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

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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.

Keywords— Placement scenarios, numerical analysis, Supply chain System

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 Transferenceimprove 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 model's 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].

This article explores the dynamic complexity of a supply chain system with Oblique Transference between two retailers in an effort to close the aforementioned gap.

We concentrate on the effects of the horizontal Oblique Transference strategy and the vertical replenishment policy on the variations in inventory and order. In two separate scenarios, we came up with the stability requirements for the supply chain system. Each of the two merchants placed orders with the upstream provider in the initial scenario. The task of placing orders is handled by just one store in the second scenario. Our actual findings in India's electrical and PC retail businesses served as the inspiration for this scenario [11]. The retailers in such businesses can meet customer demand simply by Oblique Transference from neighboring merchants, rather than making orders with upstream suppliers, hence reducing the ordering cost, stock-out cost, and inventory holding cost. This scenario, which typically occurs in one of two scenarios—either a retailer tries to offer new products or customers want to buy new products but their shop doesn't can be quite efficient at lowering inventories. The most important 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]

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 $t \in \{1, 2, 3 \ldots\}$,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. (3) 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 [14].

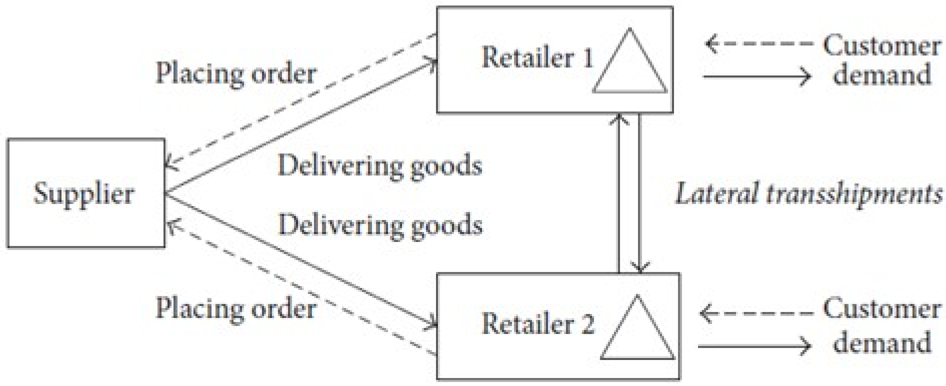


Figure 1: The structure of a supply chain system with Oblique Transference.

We consider two different scenarios in our model: scenarioξ_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 [14].

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 [15].

For the sake of simplicity, we'll assume that the two merchants' orders to the upstream supplier have a one-period lead time for replenishment. We consider the set lead time for Oblique Transference to be periods. Although some articles on Oblique Transference assume insignificant transshipment lead times, in reality, information processing time and the goal of lowering transaction costs may cause non-negligible Oblique Transference lead times. We also want to reveal how dynamic complexity and system performance are impacted by the lead time in Oblique Transference. The dynamics of time-delayed systems are widely known to be extremely complex.

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 1, 2.

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

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

Where(t) is the inventory level, $D_i(t)$ is the customer demand, and $L_i(t)$ 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 $(L_1\ (t)\ L_2\ (t)) = -1$ or sign $(L_1\ (t)\ L_2(t)) = 0$, in which

$$\text{Sign}(x) = \begin{cases} 1\, if\ x > 0 \\ 0\, if\ x = 0 \\ -1\, if\ x < 0 \end{cases} \tag{2}$$

As a result, the volume of Oblique Transference between retailer$i$ $(i \neq j)$ is determined by

$$L_i\ (t) = \varphi L\ [I_j\ (t-\tau) - I_i\ (t-\tau)], \tag{3}$$

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

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

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.

One of the main drivers of system performance is the replenishment rule. In general, demand trends, available inventory, stock-outs, and pipeline stock should be taken into consideration while making inventory decisions. However, since we believe that the lead time for replenishment is only one period, there is no pipeline stock in our model. As a result, it is believed that the inventory rule depends on both the inventory level and the demand prediction. The inventory policies corresponding to the two cases outlined above are very dissimilar.

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:

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

Where ρi is the inventory target and i is the replenishment parameter. This inventory strategy can be thought of as a feedback controller that replenishes the stock level until it reaches the desired level. As a result, with a big ρi the retailer's inventory can respond to customers quickly, while the parameter $I^T i$ should be optimized to strike a balance between the cost of inventory and the quality of customer service.

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

$$O_1(t) = F1(t) + F2(t) + [S^I_T - SI(t)], \tag{6}$$

Where ρi is the aim of system inventory and is still a replenishment parameter. It should be noted that retailer 2 did not place any orders, hence $O_2(t)$ equals 0.

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), D2 (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 = $\{\xi_1, \xi_2\}$ as the set of possibilities. Following that, a unified state space model is created as

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

in which $\xi \in$ S and

$$\mathbf{A}\xi 1 = \begin{bmatrix} 1-\theta 1000 \\ 01-\theta 200 \\ 101-\rho 10 \\ 0101-\rho 2 \end{bmatrix}$$

$$\mathbf{A}\xi_2 = \begin{bmatrix} 1-\theta 1000 \\ 01-\theta 200 \\ 101-\rho\rho \\ 0101 \end{bmatrix}$$

$$\mathbf{A}_{\xi_2} = \begin{bmatrix} 1-\theta_1 & 0 & 0 & 0 \\ 0 & 1-\theta_2 & 0 & 0 \\ 1 & 1 & 1-\rho & -\rho \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$\mathbf{B}_{\xi_1} = \mathbf{B}_{\xi_2} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -\varphi_L & \varphi_L \\ 0 & 0 & \varphi_L & -\varphi_L \end{bmatrix},$$

$$\mathbf{C}_{\xi_1} = \mathbf{C}_{\xi_2} = \begin{bmatrix} \theta_1 & 0 \\ 0 & \theta_2 \\ -1 & 0 \\ 0 & -1 \end{bmatrix},$$

$$\mathbf{D}_{\xi_1} = \begin{bmatrix} 0 \\ 0 \\ \rho_1 I_1^T \\ \rho_2 I_2^T \end{bmatrix},$$

$$\mathbf{D}_{\xi_2} = \begin{bmatrix} 0 \\ 0 \\ \rho \mathrm{SI}^T \\ 0 \end{bmatrix}.$$

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

$$\frac{\sum_{i=1}^{2} \sum_{t=1}^{N} \{c_h [I_i(t) - D_i(t)] + c_b [I_i(t) - D_i(t)]\}}{N} \tag{9}$$

Where N is the length of the simulation, c_h is the holding cost per unit, and c_b is the stock-out cost per unit.

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

$$\mathrm{TOC}=\frac{\sum_{i=0}^{n} c_o \vee o(t) \vee ¿}{N} ¿ \qquad (10)$$

Where c_o is the unit ordering cost.

For the two retailers, the average Oblique Transference cost is calculated by

$$\mathrm{LC} = \frac{\Sigma N t{=}1\ cl\ \lceil L1\ (t)}{N} \qquad (11)$$

Where c_l is the unit cost of Oblique Transference. Because Oblique Transference happen between two merchants that are close together, c_l is less than co in comparison.

The sign function that was previously introduced is used to describe the service level for the two merchants as

$$\mathrm{SL}i = \frac{1 - \Sigma N t{=}1\ \mathrm{sign}\ [Di\ (t) - Ii\ (t)]}{\mathrm{N}} \qquad (12)$$

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

$$\mathrm{BW} = \frac{\Sigma 2\ i{=}1\ \mathrm{var}\ (Oi)}{\Sigma 2\ i{=}1\ \mathrm{var}\ (Di)} \qquad (13)$$

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.

DETERMINE THE TWO SCENARIOS' STABILITY REQUIREMENTS

Stability is a critical issue for every dynamic system, including inventory systems, as researched in the literature. A stable system will eventually revert to its steady condition after being disturbed. In contrast, unstable designs will result in unfavorable changes in order and inventory, which raises costs through inventory buildup or stock-outs. As a result, stability analysis serves as a foundation for setting parameters and improving performance.

Without losing generality, we assume that the steady states of the two retailers' demand are expressed as $D\infty, i \in \{1, 2\}$,which are recognized as the mean values of the customer's demand because the demand typically varies around them. Use as $I\infty i$ and $O\infty i$, to denote the inventory level and order quantity steady states, respectively.

First, think about the case $\xi = \xi_1$, in which each of the two stores independently places an order with the upstream provider. Using the ordering procedure (5) and the inventory balance equation (1), we can determine

$$O\infty\, i = D\infty\, i + \rho i\, (ITi - I\infty\, i),\ \forall i \in \{1, 2\}\ , \quad (14)$$

$$D\infty\, i = O\infty\, i + \varphi L\, (I\infty\, j - I\infty\, i), j \neq i \in \{1, 2\}\ . \quad (15)$$

Joining (14) and (15), we can additionally get

$$I\infty\, i = I^{T}{}_{i} + \ \varphi L \rho j\, (ITj - ITi\,)$$
$$\varphi L\, (\rho 1 + \rho 2) + \rho 1 \rho 2,\ j \neq i \in \{1, 2\}\ . \quad (16)$$

From above, it is clear that the inventory objective and the discrepancy between the inventory targets of the two merchants are what determine the steady state of the inventory. In reality, a store with great demand may set a high price. In accordance with the Oblique Transference scheme, a merchant like this typically moves their goods to another. A merchant with a modest inventory aim. Setting the inventory objective should fulfill $I\infty\ i - D\infty\ i > 0$.in order to avoid stock-outs.

The second scenario $\xi = \xi_2$,, where only retailer 1 places orders with the upstream provider, will be taken into consideration in the sections that follow. Similar to this, we can find

$$I_1^{\infty}=\frac{\varphi_L SI^T + D_2^{\infty}}{2\varphi_L}$$

$$I_2^{\infty}=\frac{\varphi_L SI^T + D_2^{\infty}}{2\varphi_L}$$

The aforementioned situations allow for five alternative analyses of the supply chain system.

Case 1 is where ($\xi = \xi_1$ and $\varphi L = 0$). There is no Oblique Transference, and the two shops choose their own replenishment schedules. This particular scenario was chosen for comparison because it demonstrates the dynamic complexity that Oblique Transference brings.

Case 2 ($\xi = \xi 1$, $\varphi L \neq 0$, and $\tau = 0$).The retailers also choose their own inventory, and Oblique Transference are taken into account. Note that ($\tau = 0$) ignores the lead time of Oblique Transference.

Case 3 ($\xi = \xi_1$, $\varphi L \neq 0$, and $\tau \neq 0$).where the retailers also choose their own inventory, and Oblique Transference are included. Nevertheless, we take into account how the lead time in Oblique Transference affects the stability problem.

Case 4 ($\xi = \xi_2$, $\varphi L \neq 0$, and $\tau = 0$).In this instance, we concentrate on scenario ξ_2.To make the study more straightforward, we first exclude the influence of the transshipment lag time.

Case 5 ($\xi = \xi_2$, $\varphi L \neq 0$, and $\tau \neq 0$) is an example. In this instance, we concentrate on scenarioξ_2.Unlike Case 4; we take a non-negligible transshipment loss into consideration time.

REPRODUCTION INVESTIGATIONS/EXPERIMENTS

The stability test findings will be validated in this section. Since the two stores' consumer demand is exogenous, it has no bearing on the stability of the system. Because it is frequently used in research on supply chain system dynamics and performance, the step signal was chosen to assess the dynamics. The step signal, for instance, has been used to simulate rapid shifts in consumer demand following price promotion operations. Also measuring supply chain performance in reaction to a step change in customer demand is the well-known Supply Chain

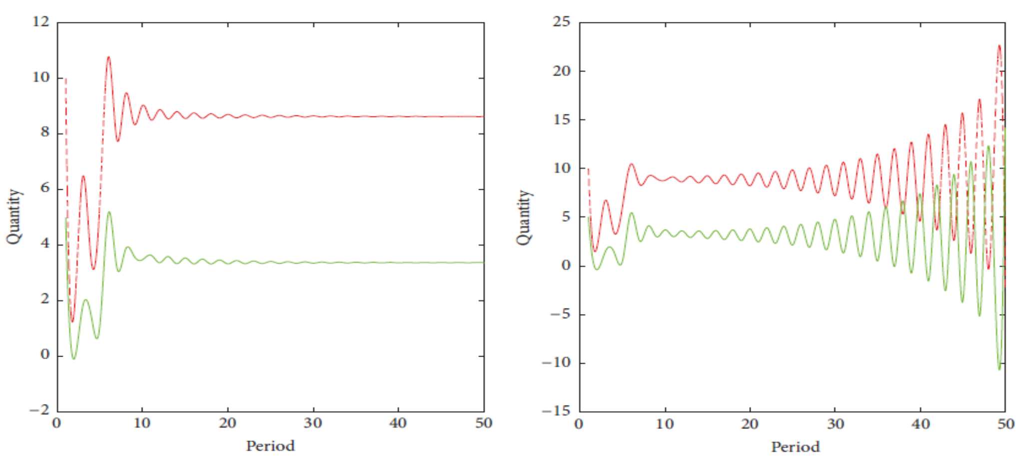
Operations Reference (SCOR) model. Retailer 1 has 4 unit demands until the fifth period and 8 unit demands after the fifth period. In any given period, it is believed that retailer 1 will have twice the amount of demand as retailer 2. Retailers 1 and 2 started out with initial values of 4 and 8 units, respectively. We arbitrarily choose the figures for the precise quantities of demands and the initial value of inventory because they have no bearing on the stability of the system. Since no feedback loops are included in the demand forecasting system, the parameters $\theta_1$and θ_2 do not affect system stability and therefore we set$\theta_1 = \theta_2 = 0.2$.

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	ρ1	□2	□	□L	□
□1	1.4	1.3	-	0.1	0
□1	1.4	1.3	-	0.2	0
□1	0.7	1.1	-	0.3	1
□1	0.7	1.1	-	0.1	11
□1	0.7	0.5	-	0.2	1
□1	0.7	0.5	-	0.3	11
□$_2$	-	-	0.5	0.10	4
□$_2$	-	-	0.5	0.10	5
□$_2$	-	-	0.5	0.10	6



Order of retailer 1

Order of retailer 2

(a) □1 = 1.4, □2 = 1.4, □L= 0.1

Order of retailer 1

Order of retailer 2

(b) □1 = 1.4, □2 = 1.4, □L= 0.2

Figure 3: Solidness approval

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 □1 = □2 = 0.2.Incurs high Oblique Transference cost,

Especially for the case □$_1$ = −□$_2$ = 1.

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

Actuality, managers should be mindful of Oblique Transference expenses, especially if there is a great distance between two outlets. Thirdly, when the parameter L assumes a moderate value, Oblique Transference are helpful in reducing the bullwhip effect because a large □L.May result in major bullwhip effect problems. One may describe the bullwhip effect as a convex function. This effect is particularly noticeable for demand that is negatively connected between the two merchants,

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.

In a decentralized supply chain, Oblique Transference improves customer service levels when each of the two stores places orders with the upstream provider, according to the simulation results. The improvement of client satisfaction, which has garnered a lot of support in the research, is one of the main motivations behind oblique transference. We also find that negatively linked demand reduces inventory costs, which is consistent with the actual results for merging enterprises.

Oblique Transference exposed this retailer to risk if just one store submits orders. We also point out that decreased oblique transference results in lower system-wide inventory costs. Our periodic model is fairly generic because it includes 5 different examples in 2 scenarios without imposing any particular demand assumptions. The results apply to a wide range of industries, including computer and electrical ones. We specifically point out that scenario 2 (the second scenario) is suitable for the network of spare parts, such as the outlets. Networks selling car parts to stores in locations where there is a shortage of space for inventory storage because of high rent.

Additionally, the demand for their products is presumably stochastic and non-stationary. Numerous approaches can be found to expand on this subject. The dynamics will be further complicated by the inclusion of replenishment lead times in our model, which is an intriguing problem. Another fascinating topic is the dynamic complexity of a supply chain network with several retailers and suppliers and how demand uncertainty spreads through a network system.

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