4.1 Introduction

Supply Chain Management (SCM) has emerged as an exciting and rewarding topic for researchers and practitioners. In the present business environment, an in-depth understanding of Supply Chain (SC) is a must to succeed. Since, SC spans many organizations; coordination among them is a prerequisite for the success of any SC. SCM deals with the flow of product, fund, information and service. The SC coordination helps to manage these flows to achieve the overall goals 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 sales or both. Fulfillment of customer requirement is always the major objective for 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 optimizing inventory and backorder/lost sales.
Simulation is a very useful and well accepted tool for predicting SC performance as discussed under the section 2.3 in the Chapter 2. This part of the study of performance of a networked supply chain with ‘price discount and delay in payment’ jointly and separately was done using simulation. It was done under both lost sale and backorder cases. Simulation modelling helped us to study the SC coordination with a realistic structure and operating parameters under dynamic business environment and to make the study useful to the academicians as well as practitioners. This study was done based on the already developed computations for profit functions of each player and the final mathematical model of profit maximization discussed in chapter3. In this study, some of the assumptions used in mathematical model were relaxed and added more players at each level of SC to match with reality. SC profit is taken as the performance measure in this study also. A sensitivity analysis is also conducted as a part of this study. Two different products were considered for the study and the data for the same was collected from the industry. The following section deals with SC model, research methods, results & analysis and conclusion.

4.2 Supply Chain 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.

4.2.1 Structure and Operating Conditions

In this study, the SC simulated consists of four retailers, two wholesalers and one manufacturer with an infinite part supplier. 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. The conceptual model of
Performance of a Network Supply Chain with Price Discount and Delay in ………

this network SC is shown in Figure 4.1. End customer demand and lead time between players are assumed to be probabilistic in nature.

In the case of price discounts, the manufacturer provides a discount to the end customers through his downstream players. So, the customer demand is more than the case of non-coordination as the 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 the manufacturer is not getting any discount from its supplier.

In the case of delay in payments, 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 profit 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.

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 wholesalers 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 infinite part suppliers (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 minimize the inventory cost. In this study, expected
variations in demand are only considered and hence safety stock is not in our scope of study.

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 no coordination mechanisms are implemented. In this case, unnecessary inventory may pile up and cause more inventory carrying cost and low SC performance. In the non coordination case, all the parameters and operating conditions (no mechanisms) used are the same as those of coordination case. The non coordination model is also analysed for both the business cases.

4.2.2 Assumptions

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

i. Products delivered from the manufacturer are of perfect quality and therefore there is no rejection at any stage.

ii. 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 buyers 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 infinite part supplier as it is only a part of SC but not considered for any computation for co-ordination benefits.
iii. Delay in payment with interest (Maximum delay in payment) provided by an upstream player to downstream player is its inventory cycle time.

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

v. The simulation is run for 365 days.

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

vii. Infinite part supplier is considered as an infinite source and is not considered for the performance measure calculations.

viii. The order quantity of retailer is its EOQ and the order quantities of wholesalers are based on the EOQ of his retailers. Accordingly, each wholesaler orders a sum of the EOQs of his retailers. But the manufacturer schedules the production batch size for a quantity equal to the order quantity of his one wholesaler to minimize the inventory cost.

ix. 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.

x. 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.

xi. No shortage/lost sale is permitted at wholesaler and manufacturer and it will occur only between retailer and customer.
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Figure 4.1: A conceptual model of a network Supply Chain consisting of four retailers, two wholesalers and one manufacturer with an infinite part supplier
4.2.3 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 \( i \),

\( k_i \) = Return on investment/interest to be paid for player \( i \).

Actual end customer demand \( D = D_0 + D_1 \times d_r \), Where \( d_r = \) discount given by the retailer, \( D_0 = \) 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 \( i \)

\( h_c_i \) = Holding cost for each player \( i \)

\( S_c_i \) = Storage cost for each player \( i \)

\( d_i = d_r = d_w = d_m = \) Discount offered by each player

\( C_i = P_i - d_i \) = Discounted purchase cost for each player \( i \)

\( t_{ij} \) = Interest free permissible delay in payments period permitted by player ‘\( i \)’ to player ‘\( j \)’ = \( t_{mw} \& t_{wr} \)

\( \tau_{ji} \) = Maximum possible delay in payments period availed by player ‘\( j \)’ from player ‘\( i \)’ = \( \tau_{rw} \& \tau_{wm} \). If \( \tau_{ji} > t_{ij} \), the player ‘\( i \)’ charges interest on player ‘\( j \)’ for the period of \( \tau - t \)
Where $j = w \ r \ i \neq j$

- $Q_i =$ Quantity ordered by each player to its upstream player
- $q_i =$ Quantity released by each player to its downstream 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
- $t_{di} =$ Time at which a player dispatches the order quantity to its customer
- $t_{ri} =$ Time at which a player receives its order quantity from its upstream player
- $k_i =$ Rate of return for each player
- $T_i =$ Inventory cycle time for player, $T_i = \frac{Q_i}{D}$

### 4.3 Methodology

In this study, this simulation modelling of a network SC coordination using price discounts and delay in payments 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 profit 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 profit functions of each stages and the total SC.

4.3.1 Supply Chain Simulation Model

The simulation modelling of the network SC shown in Figure 1 is done using “Arena simulation software”. The simulation model of the network SC consists of 3 sections i) network section ii) control section and iii) computation section. The network section shows the flow of entities or products during simulation, whereas control section deals with control and monitoring of movements in network section and finally computation section computes various parameters required for getting net SC profit. In this SC, retailers 1 & 2 are linked to wholesaler 1 and retailers 3&4 are linked to by wholesaler 2. The two wholesalers place orders with the manufacturer. The manufacturer in turn gets the required items from infinite part supplier to produce the finished goods for supply to the wholesalers.

Simulation starts with creating raw materials and components at infinite part supplier 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 fulfill continuously as and when the finished goods reach the retailer’s end. This is done only at initial stage to
ensure equal inventory at all players of each level. Hereafter, each player places the replenishment orders as per their individual requirement. The retailer places the next order (EOQ) with the wholesaler concerned when his inventory reaches equal to the expected demand from his customers during the lead time. In the case of lost sale, the replenishment orders are placed by the retailer when the inventory reaches maximum demand that is expected to occur during the lead time to ensure no ‘lost sale’ due to complete ‘stock out’ situation. In the case of back order, the reorder point at each retailer is fixed in such a way that the maximum number of total annual back orders should less than 10% of the expected average annual demand considering the goodwill of the firm. The reorder point at each wholesaler level is the EOQ of one retailer to avoid stock out situations. The production rate at manufacturer is in such a way that an inventory equal to order quantity of one wholesaler will be always available at manufacturer. Accordingly, manufacturer gets the raw materials and components from infinite part supplier (IPS) and completes the production for a quantity equal to the requirement of one wholesaler in one batch before the existing stock dispatched to the wholesaler. This is always done to ensure the requirement of one wholesaler at the manufacturer. The release of a shipment from a wholesaler or manufacturer to his downstream player occurs when the system satisfies the following two conditions i) the stock at downstream player should reach reorder point (equal to order quantity of his downstream player in the case of wholesalers and manufacturer) ii) 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 reorder point 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 will occur only due to non availability of customer desired flavour and retailer will never undergo completely out of stock situation.

To make it possible, the retailer keeps enough minimum inventories (maximum demand as per the demand pattern that can occur during the lead time) 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 pre-fixed 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 profit 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 the 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 increase based on the value of price elasticity and the discount provided and subsequently the sales revenue also increases. In the case of delay in payments, 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 his upstream player for the period that exceeds the permissible delay in payment. In this part of the study, the maximum delay in payment that can be availed by downstream player is his/her inventory cycle time. At the same time, each downstream player can invest this amount to be paid till his/her inventory cycle time and can earn some extra income to his/her 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 validation of the above mentioned simulation model was conducted by an iterative process of comparing the model to actual system behavior and
using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is judged to be acceptable. The simulation was run for 21 consecutive 365 day periods and outputs were collected avoiding the first year run (to allow for the initialization bias and for the system to acquire steady state) and only the later 20 year simulation outputs were taken for computation. This provided 20 replication data for analyzing the variability using standard deviation of SC profit.

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

4.3.2 Performance Measure and its Calculations

The performance measure of the SC in this study is taken as the ‘SC profit’ and is calculated as the sum of the individual profit 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 profit function of each player is calculated as follows.

4.3.2.1 Retailer Profit

Profit of the retailer = Sales revenue – Net cost  

\[ \text{Sales revenue} = S_r \times (P_r - d_r) \]  

Net cost = order cost + procurement cost + storage cost + interest paid to wholesaler+ backorder cost/lost sales cost – savings from investment  

4(1)

4(2)

4(3)
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Quantity ordered by the retailer = \( Q_r^* = EOQ = \sqrt{\frac{2CR}{h_r+s_r}} \) 4(4)

Discount offered by the retailer to the customer = \( d_r \)

Order cost = \( A_r \)

Procurement cost = \( Q_r \times (P_w - d_w) \) 4(5)

Storage cost = \( (sc_r) \times q_r \times (t_{dr} - t_{rr}) \) 4(6)

Holding cost = \( (hc_r) \times q_r \times (t_{dr} - t_{rr}) = 0 \) 4(7)

(‘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 of retailer =0

(Retailer do not provide any delay in payment to its customers)

Inventory cycle time of wholesaler = \( T_r = \frac{Q_r}{D} \) 4(8)

Interest paid to wholesaler = \( c_r \times Q_r \times k_m \times (\tau_{rw} - t_{wr}) \) 4(9)

Savings from the investments = \( c_r \times Q_r \times k_r \times (\tau_{rw}) \) 4(10)

Backorder cost = \( c_{br} \times n_b \) 4(11)

Lost sales cost = \( c_{lr} \times n_l \) 4(12)

4.3.2.2 Wholesaler’s profit

Profit of wholesaler = Sales revenue – Net cost 4(13)

Sales revenue = \( S_w \times (P_w - d_w) \) 4(14)
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Net cost per unit cycle = Order cost + Procurement cost + Storage cost + Holding cost + Additional holding cost + Interest paid to supplier + Cost due to loss of opportunity to invest the profit – (Savings from investment+ Interest paid by retailers )

4(15)

Quantity ordered by each wholesaler = \( 2 * Q \)

4(16)

Holding cost = \((h_c)_w \times q_w \times (t_{dw} - t_{rw}) = 0\)

4(17)

(‘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 = \( h_c w Q_r \tau_{rw} \)

4(18)

Storage cost = \((s c)_w \times q_w \times (t_{dw} - t_{rw})\)

4(19)

Inventory cycle time of wholesaler = \( T_w = \frac{Q_w}{2 \times D} \)

4(20)

Order cost = \( A_w \)

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

4(21)

Quantity y released by each wholesaler at each time against a retailer order = \( q_w \)

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

4(22)

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

4(23)

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

4(24)

Opportunity cost due to delay in payments

\[ = (c_r - c_w) \times Q_r \times k_w \times t_{wr} \]

4(25)

Backorder cost = \( c_{bw} \times n_b \)

4(26)

Lost sales cost = \( c_{lw} \times n_l \)

4(27)
4.3.2.3 Manufacturer Profit Function

Profit of manufacturer = Sales revenue – Net cost

\[ \text{Profit of manufacturer} = \text{Sales revenue} - \text{Net cost} \]

\[ \text{Sales revenue} = Q_m \times (P_m - d_m) \]

\[ \text{Net cost} = \text{Order cost} + \text{Procurement cost} + \text{Storage cost} + \text{Holding cost} + \text{Additional holding cost} + \text{Cost due to loss of opportunity to invest the profit} - \text{Interest paid by wholesalers} \]

\[ \text{Batch production quantity of manufacturer, } Q_m = 4 \times Q_r = 2 \times Q_w \]

\[ \text{Procurement cost} = c_m \times Q_m \]

\[ \text{Holding cost} = (hc_m) \times q_m \times (t_{dm} - t_{rm}) \]

\[ \text{Storage cost} = (sc_m) \times q_m \times (t_{dm} - t_{rm}) \]

\[ \text{Additional holding cost} = hQ_w \tau_{wm} \]

\[ \text{Inventory time of cycle for the supplier } T_m = \frac{Q_m}{4 \times D} \]

\[ \text{Order cost} = A_m \]

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

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

\[ \text{Backorder cost} = c_{bm} \times n_p \]

\[ \text{Lost sales cost} = c_{lm} \times n_i \]

4.3.3 Input Data

Health drink and two-wheeler industries are common and familiar to general public. So, this study is expected be more interesting to both business
community and academicians as well. Both the industries considered for this study include almost all stages in a typical supply chain so that modelling of the same became realistic one. In the case of two-wheeler, each manufacturer/dealer follows different procedures to deliver the product to the customer. From the interaction with industry, it is understood that they follow some of the principles of supply chain management even though not in complete aspect. So, we have followed a typical case of supply chain which includes manufacturer, wholesaler/distributor and dealer/retailer for this research. Regarding health drink, due to the nature of this product and its requirement, customers will not wait for it under out of stock situation. So, sale will be lost if a customer comes when the item is not in stock. This is called lost sale. But, people may wait for two wheelers at least a couple of weeks till the next shipment arrives at the retailer end and once it reaches, all the pending orders from customers will be fulfilled at first. This is called backorder. So backorder is also a demand that will be fulfilled later than desired. Each backorder and lost sale incurs an additional cost. The two coordination mechanisms: price discount and delay in payment are being practiced in these two industries in one way or other. So, this research to study the effect of combination of these mechanisms on the SC performance and sensitivity analysis under lost sale and backorder situation using a set of realistic data will be really helpful to the users.

‘Health drink’ is used as the product under lost ale to suit the situation and it belongs to FMG group. The important factor to use this product is to suit the assumption we have made that lost sale will happen only because of the unavailability of the product with desired flavour. This means that we assume the system will never be completely out of stock under the case of lost sale.

‘Two-wheeler’ is used as the product under backorder to suit the situation and it belongs to MMG group. The important factor to use this product
is to suit the backorder situation. In the case of two wheelers, customers may be willing to wait till the next shipment arrives in the case of complete out of stock situation or unavailability of two-wheeler with desired features.

This study is conducted using the data provided in Table 4.1 and 4.2 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 sales and backorder respectively. Rate of return or interest rate on investment/delay in payment is taken as 15% (normal situation) for both the cases.

Demand per day in the case of health drink (lost sale) was found to be varying in wide range and almost follows normal distribution. With the interaction with industry, it is found that variation in demand per day in the case of two-wheeler (back order) is relatively too low due to nature of the product considered in this study and seems to be matching with triangular distribution. Accordingly, It is assumed that customer demand as normal distribution for lost sales scenario whereas triangular distribution for backorder scenario. Similar to this, it is also assumed that both the occurrence of lost sale and back order follows triangular distribution but the parameter values are taken as different to suit the case of product.

| Table 4.1: Input data for lost sale situation (product – health drink) |
|-------------------|------------------|----------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| End customer demand | Player | Purchase cost/unit | Selling price | Discount Provided | Order cost (Rs) | Holding Cost/unit/year | Lost sale cost/unit | Interest rate (%) | Storage Cost/unit/year |
| Normal distribution (15, 3) | RET | 193 | 200 | 3 | 200 | 30 | 7 | 15 | 35 |
| Normal distribution (15, 3) | W.S. | 188 | 193 | 3 | 300 | 29 | - | 15 | 23 |
| Normal distribution (15, 3) | MFR | 176 | 188 | 3 | 500 | 28 | - | 15 | 20 |

Note: i) Lost sale due to desired flavour is assumed as probabilistic and follows triangular distribution (0, 0, 1), Price elasticity- 1
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ii) Lead time assumed as probabilistic and follows triangular distribution: WS to RET(1,2,3) & MFR to WS (3,4,5)

Table 4.2: Input data for Back order situation (product — bike)

<table>
<thead>
<tr>
<th>End customer demand</th>
<th>Player</th>
<th>Purchase cost/unit</th>
<th>Selling price</th>
<th>Discount Given</th>
<th>Order cost (Rs)</th>
<th>Holding Cost/unit/year</th>
<th>Backorder cost/unit</th>
<th>Interest rate (%)</th>
<th>Storage Cost/unit/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangular distribution (8,10,12)</td>
<td>RET</td>
<td>45000</td>
<td>50000</td>
<td>3000</td>
<td>10000</td>
<td>5550</td>
<td>500</td>
<td>15</td>
<td>3650</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>42000</td>
<td>45000</td>
<td>3000</td>
<td>20000</td>
<td>6750</td>
<td>-</td>
<td>15</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>MFR</td>
<td>34000</td>
<td>42000</td>
<td>3000</td>
<td>30000</td>
<td>7500</td>
<td>-</td>
<td>15</td>
<td>1400</td>
</tr>
</tbody>
</table>

Note: i) Colour related B.O is assumed as probabilistic and follows triangular distribution (0, 1, 1), MFR-Manufacturer, WS-Wholesaler, RET-Retailer, Price elasticity - 0.001

ii) Lead time assumed as probabilistic and follows triangular distribution: WS to RET (2, 3, 4) and MFR to WS (5, 6, 7)

4.4 Result and Analysis

The simulation of network SC was conducted using the coordination mechanisms of Price Discount (PD) and Delay in Payment (DIP) individually and in combination (PD & DIP) with coordination on order quantity as explained in preceding sections. Simulation was also conducted with no coordination (no coordination mechanisms are used). In this model, probabilistic demand and lead time are used and hence it is found that the monthly profit values are not the same. When we examined the profit for the first and second set of six months, they are nearly the same indicating that model has achieved steady sate. The results obtained from the simulation runs are given in Table 4.3.

The value of price discount Rs 3/- (lost sale), Rs 3000/- (backorder) and the value of interest free permissible delay in payment ‘zero’ used in this simulation, are the optimal values obtained from sensitivity analysis. But, the value of delay in payment availed by each buyer from its seller for lost sale (16 days) and backorder (13 days) was set as the buyer’s inventory cycle time in this study considering the current practice in industry.
Table 4.3: Supply Chain Performance (SC profit) under Coordination and No coordination

<table>
<thead>
<tr>
<th>Business Situations</th>
<th>Player</th>
<th>Individual profit of players under coordination(Rs)</th>
<th>SC Profit (Rs) (std deviation)</th>
<th>No Coordination</th>
<th>Coordination</th>
<th>Coordination Mechanism</th>
<th>Values of coordination mechanism</th>
<th>% Increase in SC profit under Coordination compared to No coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Player</td>
<td>Player</td>
<td>Coordination</td>
<td>Price discount</td>
<td>Individual SC profit of players under coordination(Rs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>W1</td>
<td>PD</td>
<td>M</td>
<td>225037</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W1</td>
<td>W2</td>
<td>PD</td>
<td>W1</td>
<td>36788</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W2</td>
<td>R1</td>
<td>PD</td>
<td>R1</td>
<td>40282</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R1</td>
<td>R2</td>
<td>PD</td>
<td>R2</td>
<td>24532</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R2</td>
<td>R3</td>
<td>PD</td>
<td>R3</td>
<td>22706</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R3</td>
<td>R4</td>
<td>PD</td>
<td>R4</td>
<td>21894</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>W1</td>
<td>DIP</td>
<td>M</td>
<td>10610018</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W1</td>
<td>W2</td>
<td>DIP</td>
<td>W1</td>
<td>19054754</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W2</td>
<td>R1</td>
<td>DIP</td>
<td>W2</td>
<td>19952002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R1</td>
<td>R2</td>
<td>DIP</td>
<td>R1</td>
<td>16477526</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R2</td>
<td>R3</td>
<td>DIP</td>
<td>R2</td>
<td>16548484</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R3</td>
<td>R4</td>
<td>DIP</td>
<td>R3</td>
<td>16470534</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R4</td>
<td>W1</td>
<td>DIP</td>
<td>R4</td>
<td>16528112</td>
</tr>
</tbody>
</table>

R1 — Retailer 1      W1 — Wholesaler 1      PD — Price Discounts   Maximum Delay in payment availed by the buyer = Buyer’s inventory cycle time from the seller
R2 — Retailer 2      W2 — Wholesaler 2      DIP — Delay in Payments
R3 — Retailer 3      M — Manufacturer      NC — Non coordination
R4 - Retailer 4
Chapter 4

The results given in Table 4.3 obtained from the simulation of network SC for various cases of coordination and no coordination show that the SC profit is enhanced significantly due to coordination under both lost sale and backorder cases. The Standard Deviation (SD) of the profit values obtained from the 20 simulation runs is also given in the table along with mean value of supply chain profit under various cases to have more clarity on the results. The SD is seen to vary from 0.3 to 0.7 % of the mean. The SD being so small implies that, for all practical purposes the mean may be taken as the performance measure. Therefore the change in performance from one case to the next case of use of coordination can be judged from change in mean profit figures of each case. Hence the results given henceforth only mean is shown. Under lost sale, the increase in SC profit is 2.10% in the case of price discounts, 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 profit is 3.09% in the case of price discounts, 4.06% in the case of delay in payments 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 profit 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 decrease in total order cost is due to the reduction in per unit order cost by the increase in order quantity with decrease in holding cost because of the effect of delay in payment. The improvement in performance in the case of delay in payment alone compared to price discount alone cannot be generalized as the performance of price discount depends on the price elasticity of demand also. The analysis of the hike in profit of individual players due to coordination shows that manufacturer’s profit 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 the manufacturer sacrifices for the overall benefit of the SC. Since the overall SC
Performance of a Network Supply Chain with Price Discount and Delay in ………

profit is enhanced owing to coordination, the decrease in profit for the manufacturer under coordination can be made up by proper profit sharing methodology among players to get equal rate of return for each player based on their investment. The individual hike in profit in the case of other players due to coordination is significantly high under lost sale and backorder.

The increase in profit 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 profit 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 the 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 profit 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 as the amount of reduction in cost is relatively high compared to backorder.

4.5 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 profit 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 4.4 shows the effect of different values of price discount on SC profit under both lost sale and back order cases. This analysis is done by changing the value of price discount as shown in Table 4.4. In the case of lost sale, the maximum SC profit is obtained for a price discount of Rs 3/- (case 3) and in the case of backorder, maximum SC profit is obtained for a discount of Rs 3000/- (case 3 ) given by the manufacturer to his customers through his downstream players. So, these optimal values of price discount Rs3/- for lost sale and Rs.3000/- for backorder are taken for rest of the sensitivity analysis. The variation in profit for different values of discount is also provided which will help users to take appropriate decision. The SC profit for different values of price discount showed a variation of 2.22% under lost sale and 5.21% under backorder over the five cases examined.

<table>
<thead>
<tr>
<th>Case</th>
<th>Lost sale</th>
<th>Back order</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price discount (Rs)</td>
<td>SC profit (Rs)</td>
</tr>
<tr>
<td>1</td>
<td>(d_m = d_w = d_r = 1)</td>
<td>428353</td>
</tr>
<tr>
<td>2</td>
<td>(d_m = d_w = d_r = 2)</td>
<td>431025</td>
</tr>
<tr>
<td>3</td>
<td>(d_m = d_w = d_r = 3)</td>
<td>437798</td>
</tr>
<tr>
<td>4</td>
<td>(d_m = d_w = d_r = 4)</td>
<td>433334</td>
</tr>
<tr>
<td>5</td>
<td>(d_m = d_w = d_r = 5)</td>
<td>428270</td>
</tr>
</tbody>
</table>
Table 4.5 shows the effect of change in the rate of return of different players on SC profit 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 player. From the Table 4.5, it is clear that there is a proportional change in SC profit 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 lost sale and under backorder. The variation in SC profit over the nine cases examined is 9.56% under lost sale and 2.24% under backorder.
Table 4.6 shows the effect of different values of price elasticity on the SC profit for an optimum price discount obtained earlier under both lost sale and backorder. The analysis shows that the SC profit is increasing with increase in price elasticity and the rate of increase in profit is almost constant for both the business situations. However, it is noted that the SC profit 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 profit 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 4.6: Supply Chain profit for different cases of price elasticity under lost sale and backorder

<table>
<thead>
<tr>
<th>Case</th>
<th>Price elasticity of demand (D0)</th>
<th>Lost sale</th>
<th>Back order</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SC profit (Rs)</td>
<td>Change in SC profit w.r.t case 1 (%)</td>
<td>Price elasticity (D0)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>353604</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>437798</td>
<td>23.81</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>522545</td>
<td>47.77</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>596524</td>
<td>68.69</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>676716</td>
<td>91.37</td>
</tr>
</tbody>
</table>

Table 4.7 shows the SC profit 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 the upper side (case 2) reduces the SC profit and the lower side (case 3) increases the SC profit almost equal in magnitude in both the cases. The individual increase in the order cost of retailer (case 4) reduces the SC profit 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 the retailer, change in the order cost results in compensating change in the order quantity through EOQ. Order cost change for the wholesaler and the manufacturer does not result in any compensating order quantity change. Hence it directly affects the SC profit. It is also found that when the order cost is reduced for the retailer (cases 3 & 7), the optimal price discount is also reduced from Rs.3/- to Rs 2/- and remains the same as Rs 3/- for all other cases, as the order cost of the retailer plays a major role in this model. The SC profit for different cases of order cost showed a variation of 5.17% under the lost sale over the nine cases examined.

Table 4.7: Supply Chain profit for various cases of order cost under lost sale

<table>
<thead>
<tr>
<th>Case</th>
<th>Order cost (Rs)</th>
<th>SC profit (Rs)</th>
<th>Optimal value of discount (Rs)</th>
<th>Change in SC profit w.r.t Case 1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$A_r = 200, A_w = 300, A_m = 500$</td>
<td>437798</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>$A_r = 250, A_w = 375, A_m = 625$</td>
<td>426367</td>
<td>3</td>
<td>-2.61</td>
</tr>
<tr>
<td>3</td>
<td>$A_r = 150, A_w = 225, A_m = 375$</td>
<td>449039</td>
<td>2</td>
<td>2.56</td>
</tr>
<tr>
<td>4</td>
<td>$A_r = 250, A_w = 300, A_m = 500$</td>
<td>434930</td>
<td>3</td>
<td>-0.65</td>
</tr>
<tr>
<td>5</td>
<td>$A_r = 200, A_w = 375, A_m = 500$</td>
<td>434236</td>
<td>3</td>
<td>-0.81</td>
</tr>
<tr>
<td>6</td>
<td>$A_r = 200, A_w = 300, A_m = 625$</td>
<td>431673</td>
<td>3</td>
<td>-1.39</td>
</tr>
<tr>
<td>7</td>
<td>$A_r = 150, A_w = 300, A_m = 500$</td>
<td>438114</td>
<td>2</td>
<td>0.07</td>
</tr>
<tr>
<td>8</td>
<td>$A_r = 200, A_w = 225, A_m = 500$</td>
<td>441361</td>
<td>3</td>
<td>0.81</td>
</tr>
<tr>
<td>9</td>
<td>$A_r = 200, A_w = 300, A_m = 375$</td>
<td>443377</td>
<td>3</td>
<td>1.27</td>
</tr>
</tbody>
</table>

Table 4.8 shows the effect of various cases of order cost on SC profit under backorder. The case1 is the base case. The detailed analysis shows that the increase in the order cost of all players (case2) reduces the SC profit and a decline in the order cost (case 3) of all players increases the SC profit. The individual effect of the retailer (cases 4 & 7), the wholesaler (cases 5 & 8) and
the manufacturer (cases 6 & 9) on SC profit 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 the retailer (cases 3 and 7), the optimal price discount is also reduced from Rs.3000/- to Rs.2000/- and remains the same as Rs.3000/- for all other cases. The above findings are similar for the lost sale and the backorder case and the extent of effect may be slightly different, depending on the difference in values of the order cost considered. The SC profit for different cases of order cost showed a variation of 0.64% under backorder over the nine cases examined.

Table 4.8: Supply Chain profit for various cases of order cost under back order

<table>
<thead>
<tr>
<th>Case</th>
<th>Order cost (Rs)</th>
<th>Optimal Value of discount</th>
<th>SC profit (Rs)</th>
<th>Change in SC profit w.r.t Case 1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$A_r = 10000, A_w = 20000, A_m = 30000$</td>
<td>3000</td>
<td>227795878</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>$A_r = 12500, A_w = 25000, A_m = 37500$</td>
<td>3000</td>
<td>226976856</td>
<td>-0.35</td>
</tr>
<tr>
<td>3</td>
<td>$A_r = 7500, A_w = 15000, A_m = 22500$</td>
<td>2000</td>
<td>228456778</td>
<td>0.29</td>
</tr>
<tr>
<td>4</td>
<td>$A_r = 12500, A_w = 20000, A_m = 30000$</td>
<td>3000</td>
<td>227606856</td>
<td>-0.08</td>
</tr>
<tr>
<td>5</td>
<td>$A_r = 10000, A_w = 25000, A_m = 30000$</td>
<td>3000</td>
<td>227528377</td>
<td>-0.12</td>
</tr>
<tr>
<td>6</td>
<td>$A_r = 10000, A_w = 20000, A_m = 37500$</td>
<td>3000</td>
<td>227360877</td>
<td>-0.19</td>
</tr>
<tr>
<td>7</td>
<td>$A_r = 7500, A_w = 20000, A_m = 30000$</td>
<td>2000</td>
<td>227679278</td>
<td>-0.05</td>
</tr>
<tr>
<td>8</td>
<td>$A_r = 10000, A_w = 15000, A_m = 30000$</td>
<td>3000</td>
<td>228063377</td>
<td>0.12</td>
</tr>
<tr>
<td>9</td>
<td>$A_r = 10000, A_w = 20000, A_m = 22500$</td>
<td>3000</td>
<td>228230877</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Table 4.9 shows the effect of different cases of delay in payment between various players on SC profit. Case 1(base case) shows the optimal values of delay in payment for which maximum SC profit is obtained. Case 2 &3 shows that the change in permissible delay in payment given by the manufacturer to the wholesaler (case3) affects more than the same given by wholesaler to the retailer (case 2) on the SC profit. But, the cases 6 & 7 shows that the effect of change in delay in payment taken by the wholesaler from the manufacturer (case 6) on the SC profit 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 given by the upstream payers (case 4) and decrease in delay in payment availed by the downstream players (case 5) reduces the SC profit. It is also noted that delay in payment taken by the retailer from the wholesaler does not have much effect on SC profit under both lost sale and back order. It is assumed that the maximum delay in payment taken by the downstream player form the upstream player is its 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 profit for different cases of delay in payment showed a variation of 0.084% under backorder and 0.039% under lost sale over the seven cases examined.

Table 4.9: Supply Chain profit for various cases of Delay in payment under lost sale and backorder

<table>
<thead>
<tr>
<th>Case</th>
<th>Delay in payment</th>
<th>SC profit (Rs)</th>
<th>Change in SC profit w.r.t. case 1 (%)</th>
<th>Delay in payment</th>
<th>SC profit (Rs)</th>
<th>Change in SC Profit w.r.t case 1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437798</td>
<td>0</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 13$</td>
<td>227795878</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>$t_{mw} = 0$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437671</td>
<td>-0.029</td>
<td>$t_{mw} = 0$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 13$</td>
<td>227787048</td>
<td>-0.003</td>
</tr>
<tr>
<td>3</td>
<td>$t_{mw} = 1$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437557</td>
<td>-0.055</td>
<td>$t_{mw} = 1$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 13$</td>
<td>22779467</td>
<td>-0.037</td>
</tr>
<tr>
<td>4</td>
<td>$t_{mw} = 1$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437430</td>
<td>-0.084</td>
<td>$t_{mw} = 1$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 13$</td>
<td>227706637</td>
<td>-0.039</td>
</tr>
<tr>
<td>5</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 15$</td>
<td>437787</td>
<td>-0.025</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 12$</td>
<td>227757502</td>
<td>-0.016</td>
</tr>
<tr>
<td>6</td>
<td>$t_{mw} = 0$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437783</td>
<td>-0.034</td>
<td>$t_{mw} = 0$, $t_{uw} = 1$, $\tau_{rw} = \tau_{wm} = 12$</td>
<td>227757502</td>
<td>-0.016</td>
</tr>
<tr>
<td>7</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 16$</td>
<td>437802</td>
<td>0.009</td>
<td>$t_{mw} = 0$, $t_{uw} = 0$, $\tau_{rw} = \tau_{wm} = 13$</td>
<td>227795877</td>
<td>-0.000</td>
</tr>
</tbody>
</table>

Note $\tau_{rw} = \tau_{wm} = 16 = T_r = T_w = \text{Inventory cycle time (LS)}$. Note $\tau_{rw} = \tau_{wm} = 13 = T_r = T_w = \text{Inventory cycle time (BO)}$.
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Table 4.10 shows the consolidated statement of increase in SC profit in each case with respect to each other case of coordination and no coordination. This analysis shows that the percentages of increase in SC profit is relatively high in the case of combination of PD & DIP (LS -10.03% & BO – 7.85%) and DIP (LS -6.53% & BO – 4.06) with respect to non coordination (NC) under lost sale compared to the backorder. Similarly, the increase in profit in the case of DIP and PD&DIP compared to PD is also high in the case of lost sale. The increase in profit in the case of PD & DIP compared to DIP is almost the same under both lost sale and backorder. But, when comparing NC and PD, an increase in SC profit in the case of price discounts is slightly higher under backorder than lost sale. Similarly, when comparing DIP and PD&DIP, an increase in profit in the case of PD&DIP is also slightly higher under back order than lost sale. The overall analysis shows that the increase in profit while 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 profit with each other will help the practitioners to implement the same considering all related practical issues.

Table 4.10: Increase in profit with respect to one case to other case of coordination and no coordination

<table>
<thead>
<tr>
<th>Case</th>
<th>Lost sale</th>
<th>Back order</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SC profit</td>
<td>Increase in profit w.r.t NC (%)</td>
</tr>
<tr>
<td>NC</td>
<td>397778</td>
<td>-</td>
</tr>
<tr>
<td>PD</td>
<td>406118</td>
<td>2.09</td>
</tr>
<tr>
<td>DIP</td>
<td>423758</td>
<td>6.53</td>
</tr>
<tr>
<td>PD&amp;DIP</td>
<td>437798</td>
<td>10.06</td>
</tr>
</tbody>
</table>

NC- Non coordination, PD-Price discounts, DIP-Delay in payments
4.6 Conclusion

This study conducted on network SC was to analyze its performance under coordination using different mechanisms and ‘no 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 analyze 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 profit 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 the 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 the manufacturer as it depends on the order quantity of the 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 discount and delay in payment further improves the profit significantly compared to the individual use of these coordination mechanisms. The manufacturer and the 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 to take thereby; appropriate decisions according to better control the sensitive parameters. It helped in quantifying the effect of decision variables on SC profit. This kind of insight is useful to a practicing SC specialist who has to decide which variable to control and how much to control. 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 profit.