynamics have also started to gain scholarly interest. For instance, in a three-tier supply chain system, examined the interactions between customers and suppliers as a result of price discount techniques. Reference investigated how customers and retailers interact, and how the inventory that merchants show influence consumer demand [9]. The results of earlier studies indicate that the dynamics of supply chain systems are extremely complex due to the interactions between upstream and downstream participants. To the best of our knowledge, no studies have examined the effects of Oblique Transference or other horizontal interactions between members of the same echelon on dynamic complexity [10].

Contribution of this paper is the analytical analysis we conducted to provide both delay-dependent and delay independent stability criteria, from which we demonstrate how

Oblique Transference impair the dynamics of supply chain systems. These theoretical findings are important for choosing parameters for both replenishment and subsequent transshipment in order to improve performance [12].

We illustrate the benefits of Oblique Transference in enhancing demand satisfaction and reducing the bullwhip effect through simulation exercises. Another intriguing finding is that even when one of the shops placed orders with the upstream supplier, the other can still better satisfy customer demand. The conclusions of the derivation are useful in offering broad suggestions for system development and operation [13] [14] [15].

2. New Work : Model Description

Think of a two-echelon supply chain system with a Oblique Transference between two merchants and one external supplier. Figure 1 shows the supply chain system's organizational structure. We assume that the two retailers routinely check their inventory at weekly or monthly intervals without losing the ability to generalize. The evaluation window could be for a week or a month. We assume that the upstream supplier's supply capacity is infinite in order to make the model linear. This common assumption in the literature is acceptable because it assumes that the external supplier is representative of all potential sources of supply.

During each period $t \in \{1, 2, 3, \cdots\}$, the chain of events that lead to the two retailers controlling their inventory is as follows. The supplier sends shipments to the two retailers at the start of each period that correspond to the order placed in the preceding period. Then, using demand forecasting to place orders with the upstream supplier, they move the inventory in accordance with a preset Oblique Transference contract. The leftover time in each period is used by the two shops to meet consumer demands; those that aren't met are pushed to the following period.

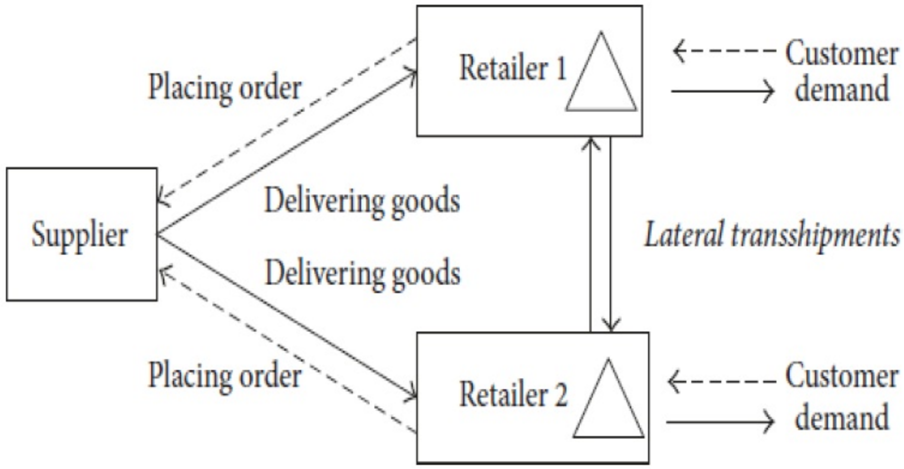


Figure : The structure of a supply chain system with Oblique Transference

We consider two different scenarios in our model: scenario ξ_1 and scenario ξ_2, where ξ_1 represents the scenario that two retailers place orders with the upstream supplier independently and ξ_2 represents the situation in which only one retailer places orders with the upstream supplier and the demand of other retailers is satisfied by only Oblique Transference. The study of the second scenario ξ_2 is motivated by our observations in electrical and PC retail industries in India.

This scenario can happen in two different circumstances: first, when a retailer tries to sell a particular new product because there may be a market for it but is unfamiliar with the distribution channels; and second, when a customer places an order for a variety of items from a retailer but some of the items are not on the retailer's selling list. The customer can instruct a retailer to buy everything in order to save time on shopping at several stores. The shop can leverage Oblique Transference in either scenario to increase sales and keep customers. The key benefit of the second scenario is the decrease in ordering and inventory costs.

The Main Notations and Symbols section is a list of the notations utilized in this study. First, we'll create a state space model using difference equations to represent the previously described event sequence. To index the ith retailer, we need the variables.

For determining the inventory level, the difference equation is expressed as

$$Ii(t+1) = Ii(t) + Oit) + Li(t) - Di(t), \tag{1}$$

Where (t) is the inventory level, (t) is the customer demand, and $L(t)$ is the amount of Oblique Transference received by retailer i. The sign of (t) indicates the direction of the inventory movement. It always satisfies

$$Sign(L_1(t)L_2(t)) = -1 \text{ or } sign(L_1(t)L_2(t)) = 0,$$

in which

$$Sign(x) = \left\{ \begin{array}{ccc} 1 & if & x > 0 \\ 0 & if & x = 0 \\ -1 & if & x < 0 \end{array} \right\} \quad (2)$$

$$L_i(t) = \varphi L[I_j(t-r) - I_i(t-r)], \quad (3)$$

in which φL is the parameter to determine the magnitude of Oblique Transference? Specifically, there are no Oblique Transference between the two retailers if $\varphi L = 0$. Conversely, the two retailers fully swap their inventory with $\varphi L = 1$. Thus, we can make the assumption $0 \leq \varphi L \leq 1$.

The exponential smoothing technique is used by the two merchants to forecast demand for each upcoming period because it is excellent at making short-term predictions. This algorithm is expressed as

$$F_i(t+1) = (t) + \theta_i[D_i(t) - F_i(t)], \quad (4)$$

where the parameter i is the smoothing coefficient and $F_i(t)$ is the predicted amount. The features of Consumer demand should be used to establish the smoothing coefficient. For instance, for steady demand, small values of θ_i are optimal, whereas for volatile demand, big values may be preferable.

Remember that in the first situation, each store takes responsibility for placing their own orders, whereas in the second scenario, only retailer 1 does so with the upstream provider. The two retailers' respective inventory policies are depicted as follows in the first scenario:

$$O_i(t) = F_i(t) + \rho_i[IT_i - I_i(t)], \quad (5)$$

In the second situation, only retailer 1 decides whether to reorder products based on the systematic inventory, which is the product of the inventory levels of the two retailers: $S_I(t) = I_1(t) + I_2(t)$. In accordance with this, retailer 1's inventory policy is displayed as

$$O_1(t) = F_1(t) + F_2[Si(t) - I_1(t)], (6)$$

we create a unified state model for the two scenarios based on the aforementioned difference equations by replacing the inventory policies (5) or (6) into the balanced inventory equation (1). Define $w(t) = [D_1(t), D_2(t)]$ as the input vector and $x(t) = [F_1(t), F_2(t), I_1(t), I_2(t)]$ as the state vector.

Assign $S = \{\xi_{1,2}\}$ as the set of possibilities. Following that, a unified state space model is created as

$$x(t+1) = A\xi x(t) + B\xi x(t-r) + C\xi w(t) + D\xi, \tag{7}$$

in which $\xi \in S$ and

$$A\xi_1 = \begin{pmatrix} 1-\theta_1 & 0 & 0 & 0 \\ 0 & 1-\theta_2 & 0 & 0 \\ 0 & 1 & 1-\rho\rho & 0 \\ 0 & 1 & 0 & 1 \end{pmatrix}$$

$$A\xi_2 = \begin{pmatrix} 1-\theta_1 & 0 & 0 & 0 \\ 0 & 1-\theta_2 & 0 & 0 \\ 0 & 1 & 1-\rho & -\rho \\ 0 & 1 & 0 & 1 \end{pmatrix}$$

$$B_{\xi_1} = B_{\xi_2} \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -\varphi_L & \varphi_L \\ 0 & 0 & \varphi_L & -\varphi_L \end{pmatrix}$$

$$C_{\xi_1} = C_{\xi_2} = \begin{bmatrix} \theta_1 & 0 \\ 0 & \theta_2 \\ -1 & 0 \\ 0 & -1 \end{bmatrix}.$$

$$D_{\xi_1} = \begin{bmatrix} 0 \\ \\ 0 \\ \rho_1 I_1^T \\ \\ \rho_1 I_1^T \\ \\ \rho_2 I_2^T \end{bmatrix}.$$

$$D_{\xi_2} = \begin{bmatrix} 0 \\ 0 \\ \rho SI^T \\ 0 \end{bmatrix}.$$

Performance Measures, section Oblique Transference play a significant part in the transfer of inventory to merchants, which has significant impact on system performance. The average total inventory cost (TIC), average total ordering cost (TOC), average Oblique Transference cost (LC), customer service level for the two stores (SL_i), and the bullwhip effect metric (BW) will all be taken into account in this study. In the sections that follow, we'll define these measures.

The average total inventory cost (TIC), which includes stock-out costs and inventory holding costs

$$TOC = \frac{\sigma 2i = 1\Sigma NT = 1\{ch[Ii(t) - Di(t)] + cb[Ii(t) - Di(t)]\}}{N}$$

Where N is the length of the simulation, *ch* is the holding cost per unit, and *cb* is the stock-out cost per unit.

The supply chain system's average ordering cost is calculated using

$$SLi = \frac{1 - \Sigma Nt = 1 sign[Di(t) - Ii(t)]}{N}.$$

The period number of stock-outs is recorded using the sign function. If we can meet client demand during the majority of the simulated periods, it means that we can raise the service level for the two retailers.

According to the bullwhip effect, demand fluctuations are amplified as one climbs up a supply chain from downstream to upstream. We examine the bullwhip effect in this study because inventory redistribution can change how people order things. The bullwhip effect for our models quantified by the order variance to demand variance ratio, which is denoted as

$$BW = \frac{\Sigma 2i = 1\ var(Oi)}{\Sigma 2i\ var(Di)}.$$

3. Elements Investigation

In this section, we analyze the dynamic complexities of the state space model in two scenarios ξ_1 and ξ_2 with the following two steps.

Analyze the steady states of the inventories of the two shops in Step 1 because these are what ultimately determine the equilibrium points because of how supply chain participants interact. The outcomes of the steady state analysis are crucial for selecting the ideal system's parameters. However, because unstable systems show different behaviors, such analysis is only applicable to stable systems.

4. Determine the Two Scenarios' Stability Requirements

The parameters $\rho_1, \rho_2, \rho, \varphi L$ and r are chosen in light of the theoretical findings in Section 3. The results of testing a total of nine simulation designs are displayed in Table 1.

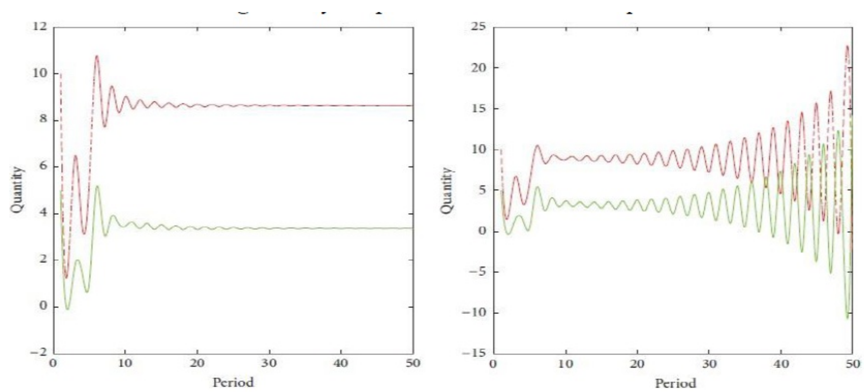
We established the inventory goals for the two stores based on the demand and lead time hypotheses.

Table 1: Reattachment plans for strength approval.

Scenario	ρ_1	ρ_2	ρ	φL	r
ξ_1	1.4	1.3	-	0.1	0
ξ_1	1.4	1.3	-	0.2	0
ξ_1	0.7	1.1	-	0.3	1
ξ_1	0.7	1.1	-	0.1	11
ξ_1	0.7	0.5	-	0.2	1
ξ_1	0.7	0.5	-	0.3	11
ξ_2	-	-	0.5	0.10	4
ξ_2	-	-	0.5	0.10	5
ξ_2	-	-	0.5	0.10	6

The pooling of the resources has the additional benefit of when the demands of the two retailers are adversely connected, inventory is more obvious. Secondly, increasing the parameter $\theta_1 = \theta_2 = 0.2$. Incurs high Oblique Transference cost, especially for the case $\theta_1 = th_2 = 1$.

This is brought on by the parallel increase in Oblique Transference.



Order of retailer 1 Order of retailer 1

Order of retailer 2 Order of retailer 2

(a) $\rho_1 = 1.4$, $\rho_2 = 1.4$, $\varphi_L = 0.1$ (b) $\rho_1 = 1.4$, $\rho_2 = 1.4$, $\varphi_L = 0.2$

Figure : Solidness approval

5. Conclusions

The goal of this essay is to look into the supply chain system's dynamic complexity in an oblique transference setting. The horizontal transshipments between two merchants, in addition to the lead time and replenishment operations, provide the framework of the complete system. In terms of system performance and stability, these inventory rules lead to numerous feedback loops and sophisticated dynamic systems. Two different scenarios are put into a state space model that we developed to understand the complexities of such a system.

Using the state space model, we looked at the stable state of the supply chain system and came up with analytical stability requirements. The stability results demonstrate that Oblique Transference worsens the system dynamics compared to traditional supply chain systems. If the amount of oblique transference rises, especially if such oblique transference has a long lead time, a supply chain system may become unstable. In the second instance, we found the intriguing finding that the needs of the two stores might still be satisfied even if only one shop placed orders with the upstream provider. We have used simulation experiments and a step signal required to validate our theoretical conclusions. We selected a variety of parameter settings to emphasize the advantages of oblique transference based on the stability findings.

References

[1] Amrani H., Khmelnitsky E., Optimal division of inventory between depot and bases, Naval Research Logistics (NRL), 64(1) (2017, 3-18.

[2] Chen A., Federgruen F. and Zhen S., Coordination mechanisms for a distribution system with one supplier and multiple retailers, Management Science, 47(5), 693-708.

[3] Disney S., Supply chain aperiodicity, bullwhip and stability analysis with Juryfs inners, IMA Journal of Management Mathematics, 19(2) (2020) 101-116, 2008.

[4] Glaze Brook K., Paterson C., Rauscher S., Benefits of hybrid Oblique Transference in multi-item inventory systems under periodic replenishment, Production Engineering Research and Development, 24(2) (2018), 311-324.

[5] Huang G., Wang J., Chen C., System resilience enhancement: Smart grid and beyond, Frontiers of Engineering Management, 4(3) (2017), 271.

[6] Hoberg K., Thonemann U. W.,Analyzing the effect of inventory policies on the no Stationary performance with transfer functions, IIE Transactions, 39(9) (2019).

[7] Jury I. E., Theory and Application of the Z-Transform Method, Econometrical, 33(4) (2016), 884, 1965.

[8] Lee H. L., Amulti-echelon inventory model for repairable items with emergency Oblique Transference, Management Science, 33(10) (2021), 1302-1316.

[9] Liu F., Song J. S. and Tong J. D. Building Supply Chain Resilience through Virtual Stockpile Pooling, Production Engineering Research and Development, 25(10) (2016), 1745-1762.

[10] Ouyang Y. and Daganzo C., Characterization of the bullwhip effect in linear, time- Invariant supply chains: some formulae and tests, Management Science, 52(10), 1544-1556.

[11] Paterson C., Kiesm Nuller, G., Glaze brook, K., Inventory models with Oblique Transference: a review,European Journal of Dynamic Research, 210(2) (2022), 125-136.

[12] Wei Y., Wang H., The impact of stock-dependent demand on supply chain dynamics, Applied Mathematical Modeling: Simulation and Computation for Engineering and Environmental Systems, 37(18-19) (2021), 8348-8362.

[13] Wu Y. and Zhang D.J., Demand fluctuation and chaotic behavior by interaction between customers and suppliers, International Journal of Production Economics, 107(1) (2021), pp.

[14] Zhang S., Li S., Zhang S., Zhang M., Decision of lead-time compression and stable operation of supply chain, Complexity, Art. ID 7436764 (2017).

[15] Zhang S., Hou Y., Zhang S., Zhang M., Fuzzy control model and simulation for nonlinear supply chain system with lead times, Complexity, Article ID 2017634, Art. ID 2017634 (2017).