CHAPTER 8

CONCLUSIONS, SUGGESTIONS AND RECOMMENDATIONS

Inventory is an important component and is one of the major decision areas in supply chain management. Inventory decisions are critical since they are primary determinants of customer service levels. 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. 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.

The increased complexity of manufacturing and distribution among global manufacturers due to greater variability and uncertainty across the supply chain suggests that a new approach for controlling and reducing inventory levels is required. Pressures and trends impacting a manufacturer’s ability to effectively manage inventory at a global level are increasing. Traditional methods such as accurate forecasting and efforts to induce flexibility in the supply chain are still necessary but not
sufficient to manage the growing multi-dimensional complexity and 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, provides ample scope to minimize or eliminate the research gap identified in this direction.

A suggested approach is to adopt inventory optimization concepts, techniques and technologies. Inventory optimization (IO) is a powerful problem solving approach backed by advanced technology. The concepts, techniques and technologies of inventory optimization help model, characterize, and account for supply chain uncertainty. This uncertainty is a key reason why manufacturers maintain higher than needed inventory levels. Inventory is a buffer against uncertainty related to variable processing and replenishment lead times, erratic demand and forecast bias or error. Thus inventory optimization has transpired into one of the most recent topics as far as supply chain management is considered.
Inventory optimization technology reveals opportunities to cut inventory by analyzing inventory performance holistically—looking into the data from across the extended supply network. Inventory optimization techniques and technologies identify smarter inventory holding rules at an item/stock keeping location-combination level and replenishment policies that increase overall supply chain planning accuracy. 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.

Meta heuristics have many desirable features to be an excellent method to solve very complex SCM problems. In general they are simple, easy to implement, robust and have been proven highly effective to solve hard problems. Even in their most simpler basic implementations, the meta heuristics have been able to effectively solve very hard and complex problems. The use of simulation has produced widespread benefits in the decision process within firms, and the decision making process can benefit enormously by having a system that is able to identify and evaluate the optimal or near optimal solution in the presence of
uncertainties. These advances are possible by the development made in heuristic research, particularly in Meta heuristics.

Meta-heuristics can be an important tool for helping managers and consultants in the decision process. To be able to respond to the challenge of integration there is the need for sophisticated decision support systems based on powerful mathematical models and solution techniques, together with the advances in information and communication technologies. Meta heuristics can play an important role in solving complex supply chain related problems derived by the importance of designing and managing the entire supply chain as a single entity.

The recent developments in the area of meta heuristics techniques will put them on the forefront to solve existing and new complex SCM problems because of the need for an integrated management approach. Their modularity, easy implementation, easy updating and adaptation to new situation combined with simulation systems and DSS can make a strong impact to help the decision process in SCM. GA and PSO are some meta heuristics that present the characteristics for a potential successful application of SCM. The developers can learn from the extensive applications of these meta heuristics to well-known
optimization problems, and this will pave the way for short development and implementation time frame.

Despite all the complexity, IO techniques and technologies are gaining ground and finding more and more applications because of recent advances in information technology and far greater computational power available at the disposable of today’s supply chain architects. Similar advancements on the operations research front have also led to newer ways to solve complex mathematical equations in acceptable time durations. This progress is a key reason for manufacturers to apply IO Techniques in their supply, manufacturing and distribution networks.

The effective management of the supply chain has become unavoidable these days due to the firm increase in customer service levels and greater emphasis on minimization of the system wide supply chain cost. Even though the major goal is to minimize the total supply chain cost, the chief concern for the inventory and supply chain managers are mainly concerned about the estimation of the exact amount of inventory at each member point in the supply chain such that the members are free of excesses and shortages. 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 raw materials sourced from a number of suppliers. All these factors pose additional challenge in extracting the specific 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.

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.

### 8.1 CONTRIBUTIONS

A generic framework for prediction analysis making use of the Meta heuristic algorithms GA and PSO for supply chain inventory optimization has been conceptualized, proposed and implemented in the present research with the major objectives to predict most probable excess stock level and shortage level occurring among different members of the supply chain and to suggest appropriate steps to be initiated by organization in order to eliminate the shortage or excess stock levels for maintenance of optimal level of inventory at all members of the supply chain so as to minimize the total supply chain cost comprising holding and shortage costs. In the present research, the focus is on using two meta heuristics: GA and PSO. Many other have similar features and have the potential to apply to SCM problem. But GA and PSO, in their simple form, present quite good results and can be in certain way representative of the latest developments in modern heuristic research.

Efficient inventory management is a complex process which entails the management of the inventory in the whole supply chain and the dynamic nature of the excess stock level and shortage level over all the periods is a serious issue when implementation is considered. In
addition, consideration of multiple products leads to very complex inventory management process. The complexity of the problem increases when more suppliers, distribution centers, agents and influence of lead times are involved. In this present research, these issues of inventory management have been focused and novel models based on GA and PSO Meta heuristics have been proposed in which the most probable excess stock level and shortage level required for inventory optimization in the supply chain is distinctively determined so as to achieve appropriate inventory levels among different partners of the supply chain leading to minimum total supply chain cost.

An innovative and efficient methodology that uses Genetic Algorithm to precisely determine the most probable excess stock level and shortage level required for single product inventory optimization in the supply chain is proposed in Chapter 4. The proposed GA model for single product inventory optimization was implemented and its performance was evaluated using MATLAB 7.4. [Appendix 10.1] The performance of Genetic Algorithm was well as predicted. The proposed genetic algorithm based approach for inventory management provided useful information to predict the excess stock level and shortage level at all members of the supply chain. This is the essential pre-requisite information that will make any kind of inventory control effective.
The optimization of inventory control in supply chain management based on genetic algorithm is analyzed with the help of MATLAB. The final chromosome obtained from the GA based analysis is the inventory level that could cause maximum increase of supply chain cost due to excess/shortage of inventory positions among various partners in the supply chain. It is inferred that controlling this resultant chromosome is sufficient to reduce the loss either due to the holding of excess stocks or due to the shortage of stocks. By focusing on the excess/shortage inventory levels and initiating appropriate steps to eliminate the same at each member of the chain, the organization can optimize the inventory levels and thus minimize the supply chain cost. The technique of GA is also compared with PSO model. [Appendix 10.4]

In addition, consideration of multiple products along with different levels of supply chain is a complex task and leads to very complex inventory management process. The complexity of the problem increases when more distribution centers and agents are involved. In this present research, these issues of inventory management have been focused in Chapter 5 and a novel GA model for multi product inventory optimization has been proposed in which the most probable excess stock level and shortage level required for inventory optimization in the supply chain is
distinctively determined which will pave the way for achieving minimum total supply chain cost.

To make the inventory control effective, the most primary objective is to predict where, why and how much of the control is required. Such a prediction is made here through the methodology proposed. To accomplish the same, Genetic algorithm is used and the optimal number of units of a product that needs to be kept in the desired level of control is determined on the basis of the knowledge of the past records. This leads to an easy estimation of the stock levels of the respective products to be maintained in the upcoming periods.

In practice, the dynamic nature of the excess stock level and shortage level, over all the periods is the typical problem occurring in inventory management. The determination of the stock level that occurs at a maximum rate is the vital operation to be performed. Thus, the maximum occurrences of stock level should be considered in order to optimize effectively. The employed fitness function of the genetic algorithm is formulated in such a way that it will consider the past periods to determine the appropriate stock levels. The proposed approach of genetic algorithm predicts the optimum stock levels to be maintained in the future by considering the stock levels of the past years such that the total supply chain cost will be maintained as minimum.
The approach suggested for the multi product inventory optimization has been implemented in the platform of MATLAB 7.4 (Appendix 10.2). The database consists of the records of stock levels held by each member of the supply chain for every period. In our implementation, the example case of five different products in circulation with the seven member supply chain network has been considered.

The final chromosome obtained from the GA based analysis is the inventory level that has the potential to cause maximum increase of supply chain cost. It is inferred that controlling this resultant chromosome is sufficient to reduce the loss either due to the holding of excess stocks or due to the shortage of stocks. By focusing on the excess/shortage inventory levels and initiating appropriate steps to eliminate the same at each member of the chain, it is possible to optimize the inventory levels and thus minimize the total supply chain cost. The technique of GA is also compared with PSO (Appendix 10.5).

Chapter 6 supplements the study outlined in chapter 5 that focuses only on a single factory and multiple products. In chapter 6, in addition, the situation of multiple factories with each factory manufacturing selective products and agents under a distribution center dealing with selective products of the supply chain is considered.
These considerations may lead to very complex inventory management process involving the possible complexities the supply chain to be dealt with in reality may pose.

Thus the complexity of the problem has been increased to a more likely supply chain structure. The proposed approach of genetic algorithm predicts the optimum stock levels of the future by considering the stock levels of the past years such that the inventory level is optimized and thus the total supply chain cost can be maintained as minimum.

As the lead time plays vital role in the increase of supply chain cost, the complexity of predicting the optimal stock levels increases. The novel and proficient approach based on PSO algorithm presented in chapter 8 reduced the total supply chain cost as it undoubtedly established the most probable surplus stock level and shortage level along with the consideration of lead time in supplying the stocks as well as raw materials that are required for inventory optimization.

PSO uses individual and group experiences to search the optimal solutions. Nevertheless, previous solutions may not provide the solution of the optimization problem. The optimal solution is changed by adjusting certain parameters and putting random variables. The ability
of the particles to remember the best position that they have seen is an advantage of PSO.

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 through out 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 of supplying raw materials. A better optimization methodology would consider all these above mentioned factors in the prediction of the optimal stock levels to be maintained. In chapter 8, an optimization methodology that utilizes the PSO algorithm, one of the best optimization algorithms, is proposed to overcome the impasse in maintaining the optimal stock levels in each member of the supply chain. Taking into account the stock levels thus obtained from the proposed methodology, an appropriate stock levels to be maintained in the approaching periods that will minimize the supply chain inventory cost can be arrived at.

Effective supply chain strategies must take into account the interactions at various levels in the supply chain. It is challenging to design and operate a supply chain so that total system wide costs are minimized and system wide service levels are maintained. Uncertainty is
inherent in every supply chain. So supply chains need to be designed to eliminate as much uncertainty as possible to deal effectively with the uncertainty that remains. Demand is not the only source of uncertainty. Delivery lead times, manufacturing yields, transportation times and component/raw material availability can also have significant impact on supply chain. Inventory and back order levels fluctuate considerably across the supply chain, even when customer demand for specific products does not vary greatly.

The two desired attributes of improved service and inventory levels seem to be not achieved at the same time since traditional inventory theory tells us that to increase service level, the firm must increase inventory and therefore cost. But recent developments in information and communications technologies, have led to the innovative approaches that allow the firm to improve both the objectives simultaneously.

The methodology proposed in chapter 7 will minimize the total supply chain cost by predicting optimal stock levels, not only by considering the past stock levels but also considering the lead time of the products to reach each supply chain member from its previous stage as well as the lead time involved in supplying the raw materials to the factory. Usually, shortage for a particular stock at a particular member, holding excess stock levels at a particular member, time required to
transport stock from one supply chain member to another i.e. lead time of a stock at a member, time taken to supply raw materials to the factory to manufacture certain products i.e. lead time of raw materials in factory, are some of the key factors that play a vital role in deciding the supply chain cost. A better optimization methodology should consider all these factors. In the proposed methodology, all the above mentioned key factors in predicting the desired stock levels for the purpose of minimizing the supply chain inventory cost are considered. Also, different priorities are assigned to those above factors. As per the priority given, the corresponding factors will influence in the prediction of optimal stock levels. Hence as per the desired requirement, the optimal stock level will be maintained by setting or changing the priority levels in the optimization procedure.

The MATLAB 7.4 is employed to implement the approach and to envision its performance. [Appendix 10.3]. As anticipated, the proposed PSO algorithm offers a superior calculation of stock levels amidst diverse stock levels at diverse members of the supply chain by its excellent performance. Thus the attained stock level provides useful information about the most probable excess stock level and shortage level among different members of the supply chain in the upcoming period, which is required for inventory optimization in the supply chain so as to achieve
minimum total supply chain inventory cost. The PSO model is also compared with GA model [Appendix 10.6].

8.2 SCOPE FOR FURTHER RESEARCH

The present research contributes to a better understanding of the issues in supply chain and to encourage further research on the applications of meta heuristics to solve complex problems in SCM. Meta heuristics can make an important contribution to carrying out the challenges posed on an integrated supply chain, especially with the new economy and electronic business. Applications of meta heuristics-based DSS for integrated supply chain management are work-in-process. In many companies, ambitious project to implement DSS to evaluate and help the decision process of the integrated supply chain have yet to be completed, and many other have not yet seriously begun initiatives in this direction. It is believed that this work should be extended sometime in the near future, as a large amount of successful applications of meta heuristics-based DSS to the SCM problems will be developed.

The output of running an IO algorithm can be fed back to the ERP, constraint based planning or other discrete planning system, adjusting inventory policies at a finite level. And together, this can have a range of applications, from modeling and optimizing safety stock across the supply chain to identifying re-order point sizes in environments with
highly erratic demand. This will facilitate increased ease of use and accessibility over time. The latest IO techniques bring the necessary computational power to solve very large optimization problems very quickly. Information technology forms the basis for successful supply chain integration. The synchronization of the various tiers can be more realistic if the planning of the customer and supplier is available on a web-based system and is integrated with the ERP system.

It is expected that in the future more combinations of simulation and optimization techniques will be developed. Meta heuristics techniques play a very important role in this direction since they can obtain very good solutions within a small time frame. It can be easily adapted and developed to solve very complex supply chain problems.

Meta heuristics, when incorporated to a DSS for SCM, can contribute significantly to the decision process, especially taking into consideration the increased complexity of the logistics problems previously presented. DSS based on meta heuristics are not currently widespread, but it appears to be growing as a potential technique to solve hard problems as the one related with SCM. Meta heuristics can be an excellent tool to be included in such a DSS for SCM.
Since all the elements of the supply chain interact and a decision on one element affects the other ones, any supply chain decision can affect the customer service. Therefore, system wide DSS that help the decision maker at strategic, tactic and operation level, to evaluate, simulate and analyze different options and scenarios, and the interaction between the players in a supply chain are of increased concern for many companies.

More sophisticated applications of information technology such as decision support systems (DSS) based on expert systems, simulation and meta heuristics systems will be applied directly to support decision making on SCM. A DSS incorporates information from the organization’s database into an analytical framework with the objective of easing and improving the decision making. A critical element in a DSS for logistics decision is the quality of the data used as input of the systems. Therefore, in any implementation, efforts should me made to have accurate data. Afterwards, the modeling and techniques applied to obtain a scenario or analysis of a logistics and supply chain situation should be adapted to the environment of the company and support the managers and executives in their decision processes. The suggested approach could also be modified to take care of certain practical considerations of management as explained under “Implications to Management”.

8.3 IMPLICATIONS TO MANAGEMENT

The organizations can make use of the proposed techniques in this present research for inventory optimization by capturing the database in the desired format to suit their respective supply chain structure, replacing the simulated data used in this research with the real data of the organization. For greater accuracy, the number of iterations should be sufficiently increased and run on the most frequently updated large database of past records. Also the organization can mention the maximum possible lower limit and upper limit for the shortage and excess inventory levels respectively, within which the inventory is expected to fluctuate among the various members of the supply chain to make the convergence faster towards optimal solution. Further if the organization can evaluate and quantify the cost involved for each shortage as well as excess of inventory at each member of the supply chain, then the exact savings due to inventory optimization in the supply chain can be calculated for the organization. Also, organization can adopt decomposition technique and use the proposed techniques for inventory optimization of high/medium/low value independent products. In this case, the organization should apply the technique for the high value items separately, medium value products separately and low value products separately for inventory optimization in the supply chain.