Chapter-II
Literature Review

The increased competitive pressure, lower product life cycle, more rigorous quality and quicker response requirements paved ways to more attention on the collaboration between players of a Supply Chain (SC). This collaboration consists of the sharing of information, resources, relevant technique and even profit. Close cooperation can result in more cost-effective production and distribution as well as a faster response to customer demand. Supply chains have a tendency to increment in intricacy and the association of various suppliers, and end customers in a network of relationships. This results in risk and vulnerability for everybody (Pfohl et al. 2010). Firms are not competing as a single firm against other individual firms, but competing as a part of SC against other supply chains. If all stages of the chain take actions together, firms can increase total SC profits. SC coordination requires each stage of the SC to take into account the impact of its actions on other stages. An increase in the cost of a SC and degradation of responsiveness results due to lack of coordination. The role of human factors on the two-level supply chain performance is addressed by Khan et al. (2012).

Coordination can be defined as performing different activities of SC jointly to achieve mutually defined goals. The central theme of multi-echelon inventory has been the coordination of lot sizing decisions among vertically integrated firms. Modern SCM can derive important insights by revisiting multi-echelon inventory models in the context of non-vertically integrated firms where pricing decisions, in addition to lot sizing decisions, need to be coordinated. When there is no coordination, the SC members act independently to maximize their own profit, which does not ensure that the parties as a whole reach an optimal result (Sajadieh and Jokar, 2009), both from economic and environmental points of view. When, there is coordination, the total SC profit/cost is maximized/minimized. But, the saving from coordination shifts to the side of the vendor. However, the losing party is usually compensated in coordinated SC (Jaber and Zolfaghari, 2008).

2.1 SUPPLY CHAIN COORDINATION
The most important challenge in SCM is to motivate every member of the SC to coordinate and direct their choices (Li and Wang, 2007). A natural means of achieving coordination is the integration of inventory decision models of players in
the SC (Goyal and Gupta, 1989). Various mechanisms have been proposed in the literature, including quantity discount contract, credit option, buy back contract, quantity flexibility contract.

2.1.1 JOINT ECONOMIC LOT SIZE (JELS)

The Inventory management and shipment policy for the various echelons of a multi-echelon SC takes place independently in the traditional inventory management system. But, the optimal lot size of one player may not be optimum to the other player of the SC. To overcome this issue, the concept of joint economic lot size may be used to minimize the total system costs with an assumption that the players of the chain cooperate. JELS leads to Joint optimization of inventory and shipment policy. Keeping in view of this, several authors developed integrated inventory models based on JELS. Banerjee (1986) developed and introduced the revolutionary concept of Joint Economic Lot Size (JELS). He assumed that the manufacturer produces on a lot-by-lot basis in response to orders from a single-retailer where the retailer experiences deterministic demand. Many shipment policies were proposed in literature for single-vendor single-buyer problem. Several authors, such as Hall (1996), Li et al. (1996), Agrawal and Raju (1996), and Miller and Kelle (1998), have shown that the joint consideration of economic lot size reduces the overall joint annual cost substantially. A more general batching and shipping policy was proposed by Hill (1999). In the proposed policy, the successive shipment size of the first m number of shipments increases by a fixed factor, whereas the remaining shipments would be of equal sized.

Siagjadi et al. (2006) proposed a new methodology of multiple shipment policy which is more beneficial than a single shipment policy considered by Banerjee (1986). In their model, multiple buyers demand one type of item from a single vendor. Mathematical model for optimal replenishment decisions in a two-level pharmaceutical supply chain comprising of a single-warehouse and one retailer is studied by Baboli et al. (2011).

Glock (2012) reviewed lot-size models related to coordinated inventory decisions between buyer and vendor. He suggested to study the coordination of supplier base in integrated inventory models and to analyze how the coordination of inventory replenishment decisions impact the cost position. Dye (2012) presented a retailer’s two-phase pricing and lot sizing problem. Generalized type demand, deterioration and unit purchasing cost functions and trade credit financing were
considered for the formulation of the model and used particle swarm optimization technique to solve the model.

Huang et al. (2010) incorporated reduction of ordering cost and permissible delay in payments into the integrated inventory decision of a vendor-buyer policy. Ho et al. (2011) developed the integrated vendor-buyer inventory model with defective items and partial backlogging. They considered order quantity, reorder point and number of shipments as decision variables. Roushdy et al. (2015) investigated Joint Replenishment Problem in a two-echelon inventory system. Authors considered centralized non-cooperative policy and centralised cooperative policy in the two-echelon inventory system with planned shortages at retailer and the warehouse. They evaluated optimum order interval for each item and common order interval and the optimum inventory planned shortage amounts. Mandal and Alikhan (2014) considered an integrated model with one-vendor and one-customer under uncertainty in cost functions. Authors developed a joint economic lot size model with deterministic demand and fuzzy costs and determined optimal solution. A three-stage mathematical model was developed by Sarmah (2010) considering setup time of the manufacturer as bottleneck for the entire SC. He found that the set up time and the rate of utilization are inversely related for the optimum savings of the manufacturer in the coordination channel.

2.1.2 TRADE CREDIT
Trade credit is a loan to the buyer offered by the vendor for a short period of time. In this mechanism, vendor allows the buyer to delay payment of the invoice of the goods supplied. The buyer pays no interest during the permissible delay period. But, the buyer has to pay interest for the period beyond the permissible period. So, trade credit is a tool to compete and generate sales. Vendor can gain competitive advantage through trade credit to the considerable extent. As trade credit develops long term relationship between vendor and buyer, this mechanism gained interest of several researchers. A note on two-level supply chain coordination mechanism for optimal replenishment quantity and re-order point under trade credit is presented by Cobb and Johnson (2014).

Jaber and Osman (2006) proposed a centralized model for a two-level SC having supplier and retailer to coordinate their orders for the minimization of local costs as well as SC cost. In the proposed model, the permissible delay is adopted as a
means of trade credit for coordinating the order quantity. Sarmah et al. (2007) proposed a mechanism for coordination and profit sharing between a manufacturer and a buyer with target profit under credit option. Chaharsoughi and Heydari (2010) proposed SC coordination model for the joint determination of order quantity and reorder point using credit option. A new dynamic two-echelon Single-vendor multiple-buyer SC model is investigated by Pourghannad et al. (2015) under vendor managed inventory with considering time value of money. This dynamic vendor managed inventory model is formulated for finding out optional sales quantity for each buyer at each period by maximizing the SC profit.

2.1.3 REVENUE SHARING
Under the mechanism of revenue sharing, a retailer pays wholesale price below marginal cost to the vendor for each unit of his purchase. In addition to that, retailer pays a percentage of his revenue to the vendor. Generally, a vendor and a buyer enters into a revenue sharing contract agreement mutually. Also, it allows a vendor and a buyer to improve the effectiveness of the SC coordination. Cachon (2003) presented an incredible survey on SC coordination with contracts in risk-neutral setting. These contracts include buy-back, revenue-sharing, quantity flexibility, and sales-discount etc. Cachon and Lariviere (2005) studied revenue-sharing contracts (RSCs) in SC models in which the revenues determined by each retailer’s purchase quantity and purchase price. They demonstrated RSCs with a single-retailer and compared revenue sharing with other SC contracts. Further, they noticed inability of revenue sharing to coordinate, when the demand depends on costly retail effort. A coordination framework for aligning the inventory decisions in decentralized supply chains (ASCEND) was presented by Piplani and Fu (2005). Their research work indicated that cost sharing and service level contracts can realize the value of coordination by each partner in the SC network.

Huang and Liu (2006) assumed decrease in demand with an increase in price and studied the decision making and revenue sharing coordination in the SC. Significant improvement in the performance of the SC system through revenue sharing coordination was concluded by the author, when the influence of the price on demand is more. He further indicated the difficulty in building a stable SC, where the influence of price on demand is less. Saha et al. (2012) examined the effect of revenue-sharing contract mechanism in a two-echelon SC under stock and price
dependent demand. They established analytically that the revenue sharing contract is able to coordinate the system and leads to win-win outcomes.

Panda (2013) showed that revenue and cost sharing contract is superior to conventional revenue sharing contract for effective coordination in two-echelon inventory model. Further, he concluded that the range of cost sharing fraction, which is leading to win-win situation is independent of the format of cost structure of retailer. Jinshi and Jiazhen (2013) developed a model to optimize the supplier-led SC by integrating the black-scholes rule and contract option. Zhu (2015) studied the integration of the three critical decisions of capacity, price and lead time in the decentralized SC with one supplier and one retailer. He proposed a franchise contract with revenue sharing and contingent rebate for aligning the interests of the players. Panda et al. (2015) explored the pricing and replenishment policies in dual-channel SC under continuous unit cost decrease over its short life cycle. They suggested a profit sharing mechanism through wholesale price adjustment to resolve the retail-etail channel conflict. Costantino et al. (2014) Proposed a novel replenishment policy based on an information sharing approach for replacing traditional policies and a simulation model for a four-echelon SC has been considered for evaluating the information sharing policy.

2.1.4 QUANTITY DISCOUNTS
The discount offered by the supplier can influence purchasing behaviour of the buyer. The application of all units’ discount contributes to reducing the buyer’s inventory cost and improving the supplier’s profit simultaneously. So, the quantity discount policy attracted much attention of the researchers as a coordination mechanism. Lee and Rosenblatt (1986) proposed an algorithm to determine a profit maximizing quantity discount pricing schedule for a single product, single-buyer model. Weng and Wong (1993), Wang and Wu (2000) modelled under constant demand with quantity discounts. They extended previous research by considering multiple buyers. Munson and Rosenblatt (1998), and Sarmah et al. (2006) extensively reviewed the research on quantity discount. Gurnani (2001) developed an analytical model in single-supplier and multiple-buyer environments. Author addressed the coordination problem of “mismatch in timing of order” and applied joint system cost consideration and quantity discounts in order to minimize the cost. The consideration of convex decreasing function of selling price for the demand and time-dependent function of
backlogging rate were made by Papchristos and Skouri (2003). They developed an inventory model with deteriorating items and quantity discount.

Sarmah, Acharya and Goyal (2006) reviewed literature pertaining to buyer-vendor coordination models having quantity discount as a coordination mechanism when the environment is deterministic. They have classified the various models and identified critical issues. A two-level SC coordination problem is studied by Sinha and Sarmah (2008), where the SC is functioning under asymmetric information environment. This condition allows the system to perform as closely as that of under complete information. Authors designed a coordination mechanism through quantity discount policy. Gorji et al. (2013) formulated a two-level SC with order quantity constraints for optimizing inventory decisions. The supplier’s finite production rate in the pricing and lot-sizing decision is considered in a two-echelon SC system by Wang et al. (2015). Authors investigated the optimization problem under decentralized situation and then solved the joint optimization problem by two sequential algorithms. Also, the SC coordination mechanism is designed through an all-unit quantity discount policy and a franchise fee.

2.2 DEMAND SENSITIVITY

The existence of retail inventory is assumed to have a spurring impact on the customers. To stimulate sales, some of the warehouses and stores display large amounts of specific items. The inventory strategy may impact the demand rate. Under these circumstances, the demand of a particular product is seen as an endogenous variable and is not supposed to be an exogenous variable as with classical inventory models. So, the demand is a function of inventory policy. The conceivable impact of this trust is that the retailer may have a motivating force to request higher lot sizes or to keep higher inventory levels, despite increased replenishing expenses or holding costs. In practice, this approach brings about extra sales, higher fill rates, and conceivably more prominent profits. Further, several researchers suggested to focus on the conditions of demand variations with time or price of the product. Also, in inventory studies, it is observed that accessibility of sufficient stock in stores is drawing more customers.

In addition, customers are not completely fulfilled by just accessibility and freshness of items; rather, they are very mindful of cost of the item in distinctive stores and take choices. Hence, the retailer’s immediate stock level and selling price
of the item affects the sales at retail level (You and Hsieh, 2007; Panda et al., 2012). Chikan and Vastag (1987) analyzed the dynamic behavior of multi-echelon productive inventory system with random supply. Goyal (1976) assumed that the inventory holding cost is independent of the price of an item in the analysis of an integrated model with single supplier single customer. In the proposed model, the author proposed a framework to minimize the total relevant cost. Kar et al. (2001) assumed infinite replenishment rate and arithmetically progressing successive replenishment cycle lengths. They developed a deterministic inventory model for a single item under linearly increasing time-dependent demand with two separate storage facilities. Abad and Jaggi (2003) considered seller’s unit selling price and length of credit period as policy variables for the seller in two-level SC, in which the end product is price sensitive. By using no-credit as the benchmark, authors analyzed non-cooperative and cooperative relationships.

Lau and Lau (2003) applied different demand-curve functions in an inventory/pricing model instead of linear demand function. They noticed that there is a substantial and unpredictable change over a very minute change in the demand by a multi-echelon inventory/pricing model. Chung and Wee (2006) developed an inventory model for a coordinated SC through pricing discount. The model was developed for an optimal replenishment and pricing policy under the change of demand linearly with price. Authors maximized the joint profit of the multi-echelon system under various profit sharing ratios. Chongchao et al (2006) studied the market demand disruption in a SC consisting of one supplier and one retailer. Authors assumed exponential demand function and penalty cost to capture the deviation cost resulting due to market demand disruption.

Esmaeili et al. (2009) modelled the seller-buyer relationship in the environment of demand sensitivity to both price and promotion under non-cooperative and cooperative situations. Chen et al. (2010) formulated a two-stage optimization problem. In this model the supplier decides the amount of the capacity reservation in the first stage. After observing the demand information, the retailer determines the order quantity and the retail price in the second stage. The seasonal demand pattern, where the demand is a function of price and time was observed by Banarjee and Sharma (2010).

A mathematical model for a single-vendor single-buyer problem with vendor managed inventory (VMI) configuration was developed by Darwish and Goyal
Vendor-managed inventory scheme for supply chain coordination is proposed by Chakraborty et al. (2015), where the buyer imposes a penalty to the vendor when the shipment quantity exceeds an upper limit.

A two-level SC model with single-manufacturer and retailer, where the demand is price dependent was developed by Syam Sunder et al. (2012). They determined optimal replenishment quantity, inventory ratio and annual total variable cost with and without coordination. Uncertainty with demand and supply in a multi-echelon SC was studied by He and Zhao (2012). They proposed a policy by combining the returns policy by the retailer and the manufacturer and the wholesale price contract used by the raw material supplier and the manufacturer. In the recent past, Pezeshki et al. (2013) investigated the price and capacity-building decisions in a coordinated SC assuming linearly decreasing demand with respect to price at the retailer point. Two linear and non-linear regression models of a two-echelon inventory system were developed by Seifbarghy et al. (2013). The findings of the work indicated that the non-linear regression model outperforms the linear model. Kaur et al. (2013) discussed the optimal ordering policy for two warehouse inventory model. They developed the model for non-instantaneous deteriorating items without shortages under stock-dependent demand. The process of coordination mechanism in a two-level supply chain with a single manufacturer and a single retailer and single kind of product under stock-dependent demand rate and trade credit option is studied by Yang et al. (2014).

Decision models for order quantity and ordering cycle were presented by Wang (2008) under decentralized and centralized scenarios. In this paper, authors analyzed the impact of the SC coordination under stock-dependent demand rate. He assumed exponentially decaying deterioration rate, developed two profit models and observed superior results in centralized policy. Thangam and Kumar (2009) modelled a two-echelon SC for perishable items by considering the demand dependent on both selling price and credit period. They developed an EPQ based model and maximized by determining the optimal selling price, credit period and replenishment time. Two-warehouse inventory problem for deteriorating items having demand rate constant is investigated by Jaggi et al. (2013). Cao et al. (2015) investigated the coordination mechanism of a supply chain with a single-manufacturer and multi retailers under market demand and production cost disruptions.
Kumar et al. (2014) developed two-echelon inventory model with a manufacturer and a retailer under exponential price dependent demand. They solved the model for optimality of inventory level, number of shipments and the total variable costs of the individual entities and the total SC under the conditions of coordination and non-coordination. Jauhari et al. (2014) developed an integrated inventory model for single-vendor, single-buyer with deterministic demand. They considered defective items with uniformly distributed defective probability, unequal sized multiple shipments from vendor to buyer and incorporated carbon emission cost in the formulation of the model. Further, they observed reduction in carbon emission cost and total cost in un-equal shipment policy, when compared to equal-sized shipment policy. A two-echelon SC consisting of a single-manufacturer and a single-retailer under the condition of quadratic price dependent demand is modelled by Kumar et al (2014). Authors considered the carrying cost, ordering cost and the transportation cost for formulating the model and evaluated the optimality of inventory decisions. Joint two-echelon inventory model with non-linear price dependent demand is developed by Karuna Kumar et al. (2014). They demonstrated that the optimality of decision variables like replenishment quantities, shipment frequencies and total relevant costs of the SC.

A bi-level model for upper level and lower level of a closed-loop single period SC was presented by Rezapur et al. (2015). Authors assumed the SC operation in a price dependent demand competitive environment. Saha and Goyal (2015) proposed joint rebate contract, wholesale price discount contract and cost sharing contracts, for a two-echelon SC under stock and price induced demand. Nagaraju et al. (2015) considered ordering/setup costs, transportation costs and carrying costs in the development of a two-echelon integrated inventory model for determining optimal lot size and inventory decisions. They demonstrated the implications of a dependence factor on the optimality of inventory levels, number of shipments and total variable costs under the price dependent demand.

Jaber and Goyal (2008) investigated coordinating order quantities in case of a three-echelon SC comprising of multiple buyers, a manufacturer and multiple suppliers. Further, he suggested a mathematical model to achieve coordination in the SC under the assumption of common cycle time for all non-identical buyers. The model facilitated the consolidation of orders by the manufacturer and there by the suppliers, which yields the reduction in order processing costs of the members of the
chain. A three-echelon SC model was developed by Kim and Park (2008) for optimizing the coordination cost. They suggested a conceptual work to align the strategic issues and the structural issues related to SCM. Further, he disclosed the effect of E-business application on such an alignment. Abdelsalam and Ellassal (2014) addressed the joint economic lot sizing problem in a three-level SC with a single-supplier, single-manufacturer and multi retailers. They assumed that the demand is stochastic in nature.

Park et al (2010) modelled a single-sourcing network design problem in a three-echelon SC with risk-pooling and lead times. Reza Sarlak and Ali Nookabadi (2011) developed a mathematical model and discussed coordination issues of a distribution system consisting of a manufacturer, supplier, and several retailers. A three-echelon production inventory model comprising of multiple suppliers, a manufacturer and multiple non competing retailers was proposed by Pal et al (2012). Authors optimized the integrated profit of the SC through optimal ordering lot sizes. By trading off inventory cost and shortage cost, an expected average cost function of a three-echelon SC is formulated by Roy et al (2012) and determined optimal replenishment order when the demand is uncertain. Naini et al. (2012) considered a decentralized SC comprising of three echelons, which is associated with procurement, production and selling one type of product in separate and independent markets. They have determined inventing, manufacturing and pricing policies simultaneously. Liu et al. (2013) researched the impact of partial information sharing in a three-echelon SC. Further, they suggested to include promotion and price reduction of retailers into the demand process. Hlioui et al. (2015) proposed to jointly integrate and coordinate production, replenishment and quantity inspection decisions in a three-stage SC control problem under stochastic dynamic context.

Fu et al. (2014) applied model predictive control strategies for controlling inventory positions and bull whip effect in a four-echelon SC. Authors noticed lower impact of demand variability in the SC with model predictive control strategies, when compared to conventional ordering policies.

2.3 MOTIVATION FOR THE WORK
In light of the competition in business processes among SCs, instead of competition among different levels of the SC, the total relevant cost of the SC is to be reduced to the extent possible to enhance SC surplus. This signifies the coordination among the
various levels of SC in terms of sharing information pertaining to demand and various costs associated at each level.

Moreover, it is a fact that the inventory associated costs of each echelon are dependent on the price of the material at that echelon and the cumulative costs, which influence the final price of the item to the customer. Hence, the competitiveness of the SC depends significantly on the price and there by demand. At the same instant, firms have to concentrate on effective utilization of the working capital, which is the source to be invested for inventories. Hence, investigation on demand variations under various configurations of price variations is worthwhile in making strategic managerial decisions.

In addition, inventory happens to be vital driver of SC, due to the justification required to both efficiency and responsiveness of the SC. SC is normally driven by demand of the end product. Though, the demand is influenced by stock, time, price, promotion etc., price may have more governance on the sales volume and thereby influences the working capital management, as money gets tied up in the form of inventories. Further, in the prevailing stiff competition, retailer ‘unit selling price is influencing the demand and different products are facing different pattern of variations. Hence, investigation of inventory optimisation under different price dependent demand variations is the motive to this work.

2.4 IDENTIFICATION OF THE PROBLEM
The extent of the literature reviewed reveals the fact that much research is in place for coordinating the SC. Researchers addressed the improvement in the functioning of two-level supply chains under various parameters. They extensively developed various coordination mechanisms to generate SC surplus. Three-echelon supply chains are also receiving attention of researchers. Though much work is carried out under various patterns of demand variations, still there is large scope to investigate coordination under price dependent demand variation in multi-echelon supply chains. Keeping in view of this, the following research gaps have been identified to carry out the research.

- Mathematical models for two-level and three-level supply chains need to be more addressed with the consideration of different costs associated with the inventory management.
Much emphasis is required for effective inventory decisions in multi echelon inventory systems under price dependent demand variations.

Developing SC coordination mechanism through inventory optimization under price dependent demand variations.

2.5 OBJECTIVES OF RESEARCH WORK

In this context, the work presented in the thesis focuses on modelling and analysis of multi echelon inventory systems in SCM with the following objectives.

- To demonstrate the optimality of decision variables, i.e. replenishment quantities and shipment policies in a two-echelon and three-echelon inventory systems under price dependent demand variations.
- To determine the optimal values of total variable costs of respective entities and the SC under price dependent demand variations.
- To study the variation in the behavioural pattern of decision variables and total variable costs with respect to model parameters (Sensitivity Analysis) under price dependent demand variations.

In light of the above, an attempt is made to develop two-echelon and three-echelon inventory models for coordinated and non-coordinated SC for tactical level decision making purposes under price dependent demand variations. Modelling and analysis of two-echelon inventory systems is presented in the next chapter.