# Inventory Management in a Lateral Collaborative Manufacturing Supply Chain: A Simulation Study

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## Abstract

Due to global competition, firms are seeking more effective Supply Chain (SC) collaboration in order to provide quality products with less cost, at the right time and in the right quantity. The present study examines manufacturing SC collaboration on the basis of holding cost, backorder cost and ordering cost. The types of collaborations for examining are: vertical, horizontal and lateral. This research emphasizes lateral collaboration in showing the impact of inventory policies ((s, S) and (s, Q) inventory policies) on SC performance. For better understanding, a conceptual model is provided which is supported by numerical example. As the study of SCs is complex in nature, a simulation approach has been employed to show the impact of lateral collaboration on performance measures, such as the total cost which is the sum of several cost components like inventory holding cost, backorder cost and ordering cost. The research work is based on two manufacturing SCs where the manufacturer is taken as the collaborative node. To allow more clarity, a separate study on each cost component has been conducted. The laterally collaborative SC has been simulated on ARENA 9.0, a simulation package. The results show that the efficacy of lateral collaboration outperforms the horizontal collaboration due to having the individual SC members more liberty to make decisions.

***Keywords:*** Supply Chain, Collaboration, Inventory Policy, Simulation

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## 1. Introduction

Today's business climate has rapidly changed and has become more competitive than ever. Businesses now not only need to operate at a lower cost in order to compete, but they must also develop their own core competencies to be distinguished from competitors and stand out in the market. Enterprises are now competing globally and traditional barriers between industries are breaking down. Thus the main goals for enterprises are maximizing the added value and reducing the total cost across the entire trading process by means of focusing on speed and certainty of response to the market. There is a real challenge for Supply Chain (SC) networks to become more efficient and more responsive to the increasingly demand of customers, driven by competitive pressures and supported by developments in information technology. Due to abovementioned market pressures and the issues involved in becoming more successful in the global market, all the SC players need to collaborate towards the same goals to be more profitable in the market and in providing a quality product in less lead time.

Collaboration is negotiated cooperation between independent parties by exchanging capabilities and in sharing burdens to improve collective responsiveness and profitability. Firms are now seeking to build a competitive advantage through SC collaboration, which leverages the resources and knowledge of suppliers and customers, and coordinates and integrates the flow of products and information across the SC (Verwaal and Hesselmans 2004, Caridi et al. 2005, Lejeune and Yakova 2005, Cao and Vonderembse 2010). Specifically, collaboration is defined as: “A long-term partnership process where SC partners with common goals work closely together to achieve mutual advantages that are greater than the firms would achieve individually” (Stank et al. 2001; Bowersox et al. 2003; Golicic et al. 2003; Manthou et al. 2004; Sheu et al. 2006). In other words, it can be said that collaboration in a supply network means long-term relationships among members through reductions in transaction costs, and increases in resource sharing, learning, and sharing of knowledge (Cousins, 2002).Thus, companies tend to focus on streamlining the cross-company processes from an extended perspective of the SC. The actual economic context forces enterprises to collaborate to survive against increasingly aggressive competition. In the current strong competitive industrial context, enterprises must react quickly to market changes. In order to face this problem, enterprises must collaborate. To maintain a competitive advantage, working together or collaborating can be a critical success factor. Collaboration may take several forms such as informal meetings or formal teams composed of members from different companies. In general, two types of collaboration can be distinguished,

namely vertical and horizontal collaboration. Vertical collaboration can be defined as collaboration between parties performing complementary activities or services while the latter indicates collaboration between parties performing the same type of activities and/or services (Naesens et al., 2004; Cruijssen et al., 2007, Naesens et al., 2009). Vertical integration takes place at different levels of the SC. The integration between the producer and the distributor enables better physical and information flows, improvements in the trade-off between the level of service and the average stock, more economical inventory management control and better transportation systems (Caputo and Mininno, 1996). Horizontal integration may overcome trade financial barriers (Manning and Baines, 2004). To overcome of both types of collaboration difficulties, a new paradigm of lateral collaboration has been developed in this study.

In the present paper, an attempt has been made to show the impact of inventory policies on the SC cost, and also with collaboration. In this study, both types of collaboration (horizontal and vertical) with lateral collaboration have been examined. From the literature review, it can be seen that horizontal collaboration is good but it does not provide decision making freedom for all the SC members. Therefore, it can be said that this study provides a new insight for researchers and practitioners on collaboration and inventory policies. To show the impact of inventory policies, two linear SCs have been considered where one follows (s, S) and the other follows (s, Q) inventory policy. As one of the most important members of the SC, the manufacturer is considered in terms of collaboration. Initially both SCs have vertical collaboration as all the members follow the same inventory policy to achieve the same goal. In horizontal collaboration, only the manufacturer can decide on sending an order to the other manufacturer and it will take more time and more cost will be incurred. To overcome this deficiency, a new paradigm of lateral collaboration has been explored and this will glean ideas from both types of collaboration. The main performance measure in this study is the total cost which is the sum of the inventory holding cost, the backorder cost and the ordering cost. A separate study for each component has been done. As the present SC context is very complex, it has been simulated in ARENA 9.0, a simulation package, so that it can provide a real decision making study.

The remainder of the paper has been organized in the following manner: section 2 provides the literature review of SC collaboration whereas section 3 provides the further understanding on collaboration in SCs. Section 4 describes the conceptual model of SC collaboration. Section 5

presents the simulation model with some parameters for the numerical analysis. Section 6 gives the results from the simulation study, discussed in detail, and the paper is concluded in section 7.

## 2. Literature Review

An inter-organizational relationship in which the participating parties agree to invest resources, mutually achieve goals, share information, (Ring and Van de Ven, 1994; Gray and Hay, 1986; Stank et al., 1999; Barrat and Oliveira, 2001) resources, rewards (Phillips et al., 2006) and responsibilities, as well as jointly make decisions, and solve problems can be depicted as collaboration. Collaboration is based on mutual trust, openness, shared risk and shared rewards that yield a competitive advantage, for better performance (Horvath, 2001). Despite the popularity and benefits of SC collaboration, many partner relationships fall short of meeting the participants' expectations (Doz and Hamel, 1998; Barringer and Harrison, 2000). Few firms have truly capitalized on the potential of SC collaboration (Min et al., 2005; Barratt and Oliveira, 2001). SC collaboration seems to have great potential, but further investigation is needed to recognize its value (Goffin et al., 2006).

According to Cao et al. (2010), collaboration has been widely discussed in a variety of disciplines, such as in transaction cost economics (TCE) (Williamson, 1975), relationship marketing (Hakansson, 1982; Jap, 2001), inter-organisational systems (Kuman and Dissel, 1996; Alstyne, 1997), strategic management (Gulati et al., 2000), SC management (Cousins, 2002, Chong et al. 2010, Chan and Zhang, 2011), and sociology (Winer and Ray, 1994). Collaboration is for sharing the costs of large investments, pooling and spreading of risk, and access to complementary resources (Swink., 2006). Similarly, firms establish close, long-term working relationships with suppliers and customers who depend on one another for much of their business, developing interactive relationships with partners who share information freely, work together when trying to solve common problems when designing new products, who jointly plan for the future, and who make their success inter-dependent (Spekman et al., 1998). More and more companies are collaborating in the SC because of market diversity, competitive pricing and shorter product life cycles. Similarly, Boomer et al. (2001) also argues that the benefits of collaboration include revenue enhancement, cost reductions and increased operational flexibility to cope with high demand uncertainties. Both practitioners and academics are increasingly interested in SC collaboration (Horvath, 2001). Malhotra et al. (2005) maintain that SC partners

are engaging in interlinked processes that enable rich information sharing and the building of information technology infrastructures that allow the processing of information obtained from their partners to create new knowledge. Their study showed how various inter-organizational relationships contributed to knowledge creation capabilities in firms (Malhotra et al., 2005).

A significant amount of research has focused on the development of SC collaboration models to make this new research area more understandable (Das et al., 2006; Deveraj et al., 2007; Zhao et al., 2008; Chen and Paulraj, 2004; Van der Vaart and Van Donk, 2008; Flynn et al., 2010, Cao et al. 2010, Cao and Zhang, 2011). Previous definitions of SC collaboration put more emphasis on process integration and less on the components of relational communication and knowledge creation (Simatupang and Sridharan, 2005). Communication is a more important factor that holds SC partners together through balanced, two-way, multilevel contact services (Mohr and Nevin, 1990; Chen and Paulraj, 2004). Further, collaboration between SC partners is not merely a pure transaction, but leverages information sharing and market knowledge creation for sustainable competitive advantage (Malhotra et al., 2005).

Collaboration implies working more closely with a shared vision and trust (Lee and Billington, 1992). Furthermore, sharing information, joint planning, joint problem solving and joint decision-making are some of the components of collaboration discussed in the literature (Kaufman et al. 2000, Peck and Juttner 2000, Manthou et al., 2004; Sheu et al., 2006, Caridi et al. 2005). Soonhong et al. (2005) revealed that sharing periodical information, either formally or informally, is regarded as the essential ingredient for collaborative partners to ease the flow of products, services and feedback from customers.

Some researchers such as Mentzer et al. (2000), Sheu et al. (2006) have worked on SC collaboration and viewed it as a business process. Whereas other researchers, such as Bahinpati et al. (2009), Naesens et al., (2009), have worked on the type of collaboration and especially on horizontal collaboration. Elofson and Robinson, 2007; Vachon and Klkassen, 2008 have worked on the SC performance during collaboration. Whereas Beamon and Chen, (2001), Caridi et al., (2005), and Green and Inman (2005) have investigated improvement of SC collaboration. Cannella and Ciancimino (2010) have studied bullwhip effect avoidance in SC collaboration.

With advanced development in computing technology in the last few decades, simulation has become a very important tool to analyse complicated problems. It is a highly flexible tool that can be used effectively for analysing complex systems, like SCs, and enables us to model such systems in detail (Jansen et al. 2001). To model the coordinated SC, Ng et al. (2001) simulated two coordinated inventory models, which were based on order-up-to policy, with alternative supply possibilities between two suppliers and two retailers. They found that a higher level of coordination leads to significant savings in the average total cost of a SC. In another study, Jansen et al. (2001) analysed the performance of several scenarios in a multi-compartment distribution system in order to satisfy customer demands for shorter lead times. Banerjee et al. (2003) studied the effects of intra-echelon shipments through simulation. Inventory replenishment decisions were made based on a coordinated common review period. Hung et al. (2006) presented a simulation study of a SC in which inventory replenishment systems and production planning had been modelled. They tested their model in a two-product divergent SC with uncertain demand, which was modelled by normal distribution. Wadhwa et al. (2010) have also done a significant work on the coordination of SC using simulation approach. Their study concluded that more advantages from cooperation and information transparency were obtainable when SC is leaner. They also highlighted that such SC initiative that motivates local optimisation at the nodes was counter-productive to SC wide performance. Datta and Chirstopher (2011) has also done a simulation study on the coordination and information sharing in SC. The findings of their research suggested that, a centralised information structure without widespread distribution of information and coordination was not effective in managing uncertainty of SC networks, even with increased frequency of information flow. As per the literature review, the present research is also based on the simulation study due to the complexity of the modelled system.

In the light of abovementioned literature review, it can be concluded that there is not a clear understanding of SC collaboration. In other words, it can be said that there is a lack of a conceptual model for SC collaboration. From the review, it is also clear that very few researchers have worked on horizontal collaboration; therefore it can be said to be an unexplored research field. There are many empirical studies on performance indicators of SC collaboration but very little research has been addressed on the SC performance during collaboration. It is thus evident that lateral collaboration is still an unexplored research area.

Due to abovementioned research gaps in the literature, the motivation of the present research is to work on lateral collaboration. In this study, inventory management has been studied by applying different inventory policies in the manufacturing SC and manufacturer works as the collaborative node. The present study also reveals the deficiency in horizontal collaboration and the supremacy of lateral collaboration over horizontal collaboration. The main performance measure is the total cost of the SC which is the sum of inventory holding cost, backorder cost and ordering cost. The impact of lateral collaboration is also shown for each component. To show the impact of inventory policy and lateral collaboration, the simulation package ARENA 9.0 has been employed.

The next section provides the definitions and the classification in SC collaboration.

## 3. Collaboration in Supply Chain

The concept of collaboration was defined by Graham and Barter (1999) within and outside the social science area. Collaboration may be defined as a relational system in which two or more stakeholders pool resources in order to meet objectives that neither could meet individually. Collaboration is an effort by two or more organizations to achieve results that they cannot achieve by working in isolation (Wang and Archer, 2007). In the case of a SC, SC collaboration can be defined as two or more autonomous firms working jointly to plan and execute SC operations (Simatupang and Sridharan, 2002). Mentzer et al. (2001) defined SC collaboration as integrating all partners into one virtual network with common goals. It is important in achieving a competitive advantage (Harison and New, 2002). Simatupang and Sridharan (2004a) showed a linkage between collaborative performance metrics and collaborative enablers. Simatupang and Sridharan (2004b) and Holweg et al., (2005) demonstrated that collaboration between partners resulted in better performance. It can deliver substantial benefits and advantages to its partners (Mentzer et al., 2000). SC collaboration is prevalent in today's business model. An organization not only optimizes itself but also collaborates with other organizations to have larger optimization planning (Chan et al., 2004). In order to achieve an integrative settlement, collaboration has been defined as an attempt to fully satisfy the concerns of the parties involved in any exchange (Esper & Williams, 2003, Chan and Zhang, 2011). The key characteristics of collaboration are identified as coherence, communication, task management, resource management, schedule management, and real-time support (Graham, 2006). Collaborative

relationships can help firms share risks (Kogut, 1988), access complementary resources (Park et al., 2004), reduce transaction costs, enhance productivity (Kalwani and Narayandas, 1995), and enhance profit performance and competitive advantage over time (Mentzer et al., 2000).

Collaboration in SCs can be classified into three types: vertical, horizontal, and lateral collaboration (Hsu & Hsu, 2009). The type of collaboration is mainly decided by the collaboration scenario and the attributes of the participants. Each type of collaborations is defined below:

***Vertical Collaboration***

The vertical collaboration can be defined as the collaboration when two or more organizations such as the manufacturer, the distributor, the carrier and the retailer, share their responsibilities, resources, and performance information to serve relatively similar end customers. This collaboration has dominated market-oriented and hierarchical governance structures in SC management. The benefits of such type of collaboration include reductions in transaction costs, increases in resource sharing, learning, and sharing knowledge.

***Horizontal Collaboration***

Horizontal collaboration occurs between partners at the same level in the manufacturing process, where the benefits of collaborative manufacturing/purchasing include lower prices due to aggregated manufacturing/purchasing quantities, reduced supply risk, reduced administration costs due to centralized purchasing activities, and networking benefits as group members communicate and interact with each other (Tella & Virolainen, 2005). Horizontal collaboration is a business agreement between two or more companies at the same level in the SC or network in order to allow greater ease of work and cooperation towards achieving a common objective. In other words, it can also be called external collaboration. It does, however, have some disadvantages like loss of flexibility, loss of control by individual SC members, high coordination costs as group members are competitors, and anti-trust problems.

***Lateral Collaboration***

Lateral collaboration combines the benefits and sharing capabilities of both vertical and horizontal integration. Integrated logistics and inter-modal transport are examples of the application of lateral integration that aim at synchronizing carriers and shippers of multi firms in a seamless effective freight transport network (Simatupang and Sridharan, 2002).

In the present study, the main emphasis is on the lateral collaboration as it works on the capabilities and overcomes the deficiencies of both types of collaboration and still is an unexplored area in research. First, the concept of lateral collaboration has been given by providing a conceptual model and by numerical analysis later on. The next section describes conceptual models of SCs with the impact of inventory policy and collaboration.

## 4. Conceptual Model

In the present study, two SCs have been considered and the impact of collaboration has been shown. In this study, the impact of horizontal collaboration and lateral collaboration on the inventory policy and on the various costs has been shown. For the conceptualization of collaboration, two linear SCs have been taken into consideration. In the first SC, there are four members: Supplier (S1), Manufacturer (M1), Distributor (D1) and Retailer (R1). This SC follows the (s, S) inventory policy i.e. the maximum inventory level is 'S' and minimum inventory level or reorder point is 's'. It is also called the 'min-max' inventory policy. The SC (SC1) has been depicted in figure 1. In SC1, three types of flow are shown: material flow, information flow and cash flow. As shown in figure 1, the maximum inventory levels are $S_s$, $S_m$, $S_d$ and $S_r$ and the minimum inventory level or reorder points are $s_s$, $s_m$, $s_d$ and $s_r$ for supplier, manufacturer, distributor and retailer respectively.

*<<Include figure 1 here>>*

In the second linear SC, there are four members: Supplier (S2), Manufacturer (M2), Distributor (D2) and Retailer (R2). This SC follows the (s, Q) inventory policy i.e. the order quantity is 'Q' and minimum inventory level or reorder point is 's'. The SC (SC2) is shown in figure 2. In this SC, three types of flow are shown: material flow, information flow and cash flow. The material flow is from supplier to retailer and the cash flow is in reverse, whereas information flow is on both sides i.e. it takes the information from both sides and provides the information to all SC members. As shown in figure 1, the order quantities are $Q_s$, $Q_m$, $Q_d$ and $Q_r$ and the minimum

inventory level or reorder points are $s_s$, $s_m$, $s_d$ and $s_r$ for supplier, manufacturer, distributor and retailer respectively.

*<<Include figure 2 here>>*

These two SCs have taken into account two different inventory policies to show the impact of inventory policies on the inventory related costs. As per the main research focus, the horizontally collaborated SC is shown in figure 3. In this SC, the manufacturers are considered as the collaborative node. The manufacturer is the most important player in the manufacturing SC. Therefore, in horizontal collaboration, the manufacturer has the decision making authority i.e. when the order is placed to other collaborative manufacturers. In horizontal collaboration, the distributor does not have the liberty to send the order directly as per the status of inventory.

*<<Include figure 3 here>>*

The main disadvantage of horizontal collaboration is the loss of control by individual SC members. To overcome this deficiency, the lateral type of collaboration has been proposed in the present research. In such collaboration, the distributor also has control in handling backorders and will help to reduce the backorder cost of the distributor as well as the retailer. The lateral collaborative SC has is shown in figure 4. From the figure, it is clear that after checking the status of inventory, the distributor can also send the order to another collaborative manufacturer. The figure shows that distributor (D1) also shares the information with manufacturer (M2), and distributor (D2) shares his demand information with manufacturer (M2). Therefore, the manufacturer does not have the full control over the other SC members.

*<<Include figure 4 here>>*

From figures 1 and 2, the impact of inventory policy is shown whereas figures 3 and 4 show collaboration in the manufacturing SC. The next section will describe the simulation or logical model with the simulation parameters.

## 5. Simulation Model

The simulation model described the logical arguments which are used to prepare the model. In this research, four simulation models have been shown. In the first two types of models i.e. the linear SC models which work on different inventory policies are described in figure 5.

*<<Include figure 5 here>>*

The logic of these SC is to just check the inventory of the node and send the order accordingly. In these models, $R_i$ is the available inventory at the retailer, $D_i$ is the inventory at the distributor. The inventory status at the manufacturer and the supplier is denoted by $M_i$ and $S_i$ respectively. The daily demand of the customer is denoted by $C_d$. The demand from the retailer, distributor, and manufacturer are $R_d$, $D_d$, and $M_d$ respectively. For the (s, S) inventory policy, the generated demand signals are:

$R_d = S_R - R_i$

$D_d = S_D - D_i$

$M_d = S_M – R_M$

For the (s, Q) inventory policy, the generated demand signals are:

$R_d = Q_R$

$D_d = Q_D$

$M_d = Q_M$

The notation used is as follows:

$R_d$, $R_i$, $S_R$, $Q_R$ = Demand, inventory level, maximum inventory, order quantity of Retailer

$D_d$ = Demand, inventory level, maximum inventory, order quantity of Distributor

$M_d$ = Demand, inventory level, maximum inventory, order quantity of Manufacturer

For horizontal collaboration, the manufacturer will make the decision to supply the order to the distributor as the manufacturer acts as the collaborative node. In such collaboration, the profit made by the manufacturer is not distributed to other members of SC. The amount of backorders

at the distributor node should not decrease as the distributor cannot take the decision to choose the manufacturer. The logical arguments of horizontal collaboration, which have been used to prepare the simulation model in the simulation package ARENA 9.0, are shown in figure 6. From the figure, it is clear that the manufacturer is the decision maker and decides on the basis of the lead time. If the lead time from manufacturer M1 ($LT_{M1}$) is greater than the delivery time from manufacturer M2 ($T_{M2}$), the manufacturer M1 will send the order to manufacturer M2. Therefore, the amount of backorders will be less and the inventory will be less, but if the lead time is less than the delivery time, the distributor will have to wait and a backorder cost will be incurred. Simultaneously, there is no profit to the distributor by such collaboration but it will reduce the overall cost of the SC. Thus, it can be said that it is beneficial but not for all the members of the SC. To overcome this deficiency, lateral collaboration is proposed in the present study.

*<<Include figure 6 here>>*

In lateral collaboration, the distributor is also a decision maker and he can decide to send the signal to manufacturer M1 or manufacturer M2. The collaboration is another name for information sharing; therefore the distributor also has information on the inventory level of both manufacturers. The distributor will check the inventory level and if there is not sufficient inventory in stock, the distributor will directly send it to the collaborating manufacturer (figure 7). In such type of collaboration, the distributor also makes a profit as costs are saved due to the early delivery of the goods. In the previous case, there is more time for the manufacturer to receive the order and then send to another manufacturer, but in lateral collaboration no other player is involved. In lateral collaboration, the backorders will be reduced but the inventory cost will be more as both manufacturers will try to fulfill the demand. Simultaneously, in the downside of the SC, there will be much fewer backorders. Therefore, in lateral collaboration, customer satisfaction, which is also another important objective of a SC, is higher. The parameters which are considered for this simulation study are as follows.

*<<Include figure 7 here>>*

***Simulation Parameters***

In the present study, some real life parameters have been chosen to verify the above concept by the numerical analysis. The demand ($\mu$=100, $\sigma$=15) comes from the customer/market, which follows a Normal distribution, at the retailer nodes. The retailer carries inventory ($R_i$=1000) and replenishes the stock from the distributors according to (s, S) and (s, Q) inventory control policy. The inventory level for the distributor is 1200 and the reorder point is 100. The inventory level for the manufacturer is only 1500 and the study has been done on the various reorder points like 100, 200, 300, 400, 500 units. There is one assumption that has been taken into consideration is that the inventory of the supplier is fulfilled immediately. The lead time for the distributor is 2 days and the lead time for the manufacturer is 7 days. The inventory holding costs are 0.10, 0.25, 0.55, and 1.0 (all are in $/unit) for the supplier, manufacturer, distributor and retailer respectively. The order costs are 10, 50, and 100 ($) for the retailer, distributor and manufacturer respectively. The very important factor, backorder costs are 32, 162, and 324 (all are in $/unit) for retailer, distributor and manufacturer respectively. The simulation has been run for one year as the decision horizon of collaboration is from 1 year to 3 years. The warming period for this study is 2 months. The results achieved from this simulation study are discussed in the next section.

## 6. Results and Discussion

In the present study, the effect of collaboration has been shown by the evaluation of two SCs and both these SCs have four players: supplier, manufacturer, distributor and retailer. One of the SCs has adopted the (s, S) inventory policy and the other one has followed the (s, Q) inventory policy. The effect of horizontal collaboration has been shown and also the impact of lateral collaboration (Both vertical and horizontal). The lateral collaboration provides the freedom for individual SC members to make decisions. Therefore, it can be said that lateral collaboration can overcome the deficiencies of vertical and horizontal collaboration. From the perspectives of all the research outcomes, it can be concluded that a collaborative SC can be evaluated on some performance measures like reducing the SC cost, adopting total quality management, closer links between demand/supply (reducing backorder cost). In the present study, the collaborative SC is evaluated on the basis of reducing the SC cost as well as reducing backorders with a tradeoff between inventory holding cost and backorder cost. The present study shows that in the horizontal collaboration, the manufacturer makes the decision to collaborate with other manufacturer to provide the product to the distributor. In the lateral type of collaboration, the distributor also has

control over the decision for buying. The distributor can directly place an order to another manufacturer. Accordingly, this section presents some interesting results obtained from a series of studies carried out in this direction.

First, the impact of collaboration has been shown on the inventory holding cost of two SCs with different inventory policies. Figure 8 shows that the graph of total inventory holding cost and manufacturer inventory levels with varying reorder point quantities for the manufacturer as the collaborative node. From this curve, it is observed that if the maximum inventory level is fixed (1500 units) with a varying the reorder point (100 to 500 units), the inventory holding cost for both SCs increases and the inventory holding cost is more for SC2 as it follows the (s, Q) inventory policy compared to SC1 which follows the (s, S) policy. At (100, 1500), the inventory cost of SC1 is 156.7 thousand ($) and 200.04 thousand ($) but at (400, 1500), the difference is very less ($291.33*10^3$ to $298.09*10^3$). This gives an insight and confirms some previous studies in which the inventory holding cost is more for the (s, Q) inventory policy. From the graph, it is also clear that the sum of the inventory costs of SC1 and SC2 is more than the inventory cost of the collaborative SC where the manufacturer acts as the collaborative node. The results also provide one interesting insight is that the inventory cost is slightly more in lateral collaboration than in horizontal collaboration as at point (500, 1500) the inventory cost in horizontal collaboration is $598.29*10^3$ ($) and for lateral collaboration it is $602.69*10^3$ ($). Therefore, it can be said that horizontal collaboration is more efficient, if the inventory holding cost is the main measure of performance of a SC.

*<<Include figure 8 here>>*

The other important aspect of performance measurement is the backordering cost, as this is the main component of cost to tradeoffs with the inventory holding cost. The results show that the (s, S) inventory policy also works well as the backorder cost is less for SC1 than SC2 (figure 9) but as the reorder point quantity (100 to 500 units) is increased, the back order cost is very less for the (s, Q) inventory policy as at (500, 1500), the backorder cost for SC2 is 467$ whereas for SC1, it is 9011$. Simultaneously, it is also clear that the sum of the backorder cost of both SCs is more than the collaborative SC. The interesting finding from this graph is that there is much less impact on horizontal collaboration whereas the main perspective is the backordering cost (at (300, 1500), the total backorder cost is 61293$ and for horizontal, it is 59696$). In horizontal

collaboration, the distributor does not have freedom to make decisions on ordering. Therefore, only the manufacturer can make the decision to send the order to another collaborator. To overcome this drawback in horizontal collaboration, vertical collaboration is also combined it, which gives the decision making power to individual SC members. From the graph it is clear that the back order cost is less in lateral collaboration than in horizontal collaboration as the distributor can make decision independently. As per the graph, the backorder cost in lateral collaboration at (400, 1500) is 16482$ whereas in horizontal, it is 20814$. Therefore, it can be said that Lateral collaboration is very effective to reduce the backorders.

*<<Include figure 9 here>>*

To show the impact of ordering cost, which is another component of total cost, a simulation study has been done. From the study, which is shown in figure 10, it is concluded that there is no significant impact due to different inventory policies (at (400, 1500), it is 31500$ for SC1 and 30400$ for SC2). Simultaneously, it is also observed that there is also not much impact on collaboration, even though the ordering cost of horizontal collaboration is less than in lateral collaboration (at (300, 1500), it is 60600$ for horizontal and 63200$ for lateral collaboration). Therefore, it can be said that horizontal collaboration works better, if the ordering cost is taken into the consideration as a main performance measure. As a conclusion, it can be stated that collaboration is not very beneficial to the ordering cost and will not help in reducing the ordering cost. In other words, it can also be said that the number of orders are increased in the case of lateral collaboration.

*<<Include figure 10 here>>*

The main objective of this study is the total cost of the SC which is the sum of the inventory holding cost, backorder cost and ordering cost. The result is shown in figure 10.

*<<Include figure 11 here>>*

From the figure, it is observed that the total cost of SC1, which follows the (s, S) inventory policy, is less than for SC2. Thus, this study also provides a new insight for decision making on the selection of the inventory policy if the total cost is considered as the performance measure. From this study, it can also be visualized that when the reorder point quantity is increased, the

total cost for lateral collaboration is slightly less than for horizontal collaboration. From the results, it is also seen that at s=100 units, the percentage profit for lateral collaboration over horizontal collaboration is 12.22% whereas at s = 500 units, the difference is only 2.91%. Therefore it can be said that if the reorder point quantity increases, the impact of collaboration will be lower. From the abovementioned studies, it can be concluded that collaboration is beneficial for the companies, as shown by the simulation.

## 7. Conclusion and Future Scope

The present research is a simulation study of SC collaboration and the manufacturer acts as the collaborative node. The main contribution of this research is in showing the impact of collaboration on inventory holding cost, backorder cost and ordering cost. This study also provides a new insight is that horizontal collaboration is not very beneficial as it has some drawbacks like loss of flexibility, loss of control of individual SC members etc. By providing both vertical and horizontal collaboration, in other words lateral collaboration, a win-win situation in the market can be achieved. This study shows that collaboration plays a crucial role on the performance of a SC. In the case of horizontal collaboration, all members of a SC do not benefit as only the collaborator node has the power of decision making. Therefore, the results encourage SC members to collaborate and achieve a win-win situation. It is also shown that the impact of inventory policy can reduce the cost. Thus, it can be concluded that lateral collaboration can reduce the overall cost of a SC and the enterprises involved can improve the real time decision making process by adopting a suitable inventory policy. It is worth to note that this is a theoretical approach to show the effect of lateral collaboration and it will enrich the literature about the collaboration in SC. It can also be implicated in the practical manner with changing some parameters. The similar approach can be applied on real world SC collaboration problems with the knowledge of SC managers to decide the simulation parameters.

Here, the performance measure is the total cost, which is the sum of the inventory holding cost, backorder cost and ordering cost. For future studies, a few more components such as transportation cost, lead time, and transportation time can be considered. Some important but intangible aspects like trust, senior management commitment, flexibility, teamwork, and patience should also be taken into account. In the present work, only linear SC has been considered. The similar approach can be applied for the multi-node, multi-product SC also. Opportunities for

further research lie in exploring the effect of collaboration at all the nodes of SC. Another important issue for research can be towards the study of the effect of postponement and collaboration simultaneously at all the levels of SC with all three types of coordination. This approach can be applied in the various types of SC with changing some parameters.

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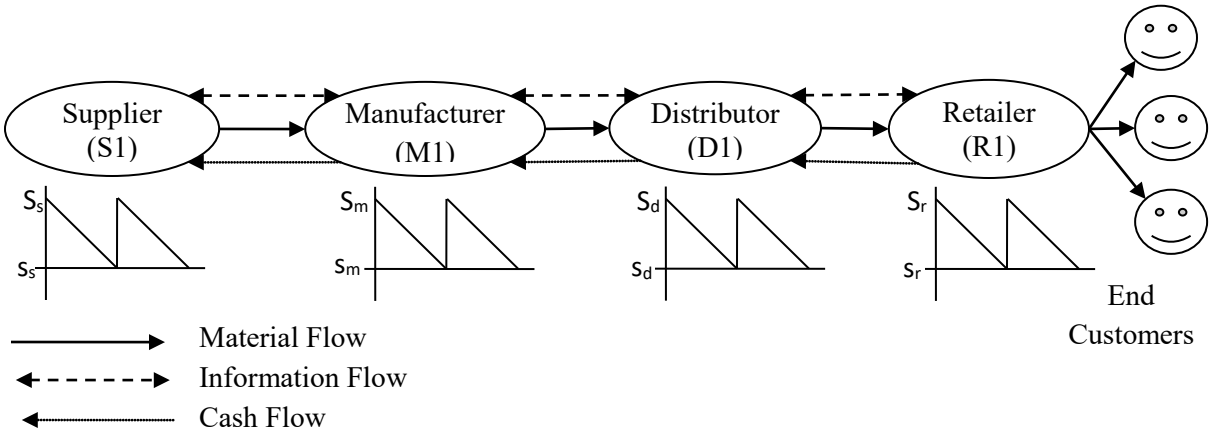


Figure 1: Structure of Supply Chain (SC1) works on (s, S) Inventory Policy

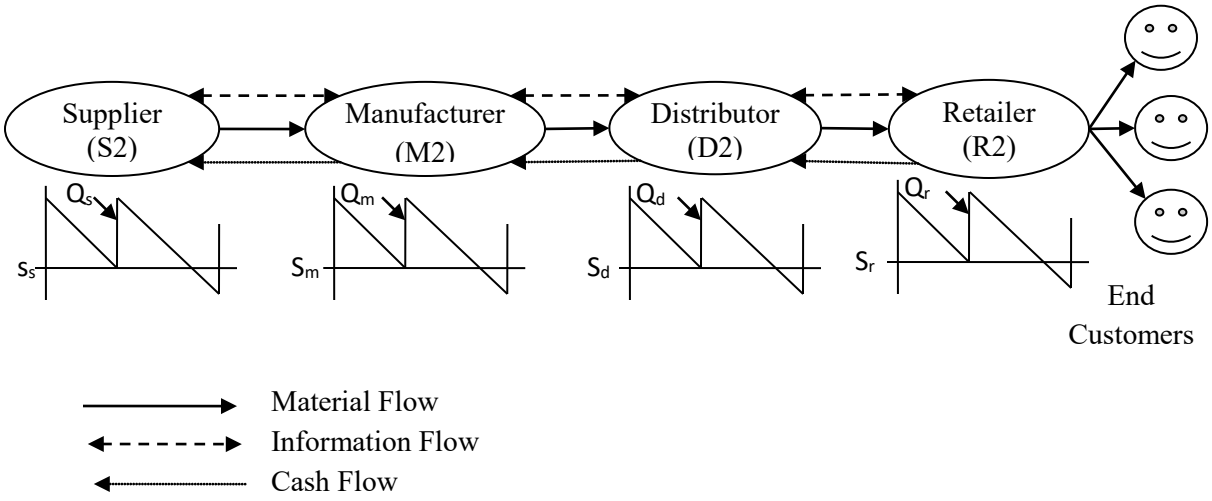


Figure 2: Structure of Supply Chain (SC2) works on (s, Q) Inventory Policy

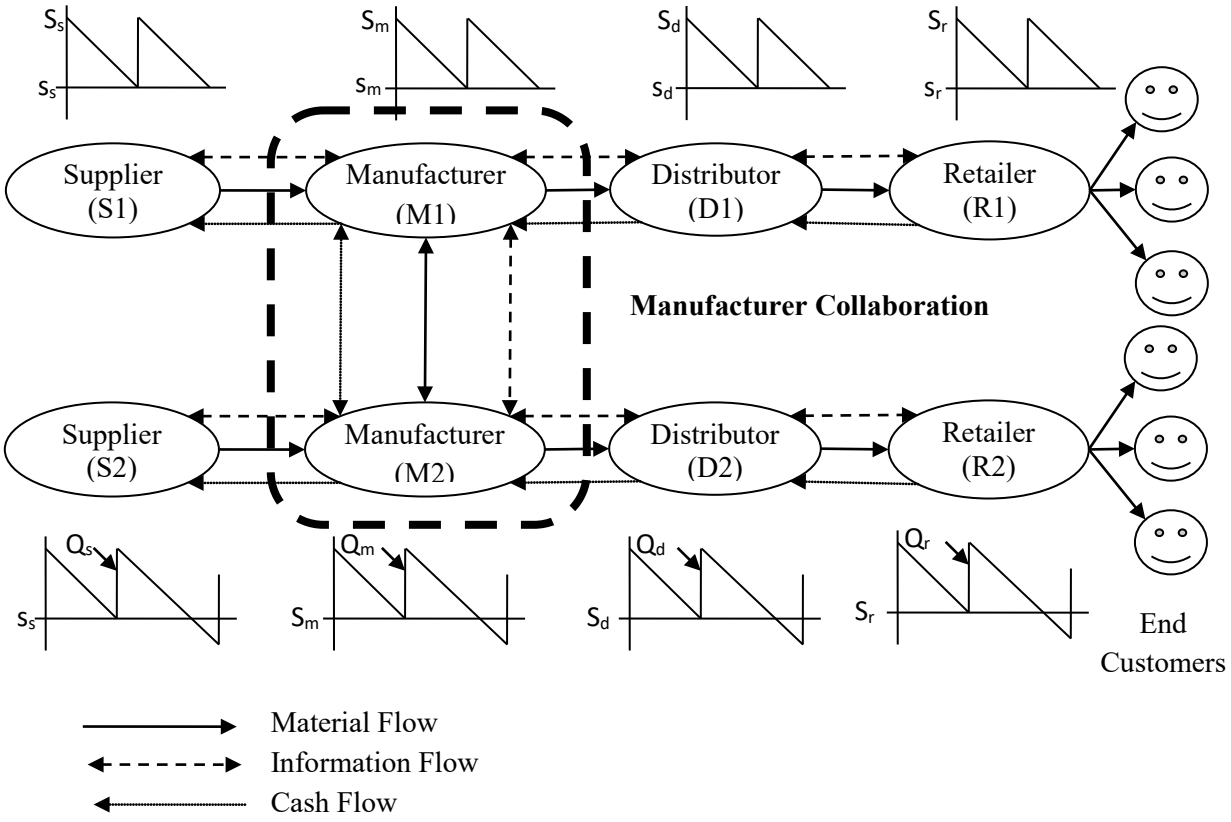


Figure 3: Structure of Horizontally Collaborated Supply Chain

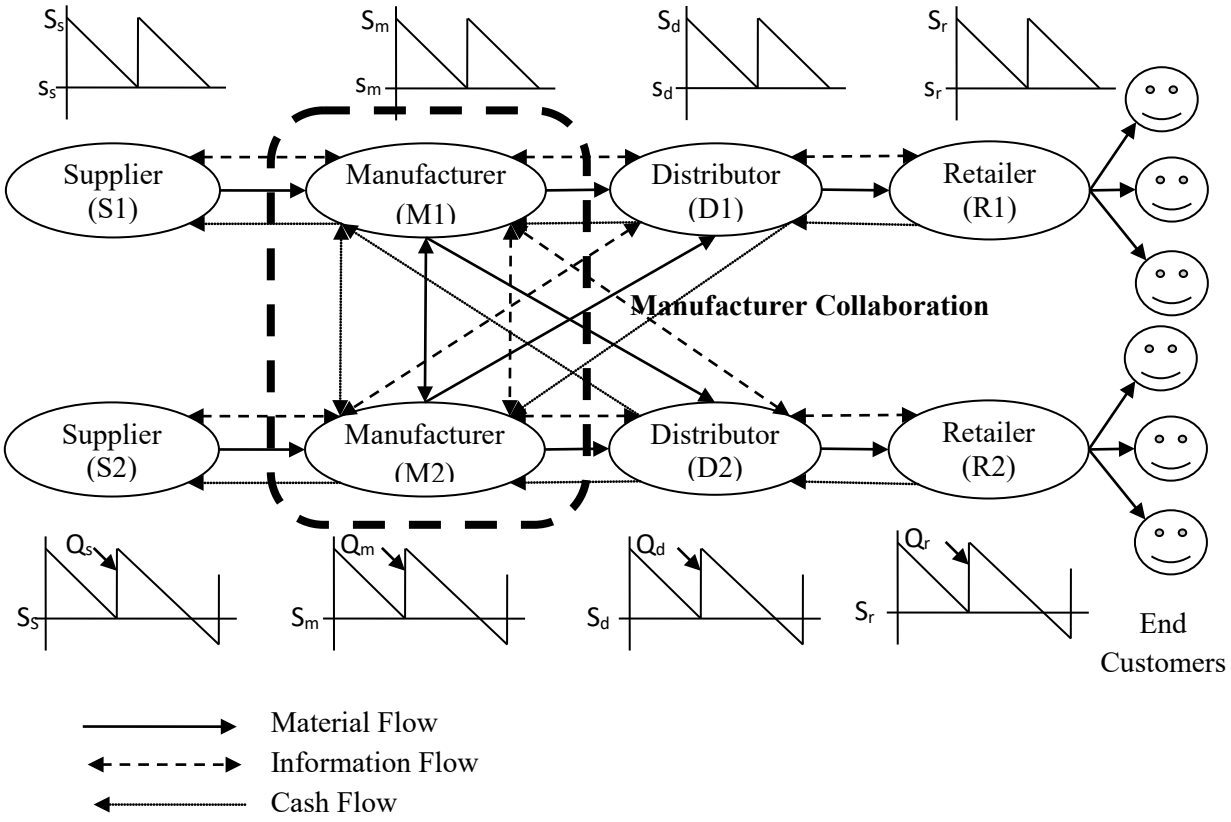


Figure 4: Structure of Lateral Collaborated Supply Chain

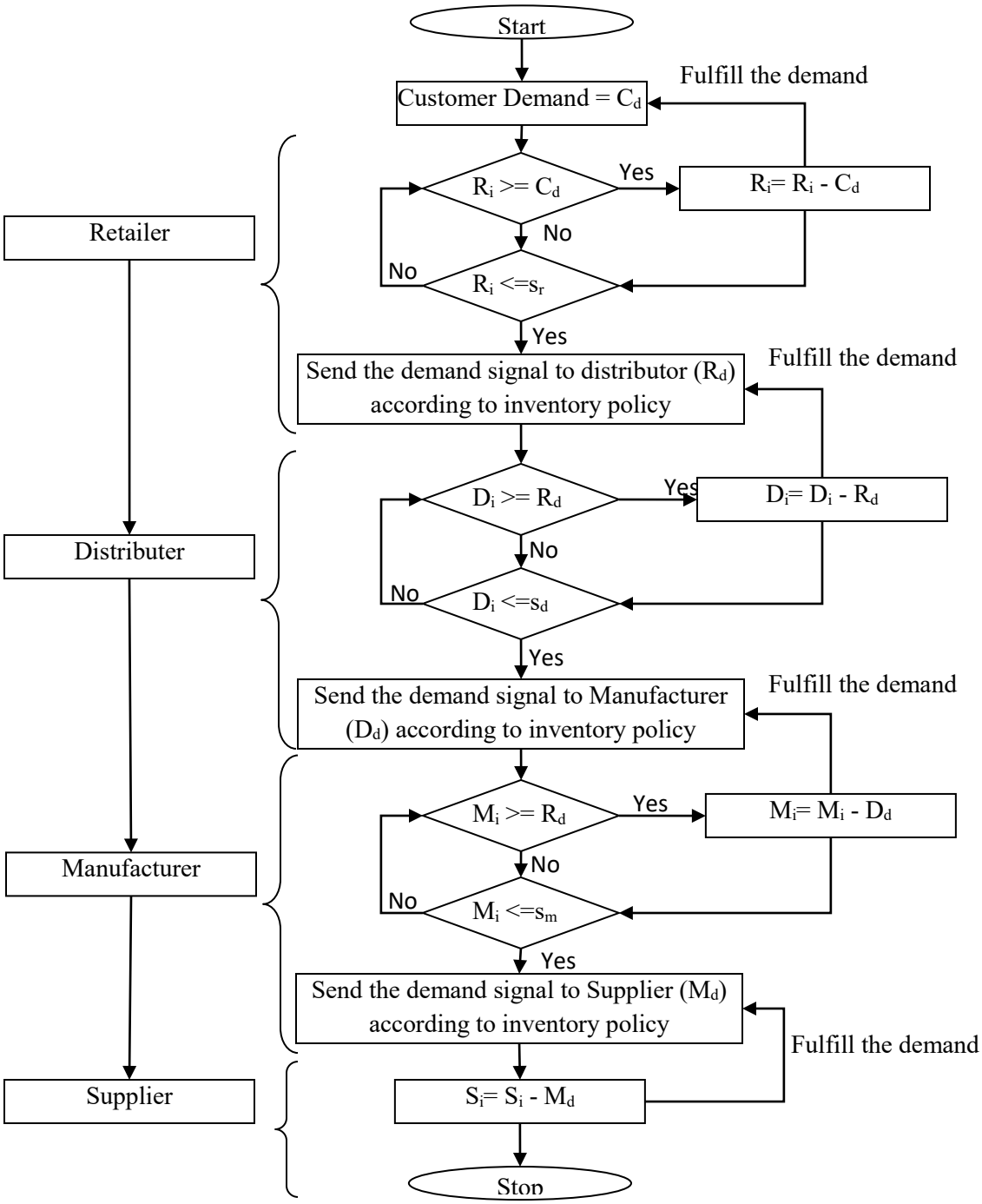


Figure 5: Simulation or Logical Model of Linear Supply Chain

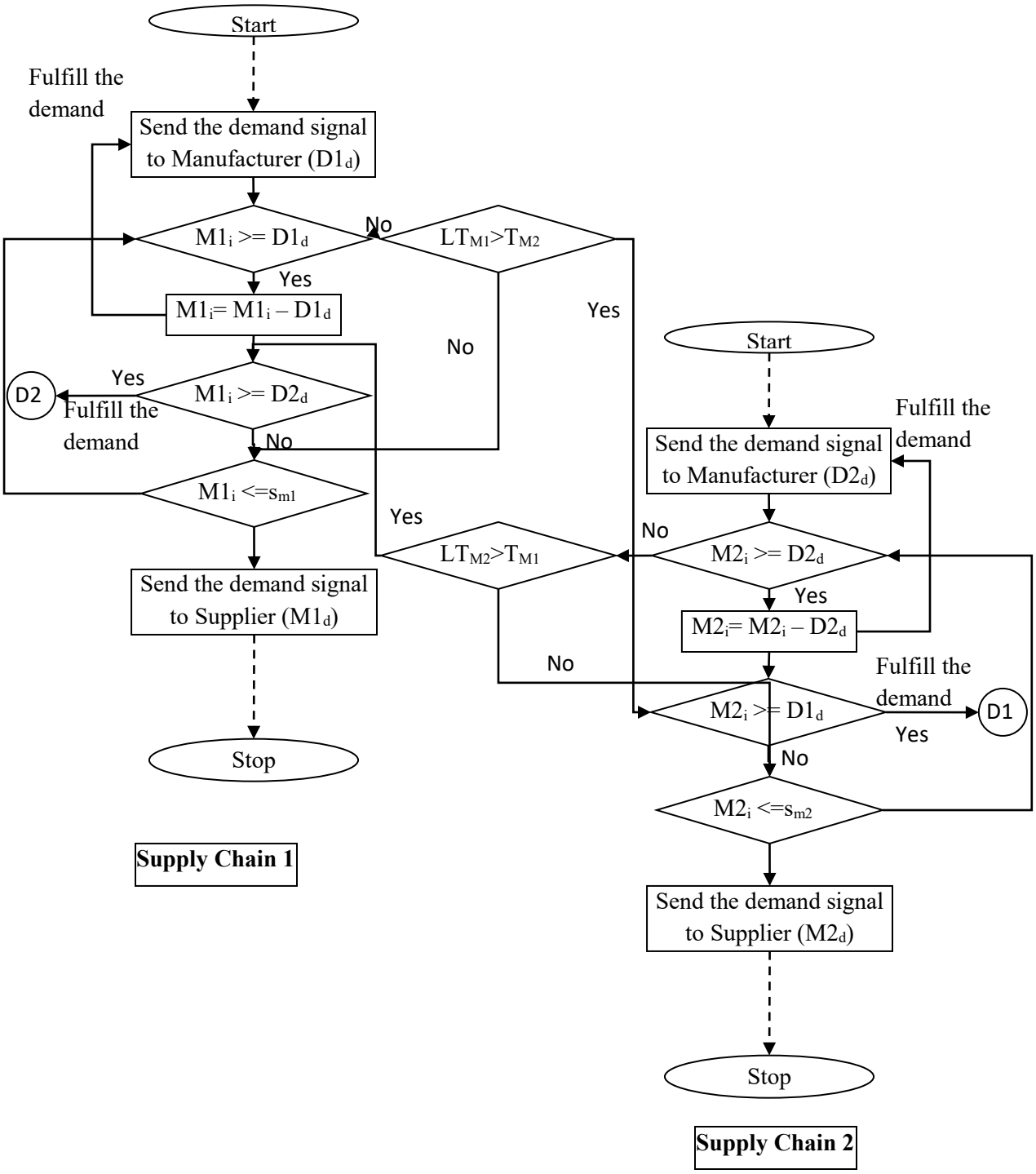


Figure 6: Simulation or Logical Model of Horizontally Collaborated Supply Chain

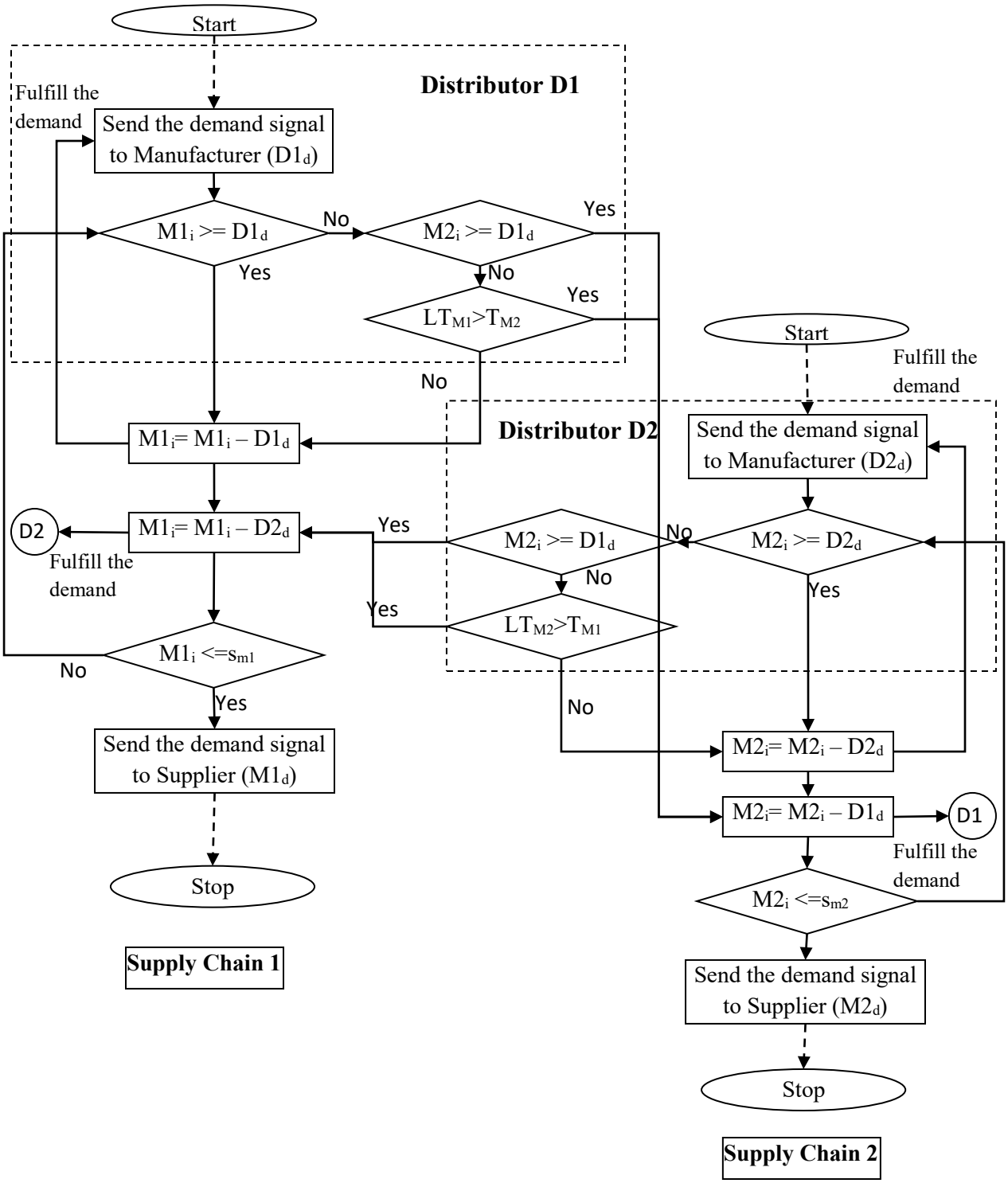


Figure 7: Simulation or Logical Model of laterally Collaborated Supply Chain

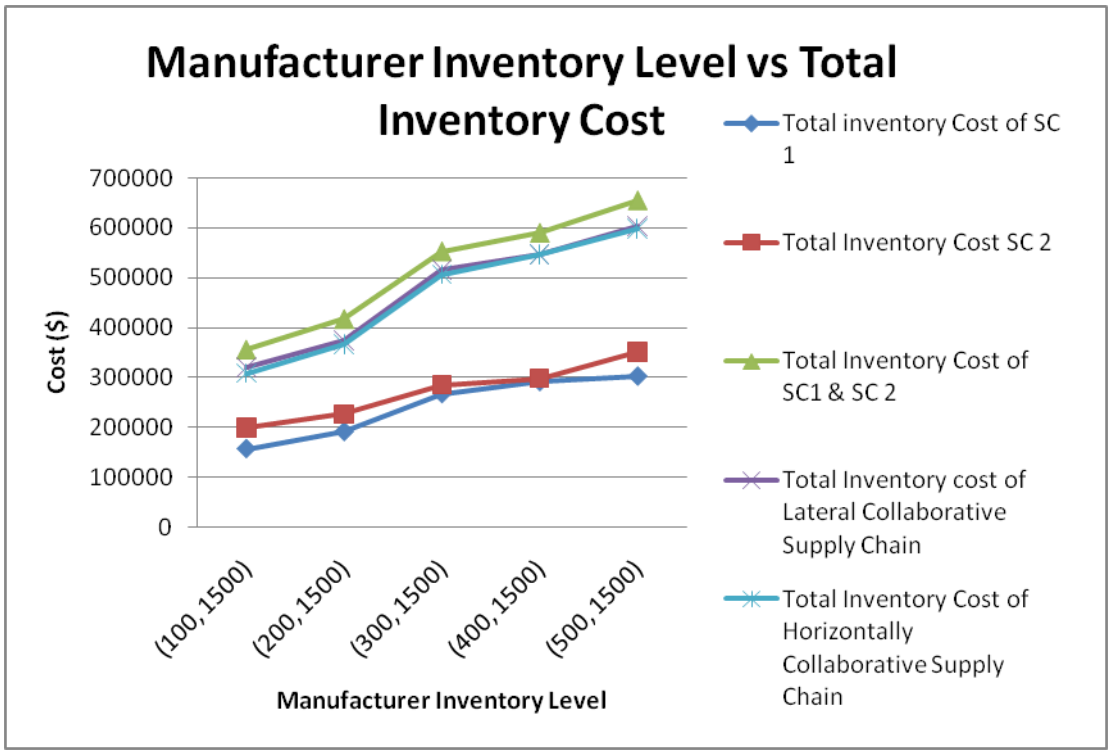


Figure 8: The variation of Total Inventory Holding Cost vs. Manufacturer Inventory levels

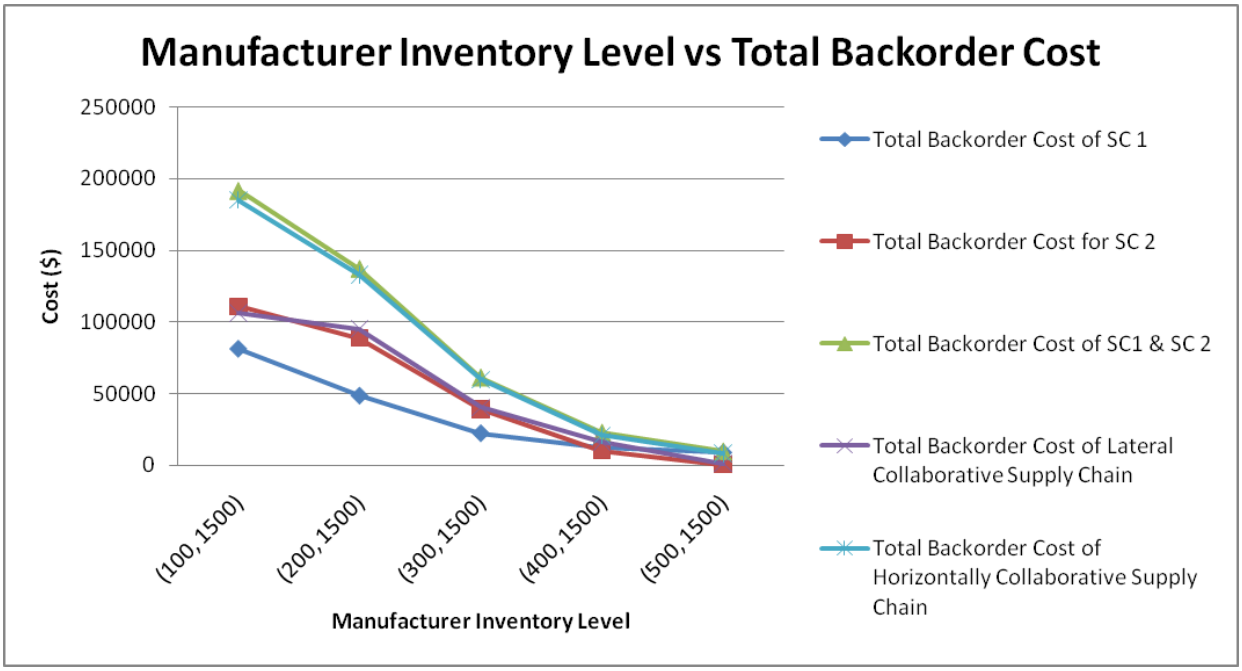


Figure 9: The variation of Total Backorder Cost vs. Manufacturer Inventory level

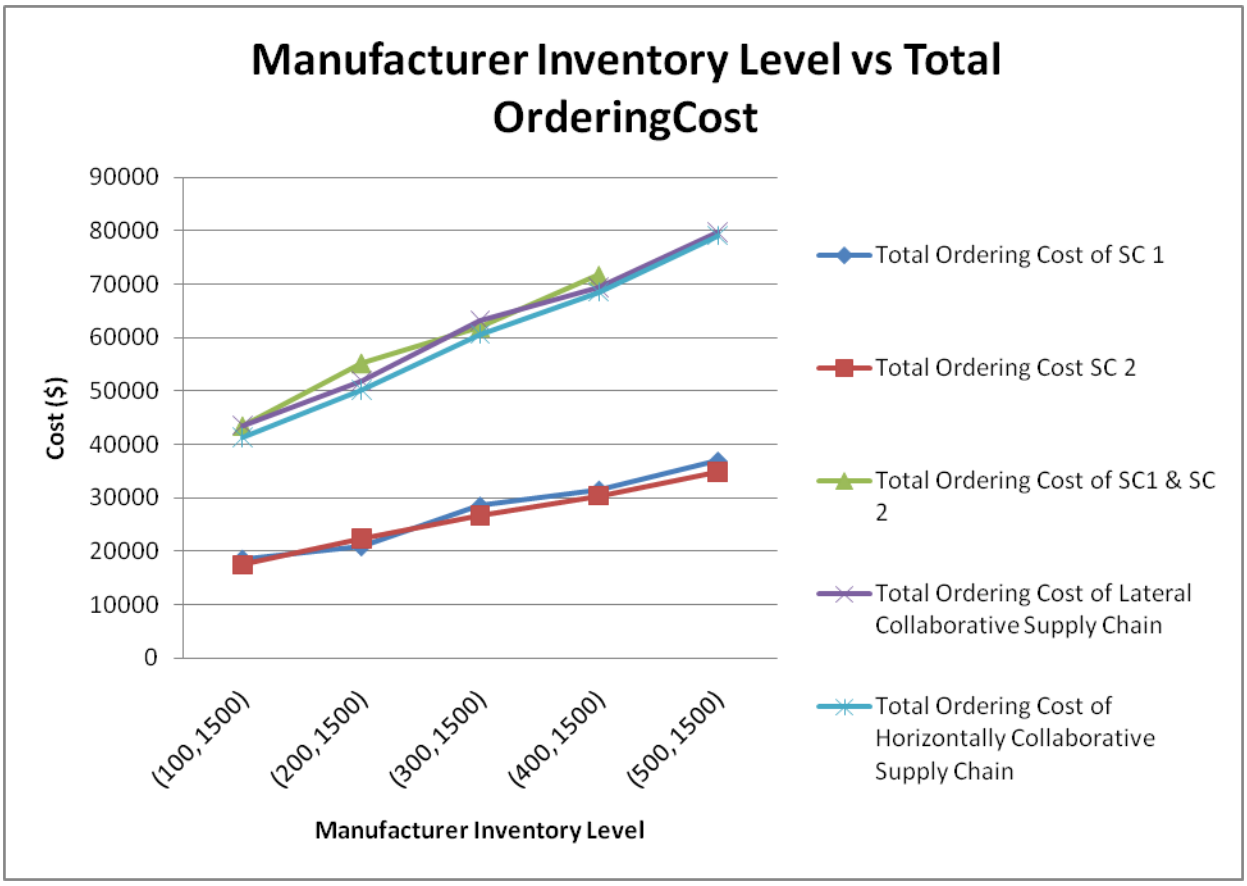


Figure 10: The variation of Total Ordering Cost vs. Manufacturer Inventory level

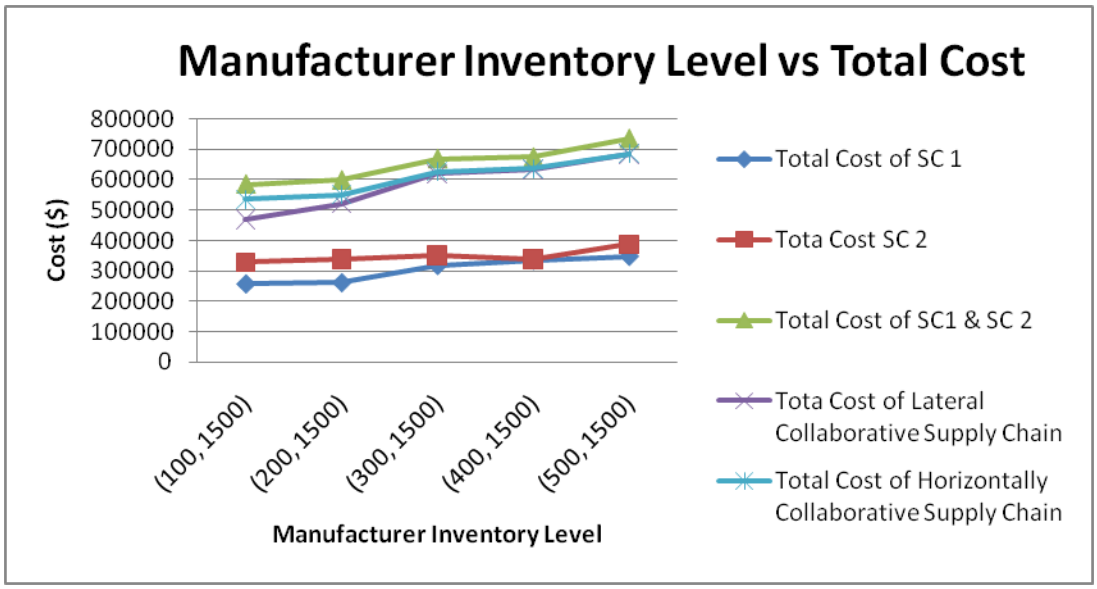


Figure 11: The variation of Total supply chain Cost vs. Manufacturer Inventory level