CHAPTER 2

LITERATURE REVIEW

An extensive review of significant researches on inventory control in supply chain management, along with a range of research methodologies employed for developing the successful framework for inventory control in SCM, is presented in this section. The reviewed inventory control models are classified and described in the following subsections.

2.1. REVIEW OF SIMULATION BASED INVENTORY CONTROL MODELS

Guaranteed delivery of high quality and low cost with minimal lead time is the main objective of the supply chain management to meet the customer demand. Having a vision on the entire supply chain of their own plans as well as those of their suppliers and customers helps the company to achieve the objective. On reviewing the benefits, functionalities and data requirement of the supply chain, Yoon Chang and Harris Makatsoris [10], suggested the modeling and supply chain simulation approach. By keenly considering the capacity and material information, it is possible to achieve the efficient supply chain management. The development of the simulation model for the supply chain management is inevitable in practical application of the concept.
The issues of supply chain management and the requirements for supply chain simulation modeling have been discussed.

There is a significant need to achieve a profound understanding of impact of decisions on the operations and the partners, when the supply chain performance target is set high by the manufacturer. The popular and appropriate mechanism for understanding supply chain dynamics is simulation. A simulation based framework for the development of adapted supply chain models from a library of software components has been developed by Jayashankar M. Swaminathan et al. [26]. The endorsement of modular construction and reuse of models for wide range of applications is influenced by the components capturing generic supply chain processes and concepts. The different entities in the supply chain operation focuses on own local constraints and objectives, and have different local views of the world are highlighted in this approach. Analyzing the performance from diverse organizational perspective is facilitated by multi-agent approach. For practical convenience, IBM practices separation of concepts from their framework for supply chain re-engineering efforts. This requires further investigation into several features of framework. (1) Development of features in messages related to cash flows to enable simulation of global environments including currency exchange rates; (2) development of processes to simulate
continuous manufacturing; and (3) incorporation of more adaptive agents that are capable of modifying their control policies during simulation based on evolving circumstances are their existing research directions.

A simple chain can exhibit the uniqueness of a chaotic system has been demonstrated by Richard D. Wilding [27]. Uncertainty experienced within the supply chain is mainly caused by the chaos generation. This is one among the number of sources of uncertainty which has to be recognized since this contributes a lot to the total dynamics experienced by the managers within the supply chain. The trade-off between the deterministic chaos, demand amplification and what are described as “Parallel Interactions” has been described by Wilding [28], which occurs between suppliers in the same tier in the supply chain. The total uncertainty experienced is generated by the combined effect of all the three. Even though in supply chains the involvement of deterministic chaos to uncertainty is small, in many other supply chains it takes a significant role to the total uncertainty experienced. For logisticians to master, quantitative techniques are going to gain much importance. A revolution had been created in many areas of science by the chaos theory. A greater understanding is gained and at the same time traditional view points have been challenged. It is undoubtedly believed
that a comparable response will be produced in the field of supply chain management by the application of chaos to the supply chain.

Nowadays, Information technology permits firms to share demand and inventory data swiftly and cheaply whereas in traditional supply chain management, only the orders are the firm’s information exchange. The value of allocating these data in a model with one supplier, N identical retailers, and stationary stochastic consumer demand is premeditated by Gerard P. Cachon and Marshall [29]. Inventory holding costs and back-order penalty costs was employed. The traditional information policy that does not use shared information and a full information policy that utilizes shared information are contrasted by them. As per the numerical analysis, they have found that the full information policy has the supply chain costs of 2.2% lower on average compared with the traditional information policy, the maximum difference between them was found to be 12.1%. Related to all sufficient policies, a simulation-based lower bound was developed by them. The value of information sharing is higher when compared with the difference in cost between traditional information policy and the lower bound. Faster and cheaper order processing are the two benefits of information technology which contains shorter lead times and small batch sizes are separated with the value of information sharing.
The manufacturers are allowed access to more accurate demand information, e.g. customer sales data, than before, by the information sharing practices such as vendor-managed inventory (VMI). Numerous studies have established the value of that type of information sharing. The inspection of how a manufacturer can combine traditional order data available from the non-VMI customers with sales data available from VMI customers in its production and inventory control and what impact that has on the manufacturer’s operational efficiency, was performed by Johanna Smaeros et al. [30] using the discrete-event simulation. They have examined how the manufacturer’s benefit, measured as reduced variability of its production load, increases as the number of VMI customers increases, through the simulation. The fact that even for products with stable demand a partial improvement of demand visibility can improve production and inventory control efficiency, but that the value of visibility, greatly depends on the target products’ replenishment frequencies and the production planning cycle employed by the manufacturer, was the discovery. The production planning and inventory control model used in the simulation provides a very simplified picture of reality even though it is somewhat more complex than earlier models. Forecasts need to be included in the model in order to deal with strong seasonality, product introductions, and promotions.
Supply chains find it difficult to achieve just-in-time inventory replenishment, thus resulting in losing sales opportunities or keeping excessive chain-wide inventories owing to the uncertainties inherent in customer demands. Two adaptive inventory-control models, a centralized model and a decentralized model were presented for a supply chain consisting of one supplier and multiple retailers by Kim et al. [31]. Satisfying a target service level predefined for each retailer was the aim of their two models. The inventory-control parameter of the supplier was safety lead time and that of retailers was safety stocks. In comparison with the most diversified inventory-control approaches, their two models did not necessitate modeling the uncertainty of customer demand as a statistical distribution, in which the control parameters are designed to adaptively change with changes in customer demand patterns, by using a reinforcement learning technique called action-value method.

A system dynamics-based methodological approach for mapping and analyzing multi-echelon food supply chains was presented by Patroklos Georgiadis et al. [32]. Their methodology linked single-echelon models as modules to construct supply chain models. The effective policies and optimal parameters for various strategic decision-making problems can be identified using the holistic model. The transportation
capacity planning process of a major Greek fast-food restaurant supply chain implemented their methodology. In addition, analyzing various scenarios (i.e. to conduct various “what-if” analyses) and answering questions about the long-term operation of supply chains using total supply chain profit as the measure of performance can be performed using their developed model. A wide range of food supply chains can employ the model by performing modifications. Hence it has proved that the policy-makers/regulators and decision-makers dealing with a wide spectrum of strategic food supply chain management issues have found their method to be useful.

A simulation-based optimization framework involving simultaneous perturbation stochastic approximation (SPSA) for optimally specifying parameters of internal model control (IMC) and model predictive control (MPC)-based decision policies for inventory management in supply chains under conditions involving supply and demand uncertainty, was presented by Jay D. Schwartz et al. [33]. The determination of controller tunings and operating targets that lead to optimal results from, either an operational or financial standpoint is permitted by the utilization of SPSA. The benefit in acting cautiously to forecasted information and gradually becoming more aggressive (with respect to feed-forward action) as more accurate demand forecasts
become available is illustrated through the results of their optimization on a single node example. The insights concerning the proper parameterization and tuning of the tactical MPC decision policy for their three echelon problem was provided by the use of their simulation-based optimization method. A function of the accuracy and magnitude of the demand forecast is to determine the amount of safety stock necessary for optimal profitability. The systematic and simultaneous determination of the financially optimal inventory targets and the move suppression values present in the MPC objective function is provided by the SPSA.

Basically, a firm can form strategic alliances with other companies to perform a particular task in a supply chain. Suppliers and retailers, or retailers among themselves can form alliances. A one-supplier two retailer supply chain, with unilateral transshipments between retailers was studied by Shuo Huang et al. [34].

The dynamic model used for the simple study about inventory cost, demonstrated its utility for studying the interdependences among different members of the same supply chain, and has been carried out by Francisco Campuzano Bolarín et al. [35]. In addition, at the tactical level of an organization or company, their model was found as a very useful tool. Their achieved tool, offers the essential parameters (auxiliary
variables) and elements (level variables and flow variables) for Demand Management, subsequent to validation of its performance. The model was capable of giving results which, once analyzed, ease the decision making process, by simple change in the values which define the parameters. The restriction in applying the results obtained to all cases is worth mentioning. The fact that it may generate different scenarios due to joint alteration of several parameters, in such a way that researchers may decide which case best adapts to the goals set. Their main focus is not about obtaining optimum results for the problem addressed. The utility of the simulation in carrying out management models, given the difficulties which some companies find to think “beyond factory gates” was illustrated by Holweg and Bicheno [36]. The effects which operational decision-making may have for an enterprise and its associates in the Supply Chain where the business process is developed, is better understood through their simulation model. System Dynamics employed allows an imperative influential component to be contributed to Supply Chain design methodology. The influence of key factors in Demand Management along each level is explained with the aid of construction and simulation of diverse supply chains.
2.2. REVIEW OF FORECASTING BASED INVENTORY CONTROL MODELS

The phenomenon known as the bullwhip effect was demonstrated to be partially appropriate to the effects of demand forecasting, by Frank Chen et al. [38]. Especially, they have shown that the variance of the orders placed by the retailer will be greater than the variance of demand if a retailer periodically updates the mean and variance of demand, based on observed customer demand data. More significantly, they have shown that this increase in variability can be drastically reduced by providing each stage of the supply chain with complete access to customer demand information. Nevertheless, the existence of bullwhip effect even when demand information is shared by all stages of the supply chain and all stages using the same forecasting technique and inventory policy, was illustrated. Their research without the several important limitations of their model and results being mentioned would be partial. The supposition that excess inventory is returned without cost is the chief disadvantage of their model. Nevertheless, the modest impact of their assumption on the increase in variability for all reasonable values of related parameters are demonstrated through the simulation results. The fact that they are not using the optimal order-up-to policy is a further limitation of their system. It is essential to indicate, nevertheless, that policies of their form are used in reality on a frequent basis. Besides,
the correlated demand process considered here does not employ the optimal forecasting technique. Nevertheless, the usage of moving average as one of the most commonly used forecasting techniques in practice is yet again indicated. In conclusion, it is evident that many of the complexities involved in real-world supply chains are not considered by their model.

Merrill Warkentin et al. [39] have filled the gap in their literature with the identification and analysis of the new informational flows that result in new types of relationships in the e-commerce market space. They focused on the role of information in the administration of supply chain relationships. It illustrates the diverse attributes of information including accuracy, timeliness and consistency besides examining the relative importance of these features in three e-commerce-enabled emerging supply chain relationships. These information flows might denote orders, invoices, request-for-quotes, demand forecasts, transfer of digital goods, re-compensation in the form of digital payments, or additional communication. Their spotlight is on every form of information flow, counting those taking place in completely new business forms and electronic marketplaces. They established, with the aid of three particular examples, as to how the introduction of web-based e-commerce technologies is changing the information flows amongst the
conventional players in the supply chain. Their analysis proposes that organizations which strategically comprehend and capitalize on the impact of these new information flows, will be presented with a position of competitive advantage in the emerging networked economy. Mass-customization websites like the ones offered by Dell.com are exposed to be mega-touch points that have a superior impact on a firm's bottom-line than conventional touch points. This reduces the number of touch points in a supply chain besides encouraging the adoption of standards for data representation. Both of these, consecutively lower the information inconsistencies and enhance the overall efficiency of the supply chain. Lastly, they have illustrated the rise of new marketplace models and the consequential new players and information flows. The theory of information quality dimensions of completeness, accuracy, currency, timeliness, precision, reliability, consistency, and relevance are implemented in these marketplace models. Five Forces Competitive Model is reevaluated considering the emerging supply chain environment. The omnipresence of web-based open protocol technologies acts as a motivation for new economic relationships and market opportunities for information utilization. These new information flows, if exploited in an appropriate manner, are capable of enabling new efficiencies in the management of the supply chain, proffering new opportunities to present greater value to the consumers by assisting in
the dynamic construction of value webs, and will have a positive effect on the economy as a whole.

A study was conducted to examine the impact of forecasting models on supply chain performance and the value of sharing information in a supply chain with one capacitated supplier and multiple retailers under demand uncertainty, by Xiande Zhao et al. [40]. They made some important findings through broad simulation experiments based on analysis of the simulation outputs. The performance of the supply chain is radically influenced by information sharing. In comparison with the sharing of only future demand information, sharing future order information with the supplier is further advantageous. Under most conditions, total cost savings for the complete supply chain are significant. The demand pattern, the forecasting model employed and capacity tightness drastically influence the value of information sharing. Generally, the value of information sharing increases with increase in accuracy of the forecast model. Under different conditions, different parties in the supply chain are benefited differently. In general, the supplier can share information under all conditions to significantly improve its total costs and service level. Nevertheless, when they share information with the supplier under some demand conditions when capacity tightness is low, there is a
possibility that the total costs and service level for retailers may still get poorer. No information, demand or order information, the three kinds of information to be shared between the supplier and the retailers are investigated in their study. Additional types of information (for example, inventory levels, capacity, planned production, etc.) can be shared as well. The impact of forecasting models and information sharing on the cost savings that can be achieved by the supplier and retailers in their production inventory systems was the objective of their study. The actual costs of sharing the information were not included and the impact of sharing information on revenue was not taken into account.

The finding that diverse coordination modes are essential to coordinate interdependent activities, guarantee visibility to equalize supply and demand, align actions and decision with the chain profitability, and acquire new capabilities from joint efforts have been presented by Togar M. Simatupang et al. [41]. On basis of the dimensions of the mutuality and the focus of coordination, four modes of coordination have been recognized: logistics synchronization, information sharing, incentive alignment, and collective learning. The four coordination modes are concurrently essential for assisting participants to advance supply chain profitability. Equipped with their concept, all players will be well aware of where there is a need for matching
processes, information, incentives and capabilities, in order that they can execute their value added tasks in support of the larger vision. The conceptual framework of the knowledge of coordination has been provided to aid the practitioners and scholars to comprehend the interplay amidst key drivers of coordination modes that have considerable impact on supply chain performance. The knowledge of coordination is beneficial for creating an ensemble of people to inquire into the key drivers of coordination modes, recognize obstacles and involve in joint problem solving.

Robert Handfield et al. [42] have studied the progress of a convertible fabric material in the supply chain for a huge automotive assembler, commencing with a large textile manufacturer in fabric formation to final assembly of the convertible top. The contemporary level of information sharing in the supply chain was analyzed and the impacts of inefficient information flows amidst the diverse tiers of suppliers were determined. There are a number of essential requirements to move forward and realize the suggested enhancements in the automotive supply chain. Their first step is a superior means to share and receive information. Presently, information is shared from time to time, the span ranging from weekly to monthly. This sort of incoherent information sharing intensifies the bullwhip effect in the supply chain. Through deep
incursion into the supply base, variability and uncertainty can be reduced significantly by eliminating demand hedging activities and delays in information transfer between different tiers of suppliers. By the elimination of demand hedging activities and delays in information transfer amidst diverse tiers of suppliers, the system as well permits assemblers to be in command of the type of information that is shared and diminishes the likelihood of data entry errors.

Jennifer Blackhurst et al. [43] have stated that two Vendor Managed Inventory (VMI) initiatives have not yet generated the degree of performance preferred by the supply chain partners involved. The yield of their research effort is intrinsic in the operations audit process utilized, the VMI initiative gaps exposed through the process, apart from steps that could be embarked to minimize or eliminate these gaps. On the whole, their paper illustrated the operations audit in terms of an iterative, collaboration evaluation process. The framework and process are proposed to provide assistance as an important mechanism for perceiving the evolution towards joint supply chain relationships. However they will necessitate extra research efforts to refine the operations audit process and framework. In addition, studies that investigated collaborative initiatives like VMI through longitudinal studies would be predominantly beneficial as successful collaborations
like Proctor and Gamble and Wal-Mart have been developed over time. Their research has testified on gaps among the expected and the actual results and characteristics of the VMI initiatives. Their discovery, also, would help future research efforts in this direction. Possibly future studies could foster the research efforts that are paying attention on gaps amid expectations/perceptions (Parasuraman et al., [44]) with an intention of analyzing the gaps over time.

An analytical model was developed by Xiande Zhao et al. [45] to reckon the effect of early order commitment (EOC) on the performance of a two-level supply chain consisting of a manufacturer and a retailer with an Auto Regressive AR (1) demand process, i.e., the demand in period t is

\[ D_t = d + \rho D_{t-1} + \varepsilon_t, \]

where \( d > 0, \, -1 < \rho < 1, \) and \( \varepsilon_t \) is usually independent identically distributed with mean zero and variance \( \sigma^2. \) By adapting EOC as indicated by the model reduces costs for the manufacturer, but increases costs for the retailer under their assumptions. To determine whether EOC can reduce the total supply chain cost in a given operational environment, they have developed a decision rule. The rule suggests that the vendor should commit orders \( L + 1 \) period in advance to exploit the supply chain savings whenever EOC is favorable. The efficiency of EOC depends on certain key factors in the operational environment, is suggested by their analysis. In particular, their results
specify that the supply chain would experience better savings from EOC when – (a) the inventory item receives less value-added activities at the retailer site; (b) the manufacturing lead time is short; (c) demand correlation over time is constructive but weak; or (d) the delivery lead time is long (if a condition exists). Though demand deviation affects the absolute costs for all members in the supply chain, it does not affect the relative percentage cost savings due to the use of EOC. Based on the quantifiable costs and savings recognized by the model, they formulated a repayment scheme for the manufacturer to share the cost savings with the retailer in substitute for contribution in EOC. The repayment is a side payment that depends on the length of EOC but not the order quantity or unit price. Also they have conversed as to how to put into action the rebate under full information sharing versus information shortage or asymmetry.

The important problem of finding computationally efficient and probably good inventory control policies for stochastic inventory control models in the presence of correlated and non-stationary (time-dependent) stochastic demands was addressed by Retsef Levi et al [46]. A marginal cost accounting scheme for stochastic inventory control models combined with cost-balancing techniques served as the basis for their approach. In particular, the expected cost of over ordering (i.e., costs
incurred by excess inventory) was balanced against the expected cost of under ordering (i.e., costs incurred by not satisfying demand on time), in each period. Especially, a worst-case guarantee of 2 for the periodic-review stochastic inventory control problem and a worst-case guarantee of 3 for the stochastic lot-sizing problem were presented. They verified that all the currently known approaches in the literature that model correlation and non-stationarity of demands over time found the results to be valid.

A typical manufacturing or distribution supply chain scenario consisting of stores, distribution centers and manufacturing facilities was studied by Mustafa Rawata and Tayfur Altıokb [47]. Different safety stock and periodic-review inventory control policies and their implications on supply chain performance was the spotlight of the authors. A simulation model was developed to analyze their supply chain network, which consists of three stores, two distribution centers and three manufacturing plants, handling three different product types, by using the Arena simulation tool. The stores and the distribution centers implemented different inventory control policies. Three policies of inventory control, 1) Fixed Safety Stock approach 2) Dynamic Safety Stock approach and 3) $(r, R)$ continuous review inventory policy is considered in a production/inventory environment consisting of a
production facility and a finished product warehouse for one type of product. The inventory policy indicates that production starts when the stock on-hand reaches \( r \) and continues until the stock level reaches \( R \). A comparison was made on \((r, R)\) policy with their performances in customer service level and the average inventory on hand.

The supply chain uncertainty was examined from a transport perspective by Vasco Sanchez Rodrigues et al. [48]. It is intended as a conceptual paper in which definitions and classifications of different types of uncertainty were developed. Hence, a wide and diverse literature on uncertainty in supply chains with many causes of uncertainty that affects transport being derived from this was created. No attempt was made to codify this in a systematic manner or to explicitly examine transport uncertainty within the context of supply chain uncertainty by the previous literature. The organizations may develop a supply chain strategy Vis-à-Vis their uncertainties by using their developed model as a template. Organizations may determine where the greatest uncertainties lie and hence develop a prioritized plan for supply chain re-engineering by initially targeting those uncertainties that result in the greatest risks to the successful operation of the supply chain, on the basis of the classification of uncertainty into the five types described. The determination of the extent to which the uncertainties can be tackled
by a single organization alone or in collaboration with other partners in the supply chain, the wider industry and government, was made by the model. The outcome of the model suggests that even as many of the causes of uncertainty and their impacts can be linked primarily to one particular member of the logistics triad. In other cases the triad member responsible for planning, organizing, procuring and managing the freight transport operation is relied upon to locate the uncertainty, is an essential one.

Physical store retailers are encountering worst of the situations. In order to deal with this rough situation, it is not only necessary for them to reduce the cost by effectively executing SCM but as well essential to initiate measures to increase profit through CRM. They are efficient by themselves. However it is possible for the retailers to have the maximum benefit once these practices are combined. Nonetheless, there exists no good application that recognizes both the business practices together. In their study, supposing that RFID system captures consumer behavior information on the sales floor, Tatsuya Inaba [49] have projected an application, where in discount prices are provided to FSP member customers on basis of their loyalty level and the discount prices are figured out to attain a target inventory turnover rate. They have as well assumed that RFID system is accessible by physical store retailers
and proposed an application to attain inventory management control, besides rewarding FSP customers in accordance with their loyalty status. In order to comprehend their application they put forth two algorithms that successfully manage an inventory turnover rate besides rewarding the FSP customers. They constructed a prototype system of the application for a proof of concept and executed a numerical study to illustrate the validity of their algorithms.

2.3. REVIEW OF BASE-STOCK BASED INVENTORY CONTROL MODELS

An attempt was made to optimize the inventory (i.e. base-stock) levels of a single product at different members in a serial supply chain with the objective of minimizing the Total Supply Chain Cost (TSCC), by Sudhir Ryan Daniel and Chandrasekharan Rajendran [11]. The performance measure considered, which is a good representation of the system-wide total cost is the TSCC. In order to optimize the base-stock levels, a genetic algorithm (GA) has been proposed. To analyze the performance of the supply chain (operating with deterministic and stochastic replenishment lead times) for the base-stock levels that are generated by the proposed GA and other solution procedures considered in this study, different supply chain settings are simulated. They demonstrated that their proposed GA required significantly less
computing effort to perform very well in terms of yielding solutions that are not significantly different from the optimal solutions (obtained through complete enumeration of solution space).

The inventory control problem for a single class assembly network which operates under a modified echelon base-stock policy was studied by Vecchio and Paschalidis [50]. An approach to find close-to-optimal echelon stock levels that minimize inventory costs while guaranteeing stockout probabilities to stay below some predefined levels was developed by them. They reduced the safety stock selection to a deterministic nonlinear optimization problem on the basis of the large deviations techniques. In addition, they analyzed as to how a supplier can interact with a buyer to reach a mutually beneficial mode of operations, using their inventory control approach. Their interaction takes the form of a supply contract by which explicit QoS guarantees is enforced. The applications in a distributed fashion with neither the supplier nor the buyer revealing their corresponding cost structures applying the joint optimization algorithm was proposed by the authors.

A model of supply chain consisting of n production facilities in tandem and producing a single product class was considered by Ioannis CH. Paschalidis et al. [51]. The finished goods inventory maintained in
front of the most downstream facility is used to meet the external demand while backlogging of unsatisfied demand was performed. The facility at stage 1 produced if inventory has fallen below a certain level \( w_i \) and idles otherwise on the basis of a base-stock production policy adopted at each stage of the supply chain. In order to minimize expected inventory costs at all stages subject to maintaining the stock out probability at stage 1 below a prescribed level, they necessitated the optimization of the hedging vector \( W = (w_1, ..., w_n) \). They made assumptions on demand and production processes that included auto correlated stochastic processes, which were relatively general modeling. They have combined analytical (Large derivations) and sample path based (perturbation analysis) techniques to solve the stochastic optimization problem. The existence of a natural synergy between those two approaches has been demonstrated.

### 2.4. REVIEW OF OPTIMIZATION BASED INVENTORY CONTROL MODELS

Sukran Kadipasaoglu et al. [9] provided a study on the market characteristics and competitive priorities, manufacturing environment, logistics and distribution activities, and supply chain planning and control activities for polymer manufacturers. They have described
polymer distribution network optimization, production/distribution planning, production scheduling, demand management, available-to-promise, and inventory planning activities pertaining to supply chain planning and control. Besides, they illustrated the applications existing in a commercial DSS that support these activities. They have as well described about diverse issues that continue to confront supply chain managers in polymer manufacturing. It encompasses forecasting for the huge number of product–customer combinations, identification of safety stock requirements, administering production schedule changes, business process management throughout DSS implementation and data mapping for decision support. Their research contributes to the supply chain literature by proffering a suitable context for investigating supply chain-related issues. Through discussion and characterization of the polymer supply chain, they recognized the specific issues of concern to potential researchers and to supply chain professionals.

The effect of product variety on supply-chain performance, which is measured in terms of expected lead time and expected cost at the retailers, was analyzed by Ulrich W. Thonemann and James R. Bradley [52]. They took a supply chain with a single manufacturer and multiple retailers into account. If setup times are significant, the effect of product variety on cost where the cost increases proportionally to the square root
of product variety is substantially greater than that suggested by the risk-pooling literature for perfectly flexible manufacturing processes. An illustration that underestimating the cost of product variety, leads companies to offer product variety that is greater than optimal was made as well. In conclusion, they illustrated that by reducing the setup time, the unit manufacturing time, the number of retailers, or the demand rate the supply-chain performance can be managed. The fact that complex mathematical approaches are often not applied in practice was recognized by the authors. Nevertheless, practitioners who used the simple models to estimate the effect of their decisions often appreciated these models.

A decision support system DESSCOM (Decision Support for Supply Chains through Object Modeling) which enables strategic, tactical, and operational decision making in supply chains was presented by Shantanu Biswas and Y.Narahari [53]. (1) DESSCOM-MODEL, a modeling infrastructure comprising a library of carefully designed generic objects for modeling supply chain elements and dynamic interactions among these elements, and (2) DESSCOM-WORKBENCH, a decision workbench that can potentially include powerful algorithmic and simulation-based solution methods for supply chain decision-making are the two chief components of DESSCOM. It is possible to rapidly create
faithful models of any given supply chain at any desired level of abstraction, by the use of DESSCOM-MODEL. For a supply chain decision problem to be solved, problem formulations that can then be solved using an appropriate strategy from DESSCOM-WORKBENCH can be obtained by the transformation of the object oriented models created at the right level of detail. A prototype of DESSCOM was devised and implemented. In order to demonstrate the use of DESSCOM to model supply chains and enable decision-making at various levels, they provided a real-world case study of a liquid petroleum gas supply chain.

The development of a supply chain coordination strategy is greatly influenced by pricing policy of an enterprise. The pricing discount policy coordinates the joint decision policy characterized by the selling price, order quantity and replenishment schedule. An optimum replenishment and pricing policy for maximizing the supplier, manufacturer and retailer’s shared profit in a price-sensitive demand with reciprocal collaboration, was developed by Shen-Lian Chung and Hui-Ming Wee [54]. A mathematical supply chain inventory model that concurrently decides the discount price, the number of deliveries and the ordering cycle time with linearly declining price dependent demand under different profit-sharing ratios was developed from their study. They derived the optimum solution of the system by applying the
mathematical model through a software. An extra profit of about 27.93% was achieved through the numerical example. When the negotiation factors decrease, there is an increase in optimal joint profit and the retailer’s extra profit, while there is a decrease in the extra profit of the manufacturer and the supplier, which is the extra profit accrued mainly to the retailer. Therefore, cooperative strategies with profit sharing must be implemented to obtain the greatest benefits for all of the players.

Péter Mileff and Károly Nehéz [55] have studied the problem in case of the collaborative relation of one supplier and one customer in accordance with the claim of a Hungarian mass-production company. Enhancing the renowned models from their literature, they optimized the cost function of the supplier into a function of the parameters, which does not eradicate the possibility of backorder and is appropriate for a discretionary time horizon. They extended the problem of a one-week production cycle to become the production of optional, n number of jointly produced weeks possible. Considering the problem to be a non-linear optimization one, they calculated the optimal inventory level. With the aid of a heuristic method in addition to the optimal inventory level, it is possible to accurately define the minimal number of jointly produced weeks required. The competence of their method was illustrated by genetic algorithm and constraint programming. The simulation results
have distinctively demonstrated that calculation time of their method is little; thus it is appropriate for fast testing of diverse policies and decision alternatives. The model thus built, offers a proper solution to deal with the product run-out problems, arising out of the seasonality of real demand, as well. They intend to extend the developed model to be appropriate for multi-product problems encompassing natural capacity constraints.

Peter Mileff and Karoly Nehez [56] have studied the problem of the collaborative relation of one supplier and one customer. Enhancing the renowned models from their literature, they optimized the cost function of the supplier into a function of the parameters, which does not eradicate the possibility of backorder. Considering the problem to be a non-linear optimization one, they calculated the optimal inventory level. In order to apply the accurate inventory policy they proposed and defined the critical quantity of the inventory. They verified the precision of the model with a 52 weeks simulation so as to control the results. In association with their simulation they projected that the model by changing the parameters can be made appropriate for achieving an optional low value of the stock correspondingly for transient observation of the varying inventory level. The model executes quickly on the simulator, thus appropriate for fast testing of a variety of policies and
decision alternatives. Further they intend to expand the decision work to more number of periods with the intention of regular investigation of several weeks, identifying all those week-pairs, where the aggregated production cost is lesser than that of individual production cost. Therefore the total cost of the production comes down with aid of the received week-pairs. They intend to create a game theory model for the problem, in which the simulation results would have compared the obtained effects. Besides they as well plan to incorporate the forecast information of the expected demand into the model, in addition to the examination of how historical data and uncertain forecast controls the inventory level.

Robust and computationally good algorithms for SC coordination and planning have been presented by Osman Murat Anlı et al. [57]. It is accomplished by incorporating non-linear lead time performance and probabilistic quality of service requirements in order to lessen SC cost. The most significant contribution of their research is the proposal and accomplishment of a practical, efficient, tractable, and robust algorithm that is capable of achieving these cost savings. It has been proved that by doing so, planning on constant lead times is not a necessary evil imposed by the presumption of insurmountable computational complexity.
Indeed, they have revealed their assumption to be incorrect and proved that industry does not have to live any longer with the unwanted consequences of the constant lead-time assumption impeding today’s production planning practice. In addition, their results influence the value of research in stochastic systems and in particular queuing network models of production systems together with analytical probabilistic approaches and Monte Carlo simulation approaches that have fascinated and continue to be a magnet for a significant portion of the research community. Their own enduring research has given importance on improving QoS Layer algorithms and enhancing fluid Monte Carlo simulation models applicable to multi echelon production systems. As a final point, they desire to emphasize that the inclusion of production system stochastic dynamics in SC coordination and production planning is mainly desirable in the outlook of the emerging sensor network and related technologies such as RFIDs. The value of these technologies’ capable of supplying reliable, affordable and timely information regarding production conditions, transportation, receiving, warehousing and retail activities, will be undoubtedly enhanced if this information is translated to significant efficiency gains in SC management.
The results on the gains of integrating pricing and inventory control for the case when inventory can be set and demand is stochastic was studied by Lisa Giml-Heersink et al. [58]. They investigated if the utilization of a reference price model to illustrate demand, augments the benefits of integration with a logistic model. They have as well studied if the base-stock list-price policy still holds for such a setting and deduced the size of potential benefits through numerical simulation. They observed that the advantages amplify remarkably when reference effects are integrated, i.e. they were capable of attaining, even with a constant standard deviation, at least 10 times the benefit attained by the joint model sans a reference price. It was as well observed that the base-stock policy holds for the reference price model. Nevertheless, excluding the two-period case with linear demand, it has not yet been possible to prove their result; however their conclusions are justifiable on extensive numerical simulations. Further, they added details to existing literature by investigating the single-period joint pricing/inventory control with backlogging and by broadening the steady-state reference price proof from Popescu and Wu [59] to the case of positive ordering cost. In addition they provide a steady-state price and inventory for the joint inventory and pricing models comprising and devoid of reference effects. Evidently, they are only at the start of comprehending combined reference price/inventory models; a common evidence of the base-stock
policy for linear demand is essential; moreover, the reliance of inventory after regulation and price on the state variables should be studied.

2.5. REVIEW OF OTHER RESEARCHES ON INVENTORY CONTROL MODELS

The significance of well-built linkages between the buyer and supplier has been expressed alike by the practitioners and researchers. For replacing the conventional adversarial roles between buyers and suppliers with mutual cooperation, management experts were called. On the other hand, customer order reservation is a common and vital practice in the business world. It has been investigated by Hiroshi Ohta and Takayuki Furutani [61] about the effect on (s, S) inventory policies for the supplier and the buyer in the supply chain system from customer order cancellations. The discount wholesale price of the supplier against the buyer has to be identified in order to encourage the buyer to cooperate, because the predictable profit of the buyer under the cooperative policy that boosts up the total expected profits of the whole system is below the independent policy.

The complexity of supply-side externalities existing among downstream retailers on supply chain performance is examined by Serguei Netessine and Fuqiang Zhang [62]. Specifically, multiple retail
firms face stochastic demand; they buy the product from the upstream wholesaler, and make stocking resolution that have an effect on all other retailers in the equal stratum. The major two sources of inefficiencies present in such a supply chain is one due to double-marginalization and the other due to externalities among retailers. At the same time as double-marginalization leads to inventory under stocking at the retail echelon, they have determined that the implications of externalities are more difficult, since different externalities can progress or decline supply chain performance (relative to the situation without externalities). They have revealed that the cause of externalities depends critically on whether the stocking evaluation of retailers shows optimistic (complimentarily) or pessimistic (substitutability) externalities and whether retailers are supervised centrally or competitively. Challenging retailers prone to under stock the product below the complementarity (evaluated to the centralized inventory management at the retail level); thus, annoying the double-marginalization effect. Supply chain coordination between retailers and the wholesaler is highly essential when there is downstream competition that shows evidence of complementarity as the fact which was finalized by them. What has been thought from the wholesaler’s point of view is, competition among retailers is preferable over centralization of retailers when externalities are downbeat and vice versa when externalities are upbeat. Besides, with
competition on complements, both retailers and the wholesaler have incentives to organize the supply chain.

Jia-Yen Huang’s [63] study aims at resolving the mathematical model proposed in Yang and Wee’s [64] research. Optimally coordinating the inventory for a weakening item among all the partners in a supply chain system with a single vendor and multiple buyers so as to reduce the average total costs is their major focus. He discovered the optimality structure and derives several fascinating properties of the most favorable objective value curve in order to resolve the problem. He suggests a search algorithm that can efficiently solve the best suited solution by making use of the theoretical aspects. He has shown that his algorithm outperforms Yang and Wee’s [64] solution approach in the journals based on his numerical experiments.

An inventory model was developed for a pre-positioned warehouse responding to a complex humanitarian emergency, which is one of the three emergency classifications to which humanitarian and non-governmental agencies respond (rapid onset and slow onset are the other two) by Benita M. Beamon and Stephen A. Kotleba [65]. The unpredictable demand patterns and long durations of complex humanitarian emergencies make them unique. A heavy emphasis is
played on quick logistics response by the high (often life-threatening) stakes of humanitarian relief. The efficiency and effectiveness of the humanitarian logistics operations (including warehousing in a complex emergency) are very important. They opted for their host organization, World Vision International to perform their field research. The response to the complex humanitarian emergency in south Sudan by the warehouse operations in Lockichoggio, Kenya prompted the data collection from this warehouse. They developed a mathematical model that optimized the reorder quantity and reorder level based on reordering, holding and back-order costs, on the basis of their recorded data. In the direction of developing strategic inventory management systems for humanitarian relief, their research is the initial step. The model assumed a continuous demand approximation, investigated a single “item” (which may be interpreted as a single type of relief kit or a single set of items) and developed order quantities that were independent of vehicle or container sizes.

For addressing the preliminary research problem of how to develop an effective material delivery model for construction of projects with near-term task level scheduling, a solution containing two features has been explained by Timo Ala-Risku and Mikko Karkkainen [66]. There are two necessities for their approach: one is material deliveries and the
other one is transparency of material availability and short response times in the supply chain. For supervising the material logistics of construction projects they have projected a possible solution. A shipment tracking-based approach has been proposed by the empirically validated solution to offer inventory transparency, and a pro-active delivery approach for well-organized material deliveries: transparency of material availability and short response times in the supply chain. Their result consists of tracking-based approach for developing inventory transparency for short-term supply chains as well as pro-active material delivery model for the materials for particular project tasks. While using the Last Planner approach in production control both of these elements are central. The offered tracking-based approach for resolving the complexity of the site and intermediate inventory management and transparency can be considered to be a valuable addition to the current body of literature. Since it is tough and often infeasible to launch conventional inventory management systems to impermanent storage locations used all through the projects, its practical relevance is emphasized in project-oriented industries.

Abdelmaguid and Dessouky [67] built-up a genetic algorithm (GA) approaches to work out the integrated inventory distribution problem. It has been denoted in the form of a 2-dimensional matrix a proper
genetic representation that paid attention on the delivery schedule. A randomized version of a formerly constructed construction heuristic is used in the GA construction phase. Two random neighborhood search mechanisms, the crossover and mutation operations, developing the suitable designs are used in the GA improvement phase. Building a suitable mechanism that permits for deliveries to customers that envelop part of their insisted necessities, which is referred to as partial deliveries is the major concern in designing the mutation operator. Partial deliveries can impart savings in transportation and shortage costs, and therefore has potential to offer improved solutions. The importance of the developed GA approach has been revealed from their results. On average, GA outperforms the formerly built-up construction algorithm and produces solutions that are within 20% from the best possible solution.

A single product, two-stage supply chain inventory model with the upstream warehouse W and the downstream retailer R which is notified periodically have been undertaken by Sangheon Han and Hirotaka Matsumoto [68]. They have exposed that the most favorable replenishment policy for R was a myopic solution which depended only on the primary supply chain inventory level under certain conditions. Moreover, they have made clear that the best possible policy at W is a base-stock policy where the optimal base-stock-level depends on the
initial supply chain inventory level. To achieve insight into the problem, numerical examples were presented. In addition, they highlighted the case where it is essential to organize inventory and transportation together. It may be reasonable to grip small replacement until a consolidated quantity gathered, if there are a fixed cost, positive lead-time, and finite capacity to replenish, even supposing it must be paid shortage costs. That is, it is an essential issue to stabilize the trade-off between scale economies linked with transportation and customer waiting.

The inventory management and the responsibility it plays in cultivating customer satisfaction have been studied by Scott Grant Eckert [69]. It looks at how food companies have been stressed to restructure their inventory systems, and the extent of such measures. How many retailers are demanding to implement a “perfect order” system and how suppliers are persistently harassed to meet the demands of these retailers has also been scrutinized. The bond between effective inventory management and customer satisfaction with the goal of having absolute orders and on time deliveries has been inspected by his studies. The idea of the research is to discover the ways of refining inventory management, through the means of rising customer satisfaction. To end with, it is worth stating that all the small business is chosen to maintain
the inventory management system as they saw how it enhanced their customer service. For that reason it is clear why several food companies are adapting similar systems.

The inventory model for fresh goods in a supply chain enclosing a single supplier and multiple challenging retailers has been offered by Quanwu Zhao and Jiaqin Yang [70] which has exogenous market price and stochastic market demand. As a result of the supplier approving a buy-back contract policy, the inventory competition among retailers can be illustrated as a multi-person game with distinctive, stable solutions which is their recommended proposed model. When the traditional single wholesale price contract system is contrasted with the above model, it exhibits that in terms of enterprise management of a retail supply chain, the enterprise (i.e., the supplier) can use the buy-back contract to synchronize the whole chain and allocate the estimated profit between the supplier and retailers in a encoded manner – a ‘win-win’ solution.

Influence of safety parameters for inventory control method on bullwhip effects has been studied for supply chain planning for multiple companies under demand uncertainty, by Haruhiko Tominaga et al. [71]. In order to represent actual planning environments where demand variances in the future periods are steadily available with regards to the
progress of time steps, they developed the production planning model for multiple companies under uncertain demand situation. The bullwhip effect caused by the inventory control method taking into consideration the safety stock was investigated. The numerical simulations were employed to examine the relationship between the total profit and bullwhip effects.

A model which considers a dynamic production environment as a NP-hard problem, using genetic algorithm, was developed to minimize the average total cost to determine the production cycles under various ordering policies, by Chih-Yao Lo [72] in their research. A numerical study was conducted to compare the ordering policies under various demands in an extensive manner in order to evaluate the performance of their approach. The number of production cycles could be optimized to generate a (R, Q) fixed replenishment point/fixed replenishment quantity inventory policy as well as an aggregative production plan could be generated to minimize the total inventory cost, both based on the reproduction interval searching in a given time horizon. A comprehensive decision support to management was provided by the available result which was at least a local optimum.
2.6 SCOPE AND MOTIVATION

A key concern for global manufacturers today is reducing inventory and inventory driven cost across their supply and distribution networks. Pressure to cut inventories continues as manufacturers no longer manage linear or stable supply chains. Also globalization of the supply chain and supply base drive higher inventories and make inventory reduction more difficult. The drive to innovate and increase the rate of new product introductions leads to high rates of new technologies adoption for next generations products, putting enormous pressure on inventory management across extended supply chains. In this context, manufacturers have difficulty reducing inventory with traditional or even advanced inventory management techniques. Today’s global manufacturers have largely hit limitations in leveraging material requirements planning and management processes and systems to cut inventories. Even advanced inventory management techniques such as sales and operations planning or developing demand-pull replenishment systems with suppliers using kanbans, have been either embraced or found to deliver less impact on overall inventory reduction than anticipated. In the last few years new paradigm has emerged: where one finds operations teams and planning teams of the manufacturers applying the latest techniques and technologies to counter supply chain
uncertainties, to improve inventory visibility, control and management across the extended supply network [88].

Inventory optimizations can help manufactures control inventory driven costs and address today's demand volatility and supply chain complexity. The key to success in Supply Chain Management (SCM) require heavy emphasis on integration of activities, cooperation, coordination and information sharing throughout the entire supply chain, from suppliers to customers. To be able to respond to the challenge of integration there is the need for sophisticated decision support systems (DSS) based on powerful mathematical models and solution techniques, together with the advances in information and communication technologies. There is no doubt about the importance of quantitative models and computer based tools for decision making in today's business environment. This is especially true in the rapidly growing area of supply chain management.

The rigid raise in customer service levels of late has made the efficient organization of the supply chain inevitable [77]. The excess or shortage of inventories persuaded the supply chain cost massively. Hence, the inventory optimization in supply chain management has emerged as one of the most recent issues.
The inventory and supply chain managers are mainly concerned about the estimation of the exact amount of inventory at each point in the supply chain free of excesses and shortages although the total supply chain cost is minimized. Owing to the fact that shortage of inventory yields to lost sales, whereas excess of inventory may result in pointless storage costs, the precise estimation of optimal inventory is indispensable. In other words, there is a cost involved in manufacturing any product in the factory as well as in holding any product in the distribution center and agent shop. More the products manufactured or held, higher will be the holding cost. Along with this, high lead time results in holding of the excess stock levels and hence the increase in the holding cost. Meanwhile, there is possibility for the shortage of products. For the shortage of each product there will be a shortage cost. Holding excess stock levels as well as the occurrence of shortage for products lead to the increase in the supply chain cost. The factory may manufacture any number of products, each supply chain member may consume a few or all the products and each product is manufactured using a number of raw materials sourced from many suppliers. All these factors pose additional challenge in extracting the exact product and the stock levels that influence the supply chain cost heavily.
Many well-known algorithmic advances in optimization have been made, but it turns out that most have not had the expected impact on the decisions for designing and optimizing supply chain related problems. For example, some optimization techniques are of little use because they are not well suited to solve complex real logistics problems in the short time needed to make decisions. Also some techniques are highly problem-dependent and need high expertise. This adds difficulties in the implementations of the decision support systems which contradicts the tendency to fast implementation in a rapidly changing world. IO techniques need to determine a globally optimal placement of inventory, considering its cost at each stage in the supply chain and all the service level targets and replenishment lead times that constraint each inventory location.

The importance of the inventory management and the relationship between inventory and customer service is essential in any company. However, the use of inventory systems in helping decision-making process has been less widespread. Most of the models well known in the literature are simple and, for example, do not consider multi product inventory management that require the same resources, or in some case do not treat all the complexities involved in inventory management as the
demand uncertainty. Also, so far the most well known inventory models and systems consider a single facility managing its inventories in order to minimize its own costs. There is only a restricted body of research in supply chain management, specifically in the area of inventory control. By review of Literature, it is evident that many of the complexities involved in real-world supply chains including the context of supply chain uncertainty in terms of demand, lead time and the associated bullwhip effect embracing the entire supply chain in general and identification and elimination of shortage as well as excess inventory simultaneously for fast implementation among the various players of a supply chain are not considered comprehensively by the previous literature and there is ample scope to minimize or eliminate the research gap identified in this direction.

Also, one important challenge in SCM is the integration and coordination of all activities in the supply chain, in particular an important issue is managing inventory in the whole supply chain minimizing the system wide cost. This requires models and DSS that are able to help decisions and suggest policies for the inventory management in the whole supply chain. To solve such a complex issue, the design of DSS which combine simulation and meta heuristics techniques, to enable the organization to provide an effective response to all
complexities involved in inventory management along the supply chain, is solicited.

2.7 THE NEED FOR THE PRESENT RESEARCH

During the last decade, manufacturing enterprises have been under pressure to competently cope with a market that is rapidly changing due to global competition, shorter product life cycles, dynamic changes of demand patterns, product varieties and environmental standards [73]. Competitiveness in today’s marketplace depends heavily on the ability of a company to handle the challenges of reducing lead-times and costs, increasing customer service levels, and improving product quality [83]. All these factors have driven business organizations to concentrate on their supply chains. Supply chain management (SCM) is seen as a mechanism that will allow companies to respond to these environmental changes and has become one of the top priorities on the strategic agenda of industrial and service businesses [73]. Supply chain management is the effective coordination and integration of different organizations with different objectives towards a common goal [83].

The challenges in supply chain management are shorter product lifecycles which involve higher demand uncertainty and acting on global markets, the supply chain complexity is further increased. Supply chain problems are often very large and complex owing to the interactions
between the entities, the length of the supply chain, the lead times of manufacturing and shipping, the complexities of modeling the individual entities, the stochastic nature of the demands, etc [83, 80]. The supply chain management has addressed the research with operational perspective in terms of four problem areas, namely inventory management and control; production planning and scheduling; information sharing, coordination, monitoring; and operation tools [81]. The task of managing volatile demand can be a major challenge for supply chain organizations which are faced with increasing pressures to lower supply chain costs while improving customer service levels [82]. Inventory control has been considered an essential problem in the management of supply chain for several decades [77].

Poor management of the supply chain can lead to excess inventories that are costly or to insufficient inventory that cannot meet its customer demands [74]. Members of the supply chain are required to pay a small daily storage fee for all components in inventory at the factory. This is called holding cost and is sufficiently high to discourage members from holding large inventories of components for long periods. Demands occurring when the system is out of stock are assumed to be back-ordered. A fixed shortage cost is incurred for each unit of demand that is back-ordered [79, 85].
2.8 OBJECTIVES

The supply chain cost can be minimized by maintaining optimal stock levels in each supply chain member. There is a necessity of determining the inventory to be held at different stages in a supply chain that will minimize the total supply chain cost i.e., minimizing holding and shortage cost. The approach aims to make use of the meta heuristic algorithms for the prediction of the optimal stock levels to be maintained, so as to minimize the total supply chain inventory cost, comprising holding and shortage costs at all members of the supply chain.

The supply chain cost increases because of the influence of lead times for supplying the stocks as well as the raw materials. Practically, the lead times will not be same throughout all the periods. Maintaining abundant stocks in order to avoid the impact of high lead time increases the holding cost. Similarly, maintaining fewer stocks because of ballpark lead time may lead to shortage of stocks. This also happens in the case of lead time involved in supplying raw materials. A better optimization methodology would consider all these additional factors in the prediction of the appropriate stock levels to be maintained and such that the total supply chain cost is minimized.
A prediction analysis making use of the Meta heuristic algorithms like Genetic algorithm and Particle Swarm Optimization algorithm is proposed that considers all these factors that are mentioned hitherto such that the analysis paves the way for minimizing the supply chain cost by maintaining optimal stock levels in each supply chain member.

The primary objectives of the present research are to:

- Propose efficient optimization methodology for minimizing total supply chain inventory cost
- Design, Develop and implement efficient meta heuristic approach for effective supply chain inventory Optimization
- Predict most probable excess stock level and shortage level occurring among different members of the supply chain
- Suggest appropriate steps to be initiated by organization in order to eliminate the shortage or excess stock levels at all members of the supply chain
- Aid decision making for maintenance of optimal level of inventory stocks by various members of the supply chain so as to minimize the total supply chain cost comprising holding and shortage costs
2.9 CONCLUDING REMARKS

For the organizations seeking practical ways to expand their competitive position in the global market and also for the academic community, supply chain management has been gaining increasing attraction. The need for effective and efficient supply chain management processes has been necessitated by the increasing complexity and magnitude of the business operations. By Review of Literature, a comprehensive survey of the significant techniques in existence for inventory control in supply chain management is presented in this chapter. There is only a restricted body of research in supply chain management, specifically in the area of inventory control. In conclusion, it is evident that many of the complexities involved in real-world supply chains including the context of supply chain uncertainty in general, identification and elimination of shortage as well as excess inventory for fast implementation among the various players of a supply chain are not considered comprehensively by the previous Literature. The fact that the overload or shortage of inventories in the supply has the potential to immensely influence the supply chain cost highlighted by various researchers [75], [87], [89] provides ample scope to minimize or eliminate the research gap identified in this direction.