CHAPTER -1

INTRODUCTION
AND
LITERATURE REVIEW

1.1 INTRODUCTION

Pre-World war II: The roots of OR (Operation Research) are as old as science and society. Though the roots of OR extend to even early 1800s, it was in 1885 when Ferderick W. Taylor emphasized the application of scientific analysis to methods of production, that the real start took place. Another man of early scientific management era was Henry L. Gantt. Most job scheduling methods at that time were rather haphazard. A job, for instance, may be processed on a machine without trouble but then wait for days for acceptance by the next machine. Gantt mapped each job from machine to machine, minimizing every delay. Now with the Gantt procedure it is possible to plan machine loadings months in advance and still quote delivery dates accurately. In 1917, A. K. Erlang, a Danish mathematician, published his work on the problem of congestion of telephone traffic. The difficulty was that during busy periods, telephone operators were many, resulting in delayed calls. A few years after its appearance, his work was accepted by the British Post Office as the basis for calculating circuit facilities. The well-known economic order quantity model is attributed to F. W. Harris, who published his work on the area of inventory control in 1915.

During the 1930s, H. C. Levinson, an American astronomer, applied scientific analysis to the problems of merchandising. His work included scientific study of customers' buying habits, response to advertising and relation of environment to the type of article sold. However, it was the First Industrial Revolution which contributed mainly towards the development of OR. Before this revolution, most of the industries were small scale, employing only a handful of men. The advent of machine tools-the replacement of man by machine as a source of power and improved means of transportation and communication resulted in fast flourishing industry. It became increasingly difficult for a single man to perform all the managerial functions (of planning, sale, purchase, production, etc.). Consequently, a division of management function took place. Managers of production, marketing, finance, personnel, research and development etc. began to appear. With further industrial growth, further subdivisions of management functions took place. For example, production department was sub-divided into sections like maintenance, quality control, procurement, production planning, etc.

World War II: During World War II, the military management in England called on a team of scientists to study the strategic and tactical problems of air and land defense. This team was under the direction of Professor P. M. S. Blackett of University of Manchester and a former naval officer. "Blackett circus", as the group was called, included three physiologist, two mathematical physicists, one astrophysicist, one army officer, one surveyor, one general physicist and two mathematicians. Many of these problems were of the executive type. The objective was to find out the most effective allocation of limited military resources to the military operations and to the activities within each operation. The application included the effective use of newly invented radar, allocation of British Air Force Planes to missions and the determination of best patterns for searching submarines. This group of scientists formed the first OR team.

The name operations research (or operational research) was apparently coined because the team was carrying out research on (military) operation. The encouraging results of these efforts led to the information of more such teams in British armed services and the use of scientific teams soon spread to western allies the United States, Canada and France. Thus through this science of operation research originated in England, the united states soon took the lead.in united states these OR teams helped in developing strategies from mining operations, inventing new flight patterns and planning of sea mines.

Post-world war II: immediately after the war, the success of military teams attracted the attention of industrial managers who were seeking solutions to their problems. Industrial operation research in U.K. and U.S.A. developed along different lines. In U.K., the critical economic situation required drastic increase in production efficiency and creation of new markets. Nationalization of a few key industries further increased the potential field for OR. Consequently OR soon spread from military to government, industrial, social and economic planning.

In U.S.A. the situation was different. Impressed by its dramatic success in U.K., defense operations research in U.S.A was increased. Most of the war experienced OR workers remained in military service. Industrial executives did not call for much help because they were returning to the peace-time situation and many of them believed that it was merely a new application of an old technique. Operation research by a variety of names in that country such as operational analysis, operation evaluation, systems analysis, system evaluation, system research and management science.

The progress of industrial operational research in U.S.A. was due to advent of second industrial revolution which resulted in *automation*- the replacement of man by machine as a *source of* *control*. The new revolution began around 1940's when electronic computers became commercially available. The electronic brains processed tremendous computational speed and information storage. But for these digital computers, operation research with its complex computational problems could not have achieved its promising place in all kinds of operational environments.

In 1950, OR was introduced as a subject for academic study in American universities since then this subject has been gaining ever increasing importance for the students of Mathematics, Statistics, Commerce, Economics, Management and Engineering. To increase the impact of operation research, the Operations Research Society of America was formed in 1950.

1.2 SCHEDULING PROBLEM

Scheduling is the task of determining when each operation is to start and finish. Since each operation is in possible completion with other operations for scarce resources of time and capacity, the job of scheduling is neither simple nor easy. Scheduling is a form of decision-making that plays a crucial role in manufacturing and service industries. In the current competitive environment effective scheduling has become a necessity for survival in the market place. Companies have to meet shipping dates that have been committed to customers, as failure to do so may result in a significant loss of goodwill. They also have to schedule activities in such a way as to use the resources available in an efficient manner **Pinedo, M.** [53].

The importance of multiple objective functions arises from the fact that a single objective can be optimized at the expense of others. A widely used technique of defining multiple objective functions is by expressing single objectives into penalty and minimizing the total penalty [59]. The researchers who studied these types of multiple objectives include **Yano** and **Kim** [36]**, Davis** and **Kanet** [20]**, Herrman** and **Kim** [28]. The weighted early/tardy and weighted early/tardy flow time fall under this category.

As an improvement of the famous **Lawler** [39] decomposition theorem for the one-machine total tardiness problem, some conditions on decompositions were obtained by **Potts** and **Wassenhowe** [54] and were used by them to make the decomposition algorithm more efficient. More conditions on the left-most decomposition position were proved and tested by **Chang et al.** [13]**. Islam** and **Eksioglu** [32] presented a tabu search approach for solving the problem. They showed that their tabu search heuristic out performs the heuristics given by **Fry et al.** [26], **Potts** and **Van Larhooven** [55], and **Holsenbeck** and **Russel** [30].

Scheduling deals with the allocation of scarce resources to tasks over time. It is a decision making process with the goal of optimizing one or more objective functions. The resources and tasks in an organization can take many forms. The resources may be machines in a workshop, runways at an airport, crew at a construction site and so on. Defined scheduling as follows:

Scheduling is the allocation of resources over time to perform a collection of tasks… Scheduling is a decision making function: it is the process of determining a schedule. Scheduling is a body of theory: it is a collection of principles, modals, techniques, and logical conclusions that provide insight into the scheduling function, **Baber** [7]. Also, **Morton** and **Pentico** [47], Scheduling is the process of organizing, choosing, and timing resource usage to carry out all the activities necessary to produce the desired outputs at the desired times, while satisfying a large number of time and relationship constraints among the activities and the resources.

Some of the various objectives on which extensive work was reported include minimizing the makespan or total completion time [27] and [50]**,** maximum lateness [37], earliness and tardiness penalties [5], mean flow time [33] etc. A vast research was reported towards the single machine tardiness problems, but little work done for solving the tardiness problem in job shops.

1.3 MACHINE ENVIRONMENT

Machine environment represents different configurations of machines in the system. First case is the single-stage production system where each job is performed either on one machine or on *m* machines in parallel. Among parallel machines identical, uniform and unrelated variants are distinguished in the following ***Figure 1.1.***

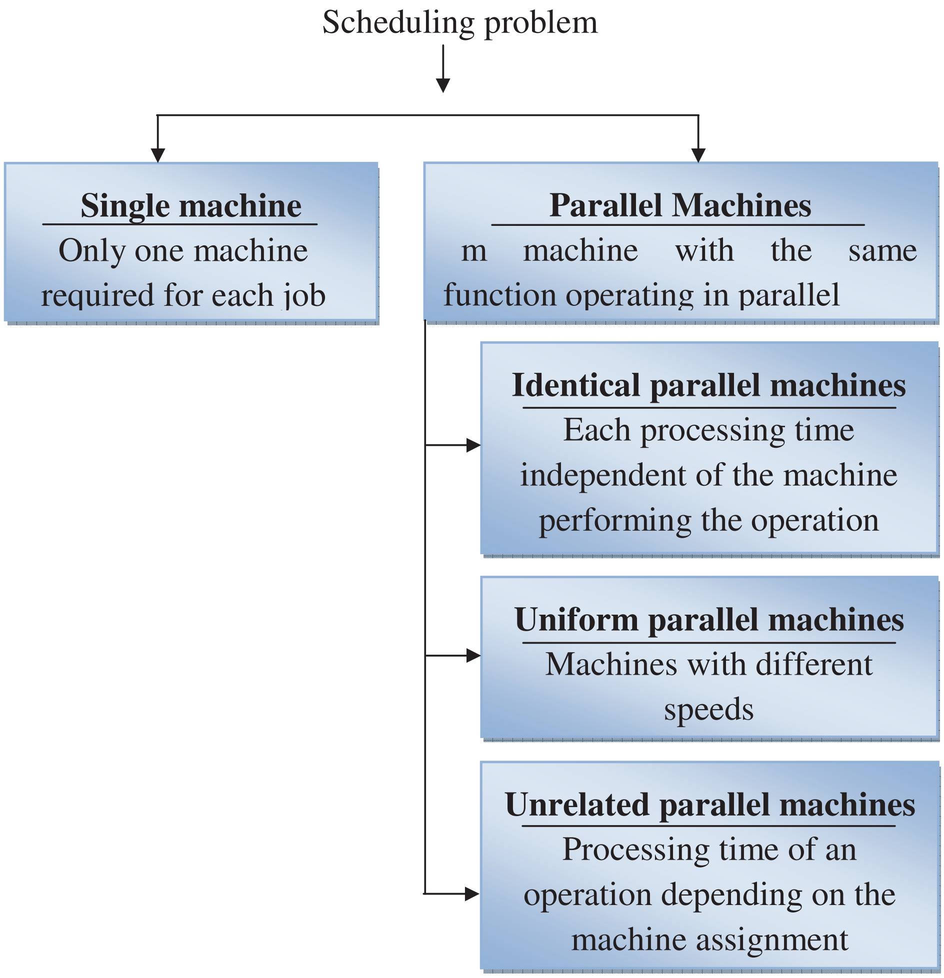

Figure1.1. *Machine environment - single stage production*

The second case is the multi-stage system in which jobs require operations on various machines. Conversely to the first case, each machine has different function. We study two subtypes are distinguished: flow shop and job shop. In the flow shop scheduling problem all jobs has the same machine routing i.e. the sequence in which operations of each job are performed on different machines is the same for every job. The job shop scheduling problem, the most formidable problem, each job has its specific, prescribed and different machine routing. Each job is processed at most once on each machine that distinguish it from the other two cases. The multi-stage production is presented in ***Figure 1.2.*** The last remark is that the common feature of all machine environments is that the machines are available to the process from the time zero.

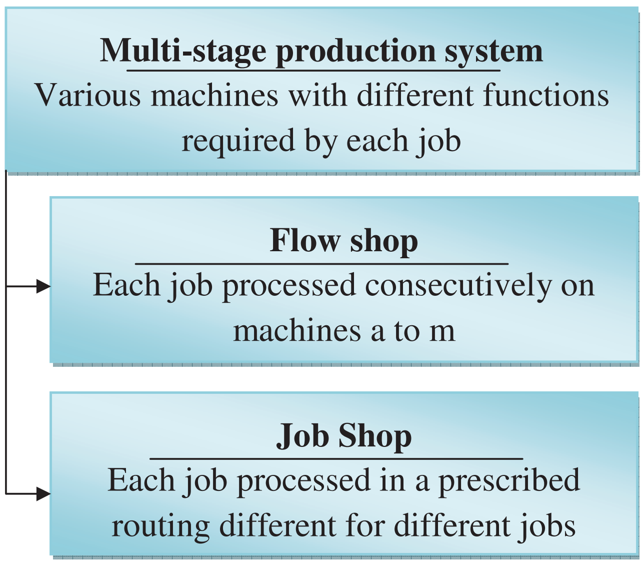

Fig.1.2

1.4 SCHEDULING TERMINOLOGY

Scheduling has been the subject of extensive research since the early 1950's. The main focus is on the efficient allocation of activities over a given amount time. Many of the early developments in the field of scheduling were motivated by problems arising in manufacturing. It was natural to employ the vocabulary of manufacturing when describing scheduling problems. Now even through scheduling work is of considerable significance in many non-manufacturing areas, the terminology of manufacturing is still frequently used. Thus resources are usually called **"machines"** and basic task modules are called **"jobs"**. Sometimes, job may consist of several elementary to as **"operations"**. Three basic pieces of information that helps to describe jobs are:

PROCESSING TIME (t_j)**:** It is the time required to process job j. The processing time, will normally include both actual processing time and set-up time.

READY TIME (r_j)**:** It is the time at which job j is available for processing.

DUE DATE (d_j)**:** The due date d_j, of job j represents the committed completion date, the date the job is promised to the customer. The completion of a job after its due date is allowed, but a penalty is incurred. When the due date must absolutely be met, it is referred to as a deadline.

The single machine common due date problem is a scenario where al1 the jobs have a common due date d. **Arthnari** [3] gave a branch and bound algorithm for the problem. **Lenstra et al.** [43] proved even if the jobs have equal processing times and a different penalty, the problem still remains NP-hard. **Morton T. E., et al.** [46] presented myopic heuristic for the problem when al1 the jobs have equaled processing times.

WEIGHT (w_j)**:** The weight w_j of job j is basically a priority factor. It denotes the importance of job j relative to the other jobs in the system. For example, a weight may represent the actual cost keeping the job in the system.

COMPLETION TIME (C_j)**:** The time at which the processing of job j is finished.

FLOW TIME (F_j)**:** The amount of time job j spends in the system. It is a measure, which indicates the waiting time of job in a system, and it gives some idea about in process inventory due to a schedule.

MAKESPAN $(C_{\max})$: The time required to complete processing of all the jobs.

LATENESS (L_j): The amount of time by which the completion time of job j exceeds its due date. Lateness measures the conformity of the schedule to a given due date. Lateness quantity taken on negative values whenever a job is completed early. Negative lateness represents better service than requested, while positive lateness represents poorer service than requested.

TARDINESS (T_j) **:** The amount of time by which a late job j is late. For operations that are early or on time, the tardiness is considered to be zero. Thus $T_j = \max(0, L_j)$.

PARALLEL AND IDENTICAL MACHINES (P_m)**:** There are m identical machines in parallel. In the remainder of this section, if m is omitted, it means that the number of machines is arbitrary; i.e., the number of machines will be specified as a parameter in the input. Each job j requires a single operation and may be processed on any one of the m machines.

UNRELATED MACHINES (R_m)**:** There are m machines in parallel, but each machine can process the jobs at a different speed. Machine i can process job j at speed S_{ij}. The time p_{ij} that job j spends on machine i is equal to P_j / S_{ij}, assuming that job j is completely processed on machine i.

NO-WAIT (nwt): The no-wait constraint is for flow shops only. Jobs are not allowed to wait between two successive machines. If nwt is not specified in the β field, waiting is allowed between two successive machines.

- The objective functions to be minimized are as follows:

Makespan $(C_{\max})$: The makespan is defined as max $(C_1, C_2, ..., C_n)$.

Maximum Lateness $(L_{\max})$**:** The maximum lateness is defined as max $(L_1, L_2, ..., L_n)$.

Total Weighted Completion Time $\left(\sum W_j C_j\right)$: The total (unweighted) completion time is denoted by $\sum C_j$.

Total Weighted Tardiness $\left(\sum W_j T_j\right)$: The total (unweighted) tardiness is denoted by $\sum T_j$.

Weighted Number of Tardy Jobs $\left(\sum W_j U_j\right)$: The total (unweighted) number of tardy jobs is denoted by $\sum U_j$.

In addition, the range of application areas for scheduling theory goes beyond manufacturing to include agriculture, hospital, transport, computer etc. Therefore, it is possible to encounter, for example, a problem in the scheduling of outpatient visits to specialists in a diagnostic clinic and to find the system described generically as the processing of “jobs” by “machines”.

1.5 ASSUMTIONS

A variety of assumptions is made in sequencing and scheduling problems the nature of these assumptions depends on the sequencing environment. The following list contains typical assumptions generally applied to scheduling problem with variations depending on the situation.

1. The set of the jobs and the set of the machines are known fixed;
2. All jobs and all machines are available at the same time and are independent;
3. All jobs and machines remain available during an unlimited period;
4. The processing time for each job on all machines is fixed, has a known probability distribution function, and sequence independent;
5. Step times are included in processing times;
6. A basic batch size is fixed for all jobs;

7. All jobs and all machines are equally weighted;
8. Each job is processed by all the machines assigned to it.

1.6 OBJECTIVES OF SCHEDULING

Some of the common objectives of scheduling are

1. Meet due dates
2. Minimize average floe time through the system
3. Minimize the total number of tardy jobs
4. Minimize the average tardiness of the jobs
5. Minimize the maximum tardiness of the jobs
6. Minimize work-in-process inventory
7. Provide for high machine utilization and
8. Minimize production costs.

In these objectives, 1-5 are aimed primarily at providing a high level of customer service and 6-8 are aimed mainly at providing high level of plant efficiency. The objectives mentioned above are often conflicting. One can do a better job of meeting due dates if more capacity is provided and if the work center capacity is less utilized. Similarly, more capacity will typically reduce flow time, but at reduced capacity utilization.

1.7 SIGNIFICANCE OF SCHEDULING

Scheduling is a decision making practice that is used on a regular basis in many manufacturing and services industries. Its aim is to optimize one or more objectives with the allocation of resources to tasks over given time periods. The resources and tasks in an organization can take a lot of different forms. The resources may be machines in a workshop, crews at a construction site, processing units in a computing environment, and runways at an airport and so on. The tasks may be operations in a production process, take-offs and landings at an airport, executions of computer programs, stages in a construction project, and so on. Each task can have a definite priority level, an earliest likely starting time and a due date. The objectives can also take many different forms and one objective may be the minimization of the completion time of the last job and another may be the minimization of the number of jobs completed after their respective due dates. Scheduling plays an important role in most manufacturing and service systems as well as in most information processing environments.

Within manufacturing scheduling, there are many different types of problem classes. These include single machine, parallel machine, flow shop, job shop, manufacturing cells and assembly line scheduling problems. Each of these problem classes is unique, and each has its own constraints and objectives. A more detailed description of each problem class is given in the following sections.

1.8 SINGLE MACHINE SCHEDULING PROBLEM

The single machine environment is very simple and basic job shop problem consisting of a single processor and n jobs. Each job has one operation to be performed. It provides a basis for heuristics for more complicated machine environments. Complicated machine environments are often decomposed into single machine sub problems. Polynomial time or heuristic algorithms are already found for most of the single machine cases. For single machine problems it has been proved that SPT (Shortest Processing Time) is optimal for finding the minimum total completion time, weighted completion time, average flow time and EDD (Earliest due date) gave better schedules for performance measures like maximum lateness, number of tardy jobs, total tardiness and other due date related objectives. In the single machine environment with ready time set at 0, MST maximizes the minimum lateness.

The basic single machine-scheduling problem is characterized by the following conditions:

- A set of independent, single operation jobs are available for processing at time zero
- Set-up time of each job is independent of its position in job sequence. So, the set-up time of each job can be included in its processing time.
- One machine is continuously available and is never kept idle when work is waiting.
- Each job is processed till its completion without break.

The following Gantt chart (***Fig 1.3***) presents single machine with n-jobs.

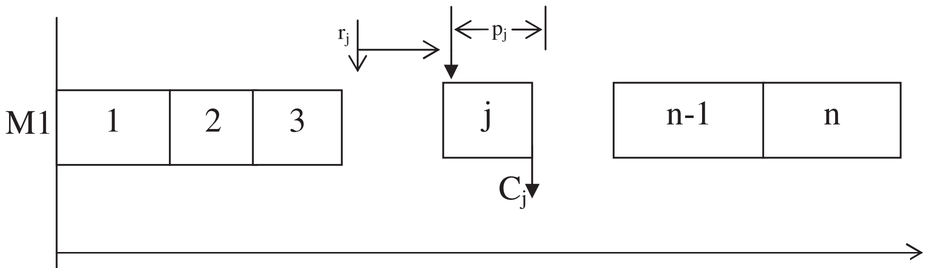

Figure 1.3. *Gantt chart*

1.9 PARALLEL MACHINE SCHEDULING

Parallel machine scheduling involves scheduling a set of tasks on two or more machines that work in parallel with each other. The machines perform identical operations and may or may not operate at the same pace. An example layout is shown in ***Figure 1.4*** - Parallel

Machine Layout. In this type of problem, the tasks are assigned to either machine for processing, and flow between machines is not allowed.

When similar type of machines are available in multiple numbers and jobs can be scheduled over these machines simultaneously, Parallel machines scheduling environment is at hand as show in ***Figure 1.4*** below

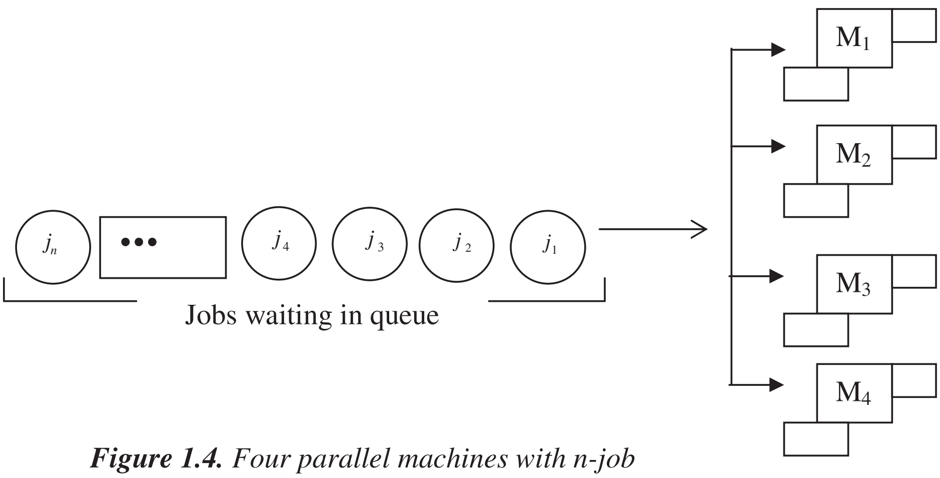

Figure 1.4. *Four parallel machines with n-job*

1.10 FLOW SHOP SCHEDULING

A flow shop scheduling problem consists of two or more machines and a set of tasks that must be processed on each of these machines. This arrangement is called a flow shop because products flow along a specific unidirectional path. In flow shop, the technological constraints demand that the jobs pass between the machines in the same order. Hence, there is a natural processing order of the machines characterized by the technological constraints for each and every job in flow shop. Frequently occurring practical scheduling problems focus on two important decisions:

- The sequential ordering of the jobs that will be processed serially by two or more machines
- The machine loading schedule which identifies the sequential arrangement of start and finish time on each machine for various jobs.

Managers usually prefer job sequence and associated machine loading schedules that permit total facility processing time, mean flow time, average tardiness, and average lateness to be minimized. The flow shop contains m different machines arranged in series on which a set of n jobs are to be processed. Each of the n jobs requires m operations and each operation is to be performed on a separate machines. The flow of the work is unidirectional; thus every job must be processed through each machine in a given prescribed order. In other words, if machines are numbered form $1,...,m$, then operations job j will correspondingly be numbered $(1, j), (2, j),...,(m, j)$. In this context, each job has been assigned exactly m operations whereas in real situations a job may have a fewer operations. Nevertheless, such a job will still be treated as processing m operations but with zero processing time correspondingly.

The general n jobs, m machine floe shop scheduling problem is quote formidable. Considering an arbitrary sequence of jobs on each machine, there are $(n!)^m$ possible schedules which poses computational difficulties. Therefore, efforts in the past have been made by researchers to reduce this number of feasible schedules as much as possible without compromising on optimality condition. Literature on flow shop process indicates that it is not sufficient to consider only schedules in which the same job sequence occurs on each machine with a view to achieving optimality. On the other hand, it is not always essential to consider $(n!)^m$ schedules in search for an optimum.

The flowshop scheduling problem is well known in the literature (**Brucker et al.** [11]; **Framinan et al.** [23]; **Cheng et al.** [16]). Since the problem is known to be NP-hard for more than two machines, many exact and heuristic approaches have been proposed to solve it. The flowshop scheduling problem is important within the manufacturing industry because it can be used to represent the scheduling of flexible manufacturing systems and production lines. In order to address the scheduling of flowshop plants, the proposed approach decomposes the problem into two levels: Planning and Scheduling. Planning level is solved using constraint programming (**Baptiste et al.** [8]; **Rodrigues et al.** [58]). A new proposition to tackle storage restrictions within constraint programming is presented. Although the simultaneous solution of planning and scheduling could be attempted, the planning purpose within this work is to prune the resulting scheduling problem. In the next sessions each of the proposed levels will be discussed and results for the scheduling of an instance of the wet-etch station problem (**Karimi et al.** [35]) will be presented. This work has been written considering batch production. However the same concepts may be applied to the scheduling of flexible manufacturing systems.

1.11 JOB SHOP SCHEDULING

The classical general job-shop scheduling problem is defined as follows: There are *n* Jobs to be processed through m machines. Each job must pass through each machine exactly once. The processing of a job on a machine is called an operation and requires a duration called the processing time. Technological constraints demand that each job should be processed through machines in a specific order. Each job has a release time and a deadline. The general problem is to find a sequence in which jobs pass between the machines which is compatible with the technological constraints and optimal with respect to some performance criterion. Various objectives such as minimizing makespan. Minimizing total tardiness etc. can be considered. The job shop scheduling problem was first formulated and examined by **Akers** and **Friedman** [1].

CRITERIA OF THE SCHEDULING PROBLEM

According to **RinnooyKan** [56] and **French** [25] the criteria for scheduling problems are classified according to three measures: completion time; due-dates, and inventory and machine utilization.

In the scheduling literature, there are other criteria such as a combination of two or more of the above mentioned criteria. Also, there are other criteria in the scheduling literature that were not mentioned above. For additional criteria, the reader can refer to **Conway, Maxwell, et. al** [19], **Baker, et. al.** [9].

- **Criteria based on completion times**

1) Completion time of job i : C_i

2) The total completion time : $\sum_{i=1}^{n} C_i$

3) The total weighted completion time : $\sum_{i=1}^{n} W_i C_i$

4) The total weighted waiting time : $\sum_{i=1}^{n} W_i \sum_{j=1}^{m} W_i$

5) Flow time of job i : $F_i = C_i - r_i$

6) Maximum completion time : $C_{\max} = \max 1,...,n\{C_i\}$.

7) The total floe time : $\sum_{i=1}^{n} F_i$

8) The total weighted flow time : $\sum_{i=1}^{n} W_i F_i$

9) Average floe time : $\overline{F}$

10) Maximum flow time: $F_{\max}$

11) Waiting time of job i : $W_i = F_i - \sum_{j=1}^{m} P_{ij}$.

12) The total waiting time : $\sum_{i=1}^{n} \sum_{j=1}^{m} W_{ij}$.

13) Average completion time: $\overline{C}$

14) Average waiting time : $\overline{W}$

1.12 DISPATCHING RULES

The scheduling problem has been solved using dispatching rules (also called scheduling rules, sequencing rule, decision rules, or priority rules). These dispatching rules are used to determine the priority of each job. The priority of a job is determined as a function of job parameters, machine parameters, or shop characteristics. When the priority of each job is determined, jobs are sorted and then the job with the highest priority is selected to be processed first.

Effect of dispatching rules: Since the scheduling problem can be viewed as a network of queues, the effect of dispatching rules can be tested using queuing network theory. During last six decades, a series of investigations was done to continue studying the outcome of dispatching rules. Several important conclusions can be obtained from those series of studies.

- The SPT rule minimizes the average flow time, average lateness, and average number in queue, average tardiness, and percentage of jobs tardy. The SPT is insensitive to due date tightness.
- COVERT rule is superior in minimizing the mean tardiness when compared to SPT and TSPT.
- Job slack rules are more effective to minimize the tardiness.
- The size of the shop is not a significant factor.
- The FCFS rule achieves a small proportion of jobs tardy if the shop is not heavily loaded.

The above conclusions have inspired researchers to study the effect of the dispatching rule in more complex and different job shop environments. Also, advancements in computer technology and software that can be used to simulate and study the job shop environment have helped researchers to do more work in this fruitful area.

Priority rules are based on one parameter (simple rule) or some combination of several parameters. Since it is difficult to predict which priority rules are the best for a given situation(e. g, the specific objectives, load, shop configuration and constraints), many simulation studies have been conducted to assess the relative effectiveness of the different rules for a variety of job shops, some common sequencing riles for scheduling a single machine problem are: First Come First Served (FCFS), SPT (Shortest Processing Time), LPT (Longest Processing Time), EDD (Earliest Due Date), and CR (Critical Ratio). In FXCFS, the sequencing of job is done according to the arrival order of the jobs at the workstation. In SPT, the jobs are sequenced in the order of increasing processing time of jobs. In contrast LPT gives the jobs sequence according to the decreasing order of the processing times. EDD sequences the jobs in the increasing order of their due date. The job shop dispatching and common priority scheduling rules are graphically represented by the following ***figure 1.5.***

Job Shop Dispatching and Common Priority Scheduling Rules

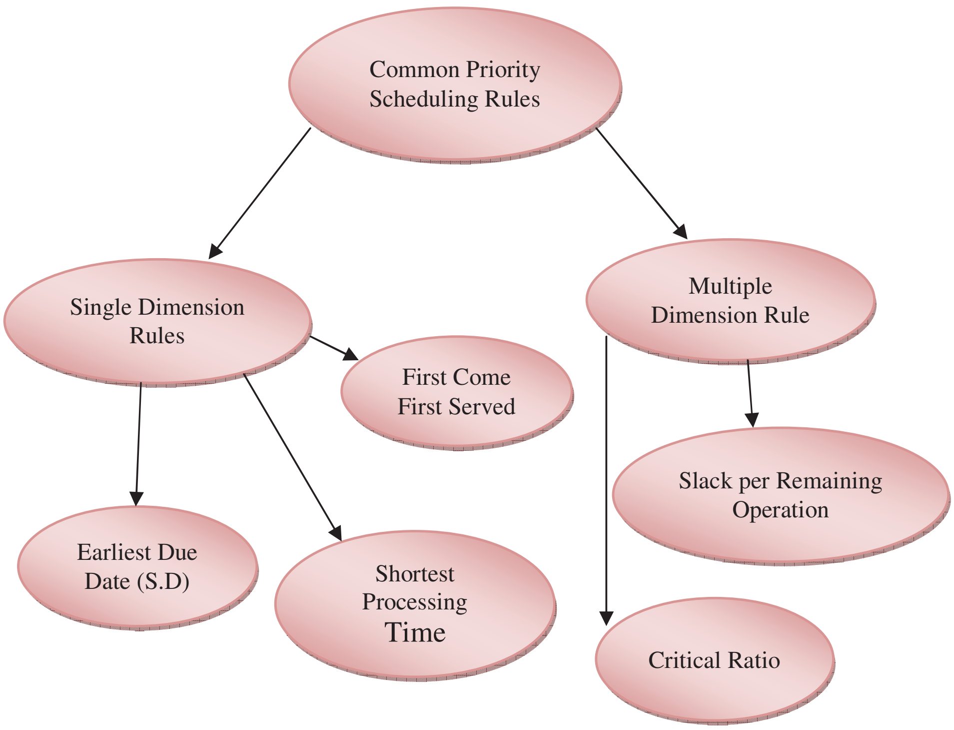

Fig.1.5

1.13 ORGANIZATION OF THE THESIS

The first chapter briefly describes the scheduling problems, their significance in the manufacturing industry and also introduces the present problem dealt with in this thesis. ***The second chapter***, we study the multi-jobs single machine scheduling problem under the effect of nonlinear job deterioration and time-dependent. The single machine scheduling problem with non-linear deterioration learning and present the complexity results concerning time dependent scheduling on a single machine. Also present the results concerning a single machine and minimization of the $C_{\max}$, $\sum C_j$ and $L_{\max}$ criterion. ***The third chapter***, Present work deals with analysis maintenance activity single-machine scheduling and due-date assignment simultaneously. The objective is to find the optimal maintenance position as well as the optimal location of the common due-date for minimizing the total of earliness, tardiness and due-date costs. To solve the scheduling problem addressed in this work, we have to determine the job sequence, the common due-date, and the location of a maintenance activity. We also present two special cases of the problem and show that they can be optimally solved by a lower order algorithm. ***The fourth chapter***, we consider a total penalty for the n job, one machine scheduling problem in which all jobs have a common due date. We prove that the optimal due date result can be generalized to the parallel machine problem. The problem of simultaneously available jobs on several parallel and identical machines. The problem is to find the optimal due date, assuming this to be the same for all jobs and we present a simple heuristic to find an approximate solution. ***The chapter fifth*****,** the problem of scheduling n single operation jobs with a common due date on m parallel machines so as to minimize the sum of the absolute lateness. In this case of non-identical machines we reduced the problem to a transportation problem that can be solved by a polynomial time algorithm. ***The chapter sixth***, we study the flow shop scheduling problem with increasing and decreasing linear deterioration on weighted dominant machines and also deal with some special case of general, no-wait permutation flow shop scheduling problem, respectively. Special cases mean that the machines form an increasing series of dominant machines, and decreasing series of dominant machines. Finally, in ***chapter seven***, this chapter consists of a comparative study on the performance of dispatching rule for job shop scheduling problems objectives including the tardy rate and maximum tardiness. The focused approach is the dispatching rules. Some dispatching ruled are selected form the literature, and their features and design concepts are discussed.

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