CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Now-a-days, there is a strong tendency towards customer orientation in the manufacturing scene. In the customer-oriented plants, orders consisting of a few parts or even one part will be transferred directly from vendors to producers, who must respond quickly to cater to the needs of the customers. In this produce-to-order environment, a great variety of orders arrive randomly. Each order has a different part mix, different processing requirements as well as individual arrival times and due dates. Thus, the production system is confronted with a continually changing flow of parts (Arzi 1995). Also, approximately 50-75% of manufactured parts fall into the categories of low volume/high variety and mid-volume/mid-variety and with the trend toward variety in products, this percentage is likely to increase (Hoitomt et al. 1993). Hence it becomes essential that the manufacturing industries of today need to be flexible to meet the changing dynamic market environments. The competitive challenge to the manufacturing sectors is to overcome the trade-off between flexibility and efficiency.

Automating the job shop can pave the way for producing a variety of parts in small lots flexibly, in this changing market scene. So the shop structure is moving toward pure job shop, coupled with automation. The technological breakthrough in manufacturing evolved with the application of computers and precise control has led to the development of such systems. Conventionally, the automated job shop is addressed as Flexible Manufacturing System (FMS), the system that can achieve both flexibility and productivity.

The various components of the FMS are generally grouped as follows (Taglia and Santochi 1993):

\begin{itemize}
\item \textit{FMS descriptions}: workstation specification, material handling system description, layout description and pallet(fixture) availability.
\item \textit{Part descriptions}: operation sequence for each part and resource requirement for each operation
\item \textit{Scheduling parameters}: tool loading and schedule specification
\end{itemize}

The hardware components of FMS are flexible enough to handle the dynamic and highly competitive market demands. In order to avail the benefits of various flexibilities
involved with FMS, they must perform at a high level to offset their high cost. The performance level depends not only on the physical composition (number and type of workstations, layout, etc.), but also on the work preparation (process plans, alternate plans, machine tooling, etc.), and on the operative management of the plant that controls the shop floor activities (Haddlock 1995). Once the FMS and Part descriptions are defined, then the performance/profitability of the system entirely depends on how efficiently the production resources are utilised (i.e. selection and assignment) and on how the selected parts are effected through the system (i.e. releasing and dispatching). The overall allocation of system resources (scheduling) determines the above decision. The issues that concern the management of the shop floor activities at the operational level (Operational Management System 'OMS') in FMS play important roles in production planning functions (Figure 1.1, Source: Bedworth and Bailey 1987) of Computer Integrated Manufacturing (CIM) systems. The OMS at the shop floor level still requires a great effort to fully exploit the benefits of flexible automation (Li and She 1994). In this context, this thesis is concerned with the operational management system of FMS as the area of research.
1.2 FMS SCHEDULING

The primary concern of the operational management system of FMS is to regulate the flow of parts smoothly, to achieve maximum performance. The related issues are:

**PRODUCTION SCHEDULING**
- assignment of machines/Work Cells (WCs) to all operations and
- allocation of specific time spans to each of them.

**MATERIAL HANDLING SYSTEM (MHS) SCHEDULING**
- regulation of the materials (raw or Work-In-Progress 'WIP') by transporting in proper sequence with proper route to the required processors (WCs) or Automated Storage/Retrival System (AS/RS) and
- ascertaining the availability of the materials at the right time without or with minimum change in their original schedule.

**AS/RS OPERATION AND CONTROL**
- storing the raw or WIP inventories of the planned scheduled parts and delivering them whenever required and with minimum bottlenecks and costs.

**TOOL MANAGEMENT**
- ensures the availability of tools and fixtures for the selected part mix,
- monitors tool status and replaces the tools on breakage.

Of all the above issues, scheduling of machines and material handling systems have been the primary concern for improving productivity.

The need of an efficient scheduling scheme is outlined with the quotations of various authors in the field of scheduling research. Hoitomt et al. (1993) stated that the production chaos, such as not having the right items when they are needed, not having equipment when it is needed, using inventory to hide problems, inflexibility, and lack of responsiveness to due date, are the attributes to problems in scheduling function. Shanker and Agrawal (1991) described the loading problem in FMS as a short-term decision that determines the utilisation of capital intensive resources and productivity of the system. Dhar (1991) indicated that a high rate of utilisation of a high capital FMS can be achieved if the FMS operational problems are effectively solved. Connors et al. (1994) addressed production planning and scheduling as a hierarchy of production-decision procedures designed to achieve a high level of on-time delivery to their customers while maintaining low inventory levels and low cycle time. Dines (1993) specified that a good scheduling model can help to: identify bottleneck resources,
predict due date performance, calculate resulting inventory levels, calculate manpower and 
machine utilisation. Kim and Yano (1993) indicated that the characteristics of FMS such as 
operational flexibility, machine flexibility, routing flexibility and so on, are the factors that 
make scheduling difficult. Lee and DiCesare (1994) described the scheduling problem as a 
challenging one, which tackles the ever-increasing complexity and flexibility of FMS. Waikar 
et al. (1995) expressed scheduling as an important function in production/operation 
management since it affects the production of quality products in a timely cost-effective 
manner. Chiu and Yih (1995) pointed out that the low productivity is often the problem with 
computer integrated manufacturing systems and is mostly due to lack of an efficient scheduling 
scheme. Hutchison (1991) indicated that scheduling decisions are important factors in FMS 
performance and therefore, maximum system performance requires that appropriate 
scheduling schemes be established for particular situations. This requires an efficient and 
dynamic factory scheduling and control procedures at the operational level. The above views 
reveal that the importance of scheduling is beyond question. Besides,

(i) A good schedule leads to high productivity through maintenance of low inventory, 
maximum utilisation of the entire system components, minimum and efficient 
movement of materials, proper capacity plans, customer satisfaction, and the like.

(ii) Study on system performance, capacity planning and development of control 
policies for efficient operation can be carried out through a scheduling model and 

(iii) Scheduling is a complicate decision-making process and the complexity of the 
problem in FMS environment is increasing since such a system has to meet many 
flexibilities, uncertainties, more than one objective, and co-ordination among many 
functions involving machining, material handling, storage, and tool management 
systems.

Also, there are numerous problems in this area to be still solved. In this study, this 
thesis concentrates on scheduling problems that arise in flexible manufacturing context. The 
concern of the thesis is the design and analysis of algorithms that generate schedules or control 
programs for the different sub systems (WCs, MHS and AS/RS) in FMS.
1.3 HEURISTIC AND SEARCH TECHNIQUES

Various types of scheduling problems are solved in different FMS environment. Varieties of algorithms are employed to get optimal or near optimal schedules. Traditionally, automatic generation of scheduling plans for job shops has been addressed using optimisation and approximation approaches (Blazewize 1995, Bruker 1995). Optimisation algorithms include enumerative procedure and mathematical programming techniques (Linear, Integer programming, Goal programming, Transportation, Network and Dynamic programming). The techniques included in approximation techniques are: Implicit enumeration (Branch-Bound 'B-B'); Decomposition (Lagrangian Relaxation 'LR'); Priority rule-based; Heuristics; Local search algorithms (Iterative-Search 'ITS', Simulated-Annealing 'SA', Threshold-Annealing 'TA', Tabu-Search 'TS'); Evolutionary Programs (Genetic Algorithms 'GA') and AI techniques (Knowledge Based 'KB' and Expert Systems 'ES'). The salient remarks concerning scheduling algorithms are (Hutchison 1991, Bruker 1996, Mattfeld 1996, Portmann 1997):

- Optimisation algorithms provide satisfactorily or optimal results if the problems to be solved are not too large and are restricted to low-dimensional over-simplified problems. With the growing uncertainty and complexity in manufacturing environment, most scheduling problems have been proven to be NP-hard, that is, the computational requirement grows exponentially as a function of the problem size, and this degrades the performance of conventional OR techniques and hence optimisation approaches are ruled out in practice. Approximation algorithms are problem-dependent and raise the problem of overcoming the difficulties between computer and human reasoning. In both the cases, the efficiency problem arises (Hutchison 1991). Any how the approximation algorithms are capable of guaranteeing the solution to be within a fixed percentage of the actual optimum and are considered urgent and useful tools for solving discrete optimisation problems.

- The quality of solutions with Branch-Bound algorithms depends on the bounds; a good bound requires a substantial amount of computation.

- Various factors such as configuration of the system, shop load levels, objective criteria, and the like govern the performance of priority dispatching rules (pdrs). The performance of the pdrs has been analysed with simulation experiment, which is evaluative rather than generative. Hence generalisation on the use of a particular rule is
difficult to establish. Priority based rules are questionable for stability and environment dependence.

- The performance of heuristics is satisfactory as long as the operating characteristics and objectives of the system remain the same. Heuristics yield good solutions, but are robust to the system.
- Local search-based heuristics are known to produce excellent results in short run times, but they are susceptible of getting stuck in local entrapments.
- Evolutionary program, which belongs to random search process, is regarded better than simulation in the sense that it guarantees near optimal solutions in actual cases. Also, by changing the evaluation parameter of the genetic search process, the solutions can be obtained for other suitable objectives and can be made more flexible. These are useful for any hard optimisation problems.
- AI techniques depend on their capability to combine miscellaneous, and situation-specific pieces of information. However, they provide solutions in a short time and are useful to address the dynamic situations.

The above discussion indicates that Heuristics, Local Search algorithms, Evolutionary search algorithms (GA based heuristics) and AI algorithms (Knowledge based schemes) are useful tools for scheduling FMS. In this context, this thesis considers a few approximation algorithms that belong to the above category for scheduling FMS.

1.4 ORGANISATION OF THE THESIS

The organisation of the rest of this thesis is as follows:

Chapter 2: The literature related to the problems concerned is reviewed.

Chapter 3: The models and problems considered in this thesis are presented.

Chapter 4: A GA for sequencing problem of a set-up constrained Flexible Manufacturing Cell (FMC) model is designed and performance is compared with a few priority dispatching rules.

Chapter 5: Three heuristics (including a GA based heuristic) are proposed for the general job shop type FMS that assumed transportation time as negligible. Their performance is compared. Further, the GA based methodology is extended i) to revise the schedule on new job arrivals and machine breakdowns, and ii) to handle alternate route choices with iterative search technique.
Chapter 6: Two knowledge-based approximation algorithms are presented, as an alternate to the heuristics proposed in Chapter 5, to provide solutions in a short time for dynamic rescheduling cases and their performances are compared.

Chapter 7: A heuristic algorithm is proposed to generate Automated Guided Vehicle (AGV) schedule and modified production schedule from the given original production schedule that is obtained neglecting transportation activities (Output of algorithms proposed in Chapter 5 or 6). This enables the integration of the operation of AGV with production. The heuristic employs vehicle dispatching rules (vdrs) for conflict resolution. The performance of few dispatching rules applied on the proposed heuristic is studied.

Chapter 8: A few heuristic algorithms (including GA) that considers the production schedule as the input to allocate the WIP inventories in AS/RS with optimal shuttle movements are addressed and their performance is compared.

Chapter 9: The results of the proposed methodologies are discussed.

Chapter 10: Conclusions along with future research directions are indicated.