8.1 CONCLUSION

In this chapter, the work presented in this thesis is concluded and potential research directions for the future work are provided.

- In chapter 1, general introduction of flow shop scheduling, the significance of sequence dependent set up time, supply chain management, and importance of integrated production and distribution in a supply chain are briefly addressed. The solution methodologies for the combinatorial optimization problems are also represented.

- In chapter 2, a vast literature review for flow shop production scheduling as well as integrated production and distribution scheduling problems is presented. Summary of literature is given at the end of the chapter and the literature gap is identified. The literature survey for the proposed meta heuristics i.e. PSO, MSA and AIS algorithms is also highlighted.

- In chapter 3, the first category, mathematical model for the Production scheduling problem in multi cell FMS is formulated with sequence-dependent change overs between processing of batches. This model has considered two cases, batch availability and job availability, respectively. In the second category, mathematical model for integrated production and distribution problem in a supply chain is formulated as mixed integer programming model. In the production
scheduling part, sequence-dependent changeovers between customer orders is considered.

- In chapter 4, solution methodology for model I problem is addressed. Three efficient meta heuristic algorithms PSO, MSA and AIS are presented to solve the model I problem. A numerical illustration was given with randomly selected input data for 7 batches and 5 machines. The performance comparison of the proposed heuristics for various problem instances is also presented.

- In chapter 5, solution methodology for model II problem is addressed. The same meta heuristic algorithms PSO, MSA and AIS are proposed to solve the model II problem. The proposed meta heuristic approaches have successfully dealt with the supply chain problems discussed in this thesis. The case study of the model II considers an integrated production and distribution scheduling problem with 4 machines, 4 products, 3 customers and 3 distribution centers. The input values given are randomly generated in uniform distribution. The performance comparison of the proposed heuristics for various problem instances is also presented.

- In chapter 6, both the models are analyzed with exact solution methodology using IBM ILOG solver engine. For model I problem, CPLEX solution as well as Lower bound solutions from CPLEX solver were obtained. For model II problem, CPLEX and CP solutions were obtained with lower bound values.

- In chapter 7, performance of meta heuristic is compared with exact solutions for the two scheduling models.

In a nutshell, this thesis considers two categories of scheduling problems. The first category of the problem deals with Production Scheduling of batches in multi cell FMS and the second category of the problem deals with Integrated Production and distribution scheduling in a supply chain.
In the first category, simple production scheduling of batches of parts considered as model I is addressed with two special cases: Batch availability model and job availability model. In both cases sequence dependent set up time is considered with the process time. Since effective managing of sequence dependent set ups is one of the critical factors to improve manufacturing system performance, it has to be considered separately from the processing time. The objective criterion we have considered for this model is the makespan criterion which is one of the best performance measure needed in industry. This model of problem belongs to NP hard. Therefore, efficient meta heuristics such as AIS, PSO and MSA have been analyzed for the said production scheduling problem. The proposed meta heuristic algorithms are validated by testing the bench mark problem instances taken from Das and Canel (2005). The solution quality of the proposed algorithms are compared with the lower bound solution and best known solution provided by CPLEX programming using ILOG Solver on the randomly generated instances of eighty problems. The comparison reveals that proposed algorithms provide solution better than CPLEX solver and very close to lower bound solution of CPLEX solver. Also the solution quality and computational time of MSA, PSO and AIS are compared with each other. It is concluded that, when solution quality is the major factor and time is not the constraint, for small size problem all the algorithms provide same solution and for large size problem AIS algorithm provide solution better than PSO and MSA. But, when time efficiency is concerned MSA performs better.

In the second category, the model I problem is extended to integrated production and distribution problem in a make to order supply chain and is considered as model II. It is evident from literature review that integrated production and distribution problem has received little attention by the researchers. In this model, we have estimated the total cost with due consideration of customer service level. The total cost is measured by summing up the production cost, transportation cost and distribution cost. In production
cost calculation, the makespan is multiplied with the factory cost or plant cost. Transportation cost depends on the mode of transport selected for batch delivery of products. The customer service performance is expressed in terms of the due date or deadline of each batch. Therefore, Shortage or back order cost based on time of delivery of products is included in the total cost calculation. The problem is obviously NP hard and combinatorial optimization problem in the strong sense. Based on the above, a mixed integer linear program (MILP) is formulated. Respecting the computational complexity of the model involved, AIS, PSO and MSA algorithms with tuned parameters are presented for performance comparison. In order to validate the performance of the proposed algorithms 20 randomly generated test problems are used. The solution quality of the proposed algorithms is compared with CP and CPLEX solver. Result shows that AIS, PSO and MSA algorithms provide solution better than CP solver, same as CPLEX solver and very close to lower bound solution of CPLEX solver. Also the solution quality and computational time of AIS, PSO and MSA are compared with each other. It is concluded that, when solution quality is the major factor and time is not the constraint, AIS algorithm is efficient than PSO and MSA. But, when time efficiency is concerned MSA performs better.

8.2 FUTURE RESEARCH SCOPE

- The future investigations to this study would be to implement other meta heuristics like ant colony optimization, artificial bee colony algorithm, firefly algorithm, sheep flock heredity algorithm, imperialist competitive algorithm etc., and study their computational performance.
- Next, the robustness of the proposed algorithms may be improved by fine-tuning the parameters relating the adjustable optimization parameter using design of experiments.
In addition, other real world parameters like fixed charge transportation in the distribution line can be added to the model.

Also, in our case, demands for all the manufacturing lots have been considered as greater than or equal to one. But in real life it need not be so. In future, this must be kept in mind if a customer does not require all products manufactured by the company.

In the next level, the product nature may be considered as perishable type with limiting horizon.

Future work includes multi objective supply chain problems with maximizing customer service level and minimizing total cost.

Capacitated vehicles with increase in number of trips used for delivery may also be considered.