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A System Dynamics Model for Joint Upstream and Downstream Partner Selection in a Supply Chain Consisting of Suppliers and Retailers

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Abstract-- *Firms no longer compete as autonomous entities and prefer to join in a supply chain alliance to take advantage of highly competitive business situation. Supply chain coordination has a great impact on strategic partnering and success of a firm in competitive business environment. In this paper, we propose a system dynamics simulation model for strategic partner selection in supply chain. Our model addresses a supply chain including suppliers and retailers. It presents an approach to simulating the tendency of each supplier (retailer) to select downstream (upstream) partner and the impact of their policies on the whole supply chain.*

Keywords: *Supply chain coordination, strategic partnering, upstream and downstream partner selection, information sharing, system dynamics.*

I. INTRODUCTION

A supply chain is a dynamic, stochastic, and complex system that may involve hundreds of participants. It can be defined as a network of suppliers, manufacturers, distributors, and retailers who are collectively concerned with the conversion of raw materials into goods which can be delivered to the customer (Khaji and Shafaei, 2011). To optimize performances of participants in a supply chain network, it should be designed and managed efficiently. Supply chain management has been recognized as an effective way to achieve the required performance measurements and, consequently, gain competitive advantages. Since partnering between firms is a common way to maintain competitive advantages in a supply chain network (Mentzer et al., 1999), partner selection has become a crucial decision-making problem for firms.

A product must pass through a number of entities contributing to the value addition of the product in supply chain network, to be delivered to the final customer. Therefore, to improve the overall performance of supply chain network in product or service delivery, its members should behave as a part of a unified system and collaborate with each other (Arshinder and Deshmukh, 2008). In a collaborative supply chain, all entities are dynamically working together to reach objectives by sharing information, knowledge, risk, and profits (Udin et al., 2006). Therefore, an effective strategic partnering within supply chain network cannot be achieved without considering the concept of coordination and information sharing.

Various authors investigated upstream partner selection in the context of supply chain management (Shui-ying and Rong-qiu, 2001; Biehl, 2005; Ha and Hong, 2005). (Shui-ying and Rong-qiu 2001) proposed a two-stage decision-making model for supplier selection. In the first stage, they selected several efficient companies according to their internal financial ratios and in the second stage, they utilized a goal programming approach to selecting the most perfect partners among them. A dynamics non-linear model was proposed to examine the choice of using Enterprise Resource Planning (ERP) systems versus Electronic Market Places (EMPs) considering value creation and competitiveness in a supply chain partnership (Biehl, 2005). A system was proposed by (Ha and Hong 2005) to evaluate partners' supply capabilities and market conditions over time by considering multiple quantitative and qualitative criteria.

Since supply chain is interactive and contains feedback loops, simulation can be an effective tool to analyze it. In risk analysis, spreadsheet simulation, system dynamics, discrete-event dynamic systems simulation, and business games are

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four types of simulation methodologies for supply chain management (Kleijnen, 2005). The use of system dynamics modeling in supply chain has been increasing recently due to dynamic nature of supply chain and the complexity of its analysis. (Angerhofer and Angelides 2000) presented an overview of system dynamics modeling in supply chain. Application of system dynamics in supply chain up to 2004 was reviewed by (Bhushi and Javalagi 2004). (Georgiadis et al. 2005) utilized system dynamics for capacity planning in a food supply chain. Analytic hierarchy process, system dynamics, and discrete-event simulation were integrated by (Rabelo et al. 2007) to model the service and manufacturing activities of multinational construction equipment in a supply chain. (Khaji and Shafaei 2011) proposed a system dynamics model for upstream and downstream partner selection in a multi-stage supply chain network consisting of suppliers, manufacturers, retailers, and customers, considering information sharing in the supply chain. They supposed that information about four factors consisting of price, quality, lead time, and service level as the most important ones in upstream partner selection was shared among entities in supply chain network. They considered order ratio and partner loyalty as two most important factors in downstream partner selection and rate allocation. Their work was restricted to the assumption that the aforementioned factors for upstream partner selection were known before decision-making and their values were constant. Thus, they utilized a fuzzy ANP approach to multi-attribute upstream partner selection. They analyzed their system dynamics model in partner selection and showed that their model for partner selection and information sharing outperformed the fixed interval order system considering supply chain costs and customer satisfaction (fixed interval order system is a classical inventory control model and the selection process is done according to the earliest due date (EDD) method).

In this paper, we propose a system dynamics model for partner selection in a two-stage supply chain network consisting of suppliers and retailers. We extend the model presented by (Khaji and Shafaei 2011) by assuming that price and service level, which are the most important factors in upstream partner selection, are dynamic and their change influences each retailer's decision-making process for supplier selection, dynamically. We also consider each retailer's order ratio and loyalty as two factors influencing downstream partner selection as mentioned by (Khaji and Shafaei 2011). Our model addresses a supply chain including suppliers and retailers. It presents an approach to simulating the tendency of each supplier (retailer) to select downstream (upstream) partner and the impact of their policies in the whole supply chain

II. NOTATIONS AND PROBLEM FORMULATION

In this section, we will present a model for partner selection for both suppliers and retailers. For the sake of simplicity, we present the model for a supply chain consisting of two suppliers and two retailers; however, without loss of generality, this model can easily be adopted for any number of suppliers and retailers. Fig (1) represents a part of the model that belongs to the first supplier. The sub-model, which is related to the second supplier, is same as the model presented for the first supplier. We can also use this model for any number of suppliers.

Now, we explain variables of the first supplier sub-model and the relationships between variables and mathematical equations, which construct the structure of the system dynamics model and will be utilized in the simulation in the next section. It is noteworthy that all of the variables existing in the sub-model related to the first supplier are also present in the sub-model that belongs to the second supplier in the same way. For simplicity, we just mention the variables for the sub-model of the first supplier. From now on, we represent the first supplier by "Supplier1" and the second supplier by "Supplier2," and the first retailer by "Retailer1" and the second retailer by "Retailer2." The level variables that are used in Supplier1 sub-model are illustrated in Table I and each of them is explained. Rate variables related to Supplier1 are also illustrated and explained in Table II. Retailer1 sub-model is also illustrated in Fig (2), and level and rate variables associated with Retailer1 sub-model are presented and explained in Tables II and III, respectively. Needless to say, Supplier2 (Retailer2) sub-model and its variables are same as Supplier1 (Retailer1) sub-model and its variables. Accordingly, the whole model including two suppliers and two retailers is illustrated in Fig (5). This model illustrates all the relationships between suppliers and retailers and shows the structure of dynamic upstream and downstream partner selection problems. In the next section, we formulate the presented model illustrated in Fig (5) and will explain how its variables are related to each other and to other auxiliary variables. In the next section, the structure of the dynamic decision-making process for partner selection considering both suppliers and retailers will be explained.

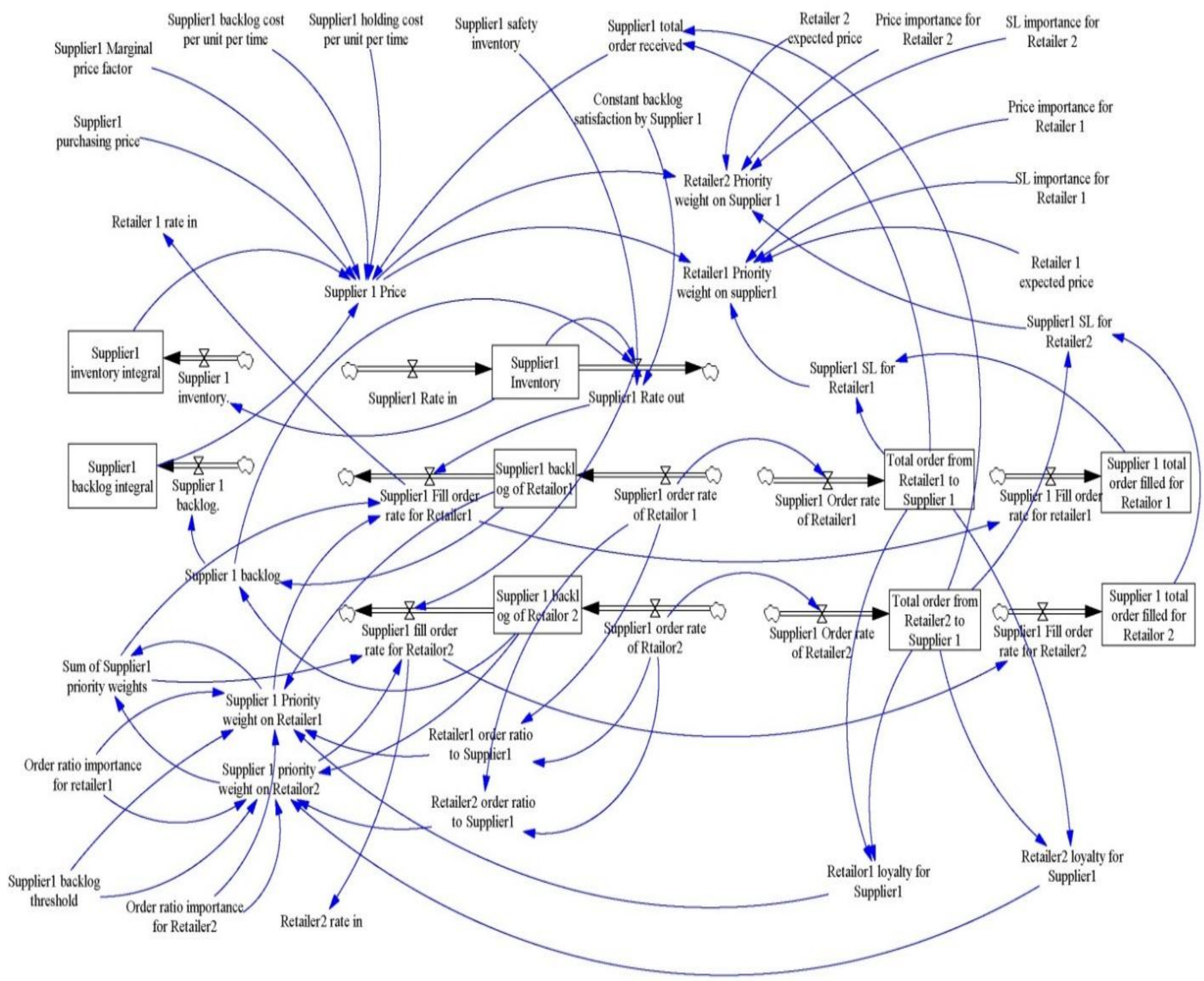

Fig 1. Supplier1 sub-model

III. SYSTEM DYNAMICS MODEL FORMULATION

Since variables and equations for suppliers are the same and different retailers have the same equations, we only present formulations for Supplier1and Retailer1.

Also, at each level of variables, the level variables of Supplier1 sub-model are calculated as the integral of rate variables that enter it minus rate variables that exit it, as follows:

$$\text{Supplier1 inventory}(t') = \int_0^{t'} (\text{Supplier1 rate in}(t) - \text{Supplier1 rare out}(t)).\,dt$$

$$\text{Supplier1 backlog of Retailer1}(t') = \int_0^{t'} (\text{Supplier1 order rate of Retailer1}(t) - \text{Supplier1 fill order rate for Retailer1}(t)).\,dt$$

$$\text{Supplier1 backlog of Retailer2}(t') = \int_0^{t'} (\text{Supplier1 order rate of Retailer2}(t) - \text{Supplier1 fill order rate for Retailer2}(t)).\,dt$$

$$\text{Total order from Retailer1 to Supplier1}(t') = \int_0^{t'} \text{Supplier1 order rate from Retailer1}(t).\,dt$$

$$\text{Total order from Retailer2 to Supplier1}(t') = \int_0^{t'} \text{Supplier 1 order rate from Retailer1}(t).\,dt$$

$$\text{Supplier1 total order filled for Retailer1}(t') = \int_0^{t'} \text{Supplier1 fill order rate for Retailer1}(t).\,dt$$

$$\text{Supplier1 total order filled for Retailer2}(t') = \int_0^{t'} \text{Supplier1 fill order rate for Retailer2}(t).\,dt$$

$$\text{Supplier1 inventory integral}(t') = \int_0^{t'} \text{Supplier1 inventory}(t).\,dt \quad (1)$$

$$\text{Supplier1 backlog integral}(t') = \int_0^{t'} \text{Supplier1 backlog}(t).\,dt \quad (2)$$

In Eq. (1), Supplier1 inventory integral is a level variable that calculates cumulative inventory multiplied by time and is used to calculate the total cost of inventory. Total inventory cost is also used to calculate the price of selling each unit of product by Supplier1. Supplier1 backlog integral in Eq. (2) is also used to calculate the total cost of backlog and has impact on Supplier1 product price. Supplier1 backlog is an auxiliary variable of Supplier1 sub-model and is calculated as follows:

$$\text{Supplier1 backlog} = \text{Supplier1 backlog of Retailer1} + \text{Supplier1 backlog of Retailer2}$$

Supplier1 price for each unit of product is dynamically calculated through the system dynamics model according to the following equation:

$$\text{Supplier1 price} = \text{Purchasing price for Supplier1} + \text{Marginal profit factor} * [(\text{Supplier1 inventory integral} * \text{Supplier1 holding cost per unit per time} + \text{Supplier1 backlog integral} * \text{Supplier1 backlog cost per unit per time}) / (\text{Supplier 1 total order received})] \quad (3)$$

TABLE I. Level variables associated with Supplier1 sub-model

Level variable	Explanation
Supplier1 inventory	Level of product inventory for Supplier1
Supplier1 backlog of Retailer1	Level of orders received by Supplier1 from Retailer1 which have not been filled yet
Supplier1 backlog of Retailer2	Level of orders received by Supplier1 from Retailer2 which have not been filled yet
Total order from Retailer1 to Supplier1	Total orders issued to Supplier1 by Retailer1 containing orders that are filled or not filled yet
Total order from Retailer2 to Supplier1	Total orders issued to Supplier1 by Retailer2 containing orders that are filled or not filled yet
Supplier1 total order filled for Retailer1	Total orders that have been filled so far for Retailer1 by Supplier1
Supplier1 total order filled for Retailer2	Total orders that have been filled so far for Retailer2 by Supplier1
Supplier1 inventory integral	Sum of inventories that Supplier1 has over time. In fact, it calculates the sum of the inventories multiplied by time. This variable is used to calculate average inventory level for Supplier1.
Supplier1 backlog integral	Sum of backlogged orders that Supplier1 has over time. In fact, it calculates the sum of the backlogged orders multiplied by time. This variable is used to calculate average backlog level for Supplier1.

TABLE II. Rate variables associated with Supplier1 sub-model

Rate variable	Explanation
Supplier1 rate in	The rate at which product arrives at supplier1 product inventory
Supplier1 order rate of Retailer1	Rate of order arrival at Supplier1 issued by Retailer1
Supplier1 order rate of Retailer2	Rate of order arrival at Supplier1 issued by Retailer1
Supplier1 fill order rate for Retailer1	The rate at which Supplier1 fills orders received from Retailer1
Supplier1 fill order rate for Retailer2	The rate at which Supplier1 fills orders received from Retailer2
Supplier1 backlog	This variable in each moment of simulation is equal to Supplier1 backlog level variable
Supplier1 inventory	This variable is equal to Supplier1 inventory level variable

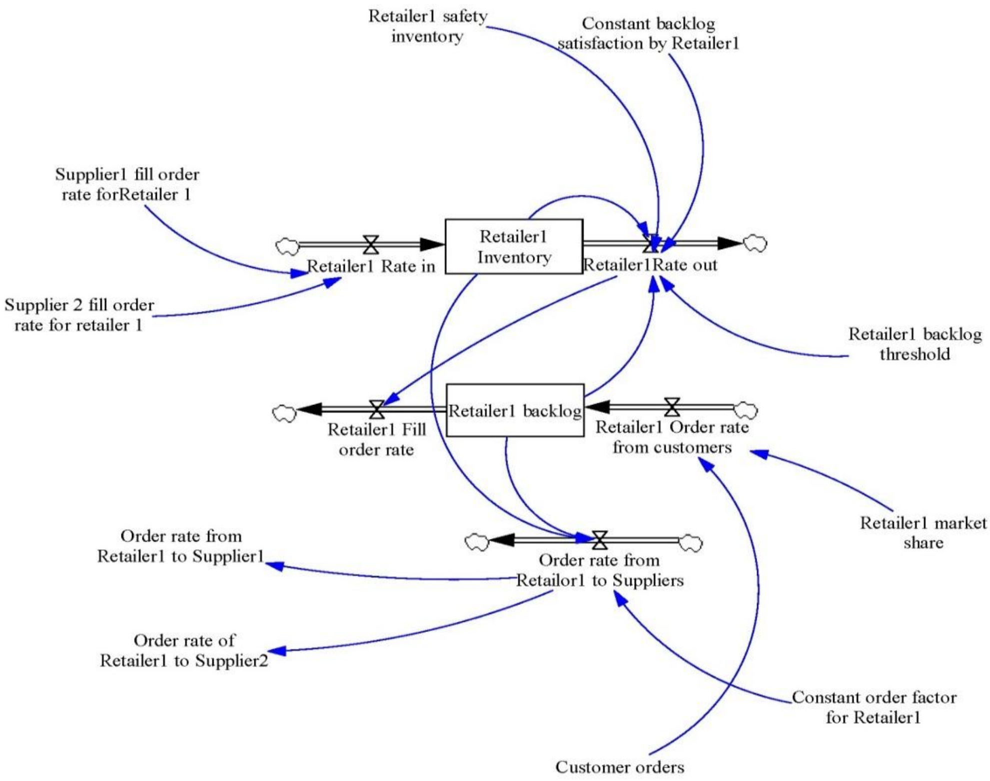

Fig 2. Retailer1 sub-model

In Eq. (3), the price of selling each unit of product by Supplier1 in each moment of time is calculated based on the sum of the total inventory cost and total backlog cost until that moment. Total cost is divided by total order received by supplier 1 until that moment to obtain the cost incurred by each unit of order. Supplier1 purchasing price for each unit of product is also counted by the price of product that supplier1 sells. Marginal profit factor is to consider supplier marginal profit in each unit of product.

Supplier1 rate in, which is a rate variable of Supplier1 sub-model, is a parameter of the model and its value is defined before simulation. Supplier1 rate out, which is also a rate variable of Supplier1 sub-model illustrated in Fig (1), is an increasing function of Supplier1 level of inventory and backlog. If Supplier1 inventory is greater than a predefined parameter named Supplier1 safety inventory, Supplier1 rate out in each moment of simulation will be calculated according to the following equation:

$$\text{Supplier1 rate out} = \text{Constant backlog satisfaction by Supplier1} * \text{Supplier1 backlog} * \text{LOG}(10 * \text{Supplier1 Inventory}/\text{Supplier1 safety inventory}) \quad (4)$$

In the case that Supplier1 inventory is lower than or equal to Supplier1 safety inventory, Supplier1 rate out will be equal to zero.

In Eq. (4), when Supplier1 inventory is lower than Supplier1 safety inventory, the phrase in parenthesis will be lower than 1 and, consequently, its logarithm will be less than 1. Thus, Supplier1 rate out will decrease, that is, the products will leave Supplier1 inventory with a smaller rate. Moreover, if Supplier1 inventory is less than Supplier1 safety inventory, Supplier1 rate out will be equal to zero. Supplier1 safety inventory and Constant backlog satisfaction by Supplier1 are input parameters of the model. Supplier1 order rate from Retailer1, which is a rate variable of Supplier1 sub-model illustrated in Fig (1), is equal to variable order rate of Retailer1 to Supplier 1, which is a rate variable of Retailer1 sub-model illustrated in Fig (2). In fact, these variables connect Supplier1 and Retailer1 sub-models to each other. Each retailer's orders will be distributed among suppliers according to each retailer's priorities for suppliers and the supplier that has greater priority weight based on a specific retailer's idea will receive more orders than other suppliers. Eq. (6) shows the way Retailer1 order rate to Supplier1 is defined:

$$\begin{aligned}\text{Order rate of Retailor 1 to Supplier1} &= \text{Retailer1 order rate to Supplier1}\\ &= \text{Order rate of Retailor1 to suppliers}\\ &\quad * \text{Retailer1 priority weight for supplier1/Sum of Retailer1 priorities}\end{aligned} \qquad (5)$$

As we mentioned before, price and service level (SL) are considered as two factors that dynamically define each retailer priorities to purchase from suppliers. We define service level of each supplier for each retailer in each moment of time as the fraction of orders issued by retailer until that moment which is responded by supplier. For example, service level of Supplier1 for Retailer1 is calculated as follows:

$$\text{Supplier1 SL for Retailer1} = \text{Supplier 1 total order filled for Retailor1/Total order from Retailer1 to Supplier1}$$

For each supplier and retailer, service level is defined dynamically over time in the same way. Consequently, priority of each retailer to buy from each supplier in each moment of time is defined based on supplier service level and price . For example, priority of Retailer1 to buy from Supplier1 is defined based on the following equation:

$$\begin{aligned}&\text{Retailer1 priority weight for Supplier1}\\ &\quad = \text{Price importance for Retailer1} * \text{Retailer1 expected price/Supplier1 Price}\\ &\quad + \text{SL importance for Retailer1} * \text{Supplier1 SL for Retailer1}\\ &\quad * \text{Supplier1 backlog of Retailor1/Supplier1 backlog threshold}\end{aligned} \qquad (6)$$

In Eq. (5), Price importance for Retailer1, Retailer1 expected price, SL importance for Retailer1, and Supplier1 backlog threshold are parameters of the model and policy parameters related to Retailer1. Price importance for Retailer1 is a preference weight defined for price based on Retailer1 opinion and SL importance for Retailer1 is a preference weight defined for service level based on Retailer1 opinion. In Eq. (6), Order rate of Retailor 1 to suppliers is defined based on the following equation:

$$\text{Order rate of Retailor1 to suppliers} = (\text{MAX}(0, \text{Retailer2 backlog} - \text{Retailer2 inventory}\ ) + \text{Retailer2 safety inventory}) * \text{Constant order factor for Retailer2} \qquad (7)$$

Eq. (7) indicates that if Retailer1 backlogged orders level is greater than its safety inventory level, it issues orders according to the difference between its inventory and backlog level. Retailer1 inventory in Eq. (7) is defined same as Supplier1 inventory level and calculated according to the following equation:

$$\text{Retailer1 inventory}(t') = \int_0^{t'} \big(\text{Retailer1 rate in}(t) - \text{Retailer1 rate out}(t)\big)dt \qquad (8)$$

Retailer1 rate out in Eq. (8) has the same definition as Supplier1 rate out and in the case that backlog level of Retailer1 is lower than or equal to Retailer1 backlog threshold, or inventory level of Retailer1 is lower than or equal to its safety inventory level, it equals zero; otherwise, it is obtained using the following equation:

$$\text{Retailer1 rate out}(t) = \text{Constant backlog satisfaction by Retailer1} * \text{Retailer1 backlog} * \text{LOG}(10 * \text{Retailer1 Inventory/Retailer1 safety inventory} \qquad (9)$$

In Eq. (8), Retailer 1 rate in is equal to total fill order rates of suppliers for Retailer1 and obtained based on the following equation:

$$\text{Retailer1 rate in} = \text{Supplier1 fill order rate for Retailor1} + \text{Supplier2 fill order rate for Retailor1} \qquad (10)$$

In Eq. (10), each supplier's fill order rate for retailers depends on its priorities for retailers as well as each retailer's order ratio and loyalty to the indicated supplier. For instance, Supplier1 fill order rate for Retailer1 is defined based on the following equation:

$$\begin{aligned}&\text{Supplier1 fill order rate for Retailer1}\\&\quad= \text{Supplier1 rate out}\\&\quad* \text{Supplier1 priority weight on Retailer1}/\text{Sum of supplier1 priority weights} \qquad (11)\end{aligned}$$

In Eq. (11), Sum of Supplier1 priority weights is the sum of Supplier1 priorities for Retailer1 and Retailer2 in the presented model and each one is defined according to order ratio and loyalty of the related retailer. For instance, Supplier1 priority for Retailer1 is defined dynamically over time as follows:

$$\begin{aligned}&\text{Supplier1 priority weight for } R\text{etailer1}\\&\quad= (\text{Loyalti importance for Retailer1} * \text{Retailor1 loyalty to Supplier 1}\\&\quad+ \text{Order ratio importance for Retailer1} * \text{Retailer1 order ratio to Supplier1}) *\\&\quad* \text{Supplier1 backlog of Retailor1}\\&\quad/\text{Supplier1 safety backlog} \qquad (12)\end{aligned}$$

In Eq. (12), Loyalty importance for Retailer1 and Order ratio importance for Retailer1 are parameters of the model and their values are defined based on Supplier1 decision-makers. We have assumed that if backlog level of Supplier1 is below (above) Supplier1 safety backlog, priority of supplier1 for Retailer1 will decrease (increase) according to their ratio. We have the following equations:

$$\begin{aligned}&\text{Retailer1 loyalty to Supplier1}\\&\quad= \text{Total order from Retailer1 to Supplier1}/(\text{Total order from Retailer1 to Supplier1}\\&\quad+ \text{Total order from Retailer2 to Supplier1})\end{aligned}$$

$$\begin{aligned}&\text{Retailer1 order ratio to Supplier1}\\&\quad= \text{Supplier 1 order rate of retailor 1}/(\text{Supplier 1 order rate of retailor 1}\\&\quad+ \text{Supplier 1 order rate of retailor 2})\end{aligned}$$

TABLE III. Level variables associated with Retailer1 sub-model

Level variable	Explanation
Retailer1 inventory	Level of product inventory for Retailer1
Retailer1 backlog	Level of orders received by Retailer1 from customers which have not been filled yet

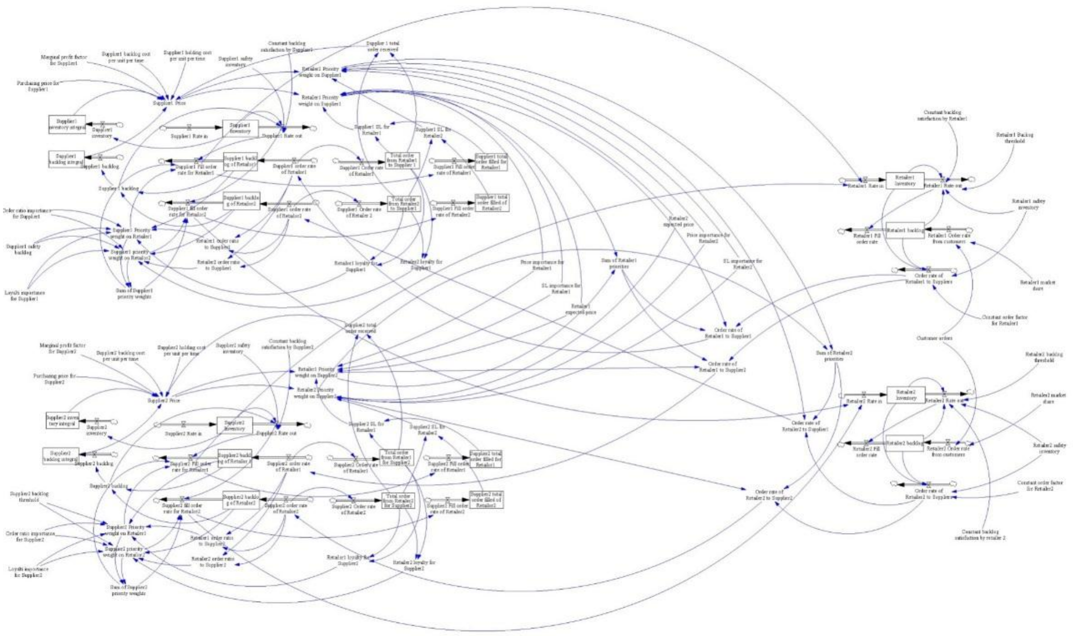

Fig 3. System dynamics model consisting of two suppliers and two retailers

TABLE IV. Rate variables associated with Retailer1 sub-model

Rate variable	Explanation
Retailer1 rate in	The rate at which product arrives at Retailer1 product inventory
Retailer1 rate out	The rate at which product leaves Retailer1 product inventory
Retailer1 order rate from customers	Rate of order arrival from customers to Retailer1
Retailer1 fill order rate	The rate at which Retailer1 fills orders received from customers
Order rate of Retailer1 to suppliers	The rate at which Retailer1 issues orders to suppliers

IV. SIMULATION AND DISCUSSION

The proposed model could be simulated considering different values for policy parameters that exist in the model, such as safety inventory level of suppliers and retailers, constant backlog satisfaction of suppliers and retailers, backlog threshold, etc. By utilizing simulation, we could see the behavior of important variables of the model. This could help us to choose policies that caused the model and, consequently, the supply chain to show better performance considering both suppliers and retailers.

We simulated the presented model considering two suppliers and two retailers using Vensim software. To simulate the model, we defined values of parameters for suppliers and retailers according to the scenario illustrated in Tables V and VI. In this scenario, we assumed that suppliers received products at equal rates from upstream partner and customer orders were equally distributed among retailers. Considering the same parameters for Supplier1 and Supplier2 and the same parameters for Retailer1 and Retailer2, according to Tables V and VI, it is obvious that the trend of variables over time must be the same for different suppliers and retailers. Fig (4) represents the rate that the product leaves Supplier1 inventory (Supplier1 rate out) or supplier2 inventory (Supplier2 rate out). It is obvious that the rate that products leave the supplier's inventory fluctuates around a constant value. Since all parameters are the same for Retailer1 and Retailer2, the rate of filling orders by suppliers for each retailer is half the Supplier1 rate out and Supplier2 rate out, as illustrated in Fig (5).

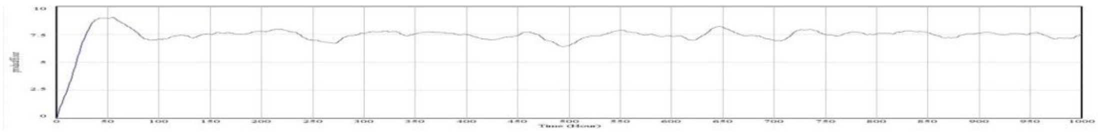

Fig 4. The rate that products leave suppliers' inventory (Supplier1 and Supplier2 rate out)

TABLE V. Values of variables associated with Supplier1 and Supplier2

Parameter	Value (distribution)
Purchasing price for Supplier1 Purchasing price for Supplier2	1000
Marginal profit factor for Supplier1 Marginal profit factor for Supplier2	1.1
Supplier1 backlog cost per unit per time Supplier2 backlog cost per unit per time	20
Supplier1 holding cost per unit per time Supplier2 holding cost per unit per time	20
Supplier1 safety inventory Supplier2 safety inventory	100
Constant backlog satisfaction by Supplier1 Constant backlog satisfaction by Supplier2	0.05
Order ratio importance for Supplier1 Order ratio importance for Supplier2	3
Loyalty importance for Supplier1 Loyalty importance for Supplier2	10
Supplier1 backlog threshold Supplier2 backlog threshold	20
Supplier1 rate in Supplier2 rate in	0.5*Uniform (5,10)

TABLE *VI. Values of variables associated with Retailer1 and Retailer2*

Parameter	Value (distribution)
Constant backlog satisfaction by Retailer1 Constant backlog satisfaction by Retailer2	0.1
Retailer1 backlog threshold Retailer1 backlog threshold	30
Retailer1 safety inventory Retailer2 safety inventory	50
Retailer1 market share Retailer2 market share	0.5
Customer orders	Uniform (10,20)
Retailer1 expected price Retailer2 expected price	2000
Price importance for Retailer1 Price importance for Retailer2	10
SL importance for Retailer 1 SL importance for Retailer 2	5

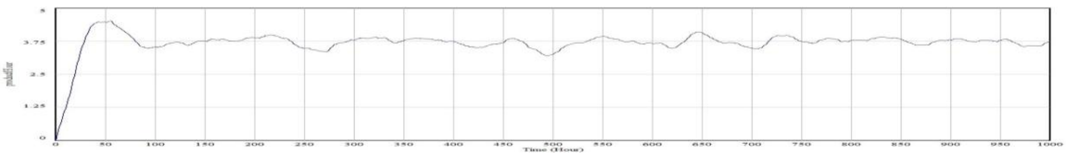

Fig 5. The rate of filling orders by suppliers for retailers (Supplier1 and Supplier2 fill order rate for Retailer1 and Retailer2)

Inventory level of suppliers is illustrated in Fig (6). It is clear from Fig (6) that inventory level of suppliers is increasing slightly over time. The level of backlogged orders from retailers for each supplier is also illustrated in Fig (7). Each supplier's backlog level for the considered scenario of parameters in Tables V and VI oscillates around a constant value.

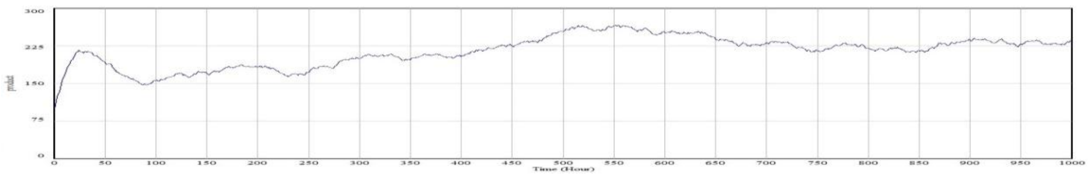

Fig 6. Inventory level of suppliers (Supplier1 and Supplier2 inventory)

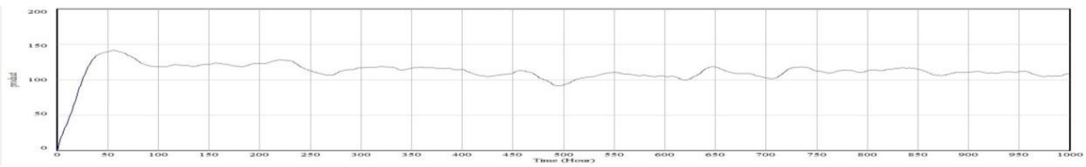

Fig 7. Suppliers' level of backlogged orders (Supplier1 and Supplier2 backlog)

The trend of suppliers' selling price according to the above-mentioned scenario for the values of parameters is depicted in Fig (8). As we see in this figure, price of selling each unit of product by each supplier slightly increases from about $1122 to about $2055. Fig (9) shows the inventory level for retailers over time and it can be seen that inventory level of retailers fluctuates around 50, which is the safety inventory level for retailers according to Table VI. As we see in Fig

(10), level of backlogged orders for retailers also oscillates around a constant number. Since all the parameters for suppliers and retailers are similar, priorities of suppliers to fill orders for retailers and priorities of retailers to buy from suppliers are the same and almost near a constant number

Now, we consider a change in model parameters. Since we cannot clearly understand changes in the model by changing more than one parameter, we consider just one parameter to change and investigate the impact of its change on the whole model. For example, we assume that market share of Retailer1 becomes greater than market share of Retailer2 and equal to 0.7, and all the values of other parameters remain constant. Inventory level of suppliers changes according to Fig (11). Each Supplier's inventory level becomes more stable and after some time, it tends to safety inventory level. It may happen because of the fact that when suppliers have to deal with one retailer instead of two retailers most of the time, they have less challenge and their product inventory level is more stable and near safety inventory level. However, it is obvious in Fig (12) that in this situation, their level of backlogged orders grows dramatically over time and their price decreases in comparison with the past, becoming equal to $1966, at the end of simulation, according to Fig (13). In comparison with the previous situation, inventory level decreases and backlog level increases, consequently leading to decrease in the price. It is noteworthy that the price is strictly dependent on the cost of inventory and backlog, according to the presented model in the previous section, and changing them changes the price. In this case, we can also see that Supplier2 fills more orders for retailers than Supplier1 does, especially near the end of simulation (Figs (14 and 15)). Also, according to Figs (14 and 15), after nearly 600 hours of simulation, the rate of filling orders for Retailer1 in some moments of simulation is equal to zero; this occurs because in these moments, the level of backlogged orders from this retailer to suppliers is less than backlog threshold of suppliers.

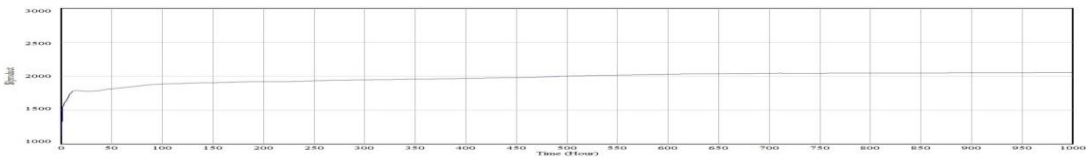

Fig 8. Price of selling each unit of product by suppliers (Supplier1 and Supplier2 price)

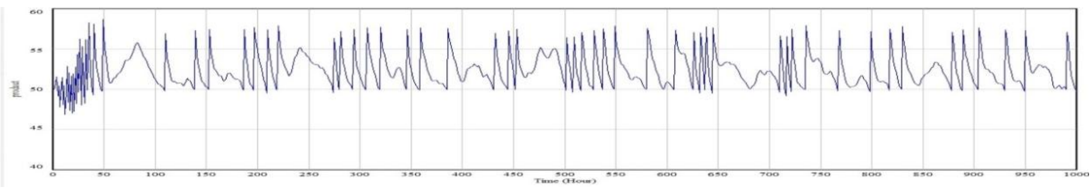

Fig 9. Inventory level of retailers (Retailer1 and Retailer2 inventory)

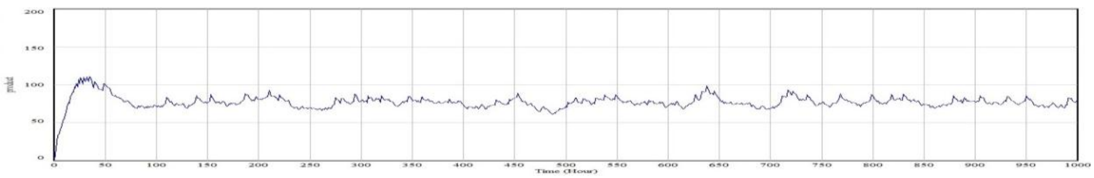

Fig 10. Retailers' level of backlogged orders (Retailer1 and Retailer2 inventory)

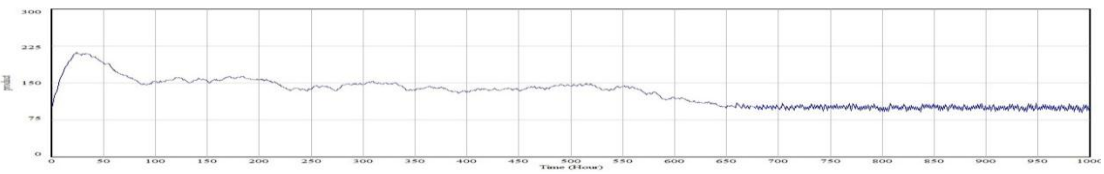

Fig 11. Inventory level of suppliers after increasing market share of Retailer1

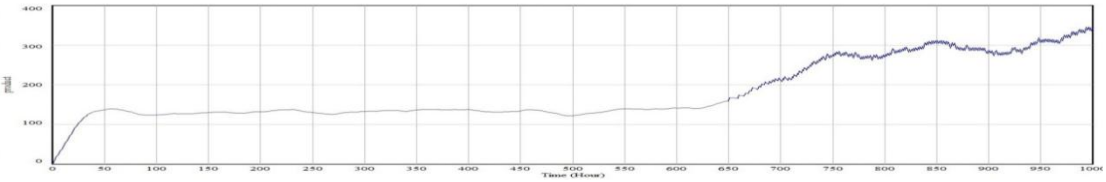

Fig 12. Suppliers' level of backlogged orders after increasing market share of Retailer1

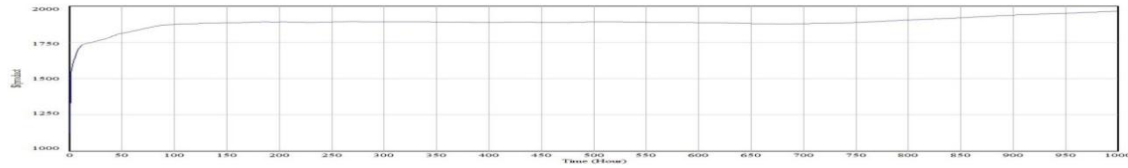

Fig 13. Suppliers' price after increasing market share of Retailer1

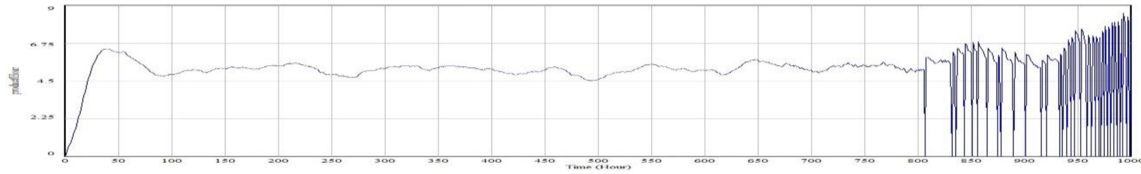

Fig 14. Order rate filling of Supplier1 for Retailer1 after increasing market share of Retailer1

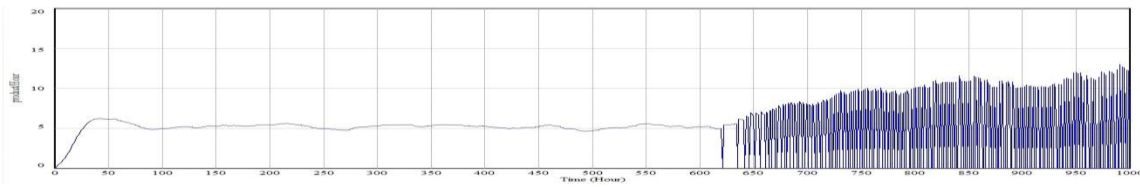

Fig 15. Order rate filling of Supplier2 for Retailer1 after increasing market share of Retailer1

We can also change other parameters, such as the policy parameters related to suppliers, to see their impact on the whole system. For example, we change the safety inventory level of Supplier1 from 100 to 30. It can be understood from Figs (16 & 17) that price of selling products by suppliers changes in comparison with the first scenario presented in Tables V and VI. It is clear from these figures that price of selling each unit of product by Supplier1 decreases in comparison with the previous scenarios and stands near \$1883 at the end of simulation, whereas the price of Supplier2 increases as compared with the previous scenarios and becomes equal to \$2337 at the end of simulation. We see that a change in policy parameters of one supplier has impact not only on its price but also on the other supplier's price. This change also has impact on priorities of retailers to buy from suppliers over time. When we compare the results obtained in the first scenario in Tables V and VI with the third scenario for changing policy parameters of Supplier1, as it is clear in Figs (18 & 19), each retailer's priority to buy from Supplier1 increases in comparison with their preference to buy from Supplier2 and this may be because of the fact that retailers prefer suppliers with smaller price to suppliers with greater service level (considering importance weights of suppliers). Each supplier's service level trend over time, according to the first scenario for the model parameters presented in Tables V and VI, is represented in Fig (18), which shows that it tends to 1. It means that after some time, suppliers fill most of the orders received from retailers. Service level of suppliers to retailers in the second scenario (in the case that 0.7 of customer orders belong to Retailer1) is depicted in Figs (19, 20, 21, & 22). According to these figures, change in the orders of Retailer1 received from customers (market share) has more significant decreasing effect on the service level received by Retailer2 than that by Retailer1.

More scenario analysis can be conducted on the presented model to become more familiar with the behavior of suppliers and retailers in the situation of changes in policy parameters and other parameters of suppliers and retailers in the system dynamics model.

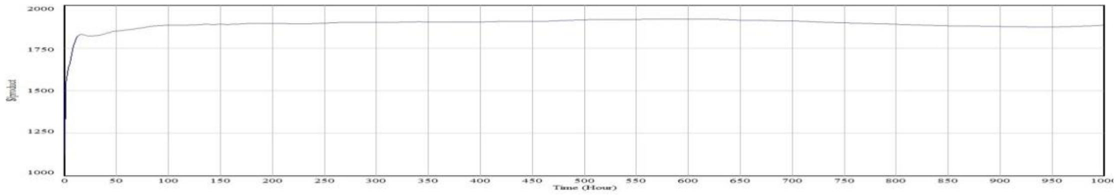

Fig 16. Price of Supplier1 after decreasing its safety inventory level

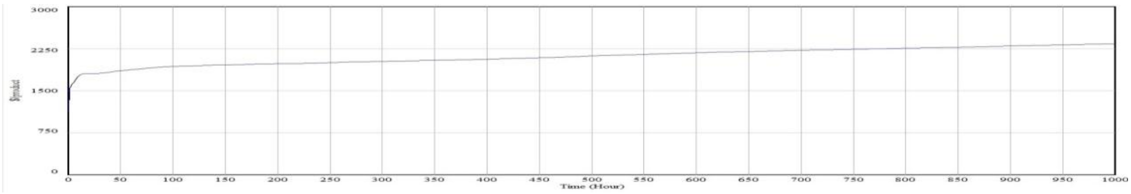

Fig 17. Price of Supplier2 after decreasing its safety inventory level

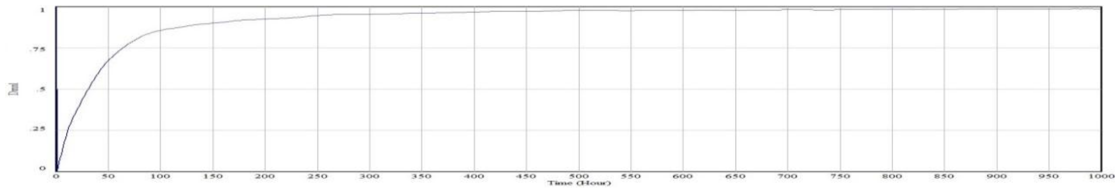

Fig 18. Service level of suppliers according to the first scenario in Tables IV and V

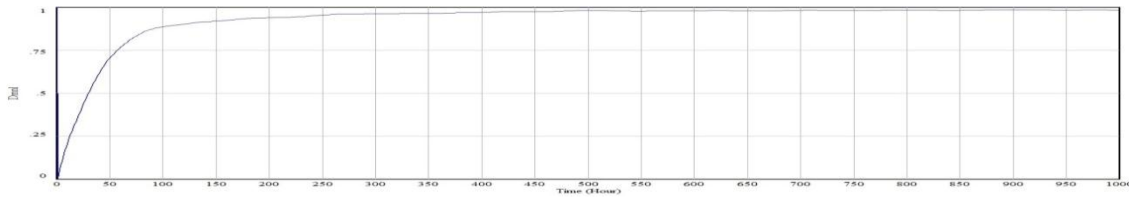

Fig 19. Service level of Supplier1 to Retailer1 after increasing market share of Retailer1

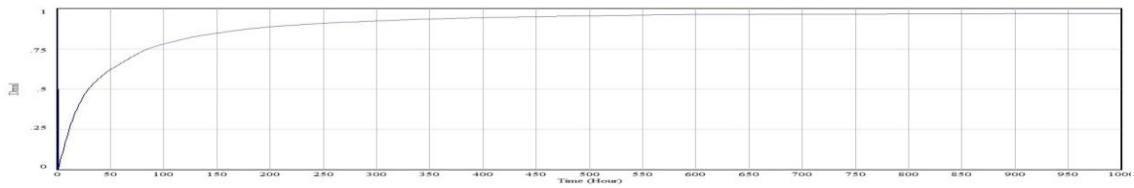

Fig 20. Service level of Supplier1 to Retailer2 after increasing market share of Retailer1

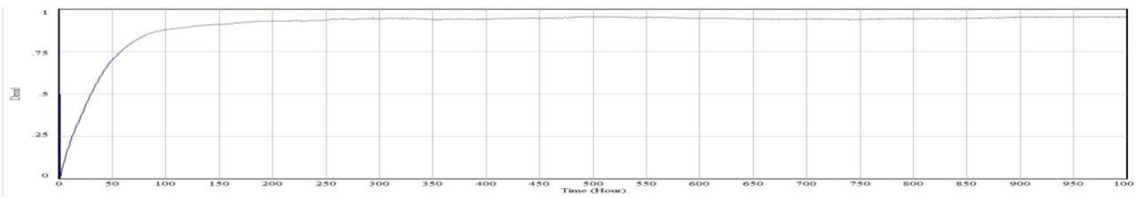

Fig 21. Service level of Supplier2 to Retailer1 after increasing market share of Retailer1

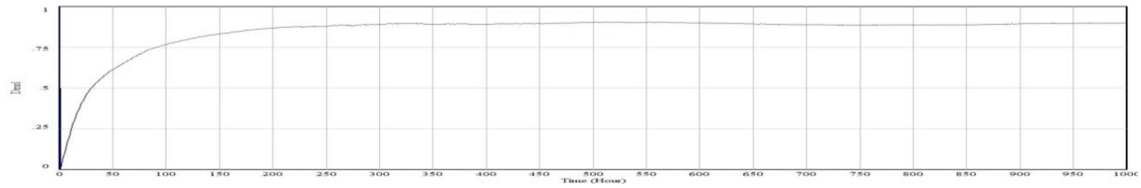

Fig 22. Service level of Supplier2 to Retailer2 after increasing market share of Retailer1

V. CONCLUSION

In this study, the strategic partnering problem was studied in a supply network considering information sharing. A model was proposed to consider both upstream and downstream partner selection in a supply chain consisting of suppliers and retailers. The proposed model had the flexibility to adapt to any number of suppliers and retailers in supply chain. Price and service level were considered as two important factors dynamically impacting on each retailer’s priorities to buy from suppliers over time. Order ratio and loyalty were also considered as factors that influenced each supplier’s priorities to sell product to retailers. The whole model consisting of two suppliers and two retailers was simulated and the impact of policy of suppliers and retailers was discussed.

To complement this work, the future research lines can be: studying the impact of different parameters related to suppliers and retailers on the behavior of the whole system, especially on product price and cost of supply chain; combining MCDM (Multi-Criteria Decision-Making) methods such as AHP (Analytical Hierarchy Process) and ANP (Analytical Network Process) with system dynamics modeling to optimize supply chain performance criteria; considering other aspects of transportation such as transportation cost and transportation time in the model to measure and evaluate the performance of supply chain; applying different policies of suppliers and retailers to fill orders and issuing orders; and considering uncertainty of parameters using probability theory or fuzzy theory.

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