CHAPTER 1

INTRODUCTION

1.1 Production Scheduling

Manufacturing companies are facing the challenge posed by stiff competition due to the changing economic environment, liberalization and globalization. In order to meet these challenges companies are trying out several strategies designed to improve their competitiveness and are critically looking at several established practices and procedures. Hence, among other things, there is a renewed interest in the theory and practice of production scheduling. In production scheduling the products to be manufactured and their quantities are determined initially. The sequence of manufacturing processes required for the production of these items are also established. The manufacturing resources are then allocated to perform production processes to realise various items. This is spread over a predetermined time. This function is known as production scheduling. The objectives of scheduling also include maximisation of the resource utilisation, minimisation of the work-in-process inventory, reduction of manufacturing lead time, etc.

1.2 Types of Manufacturing Systems

Scheduling is an important activity in all types of manufacturing systems. An understanding of the different types of manufacturing systems is therefore, vital for a critical study of the scheduling activity. This work pertains to scheduling in discrete part manufacturing industrial systems that can be broadly classified as flowshops and jobshops.

1.2.1 Flowshop

In many production situations there are more than one manufacturing resource and the jobs to be processed consist of number of operations to be performed in a specific order. A
flow shop is one where the machines are arranged in the order in which the processing of components is undertaken.

1.2.2 Jobshop

A jobshop is another kind of production environment where the flow of work may follow any pattern as indicated in Fig. 1.1.

![Job flow pattern in a jobshop](image)

**Figure 1.1 Job flow pattern in a jobshop**

There are no optimal rules or procedures for the job shops, with more than two machines and two jobs [1]. Most of the time schedulers employ typical priority dispatching rules that yield non-optimal solutions. The job after completing the processing requirement in a resource is equally likely to move to any other suitable resource. This is also known as serially routed jobshop because all the manufacturing operations of a particular job are performed one after another in a serial fashion.
In a jobshop the components enter the shop as raw materials and leave the shop as finished parts after undergoing various operations whereas in an assembly type of jobshop the machined components and bought out items wherever applicable are assembled to form a subassembly or the finished product. Parallel processing of components are undertaken to reduce the manufacturing lead time and improve productivity.

The scheduling activity gets complicated in these types of shops due to the assembly constraints and the precedence relationships of parts and processes. An assembly part at a higher level cannot be processed before all its subassemblies at a lower level are completed. Any part ready for assembly needs to wait for the corresponding mating parts to form the assembly.

1.2.3 Assembly line

Another kind of manufacturing shop in which assembly operations are involved is termed as an assembly line. Each assembly line is specially designed for some specified product types. The production scheduling problem in this kind of shop mainly concerns with balancing the various assembly station capacities.

The different types of shops discussed so far can further be classified as static and dynamic based on the nature of job arrivals. A static jobshop is one in which all the jobs to be scheduled are available at the start of the scheduling period and no further job is allowed to enter the shop during the planning horizon. In contrast, a dynamic shop allows the jobs to enter the shop at any time and as and when they enter the shop they are scheduled. Further classification of the dynamic system is a stochastic system where the process times vary randomly and a deterministic system where the process times are fixed.
1.3 Definition of the Terms related to Scheduling

In this section the key terms used in this work have been defined.

Component: A component refers to the machined or processed part that is manufactured from raw material and without any assembly requirement.

Bought-out item: It refers to the part that is purchased as standard components and used in the assemblies.

Assembly: A part that is obtained by combining two or more parts by an assembly operation is known as an assembly or assembled part. If the assembled part is the finished product then it is known as final assembly else it is known as a subassembly.

Part: A part is a common term used to refer the components, bought-out items, subassemblies, and finished product.

Job: The term job refers to the finished product made up of either a single part or an assembly. It can further be classified as string type of job and multi-level assembly job. If the finished product is a single component obtained after the required manufacturing operations performed on a basic raw material, it is known as a string type of job.

In a multi-level assembly job the finished product is made up of a number of subassemblies. The finished product is treated as belonging to level 1 and the subassemblies required to form the final assembly belong to level 2. The level 2 parts are in turn made up of parts at level 3 and so on. In this thesis, multi-level jobs have been considered for scheduling purpose.

Shop loading: The allocation of jobs to work centres is called shop loading. Loading determines the work centre which are to receive the jobs. It assigns the jobs to the work centres without specifying the order in which they will be performed. Loading is a complex
problem when several work centres are capable of performing the same job and several jobs are available.

Shop loading can be classified as finite loading and infinite loading. Infinite loading assigns jobs to work centres without regard to capacity limitations. Finite loading assigns jobs to work centres so as to never exceed their capacities.

**Sequencing or Dispatching:** Once the jobs are loaded on the work centres, the next task is to sequence them. Loading assigns jobs to work centres, but it does not specify their order of precedence. Sequencing, frequently referred to as dispatching, establishes the order in which the jobs assigned to a work centre will be processed.

### 1.4 Solution Methodologies for Production Scheduling

The various solution methodologies used for production scheduling are discussed briefly in the following paragraphs.

#### 1.4.1 Charting

There are various types of scheduling charts available. The Gantt chart is useful in showing planned work activities and actual progresses on the same time scale. Large and elaborate scheduling boards are available commercially. Nowadays PC based electronic scheduling boards are available for this purpose. These methods become impractical as the number of jobs and work centres increase.

#### 1.4.2 Priority rules and heuristics

An important decision to be made by the scheduler when a workcentre finishes operation on any part is to decide the next part to be selected for processing. It is usually made with the help of certain rules known as priority dispatching rules. FIFO (First In First
Out), SPT (Shortest Processing Time), EDD (Earliest Due Date) are some of the commonly used rules. These rules will not guarantee optimal schedules. Conflicting objectives like reduction of manufacturing lead time, work-in-process inventory and increase in machine utilisation cannot be achieved by the same set of priority dispatching rules. One set of rules that improve one objective may perform very poorly when used to optimise a different objective.

Most of the scheduling problems require large computational time as the computations are basically iterative in nature and it grows non-polynomially with respect to the problem size. If the best schedule for the problem cannot be found within a reasonable time, then the knowledge and experience of the scheduler is used to find a schedule that, though not optimal may give a better solution. The algorithms based on the above kind of knowledge and experience are known as heuristic or approximation algorithms. Branch and Bound, and Neighbourhood Search Techniques [2] are examples of such algorithms.

1.4.3 Optimisation methods

Optimisation methods give the best possible solution based on the performance criteria chosen. Unfortunately optimisation methods are suitable for only smaller problems. A variety of machine scheduling problems are NP-hard (Non-Polynomial hard), that is, the computational requirements grow exponentially as a function of the problem size. A problem of practical size may involve hundreds of machines and hundreds of products; each composed of hundreds of parts to be scheduled over a period of time. Any method for generation of optimum schedule will likely require excessive computation time and is not of practical use on a daily basis.
1.4.4 Materials requirement planning

To cope with the computational complexity, engineers often employ Materials Requirement Planning (MRP) in combination with heuristic rules to schedule individual work centres. Typically an MRP system is used to schedule parts so that precedence constraints among parts are satisfied. MRP ignores machine capacity, however, and may cause schedule to violate capacity constraints. To satisfy capacity requirements and to determine sequencing of parts at individual work centres, heuristics are often used to determine sequencing of parts at individual work centres. However, the heuristic rules usually are not well integrated with an MRP system. This is because parts are sequenced according to the rules that usually do not take into consideration the relationship among the parts within each product as established by the MRP system. As a consequence delivery of products is delayed due to the delay in the completion of any one of its parts.

1.4.5 Queueing theory

The predominant theoretical approach to stochastic scheduling is that of queueing theory. The intention to find a priority rule that leads to the optimum performance measure is made difficult due to the fact that, it is only possible to derive explicit expressions for the performance measures when the probability distribution involved have simple and compatible form [3]. In spite of a great deal of analytical results available in queueing theory, it is generally found that for a particular industrial application, none of the formulae applies exactly. A simplified problem which is amenable to an analytic solution will not, usually, model a real queueing situation. Therefore for a complete application of a queueing system in any industrial scheduling problem one almost invariably uses simulation [4]. The primary use of queueing theory formulae is for getting a general insight into the situation and for
determining how sensitive the operating characteristics of a system are to alternative decisions.

1.4.6 Simulation

Simulation is the most powerful tool available to schedule the manufacturing systems where jobs with assembly constraints are arriving continually. However it has been and it is generally labelled as a tool of last resort for managers and engineers. There are three main reasons for this state of affairs. Firstly, it is not an optimising tool and is generally used to perform a "what if" analysis. Secondly, considerable amount of skill is required to do the simulation correctly and accurately. Lastly, it is difficult to validate the model for its completeness or accuracy.

In spite of all these difficulties, researchers have used discrete event system simulation as the tool for scheduling in large, complex, and dynamic manufacturing systems as no other technique has been developed so far that can solve this problem satisfactorily [5].

A discrete event system simulation makes use of the computer model of the system to be studied. The model essentially contains a network of blocks each representing an entity of the system. The entities represent the various resources in the manufacturing system like the machines and other items like machine queues. The flow of temporary entities namely, the parts are controlled by the various logic built into the simulation program. The models make use of the next-event-time advance approach. In this approach, the collection of state variables necessary to describe the system at a particular time are initiated and the simulation clock is advanced to the next event time. Whenever a system moves from one state to another state all relevant statistical information about the system performance are collected using statistical counters. A subprogram called event routine updates the state of the system when
an event like completion of a machining operation occurs. Another subprogram computes the estimates of the desired measures of performance and produces a report when the simulation ends.

As seen from the above description, the simulation process models the system to be studied by capturing all the system details regarding the various entities and the interrelationships among them and representing those details in the simulation logic. Any operating policy used to operate the actual system can be modelled in the program in the form of the program logic and its influence on the performance measure, of interest to the analyst is obtained. This is a great advantage of discrete event simulation. At the same time, the inherent limitation of simulation is that it is not a self-optimising tool, in the sense that it can perform only a what-if analysis and cannot provide an optimum solution.

1.5 Motivation for the present work

When compared to the intensity of research work / research contributions made in the last three decades concerning scheduling of serially routed jobshops, investigations reported regarding the scheduling of multi-level assembly job shops are not many. Further the assumptions made and the limited scope of the work carried out so far reduce the usefulness of these. For example, the economic aspects of scheduling such as profit and work-in-process inventory expressed in monetary terms are not considered in these contributions. Hence, there is a potential scope to incorporate and investigate the factors not considered by the previous researchers in the field of assembly shop scheduling. Moreover, the fact that a large number of industries involved in the manufacture of products having a tree type of product structure, will benefit from such a study is an important reason to take up this work.
Three important problems faced by these industries are:

1. The difficulties faced in committing a reasonable due date to their customers and achieving a satisfactory performance with respect to adherence to due date.

2. The need to reduce the average manufacturing lead time of the products manufactured.

3. The necessity to reduce the manufacturing cost of the finished products, to remain competitive.

Hence in this thesis the above three factors are considered for investigation through simulation methodology applied to a hypothetical jobshop processing assembly type of jobs.

1.6 Overview of the thesis

The related literature in the area of jobshop scheduling has been collected and analysed in the Chapter 2. Chapter 3 discusses the simulation model of the hypothetical assembly jobshop considered in this thesis. The assumptions made regarding the incoming jobs and the jobshop have been clearly enumerated. Various factors considered in the design of the simulation experiment have also been explained in this Chapter.

Production lead time performance measures achieved by the priority dispatching rules are presented in Chapter 4. The components of production lead time with special reference to jobs having assembly constraints are discussed. New priority dispatching rules have been developed and their performances are compared with the currently used rules.

In Chapter 5, seven due date setting procedures are considered, and the due date performance measures like mean of the average lateness, tardiness, root mean square of tardiness and percentage of tardy jobs under different priority dispatching rules have been analysed. Economic evaluation of priority dispatching rules has been made in Chapter 6.
Three performance measures have been used to compare the rules based on the economies achieved by each rule.

The methodology and the rules developed in this research work have been applied to a sample problem and the related issues of this case study have been presented in Chapter 7. This case study was conducted in a small scale industry manufacturing industrial cooling towers. Development of a simulation model generator (SMG) is discussed in Chapter 8. Important conclusions of this research work have been presented and discussed in Chapter 9.

1.7 Summary

This chapter introduces the various types of discrete part manufacturing systems and points out the unique problems that are encountered in multi-level assembly jobshops. Important terms related to scheduling used in this work have been defined. It discusses the various solution methodologies for scheduling have been discussed the reasons for considering discrete event simulation as a good analysis tool for scheduling purpose have been brought out. An overview of the thesis highlighting its salient features is also presented.

A comprehensive review of the literature related to jobshop and assembly shop scheduling, priority dispatching rules, simulation, and the relevant issues has been presented in the next chapter.