International Journal of Industrial Engineering & Production Research (2016)

December 2016, Volume 27, Number 4
pp. 387 - 414

DOI: 10.22068/ijiepr.27.4.387 http://IJIEPR.iust.ac.ir/

Partners' Selection in Supply Chain Asing System Dynamics Approach

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KEYWORDS

Supply chain coordination, strategic partnering, upstream and downstream partner selection, information sharing, system dynamics, scenario analysis.

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 firm's strategic partnering and success in competitive business environment. Our model addresses a supply chain including suppliers and retailers. It presents an approach to simulate each supplier's (retailers) tendency to select downstream (upstream) partner selection and the impact of their policies in the whole supply chain. In this paper, we propose a system dynamics simulation model for strategic partner selection in supply chain. System dynamic is a well stablished tool for determining the behavior of pre-determined variables of the system called Level Variables. The proposed model has the flexibility of adapting any number of suppliers and retailers in a given supply chain. Price and service level are considered as two important factors impacting dynamically on each retailer's priorities to buy from suppliers over time. Order ratio and loyalty are also considered as factors that influencing each supplier's priorities to sell product to retailers. The whole model consisting of two suppliers and two retailers is simulated and the impact of policy of suppliers and retailers is discussed. Four scenarios are designed and their results are discussed appropriately.

1. Introduction

A supply chain is a dynamic, stochastic and complex system that might 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 performance of participants in a supply chain network, supply chain network should be designed and managed efficiently. Supply chain management has been recognized as an effective way to achieve 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

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Received 5 August 2014; revised 13 December 2016; accepted 10 April 2017

selection has become a crucial decision making problem for firms.

A product has to pass through a number of entities contributed in 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 may behave as a part of a unified system and collaborate with each other (Arshinder and Deshmukh2008). 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 select several efficient companies according to their inside financial ratios and in the second stage they utilize a goal programming approach to select the most perfect partners among them. A dynamics non-linear model is proposed to examine the choice of using Enterprise Resource Planning (ERP) systems versus Electronic Market Places (EMPs) within the context of value creation and competitiveness in a supply chain partnership (Biehl 2005). A system is 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. Risk analysis via spreadsheet simulation, system dynamics, discrete-event dynamic systems simulation and business games are 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. Authors in (Angerhofer and Angelides 2000) presented an overview of system dynamic modeling in supply chain. Application of system dynamic in supply chain until 2004 is reviewed by Bhushiand Javalagi (2004). Georgiadiset al. 2005 utilized system dynamics for capacity planning in a food supply chain. Analytic hierarchy process, system dynamics and discrete-event simulation are integrated by Rabelo et al. 2007 to model the service and manufacturing activities of a
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 factors for upstream partner selection are 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 is restricted by assuming that the aforementioned factors for upstream partner selection are known before decision making and their values are constant. So they utilized a fuzzy ANP approach for multi attribute upstream partner selection. They analyzed their system dynamics model for partner selection and showed that their model for partner selection and information sharing out performs 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 earliest due date (EDD) method).

The rest of this paper is structured as follows: Section 2 discusses the literature review on the subject matter. Section 3 is about the system dynamics theory. Research methodology is the topic of section 4 while system boundary and causal development is discussed in section 5. System dynamics model discussion is discussed in details in section 6 while System dynamics model formulation is elaborated in section 7. Model assessment and research limitations are the topics of sections 8 and 9, respectively. Simulation is the topic of section 10 and scenario analysis is the topic of section 11, respectively. Author's conclusion is given in section 12.

2. Literature Review

The essence of the systems approach is a belief that the whole is more than the sum of its parts (Mogaddam, et al. 2000). This implies that an isolated study of the components that make up a subsystem is inadequate to understand the complete system. This is because the separate parts are linked in an interacting manner and it is the interactions and interrelationships between the various components that give the system its identity and organizational integrity (Dent and Anderson, 1971; Rountree, 1977; and Spedding, 1979). Forrester (2007) argues that "powerful small models" can be used to communicate the most crucial insights of a modeling effort to the public (Ghaffarzadegan, 2011). A supply chain is a physical network in which different entities of material, cash and information are transferred (Akhbari et al. 2014a). At the start of the chain, there is some kind of supplier providing raw material and the chain ends with the customer consuming what is produced. The material typically flows in a downstream direction and cash in the opposite, whereas information flows in both directions (Mattson, 2000) and supply chain management is an integrative approach to dealing with the planning and control of materials and information from suppliers to end customers (Monczaka et al., 1998 and Jones and Riley, 1985). Qu, et al. (2014) have employed system dynamic approach to design the structure and parameters of Milk-Run Logistics system so as to achieve a statistical with optimization dynamics. This sort of hybrid approach to the SD utilization is something more to come in coming researches. Suryani et al. (2010) have employed system dynamics for demand scenario analysis and planned capacity expansion. De Marco et al. (2012) used system dynamics to assess the impact of Radio Frequency Identification (RFID) technology on retail operations. Zare Mehrjerdi (2011) employed system thinking approach to demonstrate the role of RFID in supply chain profitability engagement. Lin and Dao (2013) developed a system dynamics model of trust, knowledge sharing and stability of strategic alliance. Zhang Libo et al. (2014) studied a review of applications of system dynamics in supply chain management. System dynamics modeling has been applied, to specific health care management issues such as health care work-force planning and emergency health care provision (Royston et al 1999, Keolling, 2005), weight related health care problems (Zare Mehrjerdi, 2013a), systems thinking approach to profitability engagement (Zare Mehrjerdi, 2011, 2013c, 2015), level of job satisfaction (Zare Mehrjerdi, and Bioki, 2014b), effect of joint health care provision by different sectors (Wolstenholme 1999), and the effect of a shift from the free-to- service to self-paying service (Hirsch and Immediate 1999). Social welfare (Zagonel *et al.*, 2004), new product development (Zare Mehrjerdi and Dehghanbaghi, 2013b), sustainable development (Saeed, 1998; Honggang *et al.*, 1998; Mashayekhi, 1998), and security (Weaver and Richardson, 2006; Ghaffarzadegan, 2008; Martinez-Moyano *et al.*, 2008) are also among others that have received the attention. In addition to that a researcher has applied system dynamics model for library cost control and libraries' patron satisfaction (Zare Mehrjerdi, 2012, 2017) and then in demonstrating the probability feature of the quality function deployment in the industries as well as the service industry (2011). These models demonstrate the rich variety of areas in which SD may play a significant role, however.

Sohrabi et al. (2016) examined supplier selection in three echelon supply chain and the VMI under- price dependent demand condition. Zali et al. (2014) developed a system dynamics model for entrepreneurship research by concentrating on the literature review of the subject matter. Poorbagheri and Niaki (2014) discussed a vendor managed inventory model for single vendor, multi retailor, single warehouse supply chain system with stochastic demand. On the VMI modeling of the problem in the supply chain context, some researchers have been get involved: Bullwhip effect on the VMI supply chain (Hoseini and Zare Mehrjerdi, 2016), Rasay et al. (2015), Kim and Park (2010), Mohsen Akhbari (2014a, 2014b), and Mitra Moubed (2014) to mention a few.

Moubed et al (2015) developed a reverse supply chain taking collaboration into concentration. Various supply chain parameters are used to develop the stochastic model of the problem then meta-heuristic approaches are used to solve the problem. Akhbari et al. (2014b) contributes to the debate on the role of VMI-type contracts in supply chains by reviewing published literature during 1998-2011. A total of forty selected referred journal papers are systematically reviewed. Authors have focused on different perspectives including supply chain configuration, demand pattern, number of products and the type of protocols in party's agreement. Salehi et al. (2014) developed a system dynamics model used to evaluate the behavior of the suppliers of construction for Sepahan Equipment Manufacturing Company (STS) which is active in manufacturing of metallic equipment.

Y. Ge, J.-B. Yang, N. Proudlove and M. Spring (2004) presented a system dynamics approach for the analysis of the demand amplification problem, also known as the bullwhip effect, which has been studied fairly extensively in the literature. The construction of a system dynamics model is reported using a part of a supermarket chain system in the United Kingdom as an example. Yatsai Tseng, Weiyang Wang, Mengjue Wang (2012) has employed system dynamics as an approach for analyzing the evolutionary process of supply chain collaboration. Afshar, J., et al. (2014) developed a system dynamic model for better understanding of the blood supply chain behavioral pattern. Also the reflection of the proposed model was obtained and some comparisons among the current model and four different scenarios were investigated.

Samuel, C., et al. (2010) has analyzed a health service supply chain system in his research with this knowledge that a great deal of literature is available on the supply chain management in finished goods inventory situations while little research exists on managing service capacity when finished goods inventories are absent. Lina K. Al-Qatawneh a, Khalid Hafeez and Zain Tahboubin (2010) have proposed an integrated system dynamics framework for analyzing and modeling healthcare logistics chain. An American healthcare provider is used as an example to demonstrate the implementation of various stages of the proposed framework. Based on the systems analyses, causal relationships were developed and an EOQ based computer simulation model was built and tested. To understand the dynamic behavior of the variables that can play a major role in the performance improvement in a supply chain, a system dynamics based model was proposed by Ashish Agarwal and Ravi Shankar (2005). This model provides an effective framework for analyzing different variables affecting supply chain performance. Yihui Tian, Kannan Govindan, Qinghua Zhu (2014) proposed system dynamics model for guiding the subsidy policies to promote the diffusion of green supply chain management in China. The relationships of stakeholders such as government, enterprises, and consumers are analyzed through evolutionary game theory. The green supply chain management diffusion process is simulated by the model with a case study on Chinese automotive manufacturing industry.

In this paper, authors 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 simulate each supplier's (retailers) tendency to select downstream (upstream) partner selection and the impact of their policies in the whole supply chain.

3. Systems Dynamic Theory

From the concept of causal relationship, it indicates one element affecting another element. To model causality, we need to develop a causal loop diagram abbreviated as CLD. To build such diagrams we start with two elements from many and then identify one as A and the other as B. Meantime, we need to think of an influence with the direction, indicated by an arrow, starting from A and ending to B when we are looking at the impact of A on B. The reverse is true if we look at the impact of B on A. Each influence (arrow) has an indicator as to whether the influenced element is changed in the same (with + sign or S) or opposite (with – sign or O) direction as the influencing element. In this regard, Richardson (1986) indicated that the positive relationship refers to 'a condition in which a casual element, A, results in a positive influence on B, where the increase of A value responds to the B value with a positive increase. He also writes negative relationship refers to 'a condition in which a causal element, A, results in a negative influence on B, where the increase of A value responds to the B value with a decrease'. With this background, a simplest diagram (Fig. 1) is comprised of two elements of "Raw material purchasing price" (RMPP) and "Final price of goods" (FPG) that can be constructed as follow:

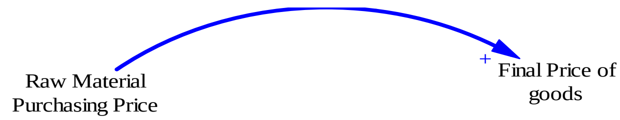

Fig. 1. Cause and effect relation between two factors

From this diagram there are only a couple of things which are implied:

- "Raw material purchasing price" and "Final price of goods" are elements of the model.
- "Raw material purchasing price" influences "Final price of goods" in the same (+) direction as "Raw material purchasing price". This means that as "Raw material purchasing price" increases, the level of "Final price of goods" also increases.

The dynamic movement of the system can be caused by a feedback loop, and there are two types of feedback: reinforcing loop and balancing loop. As illustrated above, increases in "Raw material purchasing price" increases the level of "Final price of goods", which again increases the "Final price of goods" causes the purchasing price of raw material to increase (by the passage of time). Such a loop is known as reinforcing loop and usually is shown with R sign. To the contrary, as "final price of goods" increases the customer satisfaction toward the price decreases but when the customers' satisfaction toward our goods is high more of the same product would be bought and as a result of that, in the long run, the final price of the good would decrease, because the income would increase.

Systems archetype is composed of many circulations formed as a result of all kinds of problems that affect one another in society. Senge and Lannon (1990) classified these circulations into nine major systems archetypes: (1) Delayed balancing process; (2) Limitation to goals; (3) Shifting the burden; (4) Temporary solution; (5) Escalation; (6) Success; (7) Common tragedy; (8) Failure; (9) Growth and underachievement; Fixes that Fail; and (11) Accidental Adversaries. In the section that follows we describe three of these basic system thinking theories.

4. Research Methodology

The study process in this article is comprised of following eight steps:

a. Identification of system and boundaries of that
b. Identification of internal and external variables
c. Development of causal diagram
d. Determination of variables associated with the rate and Level variables
e. Development of Stock and flow diagram
f. Development of the mathematical model of the problem in the Vensim
g. Simulation of model using Vensim computer software
h. Verification, validation and scenario analysis of the problem.

5. Systems Boundary and Causal Development

System thinking is a conceptual framework for problem-solving that considers problems in their entirety. Problem-solving in this way involves pattern finding to enhance understanding of, and responsiveness to, the problem. Outcomes from systems thinking depend heavily on how a system is defined because systems thinking examine relationships between the various parts of the system. Boundaries must be set to distinguish what parts of the world are contained inside the system and what parts are considered the environment of the system. The environment of the system will influence problem-solving because it influences the system, but it is not part of the system.

What makes using system thinking different from other approaches to studying complex systems is the use of feedback loops. According to the concept of system thinking, reality is made up of circles, but people usually see straight lines, which is a major limitation to see and understand the system and make the right decision related to that system. Peter M. Senge, Director of the Centre for Organizational Learning at MIT's Sloan School of Management in Boston/USA, described the systems thinking technique in his book: The Fifth Discipline (New York:

Currency Doubleday, 1990). The concept of system thinking is derived from a computer simulation model developed by Jay W. Forrester to deal with management problems (1961, 1971, 1985).

Tab. 1. Variables identifying the system boundary

Internal Variables	External Variables
Supplier1 inventory	Supplier 1 marginal price factor
Supplier1 backlog of Retailer1	Supplier 1 purchasing price
Supplier1 backlog of Retailer2	Supplier 1 backlog cost per unit per time
Total order from Retailer1 to Supplier1	Supplier 1 safety inventory
Total order from Retailer2 to Supplier1	Supplier 1 total order received
Supplier1 total order filled for Retailer1	Supplier 1 price
Supplier1 total order filled for Retailer2	Supplier 1 backlog threshold
Supplier1 inventory integral	Retailor 1expected price
Supplier1 backlog integral	Retailor 2 expected price
Supplier 1 SL for retailor 1	Price importance for retailor 1
Supplier 1 SL for retailor 2	Price importance for retailor 2
Retailor 1 loyalty for supplier 1	SL importance for retailor 1
Retailor 2 loyalty for supplier 2	SL importance for retailor 2
Retailor 1 Priority weight on supplier 1	Constant backlog satisfaction by supplier 1
Retailor 2 priority weight on supplier 2	Retailor 1 rate in
	Retailor 2 rate in
	Order ratio importance for retailor 1
	Order ratio importance for retailor 2

6. System Dynamics Model Description

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 but without loss of generality, this model can easily be adapted for any number of suppliers and retailers. Fig.2 represents a part of model that belongs to the first supplier. The sub model that is related to the second supplier is the same as the model presented for the first supplier. We can also use this model for any number of suppliers in the whole model.

Now we explain variables of first supplier sub model and the relationships between variables and mathematical equations which construct the structure of system dynamics model and will be utilized in simulation in the next section. It has to be mentioned that, all of the variables that exist in the sub model related to first supplier also exist in the sub model that belongs to the second supplier in the same way. For simplicity we just mention the variables of sub model related to the first supplier. From now on, we represent the first supplier as "Supplier1", the second supplier as "Supplier2", the first retailer as "Retailer1" and the second retailer as "Retailer2". Level variables that are used in Supplier1 sub model are illustrated in Table 2 and each of them is explained. Rate variables related to Supplier1 are also illustrated and explained in Table 3. Retailer1 sub model is also illustrated in Fig.3. The level and rate variables associated with Retailer1 sub model are presented and explained in Table 3 and Table 4, respectively. Needless to say, Supplier2 (Retailer2) sub model and its variables are the same as Supplier1 (Retailer1) sub model.

Consequently, the whole model including two suppliers and two retailers can be developed for illustration and simulation purposes. However, the model used for simulation purposes is not presented here but it is simply an illustration of all of relationships between suppliers and retailers showing the structure of dynamic upstream and downstream partner selection problems.

In the next section, we formulate the presented model illustrated in Fig.2 and will explain how its variables are related to each other and to other auxiliary variables. In the next section, the structure of dynamic decision making process for partner selection considering both suppliers and retailers will also be explained.

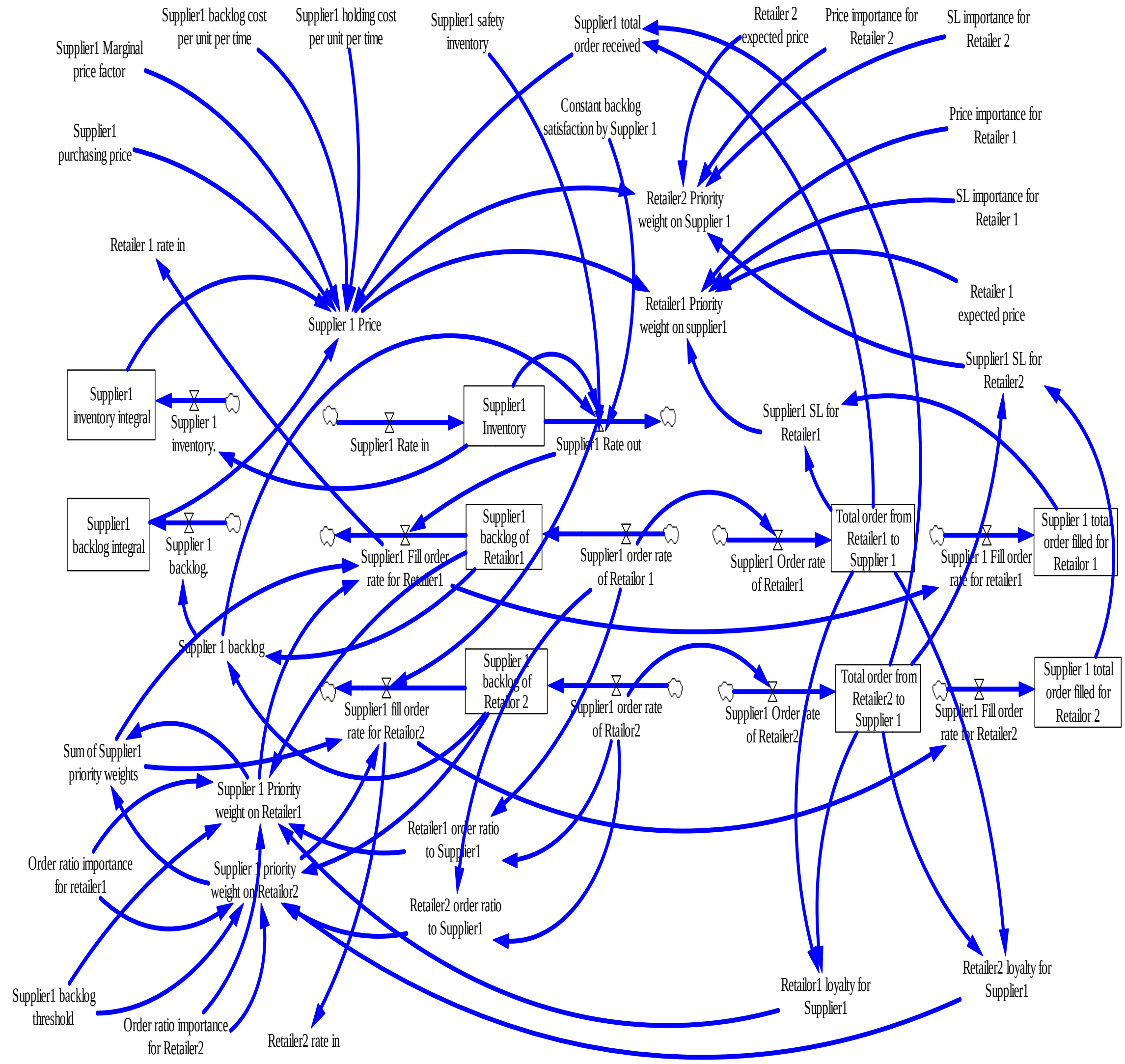

Fig. 2. Supplier1 sub model

7. System Dynamics Model Formulation

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

Since, each level variable is integral of rate variables that enter it minus rate variables that exit it, following equations stand for level variables in Supplier1 sub model:

$\text{Supplier1 inventory}(t') =$

$\text{Supplier1 backlog of Retailer1}(t')$

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

$\text{Supplier1 backlog of Retailer2}(t')$

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

$$\text{Total order from Retailer1 to supplier1}(t') = \int_0^{t'} \text{Supplier1 order rate from Retailer1}(t).\,dt$$

$$\text{Total order from Retailer2 to supplier1}(t') = \int_0^{t'} \text{Supplier 1 order rate from Retailer1}(t).\,dt$$

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

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

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

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

In equation (1), *Supplier1 inventory integral* is a level variable that calculates cumulative inventory multiplied by time and is 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 equation (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 dynamic model according to following equation:

$$\text{Supplier1 price} = \text{Purchasing price for supplier1} + \text{Marginal profit factor} *$$

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

Tab. 2. Level variables associated with Supplier 1 sub model

Level variable	Explanation
Supplier1 inventory	Level of product inventory for supplier1
Supplier1 backlog of Retailer1	Level of orders received by supplier1 from retailer1which has not been filled yet.
Supplier1 backlog of Retailer2	Level of orders received by supplier1 from retailer2which has not been filled yet.
Total order from Retailer1 to Supplier1	Total orders issued toSupplier1byRetailer1 containing orders that are filled or not filled yet.
Total order from Retailer2 to Supplier1	Total orders issued toSupplier1 byRetailer2 containing orders that are filled or not filled yet
Supplier1 total order filled for Retailer1	Total orders that has been filled so far for Retailer1 by Supplier1.
Supplier1 total order filled for Retailer2	Total orders that has been filled so far for Retailer2 by Supplier1.
Supplier1 inventory integral	Sum of inventories that Supplier1 has over time. Actually it calculates sum of 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. Actually it calculates sum of backlogged orders multiplied by time. This variable is used to calculate average backlog level for Supplier1.

Tab. 3. Rate variables associated with Supplier 1 sub model

Rate variable	Explanation
Supplier1 rate in	The rate at which product arrives to supplier1 product inventory.
Supplier1 order rate of Retailer1	Rate of order arrival toSupplier1 issued by Retailer1.
Supplier1 order rate of	Rate of order arrival toSupplier1 issued by Retailer1.

Retailer2	
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.

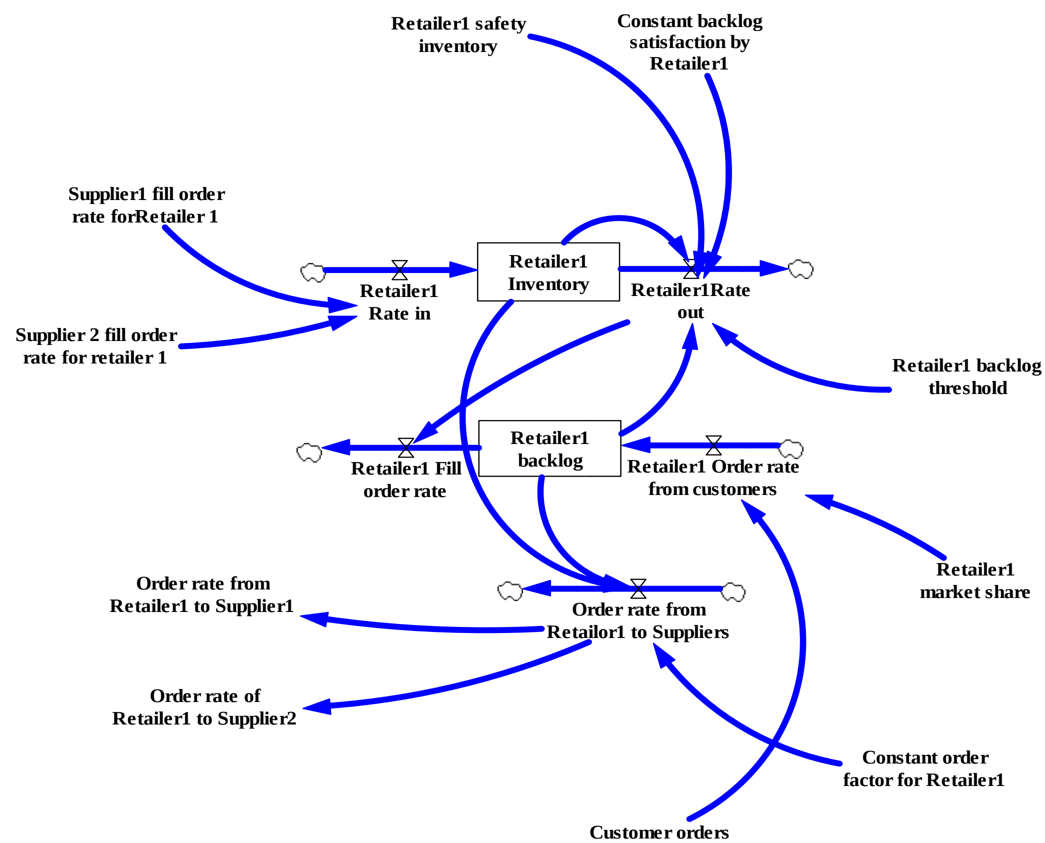

Fig. 3. Retailer 1 sub model

In equation (3), the price of selling each unit of product by supplier1 in each moment of time is calculated based on sum of total inventory cost and total backlog cost until that moment. Total cost is divided by total order received by supplier 1 till that moment to obtain cost incurred by each unit of order. Supplier1 purchasing price for each unit of product is also counted in 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 for model and its value is defined before simulation. *Supplier1 rate out* which is also a rate variable of Supplier1 sub model illustrated in Fig.2, 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 following equation:

$$\begin{aligned}&\text{Supplier1 rate out}\\&= \text{Constant backlog satisfaction by Supplier1}\\&* \text{Supplier1 backlog} * \text{LOG}(10 *\\&\text{Supplier1 Inventory}/\text{Supplier1 safety inventory})\end{aligned} \tag{4}$$

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

In equation (4), when Supplier1 inventory is less thanSupplier1 safety inventory**,** the phrase in parenthesis will be less than 1 and consequently logarithm will be less than 1. In result, Supplier1 rate out will decrease and actually products will leave Supplier1 inventory with 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 supplier1are input parameters of the model. Supplier1 order rate from retailer1 which is a rate variable of Supplier1 sub model illustrated in Fig.2, is equal to variable order rate of retailer1 to supplier 1 which is a rate variable of Retailer1 sub model illustrated in Fig. 3. Actually, these variables connect supplier1 and retailer1 sub models together. Each retailer's orders will be distributed among suppliers according to each retailer's priorities on suppliers and the supplier that has greater priority weight based on a specific retailer's idea will receive more orders than other suppliers. Equation (5) shows the way Retailer1 order rate to Supplier1is defined:

$$\begin{aligned}\text{Order rate of Retailor 1 to Supplier1} &= \text{Retailer1 order rate to Supplier1}\\&= \text{Order rate of Retailor1 to suppliers}\\&* \text{Retailer1 Priority weight on supplier1}/\text{Sum of retailer1 priorities}\end{aligned} \tag{5}$$

As we mentioned before, price and service level (SL) are considered as two factors that dynamically defines 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 till that moment which is responded by supplier. For example, service level of supplier1 for Retailer1 is calculated as follows:

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

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:

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

In equation (6), *Price importance for Retailer1*, *Retailer1 expected price*, *SL importance for Retailer1* and *Supplier1 backlog threshold* are parameters of the model and are 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 and is defined based on Retailer1 opinion. In equation (7), *Order rate of retailor 1 to suppliers* is defined based on following equation:

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

Equation (7) indicates that if Retailer1's backlogged orders level is greater than his(her) safety inventory level, he(she) issues orders according to difference between his(her) inventory and backlog level. *Retailer1 inventory* in equation (7) is defined the same as Supplier1's inventory level and is calculated according to following equation:

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

Retailer1 rate out in equation (8) has the same definitionas*Supplier1 rate out* and in the case that backlog level of Retailer1 is less than or equal to *Retailer1 backlog threshold* or inventory level of Retailer1 is less than or equal to his(her) safety inventory level, it equals to zero and otherwise it is obtained using the following equation:

$$\text{Retailer1 rate out}(t) = \text{Constant backlog satisfaction by Retailer1} * \text{Retailer 1 backlog} * \text{LOG}(10 * \text{Retailer1 Inventory}/\text{Retailer1 safety inventory} \quad (9)$$

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

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

In equation (10), Each Supplier's fill order rate for retailers depend on his (her) priorities on retailers and it is also dependent to each retailer's order ratio and loyalty for indicated supplier. For instance, Supplier1 fill order rate for Retailer1 is defined based on following equation:

$$\text{Supplier1 fill order rate for Retailer1} = \text{Supplier1 Rate out} * \text{Supplier1 Priority weight on} \frac{\text{retailer1}}{\text{Sum}} \text{of supplier1 priority weights} \quad (11)$$

In equation (11), *Sum of supplier 1 priority weights* is the sum of supplier1 priorities on Retailer1 and Retailer2 in the presented model and each of one is defined according to order ratio and loyalty of related retailer. For instance, Supplier1 priority on Retailer1 is defined dynamically over time as follows:

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

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

$$\text{Retailer1 loyalty for Supplier1} = \text{Total order from Retailer1 to Supplier1}/(\text{Total order from Retailer1 to Supplier1} + \text{Total order from Retailer2 to Supplier1})$$

$$\text{Retailer1 order ratio to supplier1} = \text{Supplier 1 order rate of retailor 1}/(\text{Supplier 1 order rate of retailor 1} + \text{Supplier 1 order rate of retailor 2})$$

Tab. 4. Level variables associated with Retailer 1 sub model

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

Tab. 5. Rate variables associated with Retailer 1 sub model

Rate variable	Explanation
Retailer1 rate in	The rate at which product arrives to 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.

8. Model Assessment

There are three steps in determining if a simulation is an accurate representation of the actual system considered, namely, verification, validation and credibility (Garzia and Garzia, 1990). Each of these is discussed briefly below.

8.1 Model Verification

Model verification is often defined as "ensuring that the computer program of the computerized model and its implementation are correct" (Sargent, 2011). Verification of computer programs is considered a part of computer programming in general, and error finding and debugging, in particular. Computer programs may work with the codes prepared by the users even if the logic used by the programmer is incompatible with the modeling purpose. In this case, the results may be unacceptable. In some cases, the errors are not simply traceable, however. Usually, scientific computer languages help programmers to verify computer codes and debugging up to a certain level. Vensim PLE software has the capability for verification purposes. For this purpose, the "structure check" which includes "formulas check" and "units check," is used to find whether there are formulas or units errors in the model of the problem. After successful completion of checking the formulas and units loaded into the software the model of choice is simulated.

8.2 Model Validation

Conceptual model validation is the process of determining whether the theories and assumptions underlying the conceptual model are correct and reasonable for the intended purpose of the model. Giannanasi et al. (2001) have defined validation as the process of determining the simulation model based on an acceptably accurate representation of reality. The objective is to achieve a deeper understanding of the model. Validation deals with the assessment of the comparison between 'sufficiently accurate' computational results from the simulation and the actual/hypothetical data from the system (Martis, 2006). The Vensim PLE (2008) software allows model validation using the "reality check", the option that the system provides. One can use that for comparing simulation results with perceived reality. The smaller difference between them can guide us that model is adequately addressing the problem to which it is being applied. To validate the proposed model, some well knowns conventional tests such as boundary efficiency test, unit consistency test, parameter evaluation test, cumulative error test, and extreme value test are performed.

8.3 Model Credibility

Credibility or operational validation is defined as determining whether the behavior of the model output has sufficient accuracy for the model's intended purpose over the domain of the model's intended applicability Sargent (2011), and Martis (2006).

9. Research Limitations

As it is stated by Sterman (2000) "all models are wrong, so no models are valid or verifiable in the sense of establishing their truth. The question facing client and model builder is never whether a model is true but whether it is a useful one". We can only say dynamic system is a good tool for studying complex systems.

10. Simulation and Discussion

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

We have 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 scenario illustrated in Table 6 and Table 7. In this scenario we assumed that suppliers receive products at equal rate from upstream partner and also customer orders are equally distributed among retailers. Considering the same parameters for Supplier1 and Supplier2 and also the same parameters for Retailer1 and Retailer2 according to Table 6 and Table 7, it is obvious that variables trend over time must be the same for different suppliers and different retailers. Fig.4 represents the rate that product leaves supplier1 inventory (Supplier1 rate out) or supplier2 inventory (Supplier2 rate out). It can be seen that the rate that products leave supplier's inventory is fluctuating 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 the half of Suppliers1 rate out and Supplier2 rate out and is illustrated in fig 5.

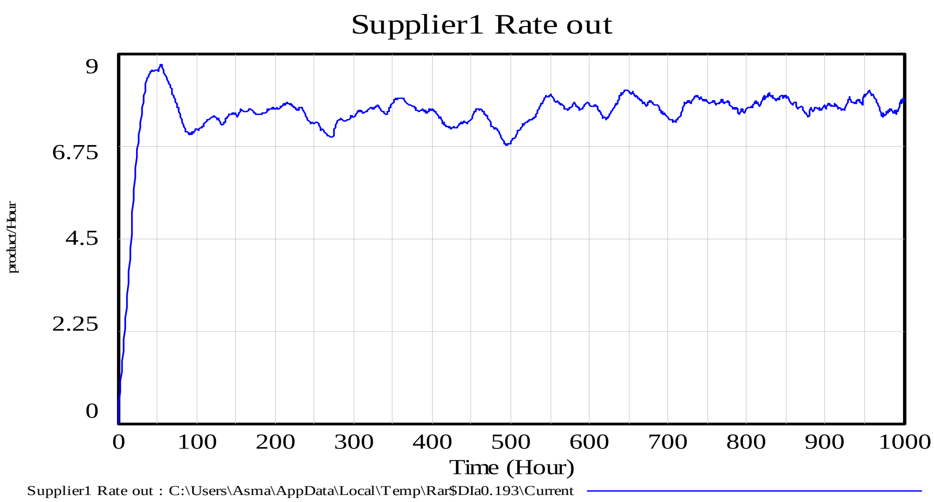

Fig.4. The rate that products leave suppliers inventory (Supplier1 (2) rate out)

Tab. 6. Value 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)

Tab. 7. Value of variables associated withRetailer1 and Retailer2

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

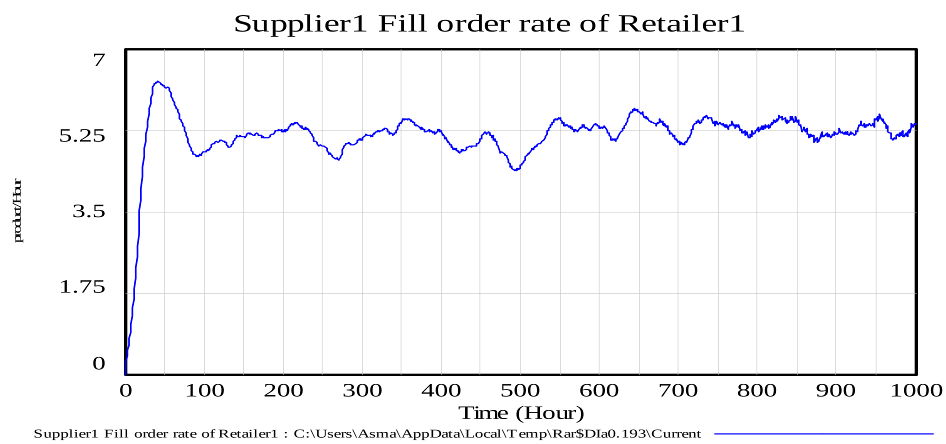

Fig. 5. The rate of filling orders by suppliers for retailers (Supplier1 (2) fill order rate for Retailer1 (2)

Figures 6 (a) and (b) demonstrates "components that supplier 1 fill order rate for retailer 1impacts on" and the "components influencing the supplier 1 fill order rate for retailer 1", respectively. Inventory level of suppliers is illustrated in Fig. 7 (a). It is clear from Fig.7 (a) that inventory level of suppliers is increasing slightly over time and then taking a declining trend after hours 550. The level of backlogged orders from retailers for each supplier is also illustrated in Fig.7(b). Each supplier's backlog level for the considered scenario of parameters in Table 6 and Table 7 is oscillating around a constant value.

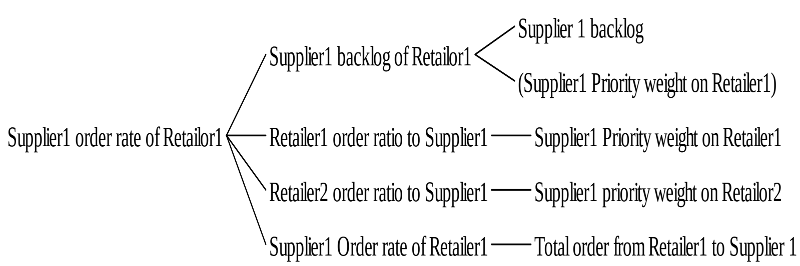

Fig.6 (a). Components that supplier 1 order rate of Retailer 1 impacting on

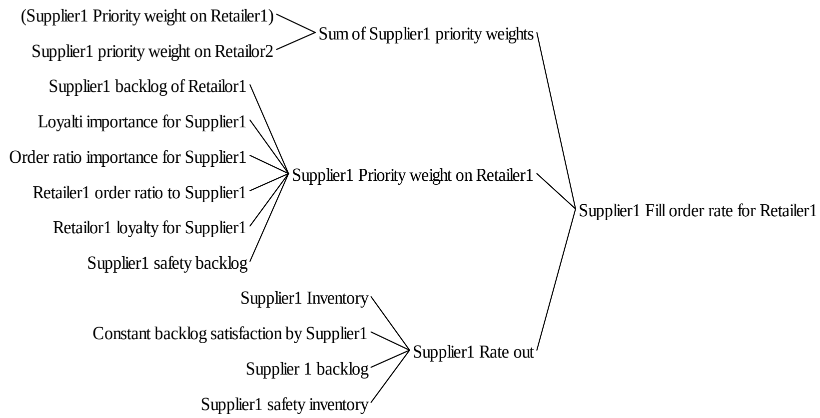

Fig.6 (b). Components influencing the supplier 1 fill order rate for Retailer 1

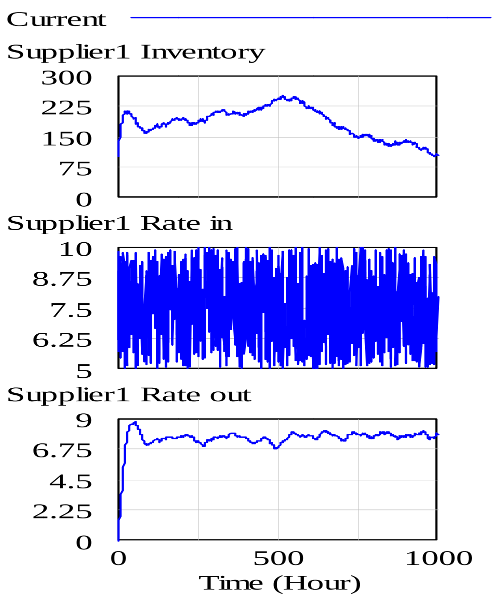

Fig. 7(a): Supplier 1 inventory level along with its rate in and rate out

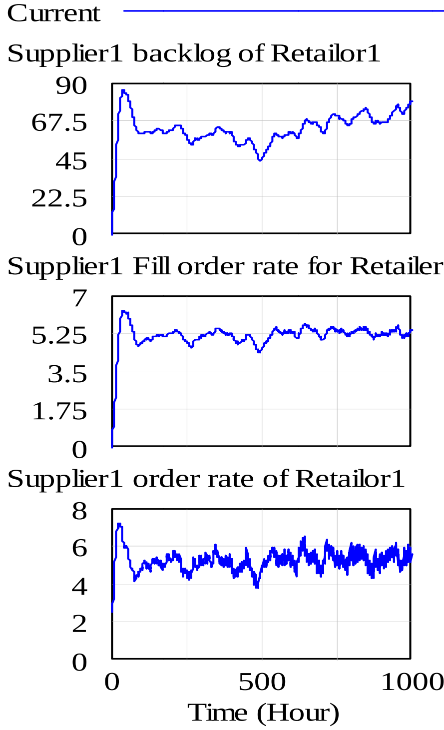

Fig. 7(b). Supplier 1 backlog of retailer 1 along with its fill or der rate and order rate of retailer 1

11. Scenario Analysis

This section is devoted to the analysis of four scenarios as are discussed one by one below.

11.1 Scenario 1

The trend of suppliers selling price according to above mentioned scenario of parameters values is depicted in Fig.8(a) and 8(b). As we see in this figure 8(b), the price of selling each unit of product by each supplier is increasing slightly from about 1127.5 to about 2156.18. Fig.9 shows the inventory level for retailers over time and it can be seen that inventory level of retailers is fluctuating around 50 that is safety inventory level for retailers according to Table 7. As we see in Fig.10, level of backlogged orders for retailers is also oscillating around a constant number.

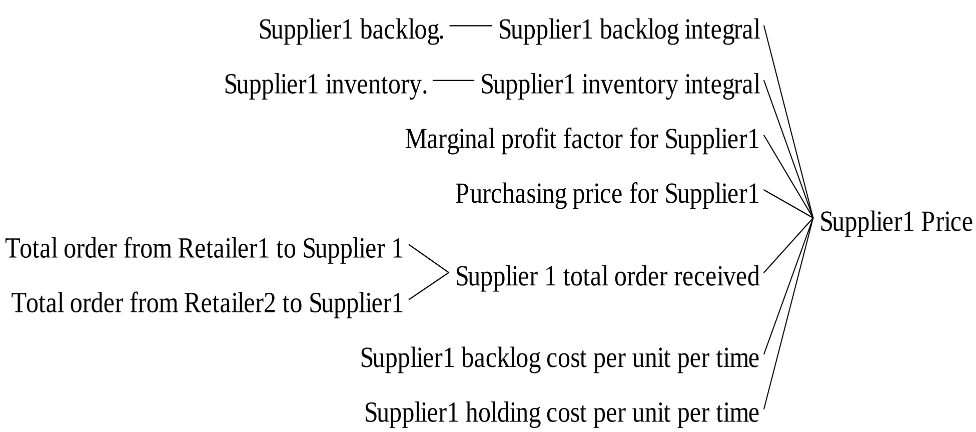

Fig. (8a). Components impacting the price of selling each unit of product by suppliers (Supplier1 (2) price)

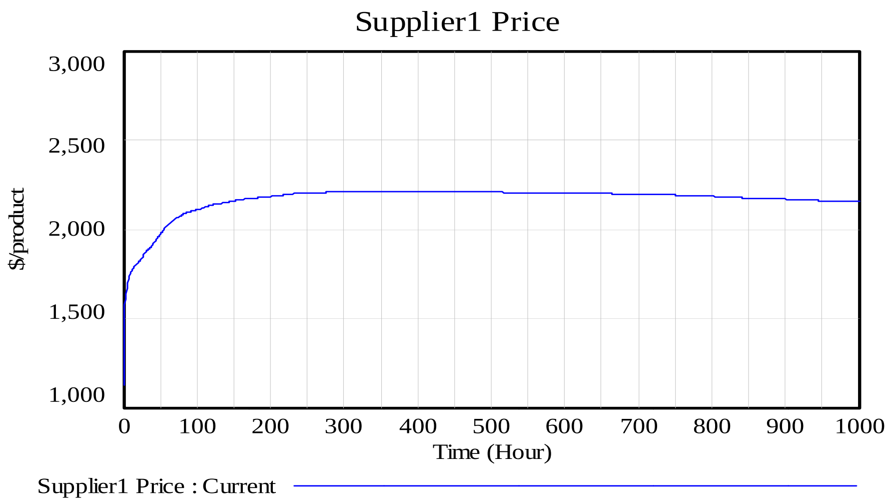

Fig. (8b). Price of selling each unit of product by suppliers (Supplier1 (2) price)

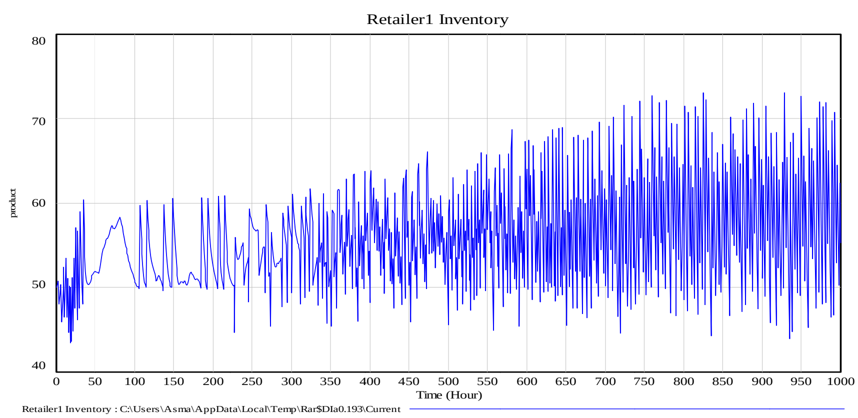

Fig. 9. Inventory level of retailers (Retailer1 (2) inventory)

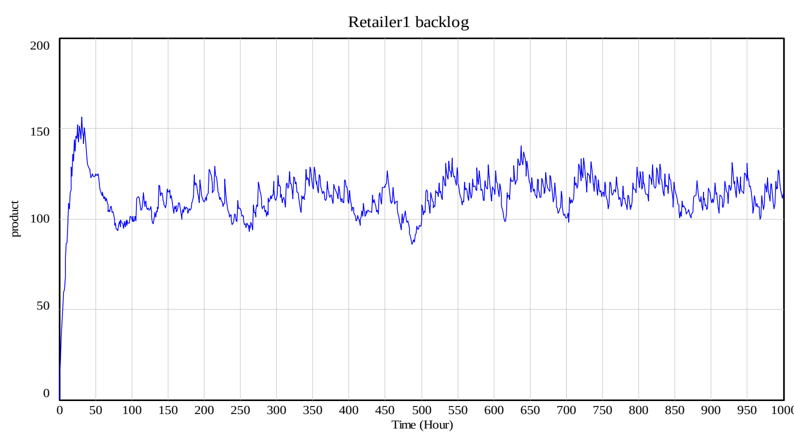

Fig. 10. Retailers level of backlogged orders (Retailer1 (2) inventory)

11-2. Scenario 2

Now, we consider a change in model parameters. Since we cannot understand changes in model clearly by changing more than one parameter, we consider just one parameter to be changed and investigate the impact of its change on the whole model. For example, we assume that market share of retailer1 become greater than market share of retailer 2 and be equal to 0.7 and all of other parameters values are like before. Inventory level of suppliers changes according to Fig.11. Each Supplier's inventory level become more stable and after some time it tends to safety inventory level (104.61 for supplier 1 and 90.24 for supplier 2). It might happen because of the fact that when suppliers most of the time have to deal with one retailer instead of two retailers, they have less challenge and their product inventory level is more stable and near safety inventory level. But, it can be seen from Fig.12 that in this situation their level of backlogged orders grows dramatically over time. In this case we can also see that supplier2 fills more orders for retailers as compared to supplier1specially near the end of simulation (Fig.14 and Fig.15). It can also be seen from Fig.14 and Fig.15 that in the case that after nearly hour 600 of simulation, the rate of filling orders for Retailer1 in some moments of simulation are equal to zero and it occurs because in these moments level of backlogged orders from this retailer to suppliers is less than backlog threshold of suppliers. Figure 13 shows supplier 1 price after increasing retailer1's market share, however.

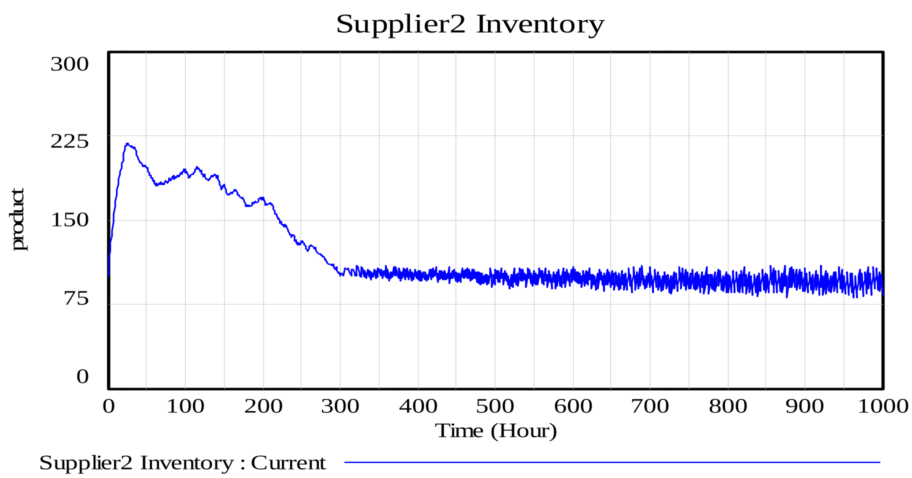

Fig. 11. Inventory level of suppliers after increasing Retailer 1's market share

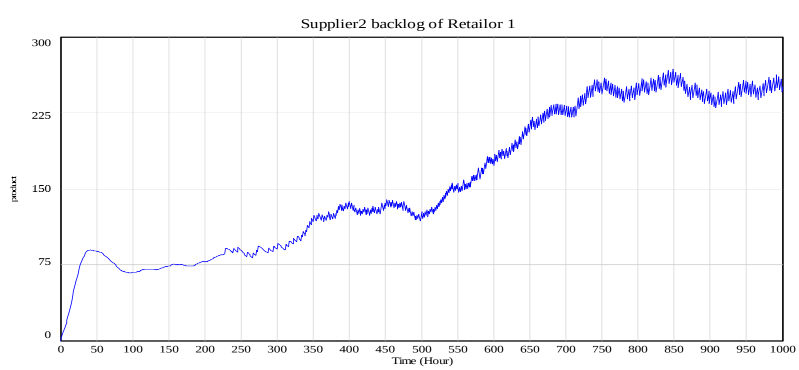

Fig. 12. Suppliers level of backlogged orders after increasing Retailer 1's market share

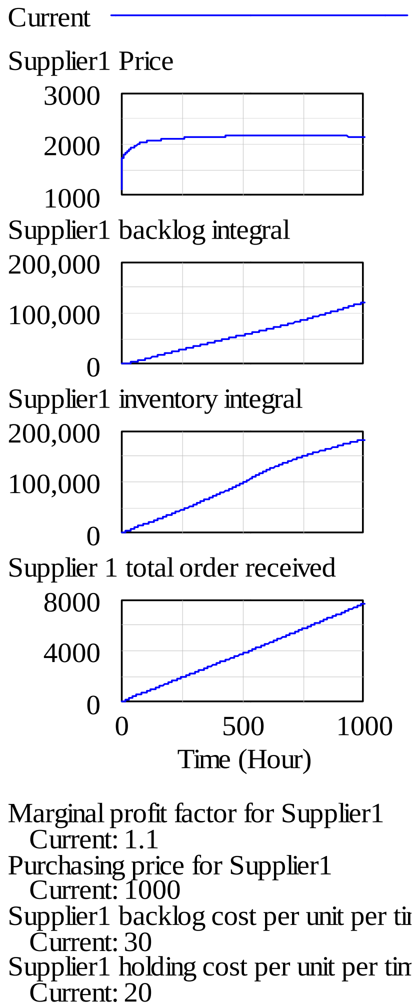

Fig. 13. Supplier 1 price after increasing Retailer 1's market share

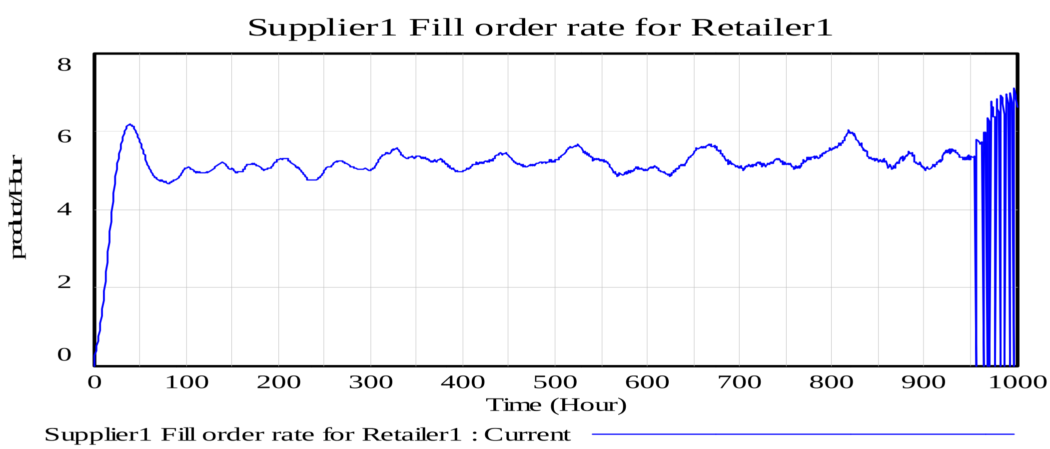

Fig. 14. Supplier 1 fillorder rate for retailer1 after increasing Retailer1's market share

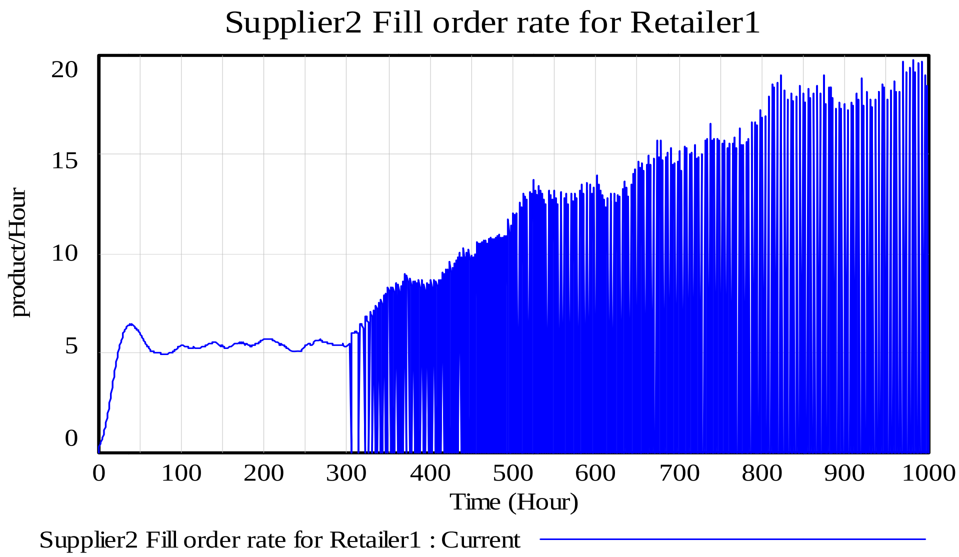

Fig. 15. Supplier 2 fill order rate for retailer1 increasing Retailer1's market share

11-3. Scenario 3

We can also change other parameters like 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 Fig.16 and Fig.17 that price of selling products by suppliers change in comparison to the first scenario presented in Table 6 and Table 7. It is clear from these figures that price of selling each unit of product by Supplier1 is decreased in comparison to previous scenarios and stands near 2027.52 at the end of simulation whereas Supplier2's price changes as compared to previous scenarios and is equal to 1958.43 at the end of simulation. We see that a change in one supplier's policy parameters have impact on not only its price but also on other supplier's price. This change has also impact on priorities of retailers to buy from suppliers over time. When we compare the results obtained in the first scenario in Table 6 and Table 7 with the third scenario obtained from changing policy parameter of Supplier1, it is clear from Fig.18 and Fig.19 that each retailer's priorities to buy from Supplier1 increases as compared to their preference to buy from Supplier2 and it might be because of the fact that retailers prefer suppliers with lower price than suppliers with higher service level (considering importance weights of suppliers). Each supplier's service level trend over time according to the first scenario of model parameters presented in Table 6 and Table 7, is represented in Fig.18 and it is clear that it tends to 1. It means that after some time, suppliers fill the most of orders received from retailers. Service level of suppliers to retailers in the second scenario (in the case that 0.7 of customer orders belongs to Retailer1) is depicted in Fig.19, Fig.20, Fig.21 and Fig.22. Based on these figures, change of Retailer1's orders received from customers (market share) have more effect on service level received by Retailer2 than by Retailer1 and decreases it more.

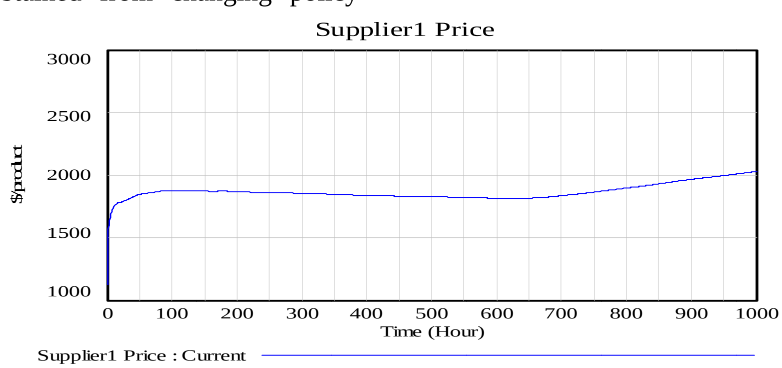

Fig. 16. Supplier 1's price after decreasing spplier1's safety inventory level

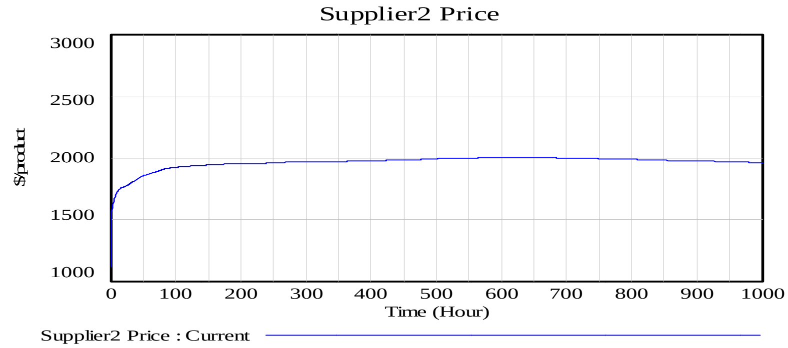

Fig. 17. Supplier 2's price after decreasing spplier1's safety inventory level

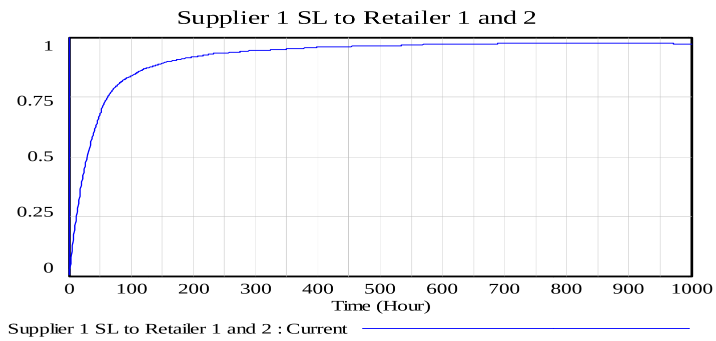

Fig. 18. Suppliers service level according to the first scenario in table 5 and table 6

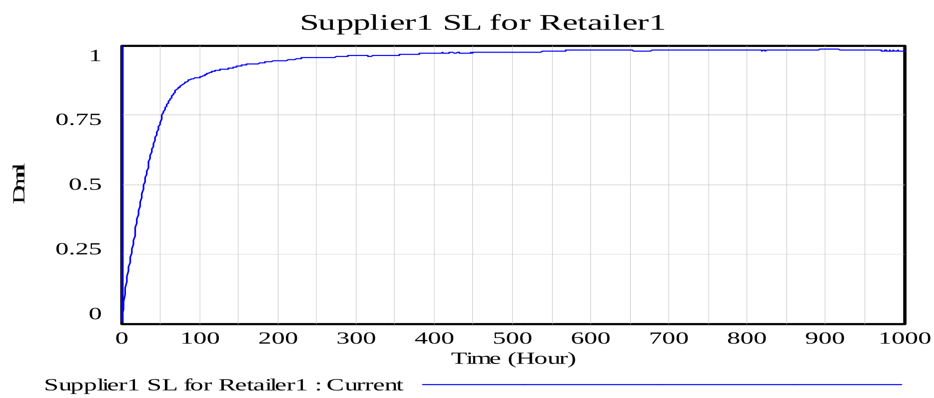

Fig. 19. Supplier1 service level to retailer1 after increasing Retailer1's market share

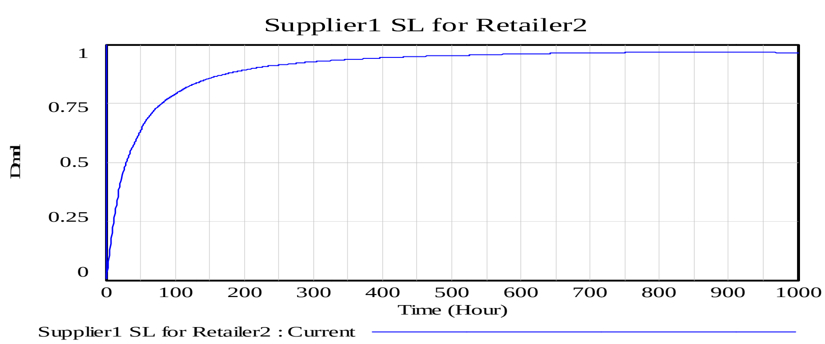

Fig. 20. Supplier1 service level to retailer 2 after increasing Retailer 1's market share

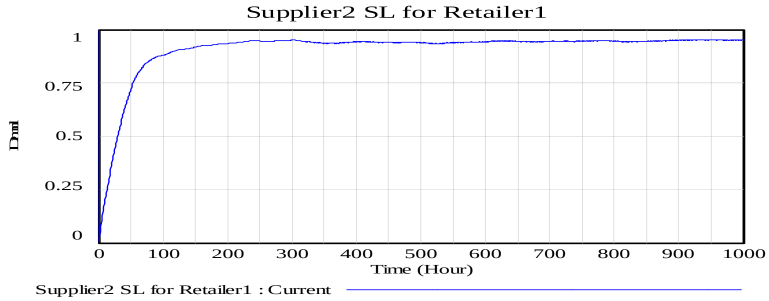

Fig. 21. Supplier 2 service level to retailer1 after increasing Retailer 1's market share

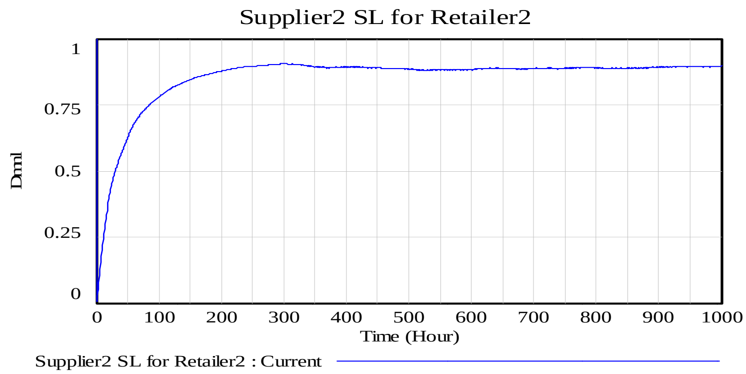

Fig. 22. Supplier 2 service level to retailer 2 after increasing Retailer 1's market share

11-4. Scenario 4

More scenario analysis can be conducted on the presented model to become more familiar with the suppliers and retailers' behavior. In this scenario we only assume that the purchasing price for supplier 1 is 900 instead of 1000. Taking this key variable into consideration we can see the changes shown by the figures below in the behavior of the system on some of our system variables as such Supplier 1 price, supplier 1 inventory level, supplier 1 inventory integral and supplier 1 backlog integral. The supplier 1 price starts at 1017.5 and ends at 2090.9 at the hours of 1000 of simulation (see Fig. 23). The inventory level takes values around 150 and then declines to 100 and stay at that level after hours 675 (See Fig. 24). Figures 25 and 26 exhibit the inventory level integral and the backlog integral after decreasing the purchasing price of supplier 1 by 10 percent.

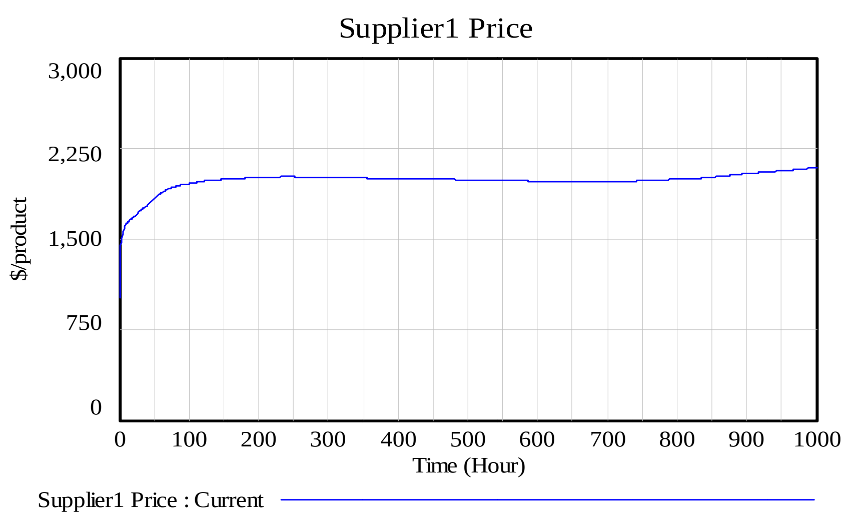

Fig. 23. Supplier 1 price after decreasing the purchasing price of supplier 1 by 10 percent

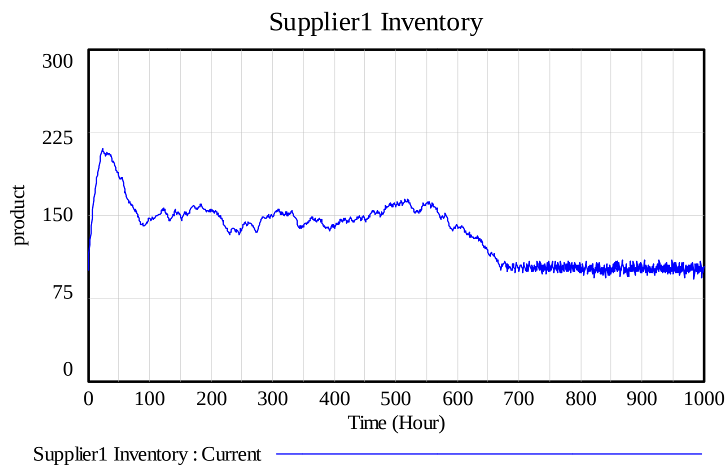

Fig. 24. Supplier1 inventory level after decreasing the purchasing price of supplier 1 by 10 percent

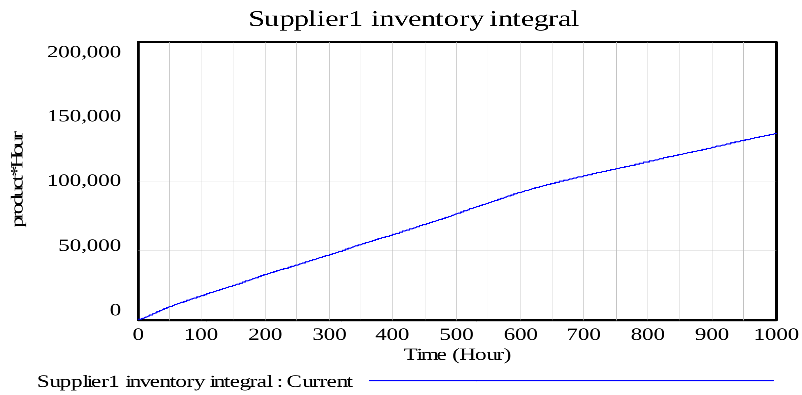

Fig. 25. Supplier1 inventory integral after decreasing the purchasing price of supplier 1 by 10 percent

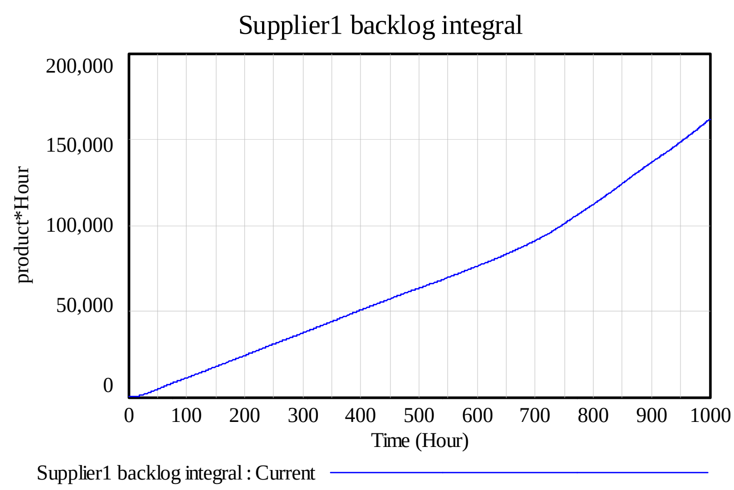

Fig. 26. Supplier1 backlog integral after decreasing the purchasing price of supplier 1 by 10 percent

12. Conclusion

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

To complement this work, future research lines have been identified: studying the impact of different parameters related to suppliers and retailers on the behavior of whole system and specially on product price and cost of supply chain; combination of MCDM (Multi-Criteria Decision Making) methods such as AHP (Analytical Hierarchy Process) and ANP (Analytical Network Process), strategic system selection (Zare Mehrjerdi, 2014a), with system dynamics modeling to optimize supply chain performance criteria; Considering other aspects relating to transportation such as transportation cost and transportation time in model to measure and evaluate the performance of supply chain; applying different policies of suppliers and retailers to fill orders and issuing orders; Considering uncertainty in parameters using probability theory or Fuzzy theory.

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