Simulation modelling and analysis of a network supply chain coordination using price discount along with delay in payment under lost sale and backorder

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Abstract: Coordination among supply chain (SC) members is essential to enhance its overall performance. The effect of various coordination mechanisms on SC performance is an area of research interest. In this study, two mechanisms ‘price discount’ and ‘delay in payment’ are used separately and simultaneously to coordinate a network SC under a simulated business environment. Discrete event simulation modelling is used to study the performance of the network SC in this study. Lost sale and backorder are the two cases simulated as most business has one of these. The results show that coordination improves the performance of the SC compared to non-coordination case and the simultaneous use of ‘price discount’ along with ‘delay in payment’ further enhances the SC surplus significantly compared to the individual use of either price discount or delay in payment. The extent of improvement in performance in each case is also reported, since this is very relevant for the decision maker who compares the effort to be taken and benefits that accrue before adopting a system. Sensitivity analysis has also been conducted.

Keywords: supply chain; coordination; simulation modelling; price discounts; delay in payments; backorder; lost sales; performance.

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1 Introduction

Supply chain management (SCM) has emerged as an exciting and rewarding topic for researchers and practitioners. SCM deals with the flow of product, fund, information and service. The SC coordination helps to manage these flows to achieve the overall goal of the SC. To ensure SC coordination and to improve its performance thereby, suitable coordination mechanisms have to be implemented individually or in combination based on the nature of the SC. Most businesses have either backorder or lost sale or both. Fulfilment of customer requirement is always the major objective for the long-term success. The way to achieve this is by implementing proper coordination mechanisms for motivating the SC members to act for overall SC performance and by optimising inventory and backorder/lost sales.

1.1 Literature review

Some studies on SC coordination and simulation modelling reported in literature are discussed next. Arshinder et al. (2008) reported various perspectives on SC coordination issues, mechanisms available for coordination and identified the gaps existing in the literature. They also recommended simulation modelling and analysis of SC coordination with combination of different mechanisms to address various issues for the future research. The following studies have used various forms of either quantity discount or delay in payment in different operating environment to enhance the coordination and thereby to improve the performance of SC. Munson and Rosenblatt (2001) suggested 'quantity discounts' as a mechanism by which a company can coordinate its purchasing and production functions and create an integrated plan that dictates order and production quantities throughout a three level SC and explored the benefits that can be obtained from it. Li and Liu (2006) developed a model for illustrating how to use quantity discount policy to achieve SC coordination and found that surplus under coordination is more than the case of 'non-coordination'. Jaber and Osman (2006) conducted a study on coordination of two-level SC with delay in payments and surplus sharing and found that coordination using delay in payments enhances the overall performance and surplus sharing satisfies both the players in the SC. Chen and Kang (2007) developed an integrated inventory model with permissible delay in payments for determining the optimal replenishment time interval and replenishment frequency. They also found the methodology to allocate the cost savings from the coordination. Sarmah et al. (2007) presented a credit scheme for coordination between two parties of SC and developed a simple procedure for equitable distribution of surplus generated in the channel through credit mechanism when both the parties have certain amount of target surplus from the business and when there is no target surplus and numerical studies shows that coordination mechanism enhances the individual surplus of both the members. Jaber et al. (2006) also did a study on coordination of a three-stage SC with price discounts and surplus sharing with price dependent demand and reported that coordination is essential for improving SC performance. Shin and Benton (2007) developed a quantity discount model (Buyer's risk adjustment model) that resolves the practical challenges associated with implementing quantity discount policies for SC coordination between supplier and buyer and this model allows the supplier to offer discounts that capitalise on the original economic lot sizes and share the buyer's risk of temporary overstocking under uncertain demand and found that it is a feasible alternative for SC coordination. All these studies are conducted for a SC with a two or three level structure for a static environment and general business situation by using mathematical modelling.

Simulation modelling helps the researcher to study the SC coordination with a realistic structure and operating parameters under dynamic environment. The following are some of the studies which describe the issues of simulation or use simulation as a methodology for modelling to incorporate the dynamic nature of the SC. Kuhl et al. (2005) presented the development of conceptual models that can be used in the creation of four level SC simulation projects to study the collaboration practices. Ingalls et al. (2004) developed a system to aid professionals from management and logistics areas to evaluate the performance of SCs through computer simulation. Thierry et al. (2010) also provided an overview of the main concepts that relate to simulation studies of SC management systems. They highlighted some of the modelling and simulation challenges with respect to SC design decisions, control policies, degree of systematic decomposition of SCM system and distribution level of the system with possible solutions. Chang and Makatsoris (2001) reported the benefits, functionalities and data requirement of the SC which are required for SC simulation. Swaminathan et al. (1998) developed a SC modelling frame work to overcome the time and effort required to develop models with sufficient fidelity to the actual SC of interest. Using this approach, SC models are developed from software components that represents types of SC agents (e.g., retailers, manufacturers transporters, etc.), their constituent control elements (e.g., inventory policy), and their interaction protocols (e.g., message types). Min and Zhou (2002) synthesise past SC modelling efforts and identifies key challenges and opportunities associated with SC modelling. This study also provided various guidelines for the successful development and implementation of SC models. Persson and Olhager (2002) presented a SC simulation study concerned with manufacturing of mobile communication systems to evaluate alternative SC designs with respect to quality, lead times and costs as the key performance parameters and to increase the understanding of the interrelationships among these and other parameters relevant for the design of the SC structure. Pundoor and Herrmann (2006) described a SC simulation framework with the SC operations reference model they built simulation models that integrate discrete event simulation and spreadsheets to analyse the impact of rescheduling frequency on the SC performance. Klimov and Merkuryev (2008) investigated the problems related to SC risk identification and simulation-based risk evaluation. Initially, this study dealt about the risk recognition in SCM and additional risks connected with SC reliability. In the second part of the study, a numerical example within which a simplified SC system is defined and corresponding risk evaluation is performed. Johansson et al. (2010) studied the issue of channel coordination for a SC consisting of one supplier and two retailers, facing stochastic demand that is sensitive to both sales effort and retail price and developed a decision support tool using simulation optimisation for SC coordination with revenue sharing or buyback contract to find out the optimum decision variables. Paes (2012) proposed a framework to model a SC where each SC entity is modelled as a system, hierarchically composed of sub-systems to the required level of abstraction. Each system has operations which determine its inputs, outputs, time and capacity. The framework was tested in DELMIA V6 Production System. Performance is evaluated using system utilisation, through-put, order fulfilment time, inventory, collected during simulation. This framework allows incremental modelling and easy modification of system structure and operations. Lee et al. (2002) considered the issue that SC systems are neither completely risk nor continuous and developed a model with the aspects of both discrete event and continuous simulation.

1.2 Problem description

Most of the studies described in Section 1.1 either use different versions of ‘quantity discount’ or ‘delay in payment’ separately to improve the performance of SC with static operating environment. But, combination of these mechanisms to improve the SC performance under a realistic operating environment is not available in the literature. Further, either backorder or lost sale situation is common in almost all business. So, the study of supply chain performance under lost sale and backorder cases is also important and it is rare in the literature. As discussed earlier, simulation modelling is an appropriate methodology to incorporate all these realistic features of a SC. So, this study of simulation modelling and analysis for a network SC in a dynamic business environment with a combination of price discount and delay in payment as coordination mechanisms under both backorder and lost sale cases is relevant to the field of supply chain coordination. Because, these two cases of lost sale and backorder for a network SC under dynamic operating parameters with a combination of two very common coordination mechanisms (SC contracts) makes the scenario a realistic and frequently found one. Simulation modelling helped to create a business scenario matching with reality and makes the study useful to the academicians as well as practitioners. Apart from this, a sensitivity analysis is also conducted as a part of this study. This will be further helpful to the SC practitioners. The following section deals with SC model, research methods, results and analysis, conclusion and scope for further research.

2 SC conceptual model

The structure and operating conditions of SC, assumptions made and notations used in this study are detailed in this section. The diagrammatic representation of the conceptual model is also provided. The detailed description about the business cases and coordination mechanisms is also incorporated to provide a clear concept about the study.

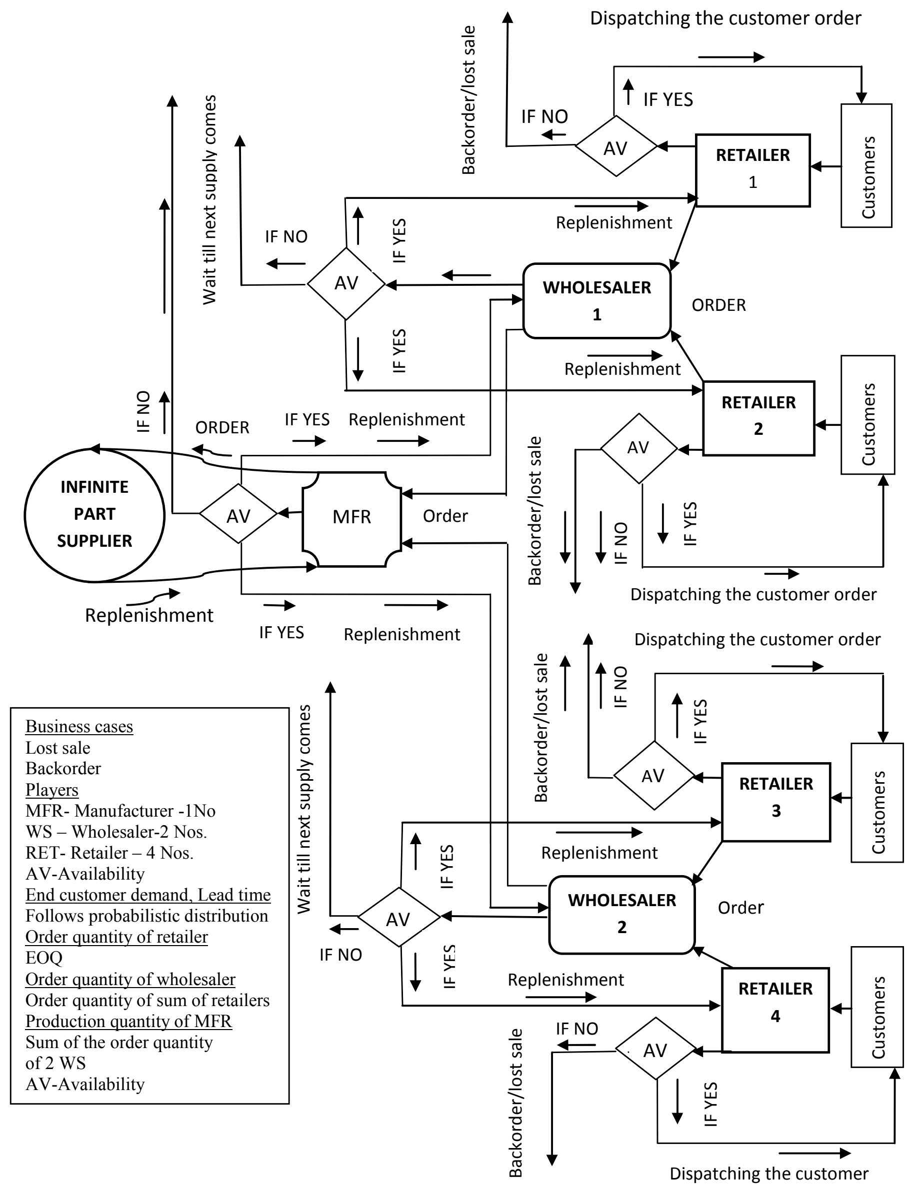
2.1 Structure and operating conditions

In this study, the SC simulated consists of four retailers, two wholesalers and one manufacturer with an infinite part supplier (IPS). To coordinate this SC, price discount and delay in payment are used separately and jointly as coordination mechanisms under both lost sale and backorder cases. Price discount is a coordination mechanism given by the upstream player to the downstream player to enhance the demand. 'Delay in payment' is also a coordination mechanism by which the holding cost of the buyer decreases and thereby the order quantity of the buyer increases. Both the mechanisms enhance the volume of business throughout the SC. This also benefits both the buyer and the seller the buyer in different ways. Details are given in the following section. The conceptual model of this network SC is shown in Figure 1. End customer demand and lead time between players are assumed to be probabilistic in nature.

In the case of price discount, the manufacturer provides a discount to the end customers through his downstream players in this study. It means that manufacturer provides an optimum discount to the two wholesalers and the two wholesalers provide the same discount to its retailers. So, the customer demand is more than the case of non-coordination as the end customer demand is assumed to be price elastic. In this model, a realistic value is taken for the price elasticity for each of the business cases. It is assumed that manufacturer is not getting any discount from its supplier.

In the case of delay in payment, each player in the SC (upstream player) is ready to provide a permissible delay in payment to his buyer (downstream player) for which no interest has to be paid. In addition to this, there is a provision for the buyer (downstream player) to avail more delay in payment than that permitted, for which interest has to be paid by the buyer (downstream player) to its seller (upstream player), for the period exceeding the permissible delay in payment period. So, if the downstream player avails a delay in payment more than the permitted period by the upstream player, the upstream player will get an additional income in the form of interest from the downstream player. This will usually be done if the downstream player can earn more than the interest to be paid, by delaying payments. Further, the holding cost of each player will be significantly reduced due to delay in payment and consequently the order quantity also increases. In this study, the sellers (manufacturer and wholesalers) lose the opportunity to invest the surplus for the period of permissible delay in payment as no interest is charged for that period. But, the retailer does not incur this opportunity cost due to the reason that it is not providing any delay in payment to its customers as only cash sale is assumed to take place. Another important thing is that even though the shipment sent by the upstream player reaches the downstream player (manufacturer to wholesaler and wholesaler to retailer), the upstream player carries its financial burden till the downstream player pays for it. It means that the upstream players incur an additional holding cost for each shipment delivered to the downstream player for a period by which the payment is delayed by the downstream player. This additional holding cost is different from the normal holding cost. It is to be noted that retailers do not incur any additional holding cost as they do not provide any delay in payment to their customers.

Figure 1 A diagram showing the SC network consisting of four retailers, two wholesalers and one manufacturer with an IPS



In this model, it is assumed that the players are coordinating with each other on order quantity in such a way that each retailer places its EOQ on its wholesaler and each one of the wholesaler in turn places order for the sum of the EOQ of its retailers on manufacturer. The manufacturer gets the raw materials and components from the IPSs (considered as universe) as per the order for manufacturing. The customer demand and the lead time between two successive players are assumed to be dynamic in nature. In this study, replenishment orders are placed by all players considering the demand during the lead time. In the case of retailers, the replenishment orders (reorder point) are placed considering the expected average demand from their customers during the lead time. In the case of upstream players (wholesalers and manufacturer), the demand during the lead time is equal to the order quantity of his one downstream player. It means that during the lead time, the upstream players are expecting only one order from any one of his downstream players. This is the reason for all the upstream players placing the replenishment order when the inventory reaches the order quantity of his one downstream player to avoid any stock out situation during the lead time. So, the reorder point is the point at which inventory reaches the order quantity of his one downstream player. The overall objective of this ordering policy is to avoid stock out situation and to minimise the inventory cost.

As mentioned earlier, two business situations are considered in this study. In the case of lost sale situation, the sale is lost if the retailer is out of stock for the SKU demanded therefore, lost sale may occur. In the case of back order situation, the customers will be ready to wait till the next shipment arrives. These two situations occur only at the retailer-customer interface.

In the case of 'non-coordination' model, it is assumed that each player places order for its own economic order quantity on its upstream player and 'non-coordination' mechanisms are implemented. In this case, unnecessary inventory may pileup and causes more inventory carrying cost and low SC performance. In the 'non-coordination' case, all the parameters and operating conditions (no mechanisms) used are same as those of coordination case. The 'non-coordination' model is also analysed for both the business cases.

2.2 Assumptions

The following are the assumptions based on which this study of simulation modelling and analysis of a network SC is conducted.

1. Products delivered from manufacturer are of perfect quality and therefore there is no rejection at any stage.
2. Delay in payment is permitted and availed by each player from its upstream player without interest and with interest up to a maximum of the buyer's inventory cycle time. Manufacturer does not avail and retailers do not permit delay in payment. Similarly, price discounts are given by manufacturer to the customers through its downstream players and manufacturer does not avail discounts from IPS as it is only a part of SC but not considered for any computation for coordination benefits.
3. Delay in payment with interest (maximum delay in payment) provided by an upstream player to downstream player is its inventory cycle time.

4 Price elastic end customer demand, cost parameters do not vary over time, and each player is financially capable of settling his balance with the preceding player at any point in time in a single payment. Linear storage cost per unit time is taken.

5 The simulation is run for 365 days.

6 SC either follows lost sales situation or backorder case but not both.

7 IPS is considered as infinite source and is not considered for performance measure calculations.

8 The order quantity of retailer is its EOQ and the order quantities of other retailers are based on the EOQ of his retailers. Accordingly, each wholesaler orders sum of the EOQs of its retailers and manufacturer schedules the production batch size for a quantity equal to the sum of order quantities (sum of the EOQs of all the retailers) of his wholesalers.

9 The maximum number of total annual backorders for each retailer is limited to ten percentage of the total annual expected average demand of each retailer.

10 The retailer keeps enough minimum inventory to ensure that lost sale is occurring only due to the unavailability of product with customer desired features (SKU demanded not in stock) and not due to retailer's zero stock.

2.3 Notations

i a subscript identifying a specific player in a SC; $i = s, m, w, r$ (s = supplier, m = manufacturer, w = wholesaler, r = retailer)

A_i order cost for player i

c_i procurement cost for player i

k return on investment/interest to be paid for player i

Actual demand $D = D_0 + D_1 \times d_r$

d_i discount given by the player i

where

D_0	initial demand
D_1	elasticity of demand
P_i	selling price for each player i
S_i	sales for each player i
C_i	purchase cost for each player i
h_i	holding cost for each player i
s_i	storage cost for each player i
d_i	discount offered by each player i
$c_i = (P_i - d_i)$	discounted purchase cost for each player i

t_{ij} interest free permissible delay in payments period permitted by player 'i' to player 'j' = t_{mw} and t_{wr}

τ_{ji} maximum possible delay in payments period taken by player 'j' from player 'i' = τ_{rw} and τ_{wm}, If $\tau_{ji} > t_{ij}$, the player 'i' charges interest on player j for the period of $\tau - t$

where $i = w$, m and $j = w$, r, $i \neq j$

Q_i quantity ordered by each player

q_i quantity delivered by each player

n_{bi} number of backorders for each player

n_{li} number of lost sales for each player

c_{li} lost sales cost for each player

c_{bi} backorder cost for each player

k_i rate of return for each player

T_i inventory cycle time for player, $T_i = \frac{Q_i}{D}$.

3 Methodology

In this study, this simulation modelling of a network SC coordination using price discount and delay in payment separately and in combination under backorder and lost sale cases is done to analyse its performance under various aspects compared to the 'non-coordination' case. Initially, mathematical modelling is done to develop various expressions for the different parameters of the SC system. Simulation modelling and analysis are done to incorporate the dynamic nature of the various parameters of the SC in the analysis. The SC surplus is considered as the performance measure in this study. The SC performance is computed for coordination and 'non-coordination' cases with different coordination mechanisms to analyse the effect of implementing these mechanisms for coordination in the SC. A sensitivity analysis is also conducted to analyse the effect of various parameters on SC performance. The following sections deal with the simulation model and surplus functions of each stages and the total SC.

3.1 SC simulation model

The simulation modelling of the network SC shown in Figure 1 is done using 'Arena simulation software'. The simulation was run for 365 days for the SC. The simulation model of the network SC consists of three sections:

1 network section

2 control section

3 computation section.

The network section shows the flow of entities or products during simulation whereas control section deal with control and monitoring of movements in network section and finally computation section computes various parameters required for getting net SC surplus. In the SC, retailers 1 and 2 are linked to wholesaler 1 and retailers 3 and 4 are linked to by wholesaler 2. The two wholesalers place orders with the manufacturer. The manufacturer in turn gets the required items from IPS to produce the finished goods for supply to the wholesalers.

Simulation starts with creating raw materials and components at IPS and supplied to the manufacturer where finished goods are produced equal to the sum of the EOQs of four retailers. Then, the finished goods from the manufacturer are dispatched immediately to the two wholesalers equally and these in turn are dispatched to the retailers concerned equally again. Customer requirement will be started to fulfil continuously as and when the finished goods reach the retailer's end. The retailer places the next order (EOQ) with the wholesaler concerned when the inventory reaches the reorder point. In the case of lost sale, the reorder point provided at each retailer is the maximum demand that is expected to occur during the lead time to ensure 'no stock out'. As the variation in demand at each retailer is relatively high compared to backorder situation, fine tuning is required while fixing the reorder point at each retailer to ensure minimum inventory in the case of lost sale. The reorder point provided at each wholesaler level is the EOQ of one retailer to always ensure the availability of the requirement of one retailer. The manufacturer also keeps a reorder point equal to order quantity of one wholesaler. Accordingly, the manufacturer gets the raw materials and components from IPS and completes the production for a quantity equal to the requirement of one wholesaler in one batch just before the existing stock dispatched to the wholesaler. This is done to ensure the requirement of one wholesaler always at manufacturer's end. The release of a shipment from a wholesaler or manufacturer to his downstream player occurs when the system satisfies the following two conditions:

1 the stock at downstream player should reach reorder point

2 the earlier shipment must have reached the corresponding downstream player.

To ensure the second condition, a parameter called 'no release time' equal to the maximum lead time between those two players concerned is set in the system. So, a player will always check before it releases the shipment whether it is under 'no release time or not' in addition to the safety level condition of the other player.

In the case of lost sale situation, the end customer demand is assumed to be normally distributed. Health drink is considered as the product for lost sale situation. In this case, the lost sale can be occurred only due to unavailability of customer desired flavour and retailer will never undergo completely out of stock situation. To make it possible, the retailer keeps enough minimum inventories to avoid out of stock as the inventory cost is much lesser than lost sale cost. The lost sale cost is one which is incurred by the retailer when lost sale occurs and it is taken as his profit that would have been obtained if the sale had happened. The occurrence of the above mentioned lost sale due to non-availability of health drink with desired flavour is assumed to be probabilistic and follows normal distribution in this model. The lead time between players for placing and receiving an order is assumed to follow triangular distribution.

In the case of back order situation, the end customer demand is assumed to follow triangular distribution. In this part of the study, 'two wheeler' (bike) is considered as the product for backorder situation and it is assumed that the customer is ready to wait till the next order arrives if the retailer is under 'out of stock' or product with customer desired features is not available. The backorders occurred during a particular retailer's inventory cycle time will be fulfilled from the next shipment and the remaining quantity of that shipment after fulfilling the backorders only will be available at retailer for the business till next shipment arrives. In this case, retailer will incur a backorder cost for each product of the back order and it is assumed to be much less than the profit of the retailer. In this model, it is prefixed that the total back order of each retailer during a year should not exceed ten percentage of the total average expected demand of one retailer. The back orders are permitted only at retailer level. The lead time between players for placing and receiving an order is assumed to follow triangular distribution.

The control section of this simulation model regulates the various processes occurring in the network model. The revenue and various costs are calculated in the computation section of the simulation model where all the expressions corresponding to each parameter in the SC surplus functions are provided.

In this study, two coordination mechanisms; 'price discount', 'delay in payment' are used separately and simultaneously to coordinate the SC. In the case of price discounts, an appropriate value for price elasticity is assumed for an optimum value of price discount given by manufacturer to the customers through his downstream players to enhance the demand as it is price elastic. So, the end customer demand at each retailer will enhance based on the value of price elasticity and the discount provided and subsequently the sales revenue also increases. In the case of delay in payment, each downstream player will be provided a permissible delay in payment by its upstream player and for which no interest for the amount has to be paid. But, interest has to be paid by the downstream player to its upstream player for the period that exceeds the permissible delay in payment. In this study, the maximum delay in payment that can be availed by downstream player is his inventory cycle time. At the same time, each downstream player can invest this amount to be paid till his inventory cycle time and can earn some extra income to his revenue. Further, the holding cost of each player will be significantly reduced due to delay in payment and thereby EOQ of each player also increases. Finally, overall performance of the network SC is expected to improve.

The values of each input parameters are provided in Tables 1 and 2 for backorder and lost sale cases respectively and they have been collected from market study done in Kerala. In this study, the simulation is run for 365 days and during the process, cost and revenue occurring on daily basis are calculated and summed to get the net amount of SC surplus at the end of the simulation run. Finally, the sum of each cost and revenue during the simulation process for entire period is obtained. The net SC surplus obtained at the end of simulation process under various operating conditions is used as the performance measure of the SC.

3.2 Performance measure and its calculations

The performance measure of the SC in this study is taken as the 'SC surplus' and is calculated as the sum of the individual surplus of four retailers, two wholesalers and the manufacturer. Simple interest is used for calculating the return on investment and interest on amount of purchase cost to be paid. The surplus function of each player is calculated as follows.

3.2.1 Retailer surplus function

Surplus of the retailer = Sales revenue – Net cost

Sales revenue = $S_r \times (P_r - d_r)$

$$\begin{aligned}\text{Net cost} &= \text{order cost} + \text{procurement cost} + \text{storage cost} \\ &\quad + \text{interest paid to wholesaler} + \text{backorder cost / lost sales cost} \\ &\quad - \text{savings from investment}\end{aligned}$$

Quantity ordered by the retailer = $Q_r^* = EOQ = \sqrt{\dfrac{2A_r R}{(h_r + s_r)}}$

where A_r = order cost and R = annual demand

Discount offered by the retailer to the customer = d_r

Quantity y released by each retailer at each time against its customer demand = q_r

Order cost = A_r

Procurement cost = $Q_r \times (P_w - d_w)$

Storage cost = $(s_r) \times q_r \times (t_s - t_r)$

Holding cost = $(h_r) \times q_r \times (t_s - t_r) = 0$('Zero' in the case of delay in payments taken by the retailer is equal to (assumed in this study) or greater than its inventory cycle time)

Additional holding cost = $h_w Q_w \tau_{rw} = 0$ (Retailer do not provide any delay in payment to its customers)

Interest paid to wholesaler = $c_r \times Q_r \times k_m \times (\tau_{rw} - t_{wr})$

Savings from the investments = $c_r \times Q_r \times k_r \times (\tau_{rw})$

Backorder cost = $c_{br} \times n_b$

Lost sales cost = $c_{lr} \times n_l$

3.2.2 Wholesaler's surplus function

Surplus of wholesaler = Sales revenue – Net cost

Sales revenue = $S_w \times (P_w - d_w)$

$$\begin{aligned}\text{Net cost per unit cycle} &= \text{Order cost} + \text{Procurement cost} + \text{Storage cost} \\ &\quad + \text{Holding cost} + \text{Additional holding cost} \\ &\quad + \text{Interest paid to supplier} + \text{Cost due to loss of} \\ &\quad \text{opportunity to invest the surplus} \\ &\quad - \text{Savings from investment} - \text{Interest paid by retailers}\end{aligned}$$

Quantity ordered by each wholesaler $=2*Q_r^*$

Holding cost $=(h_w)\times q_w \times (t_s - t_r)$('Zero' in the case of delay in payments taken by the wholesaler is equal to (assumed in this study) or greater than its inventory cycle time)

Additional holding cost $= h_w Q_r \tau_{rw}$

Inventory cycle time of wholesaler $= T_w = \dfrac{Q_w}{D}$

Order cost $= A_w$

Procurement cost $= Q_w \times (P_m - d_m)$

Quantity y released by each wholesaler at each time against a retailer order $= q_w$

Storage cost $=(s_w)\times q_w \times (t_s - t_r)$

Interest paid to manufacturer $= c_w \times Q_w \times k_m \times (\tau_{wm} - t_{mw})$

Interest received from retailer $= c_r \times Q_r \times k_w \times (\tau_{rw} - t_{wr})$

Savings from the investments $= c_w \times Q_w \times k_w \times (\tau_{wm})$

Opportunity cost due to delay in payments $=(c_r - c_w)\times Q_r \times k_w \times t_{wr}$

Backorder cost $= c_{bw} \times n_b$

Lost sales cost $= c_{lw} \times n_l$

3.2.3 Manufacturer surplus function

Surplus of manufacturer = Sales revenue − Net cost

Net cost = Order cost + Procurement cost + Storage cost + Holding cost
+Additional holding cost + Cost due to loss of opportunity to
invest the surplus − *Interest paid by wholesalers*

Batch production quantity of manufacturer $= 4\times Q_r = 2\times Q_w$

Sales revenue $= Q_w \times (P_m - d_m)$

Procurement cost $= c_m \times Q_m$

Holding cost $=(h_w)\times q_w \times (t_s - t_r)$

Additional holding cost $= h_m Q_w \tau_{wm}$

Inventory time of cycle for the supplier $T_m = \dfrac{Q_m}{D_m}$

Interest received from wholesaler $= c_w \times Q_w \times k_m \times (\tau_{wm} - t_{mw})$

Opportunity cost due to delay in payments $= (c_w - c_m) \times Q_w \times k_m \times t_{mw}$

Backorder cost $= c_{bm} \times n_b$

Lost sales cost $= c_{lm} \times n_l$

3.3 Input data

This study is conducted using the data provided in Tables 1 and 2 for lost sales and backorder, respectively and it is collected from the industrial market concerned. The price elasticity for the demand is taken as 1 and 0.001 for lost sale and backorder, respectively. Rate of return or interest rate on investment/delay in payment is taken as 15% (normal situation) for both the cases.

4 Result and analysis

The results obtained from the simulation of network SC for various cases of coordination and 'non-coordination' is shown in Table 3.

The results obtained from the simulation of network SC for various cases of coordination and 'non-coordination' is shown in Table 3. It shows that the SC surplus is enhanced significantly due to coordination under both lost sale and backorder cases. Under lost sale, the increase in SC surplus is 2.10% in the case of price discount, 6.53% in the case of delay in payment and 10.01% in the case of a combination of price discount and delay in payment, compared to 'non-coordination'. Under backorder, the increase in surplus is 3.09% in the case of price discount, 4.06% in the case of delay in payment and 7.85% in the case of a combination of price discount and delay in payment, compared to 'non-coordination'. In the case of delay in payment, increase in SC surplus is relatively high compared to the case of price discount under both the cases. This is due to the decrease in total order cost of each player in the case of delay in payment compared to the other. The analysis of the hike in surplus of individual players due to coordination shows that manufacturer's surplus is reduced due to coordination especially in the case of price discount alone. This is due to the fact that manufacturer is not getting any discount or delay in payment from his upstream player and manufacturer sacrifices for the overall benefit of SC. Since the overall SC surplus is enhanced owing to coordination, the decrease in surplus for manufacturer under coordination can be made up by proper surplus sharing methodology among players to get equal rate of return for each player based on their investment. The individual hike in surplus in the case of other players due to coordination is significantly high under lost sale and backorder.

Table 1 Input data for lost sale situation (product – health drink)

End customer demand	*Player*	*Purchase cost/unit*	*Selling price*	*Discount provided*	*Lead time*	*Order cost (Rs)*	*Holding cost/unit/year*	*Lost sales cost/unit*	*Interest rate (%)*	*Storage cost/unit/year*
Normal distribution (15, 3)	RET	193	200	3	Triangular distribution	200	30	7	15	35
	WS	188	193	3	WS to RET (1, 2, 3)	300	29	-	15	23
	MFR	176	188	3	MFR to WS (3, 4, 5)	500	28	-	15	20

Note: Lost sale due to desired flavour is assumed as probabilistic-triangular distribution (0, 0, 1), price elasticity-1.

Table 2 Input data for back order situation (product – bike)

End customer demand	*Player*	*Purchase cost/unit*	*Selling price*	*Discount provided*	*Lead time*	*Order cost (Rs)*	*Holding cost/unit/year*	*Backorder cost/unit*	*Interest rate (%)*	*Storage cost/unit/year*
Triangular distribution (8, 10, 12)	RET	45,000	50,000	3,000	Triangular distribution	10,000	5,550	500	15	3,650
	WS	42,000	45,000	3,000	WS to RET (2, 3, 4)	20,000	6,750	-	15	1,800
	MFR	34,000	42,000	3,000	MFR to WS (5, 6, 7)	30,000	7,500	-	15	1,400

Notes: Colour related B.O. is assumed as probabilistic-triangular distribution (0, 1, 1) MFR-manufacturer, WS-wholesaler, RET-retailer, price elasticity-0.001.

Table 3 SC performance (SC surplus) under coordination and 'non-coordination'

		'Non-coordination'		*Coordination*							
						Values of coordination mechanism					
							Delay in payment (days)				
Business situations	*Player*	*Individual surplus of players under 'non-coordination' (Rs)*	*SC surplus (Rs)*	*Coordination Mechanism*	*Player*	*Price discount (Rs)*	*Permitted by each upstream player*	*Availed by each downstream player*	*Individual SC surplus of players under coordination (Rs)*	*SC surplus (Rs)*	*% increase in SC surplus under coordination compared to 'non-coordination'*
Lost sales	M	225,037	397,778	PD	M	3			172,878	406,118	2.10
					W1	3			44,962		
					W2	3			45,051		
	W1	38,787			R1	3			36,026		
					R2	3			36,311		
					R3	3			35,614		
	W2	40,282			R4	3			35,273		
				DIP	M	-	0	19	232,815	423,758	6.53
					W1	-	0	19	40,261		
	R1	24,531			W2	-	0	19	40,248		
					R1	-	0	19	27,982		
					R2	-	0	19	27,993		
	R2	24,538			R3	-	0	19	27,442		
					R4	-	0	19	27,014		
				PD and DIP	M	3	0	19	198,183	437,798	10.01
	R3	22,705			W1	3	0	19	53,249		
					W2	3	0	19	51,218		
					R1	3	0	19	33,950		
	R4	21,894			R2	3	0	19	34,252		
					R3	3	0	19	33,099		
					R4	3	0	19	33,844		

Notes: R1 – retailer 1; W1 – wholesaler 1; PD – price discounts; maximum delay in payment availed by the buyer = buyer's inventory cycle time; R2 – retailer 2, W2 – wholesaler 2, DIP – delay in payments; R3 – retailer 3; M – manufacturer; NC – 'non-coordination'; R4 – retailer 4.

Table 3 SC performance (SC surplus) under coordination and 'non-coordination' (continued)

Business situations	*Player*	*'Non-coordination'*		*Coordination*							*% increase in SC surplus under coordination compared to 'non-coordination'*
		Individual surplus of players under 'non-coordination' (Rs)	*SC surplus (Rs)*	*Coordination Mechanism*	*Player*	*Values of coordination mechanism*			*Individual SC surplus of players under coordination (Rs)*	*SC surplus (Rs)*	
						Price discount (Rs)	*Delay in payment (days)*				
							Permitted by each upstream player	*Availed by each downstream player*			
Back order	M	106,170,018	211,201,430	PD	M	3,000		-	94,319,907	217,732,132	3.09
					W1	3,000		-	22,312,118		
					W2	3,000		-	22,255,137		
	W1	19,054,753			R1	3,000		-	19,794,685		
					R2	3,000		-	19,635,766		
					R3	3,000		-	19,727,413		
	W2	19,952,001			R4	3,000		-	19,687,102		
				DIP	M	-	0	16	113,968,716	219,782,106	4.06
					W1	-	0	16	19,064,527		
	R1	16,477,526			W2	-	0	16	19,066,247		
					R1	-	0	16	16,791,214		
					R2	-	0	16	17,095,746		
	R2	16,548,484			R3	-	0	16	16,950,674		
					R4	-	0	16	16,844,978		
				PD and DIP	M	3,000		16	91,064,325	227,795,878	7.85
	R3	16,470,533			W1	3,000		16	25,276,284		
					W2	3,000		16	24,832,954		
					R1	3,000		16	21,569,455		
	R4	16,528,111			R2	3,000		16	21,688,754		
					R3	3,000		16	21,798,595		
					R4	3,000		16	21,565,507		

Notes: R1 – retailer 1; W1 – wholesaler 1; PD – price discounts; maximum delay in payment availed by the buyer = buyer's inventory cycle time; R2 – retailer 2, W2 – wholesaler 2, DIP – delay in payments; R3 – retailer 3; M – manufacturer; NC – 'non-coordination'; R4 – retailer 4.

The increase in surplus due to coordination varies even for players at the same level. This is due to the dynamic nature of operating parameters including demand and lead time for each player during the period of simulation. As mentioned above, the overall analysis shows that SC surplus is significantly enhanced owing to coordination especially in the case of delay in payment. So, the delay in payment can be implemented as a coordination mechanism considering the investment potential of each player and the possibility of getting the payment after the given delay in payment. Price discount can also be implemented based on the existing or expected price elasticity of demand to improve the performance. In the case of delay in payment, the economic order quantity of retailer and the order quantity of other players also increases and more quantity of products will be available with each player to meet the demand. So, the end customer demand of the product is very important in the case of delay in payment also to get better performance.

The in-depth analysis shows that the increase in SC surplus due to coordination is relatively high (except in the case of price discount alone) in the case of lost sale compared to backorder. It indicates that the effect of coordination is relatively high in the case of lost sale.

5 Sensitivity analysis

A detailed study on the already developed simulation model of SC coordination using price discount and delay in payment for both lost sale and backorder is conducted to analyse the effect of various system parameters on the performance of the SC. The sensitivity analysis is conducted for the case of combination of price discount and delay in payment under both lost sale and backorder. In that model, sensitivity of SC surplus was checked for changes in price discount values, rate of return, price elasticity, order cost and delay in payment. In all the tables of sensitivity analysis results, bold letters are used to indicate the optimum/recommended values for that parameter. The methodology used, the system parameters considered and the results obtained from the sensitivity analysis are as follows.

Table 4 shows the effect of different values of price discount on SC surplus under both lost sale and back order cases. This analysis is done by changing the value of price discount as shown in Table 4. In the case of lost sale, the maximum SC surplus is obtained for a discount of Rs 3/– (case 3) and in the case of backorder, maximum SC surplus is obtained for a discount of Rs 3,000/– (case 3) given by manufacturer to his customers through its downstream players. So, these optimal values of discount Rs 3/– for lost sale and Rs.3,000/– for backorder are taken for rest of the sensitivity analysis. The variation in surplus for different values of price discount is also provided which will help users to take appropriate decision. The SC surplus for different values of price discounts showed a variation of 2.22% under lost sale and 5.21% under backorder over the five cases examined.

Table 4 SC surplus for various price discounts under lost sale and backorder

Case	*Lost sale*		
	Price discount (Rs)	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$d_m = d_w = d_r = 1$	428,353	-
2	$d_m = d_w = d_r = 2$	431,025	0.62
3	$d_m = d_w = d_r = 3$	**437,798**	2.20
4	$d_m = d_w = d_r = 4$	433,334	1.16
5	$d_m = d_w = d_r = 5$	428,270	–0.01
Case	*Back order*		
	Price discount (Rs)	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$d_m = d_w = d_r = 1{,}000$	224,178,665	-
2	$d_m = d_w = d_r = 2{,}000$	227,143,962	1.32
3	$d_m = d_w = d_r = 3{,}000$	***227,795,878***	1.61
4	$d_m = d_w = d_r = 4{,}000$	224,069,819	–0.04
5	$d_m = d_w = d_r = 5{,}000$	216,514,760	–3.41

Note: Bold letters indicates the optimum/recommended case of price discount.

Table 5 SC surplus for various rate of return under lost sale and backorder

Case	*Lost sale*		
	Interest rate (%)	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$k_r = 15, k_w = 15, k_m = 15$	**437,798**	-
2	$k_r = 10, k_w = 10, k_m = 10$	416,891	–4.78
3	$k_r = 20, k_w = 20, k_m = 20$	458,706	4.78
4	$k_r = 15, k_w = 15, k_m = 20$	438,328	0.12
5	$k_r = 15, k_w = 15, k_m = 10$	437,269	–0.12
6	$k_r = 20, k_w = 15, k_m = 15$	447,753	2.27
7	$k_r = 10, k_w = 15, k_m = 15$	427,843	–2.27
8	$k_r = 15, k_w = 20, k_m = 15$	448,222	2.38
9	$k_r = 15, k_w = 10, k_m = 15$	427,375	–2.38
Case	*Back order*		
	Interest rate (%)	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$k_r = 15, k_w = 15, k_m = 15$	**227,795,878**	-
2	$k_r = 10, k_w = 10, k_m = 10$	225,232,140	–1.12
3	$k_r = 20, k_w = 20, k_m = 20$	230,359,615	+1.12
4	$k_r = 15, k_w = 15, k_m = 20$	227,895,918	0.04
5	$k_r = 15, k_w = 15, k_m = 10$	227,695,837	–0.04
6	$k_r = 20, k_w = 15, k_m = 15$	229,119,839	0.58
7	$k_r = 10, k_w = 15, k_m = 15$	226,471,916	–0.58
8	$k_r = 15, k_w = 20, k_m = 15$	228,935,613	0.50
9	$k_r = 15, k_w = 10, k_m = 15$	226,656,142	–0.50

Note: Bold letters indicates the optimum/recommended case of interest rate.

Table 5 shows the effect of change in the rate of return of different players on SC surplus under both lost sale and backorder. Case 1 is the base case and it indicates normal situation. Case 2 indicates recession situation (decreased rate of return) and case 3 indicates boom situation (increased rate of return) for all the players and the rest of the cases are the mixture of the first three situations for each players. From Table 5, it is clear that there is a proportional change in SC surplus with change in rate of return of any player. Therefore, the return should be kept at highest possible level by each player. But, it is clear that the individual effect of change in rate of return of wholesaler and retailer is relatively high compared to manufacturer and this trend is also the same under both lost sale and backorder cases. The variation in SC surplus over the nine cases examined is 9.56% under lost sale and 2.24% under backorder.

Table 6 shows the effect of different values of price elasticity on the SC surplus for an optimum price discount obtained earlier under both lost sale and backorder. The analysis shows that the SC surplus is increasing with increase in price elasticity and the rate of increase in surplus is almost constant for both the business situations. However, it is noted that the SC surplus levels are consistently higher in backorder case. The base case taken here (case 1) has a situation where discount is given but no increase in demand occurs as price elasticity of demand is zero. The SC surplus for different values of price elasticity showed a variation of 91.37% under lost sale and 121.08% under backorder over the five cases examined.

Table 6 SC surplus for different cases of price elasticity under lost sale and backorder

Case	*Price elasticity of demand (D_0)*	*Lost sale*		*Price elasticity (D_0)*	*Back order*	
		SC surplus (Rs)	*Change in SC surplus w.r.t. case 1 (%)*		*SC surplus (Rs)*	*Change in SC Surplus w.r.t. case 1 (%)*
1	0	353,604	-	0	173,519,098	-
2	1	437,798	23.81	0.001	227,795,878	31.28
3	2	522,545	47.77	0.002	281,857,276	62.43
4	3	596,524	68.69	0.003	329,350,527	89.80
5	**4**	**676,716**	**91.37**	**0.004**	**383,621,497**	**121.08**

Note: Bold letters indicates the optimum/recommended case of price elasticity of demand.

Table 7 shows the SC surplus for different values of order cost under lost sale. The case 1 is the base case. The detailed analysis shows that the equal change in the order cost of all players on upper side (case 2) reduces the SC surplus and lower side (case 3) increases the SC surplus almost equal in magnitude in both the cases. The individual increase in order cost of retailer (case 4) reduces the SC surplus relatively less than the case of individual increase in order cost of wholesaler (case 5) or manufacturer (case 6). This is due to the fact that only in the case of retailer, change in order cost results in compensating change in order quantity through EOQ. Order cost change for wholesaler and manufacturer does not result in any compensating order quantity change. Hence, it directly affects the SC surplus. It is also found that when the order cost is reduced for retailer (cases 3 and 7), the optimal discount is also reduced to Rs 2/– and remains same as Rs 3/– for all other cases as the order cost of retailer plays major role in this model. The SC surplus for different cases of order cost showed a variation of 5.17% under lost sale over the nine cases examined.

Table 7 SC surplus for various cases of order cost under lost sale

Case	*Order cost (Rs)*	*SC surplus (Rs)*	*Optimal value of discount (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$A_r = 200$, $A_w = 300$, $A_m = 500$	437,798	3	-
2	$A_r = 200$, $A_w = 375$, $A_m = 625$	426,367	3	–2.61
3	$A_r = 150$, $A_w = 225$, $A_m = 375$	**449,039**	**2**	**2.56**
4	$A_r = 250$, $A_w = 300$, $A_m = 500$	434,930	3	–0.65
5	$A_r = 200$, $A_w = 375$, $A_m = 500$	434,236	3	–0.81
6	$A_r = 200$, $A_w = 300$, $A_m = 625$	431,673	3	–1.39
7	$A_r = 150$, $A_w = 300$, $A_m = 500$	438,114	2	0.07
8	$A_r = 200$, $A_w = 225$, $A_m = 500$	441,361	3	0.81
9	$A_r = 200$, $A_w = 300$, $A_m = 375$	443,377	3	1.27

Note: Bold letters indicates the optimum/recommended case of order cost.

Table 8 shows the effect of various cases of order cost on SC surplus under backorder. The case 1 is the base case. The detailed analysis shows that the increase in order cost of all players (case 2) reduces the SC surplus and decline in order cost (case 3) of all players increases the SC surplus. The individual effect of retailer (cases 4 and 7), the wholesaler (cases 5 and 8) and the manufacturer (cases 6 and 9) on SC surplus is same as found in the case of lost sale and the reason also remains same. It is also found that when the order cost is reduced for retailer (cases 3 and 7), the optimal discount is also reduced and remains same for all other cases. The above findings are same for the lost sale and backorder case and the extent of effect may be slightly different depending on the difference in values of order cost considered. The SC surplus for different cases of order cost showed a variation of 0.65% under backorder over the nine cases examined.

Table 8 SC surplus for various cases of order cost under back order

Case	*Order cost (Rs)*	*Optimal value of discount*	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$A_r = 10{,}000$, $A_w = 20{,}000$, $A_m = 30{,}000$	3,000	227,795,878	-
2	$A_r = 12{,}500$, $A_w = 25{,}000$, $A_m = 37{,}500$	3,000	226,976,856	–0.35
3	$A_r = 7{,}500$, $A_w = 15{,}000$, $A_m = 22{,}500$	**2,000**	**228,456,778**	**0.29**
4	$A_r = 12{,}500$, $A_w = 20{,}000$, $A_m = 30{,}000$	3,000	227,606,856	–0.08
5	$A_r = 10{,}000$, $A_w = 25{,}000$, $A_m = 30{,}000$	3,000	227,528,377	–0.12
6	$A_r = 10{,}000$, $A_w = 20{,}000$, $A_m = 37{,}500$	3,000	227,360,877	–0.19
7	$A_r = 7{,}500$, $A_w = 20{,}000$, $A_m = 30{,}000$	2,000	227,679,278	–0.05
8	$A_r = 10{,}000$, $A_w = 15{,}000$, $A_m = 30{,}000$	3,000	228,063,377	0.12
9	$A_r = 10{,}000$, $A_w = 20{,}000$, $A_m = 22{,}500$	3,000	228,230,877	0.19

Note: Bold letters indicates the optimum/recommended case of order cost.

Table 9 shows the effect of different cases of delay in payment between various players on SC surplus. Case 1 (base case) shows the optimal values of delay in payment for which the maximum SC surplus are obtained. Cases 2 and 3 show that the change in permissible delay in payment given by manufacturer to the wholesaler (case 3) affects more than the same given by wholesaler to retailer (case 2) on the SC surplus. But, the Cases 6 and 7 show that the effect of change in delay in payment taken by the wholesaler from the manufacturer (case 6) on the SC surplus is relatively high compared to the same taken by retailer from the wholesaler (case 7). It is also found that the increase in permissible delay in payment (case 4) and decrease in delay in payment given by the upstream players (case 5) reduces the SC surplus. It is also noted that the delay in payment taken by retailer from wholesaler does not have much effect on SC surplus under both lost sale and back order. It is assumed that the maximum delay in payment taken by the downstream player from the upstream player is his inventory cycle time under both lost sale ($\tau_{rw} = \tau_{wm} = T_r = T_w = 16$) and backorder ($\tau_{rw} = \tau_{wm} = T_r = T_w = 13$) cases. The SC surplus for different cases of delay in payment showed a variation of 0.08% under backorder and 0.03% under lost sale over the seven cases examined.

Table 9 SC surplus for various cases of Delay in payment under lost sale and backorder

Case	*Lost sales (LS)*		
	Delay in payment	*SC surplus (Rs)*	*Change in SC surplus w.r.t. case 1 (%)*
1	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 16$	**437,798**	**0**
2	$t_{mw} = 0$, $t_{wr} = 1$, $\tau_{rw} = \tau_{wm} = 16$	437,671	–0.029
3	$t_{mw} = 1$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 16$	437,557	–0.055
4	$t_{mw} = 1$, $t_{wr} = 1$, $\tau_{rw} = \tau_{wm} = 16$	437,430	–0.084
5	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 15$	437,787	–0.025
6	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = 16$, $\tau_{wm} = 15$	437,783	–0.034
7	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = 15$, $\tau_{wm} = 16$	437,802	0.009
Case	*Back order (BO)*		
	Delay in payment	*SC surplus (Rs)*	*Change in SC surplus w.r.t. actual case 1 (%)*
1	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 13$	**227,795,878**	-
2	$t_{mw} = 0$, $t_{wr} = 1$, $\tau_{rw} = \tau_{wm} = 13$	227,787,048	–0.003
3	$t_{mw} = 1$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 13$	227,709,467	–0.037
4	$t_{mw} = 1$, $t_{wr} = 1$, $\tau_{rw} = \tau_{wm} = 13$	227,706,637	–0.039
5	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = \tau_{wm} = 12$	227,757,502	–0.016
6	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = 13$, $\tau_{wm} = 12$	227,757,502	–0.016
7	$t_{mw} = 0$, $t_{wr} = 0$, $\tau_{rw} = 12$, $\tau_{wm} = 13$	227,795,877	–0.000

Notes: $\tau_{rw} = \tau_{wm} = 16 = T_r = T_w$ = inventory cycle time (LS); $\tau_{rw} = \tau_{wm} = 13 = T_r = T_w$ = inventory cycle time (BO). Bold letters indicates the optimum/recommended case of delay in payment.

Table 10 shows the consolidated statement of increase in SC surplus in each case with respect to each other case of coordination and ‘non-coordination’. This analysis shows that the percentages of increase in SC surplus is relatively high in the case of combination of PD and DIP (LS – 10.03% and BO – 7.85%) and DIP (LS – 6.53% and BO – 4.06%) with respect to ‘non-coordination’ (NC) under lost sale compared to the backorder. Similarly, the increase in surplus in the case of DIP and PD&DIP compared to PD is also high in the case of lost sale. The increase in surplus in the case of PD and DIP compared to DIP is almost same under both lost sale and backorder. But, when comparing NC and PD, an increase in SC surplus in the case of price discount is slightly higher under backorder than lost sale. Similarly, when comparing DIP and PD&DIP, an increase in surplus in the case of PD&DIP is also slightly higher under back order than lost sale. The overall analysis shows that the increase in surplus when using PD and DIP simultaneously is significantly high compared to any other cases under both lost sale and backorder. This comparative statement of increase in surplus with each other will help the practitioners to implement the same considering all related practical issues.

Table 10 Increase in surplus with respect to one case to other case of coordination and 'non-coordination'

Case	*Lost sale*			
	SC surplus	*Increase in surplus w.r.t. NC*	*Increase in surplus w.r.t. PD*	*Increase in surplus w.r.t. DIP*
NC	397,778	-	-	-
PD	406,118	2.09	-	-
DIP	423,758	6.53	4.34	-
PD&DIP	437,798	10.01	7.80	3.31
Case	*Back order*			
	SC surplus	*Increase in surplus w.r.t. NC*	*Increase in surplus w.r.t. PD*	*Increase in surplus w.r.t. DIP*
NC	211,201,430	-	-	-
PD	217,732,132	3.09	-	-
DIP	219,782,106	4.06	0.94	-
PD&DIP	227,795,878	7.85	4.62	3.64

Notes: NC – non-coordination, PD – price discounts, DIP – delay in payments

6 Conclusions and scope for further research

This study conducted on network SC was to analyse its performance under coordination using different mechanisms and 'non-coordination' for lost sale and backorder cases. The operating conditions of the SC in this study are made dynamic in nature to make the system realistic and useful to the business community. Apart from this, the modelling and analysis of the network SC is conducted under both lost sale and backorder cases which represent SC in most business systems. Price discount and delay in payment are the two common mechanisms used separately and jointly to coordinate the SC in this study. This will help the practitioners to know the relative benefits of each case compared to the other and to take appropriate decisions considering all aspects. Sensitivity analysis conducted in this study to analyse the impact of various system parameters on the SC performance will further help in the case of variation in operating conditions. It also reveals the incremental surplus for each case with other. In each case of analysis, the extent of benefit that can be obtained from coordination is found out, which is to the extent of 8% in the case of back order and 10% in the case of lost sale compared to 'non-coordination'.

The overall analysis shows that coordination improves the performance of the SC significantly. Among two coordination mechanisms, the effect of delay in payment on SC performance is found to be slightly better compared to the case of price discount. This is due to the decrease in total order cost of each player due to increase in order quantity by the effect of delay in payment provided by the wholesaler to the retailer. This in turn increases the order quantity of the wholesaler and manufacturer as it depends on the order quantity of retailer. Apart from all these factors, the price elasticity of demand is also a major factor to decide the effect of price discount on the SC performance. So, we cannot always say that the effect of delay in payment on SC performance is better than the effect of price discount. However, the joint effect of price discounts and delay in payments further improves the surplus significantly compared to the individual use of these coordination mechanisms. The manufacturer and wholesaler improve their performance by ordering the sum of EOQ of their retailers and sum of the ordering quantity of wholesalers respectively. This individual improvement in performance of each player is due to the reduction in inventory cost by keeping the products exactly as per the requirement of the downstream player for minimum possible time to avoid both stock out and excess stock. Finally, this coordination on order quantity also supports the overall performance of SC under each case of coordination mechanisms.

The sensitivity analysis conducted in this study is to understand the effect of change in various operating parameters and thereby to take appropriate decisions to control the sensitive parameters better. It helped in quantifying the effect of decision variables on SC surplus. This kind of insight is useful to a practicing SC specialist who has to decide which variable to control and how much to control. It is important that while implementing the 'price discount', the purchasing power, the culture and social setup, attitude and approach of the targeted end customers are to be taken in to account. Similarly, while implementing 'delay in payment', the payment capacity and goodwill of the end customers are to be ensured. Analysis on various cases of price discount gave us the optimum value of price discount for the given set of input data collected from the concerned industry for lost sale and back order cases. This being specific cases, the numerical results obtained are not directly applicable to other cases. However, the general trends and more so, the methodology followed for the sensitivity analysis may be used to gain insights regarding the effect of changes in decision variables on SC surplus.

This work is conducted to study and analyse the individual and combined effect of price discounts and delay in payments along with coordination on order quantity for a network SC under dynamic operating conditions and to understand the impact of various operating parameters on the SC performance. It can be extended to more number of players at each stage in the SC, which makes the study more realistic. Apart from this, studies can be conducted using various categories of coordination mechanisms addressing a variety of real issues such as disruptions, fuzziness, information sharing, pricing, technology, and joint decision making of SC. Agile SC is another area of research to be addressed in depth to cope up with the present highly dynamic and competitive business environment.

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