**Unit 5 (Job sequencing)**

Job sequencing is the arrangement of the task that is to be performed or processed in a machine in that particular order. Job sequencing problem has become the major problem in the computer field. A finite set of n jobs where each job consists of a chain of operations and a finite set of m machines where each machine can handle at most one assignment at a time. Each assignment needs to be evaluated during an uninterrupted period of a given length on a given machine and our Purpose is to find a inventory, that is, an allocation of the operations to time intervals to machines that has minimal length.

Solving a problem or getting a job done by a computer can be quite a demanding task. This is because it requires considerable thought, careful planning, and attention to details. It can also be challenging and exciting with possibilities for creative satisfaction. This is because when we are solving a problem with a computer, we are essentially teaching a dumb servant how to do a job. We have already seen that the description of how to do work is initially prepared in form of an algorithm and we did give a definition! But that definition is to be used with some care.

**Objective of Job Sequencing**

* + Job completions should not be “late” (about due dates).
	+ The course of the time during which a job stays in the system should be “minimum” (about flow time)
	+ It is greedy to fully utilize the capacities of work centers (about work center utilization).

A schedule is a job sequence determined for every machine of the processing system. Scheduling is a decision-making process of allocating limited resources to activities over time. The schedule can be characterized by starting or completion times of all operations of the jobs. The objective is to construct a schedule that minimizes a given objective function. The scheduling task is shown in figure 1.



# Fig 1: Scheduling Task

Standard scheduling requirements are specified as follows.

* + A job cannot be processed by two or more machines at a time,
	+ A machine cannot process two or more jobs at the same time.

Depending on the type of scheduling system, specific constraints should be satisfied (jobs may be released at different times, there may be allowed preemption of jobs by other jobs, etc.).The various scheduling issues are described as follows

* + Scheduling accord with the timing of operations
	+ The assignment is the allocation and prioritization of demand
	+ Significant issues are the type of scheduling, backword or forward
	+ The criteria for priorities

There are two types of scheduling. They are

* + Forward scheduling
	+ Backward scheduling

Forward scheduling starts as soon as the requirements are known. It produces a feasible schedule though it may not meet due dates. It frequently results in buildup of work in process inventory.



# Fig 2: Types of scheduling

Backward scheduling begins with the due date and schedules the final operation first. Schedule is produced by working conversely though the processes Resources may not be available to accomplish the schedule. The forward and the backward scheduling is shown in the figure 2.

In a typical job scheduling conditions, there is a centralized scheduling stage with a set of on-demand technologies to support its functions. The IT operations and significance scheduling teams interact with the scheduler through a client tier or a Web interface. Conventionally, job scheduling solutions performed their work using platform specific promotors, including Microsoft Windows, UNIX, Linux, and mainframe operating systems. Job scheduling solutions schedule, define and manage application jobs, which are the individual steps needed to deliver the services. There has also been an effort to integrate and schedule jobs using the latest business intelligence, data warehouse, transform, and extract, load (ETL) applications. These solutions require integration of database activities.

The solutions process data from multiple applications across the enterprise to deliver the business insight required to make the right strategic decisions at the right time. Administering dependency logic and automating job step sequencing are critical to the delivery of relevant and timely information for strategic decision making. Job scheduling solutions can also manage backup, file delivery, and storage processes. More recently, job schedulers have been integrated with virtualization solutions and certain cloud services that have the capability to schedule jobs in a virtualized environment.

# SEQUENCING N JOBS IN TWO MACHINES

The N jobs can be sequenced in two machines by the following steps.

* + - Calculate the time deviation table for the sequencing problem.
		- The cell which has both the time deviation vectors as zero for machine 1, perform that job first.
		- If more than one cell has both vectors as zero then calculate sum deviation of the corresponding columns. Cell which has largest sum deviation is performed first and so on.
		- Similar steps are followed for machine 2 but here the jobs are performed lastly.
		- Again calculate the reduced time deviation table for all non assigned jobs and continue the steps mentioned above.
		- Stop the process if we get sequence involving all jobs.
		- Arrange the obtained sequence in reverse order to get minimum total elapsed time.

Sequencing N jobs in two machines can be explained by the following example.

**Example:** Processing of N jobs in two machines is given as follows

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J5 | J6 | J7 | J8 | J9 |
| M1 | 2 | 5 | 4 | 9 | 6 | 8 | 7 | 5 | 4 |
| M2 | 6 | 8 | 7 | 4 | 3 | 9 | 3 | 8 | 11 |

The time deviation table will be first calculated for the given problem according to the equations (1) and (2). The table is as follows

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J5 | J6 | J7 | J8 | J9 |
| M1 | (7,4) | (4,3) | (5,3) | (0,0) | (3,0) | (1,1) | (2,0) | (4,3) | (5,7) |
| M2 | (5,0) | (3,0) | (4,0) | (7,5) | (8,3) | (2,0) | (8,4) | (3,0) | (0,0) |

The jobs J4 of machine 1 and J9 of machine 2 has both vectors zero and is assigned as follows

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J4 |  |  |  |  |  |  |  | J9 |

The reduced time duration table for the remaining jobs is as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J5 | J6 | J7 | J8 |
| M1 | 2 | 5 | 4 | 6 | 8 | 7 | 5 |
| M2 | 6 | 8 | 7 | 3 | 9 | 3 | 8 |

The time deviation table is calculated for this sequence as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J5 | J6 | J7 | J8 |
| M1 | (6,4) | (3,3) | (4,3) | (2,0) | (0,1) | (1,0) | (3,3) |
| M2 | (3,0) | (1,0) | (2,0) | (6,3) | (0,0) | (6,4) | (1,0) |

Job J6 in machine 2 has both the vectors as zero and so it is assigned to the sequence as

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J4 |  |  |  |  |  |  | J6 | J9 |

The time duration table for the jobs J1, J2, J3, J5, J7, and J8 is specified and the jobs J4, J6, J9 will not be specified in this table since it is assigned to the machines as shown above.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J5 | J7 | J8 |
| M1 | 2 | 5 | 4 | 6 | 7 | 5 |
| M2 | 6 | 8 | 7 | 3 | 3 | 8 |

The time deviation table for the above jobs is calculated as follows

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J5 | J7 | J8 |
| M1 | (5,4) | (2,3) | (3,3) | (1,0) | (0,0) | (2,3) |
| M2 | (2,0) | (0,0) | (1,0) | (5,3) | (5,4) | (0,0) |

The jobs J7 in machine 1, J2 and J8 in machine 2 have both vectors zero and it is assigned as follows

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J4 | J7 |  |  |  | J2 | J8 | J6 | J9 |

The time duration table for the remaining jobs J1, J3, J5 is given as follows

|  |  |  |  |
| --- | --- | --- | --- |
| Jobs/Machines | J1 | J3 | J5 |
| M1 | 2 | 4 | 6 |
| M2 | 6 | 7 | 3 |

The time deviation table for the above jobs is calculated as follows

|  |  |  |  |
| --- | --- | --- | --- |
| Jobs/Machines | J1 | J3 | J5 |
| M1 | (4,4) | (2,3) | (0,0) |
| M2 | (1,0) | (0,0) | (4,3) |

Here J5 in machine 1 and J3 in machine 2 contain both the vectors as zero and so it is assigned and the remaining J1 is also assigned as follows

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J4 | J7 | J5 | J1 | J3 | J2 | J8 | J6 | J9 |

This sequence is then arranged in the reverse order from last obtained job to the machine 1 jobs and machine 2 jobs. It is represented as follows

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J1 | J5 | J7 | J4 | J9 | J6 | J8 | J2 | J3 |

The above sequence is the required sequence for the given problem. The minimum total elapsed time is calculated for this job sequence. The total elapsed time is given as Total Elapsed Time = Time between starting the first job in the optimum sequence on machine 1 and completing the last job in the optimum sequence on machine M.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Job sequence | Time-in | Machine 1 | Time-out | Time-in | Machine | 2 | Time-out |
| 1 | 0 | 2 | 2 | 8 |
| 5 | 2 | 8 | 8 | 11 |
| 7 | 8 | 15 | 11 | 14 |
| 4 | 15 | 24 | 14 | 18 |
| 9 | 24 | 28 | 18 | 29 |
| 6 | 28 | 36 | 29 | 38 |
| 8 | 36 | 41 | 38 | 46 |
| 2 | 41 | 46 | 46 | 54 |
| 3 | 46 | 50 | 54 | 61 |

The minimum total elapsed time thus obtained is 61 hours.

# SEQUENCING N JOBS IN THREE MACHINES

The N jobs can be sequenced in three machines by the following steps

* + - Calculate the time deviation table for the sequencing problem.
		- The cell which has both the time deviation vectors as zero for machine 1, perform that job first. If both the time deviation vectors are zero in machine 3 then perform that job in the last and if the vectors are zero in machine 2 then find the sum of deviation vectors separately for above and below of the zero cell. Compare both the deviations.
		- Perform that particular job first if the sum of deviation vectors above the cell is less than the other one. If both are same then perform the job either in first or last.
		- Again calculate the reduced time deviation table for all non assigned jobs and continue the steps mentioned above.
		- Stop the process if we get sequence involving all jobs.
		- Arrange the obtained sequence in reverse order to get minimum total elapsed time.

**Example:** N jobs to be processed in three machines are given as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J5 | J6 | J7 |
| M1 | 3 | 8 | 7 | 4 | 9 | 8 | 7 |
| M2 | 4 | 3 | 2 | 5 | 1 | 4 | 3 |
| M3 | 6 | 7 | 5 | 11 | 5 | 6 | 12 |

The time deviation table will be first calculated for the given problem according to the equations (1) and (2). The table is as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J5 | J6 | J7 |
| M1 | (6, 3) | (1, 0) | (2, 0) | (5, 7) | 0, 0) | (1, 0) | (2, 5) |
| M2 | (1, 2) | (2, 5) | (3, 5) | (0, 6) | (4, 8) | (1, 4) | (2, 9) |
| M3 | (6, 0) | (5, 1) | (7, 2) | (1, 0) | (7, 4) | (6, 2) | (0, 0) |

Jobs J5 in machine 1 and J7 in machine 3 have both the vectors zero and so they are assigned to job sequence as follows

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| J5 |  |  |  |  |  | J7 |

The time duration table for the jobs other than J5 and J7 are given as follows

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J6 |
| M1 | 3 | 8 | 7 | 4 | 8 |
| M2 | 4 | 3 | 2 | 5 | 4 |
| M3 | 6 | 7 | 5 | 11 | 6 |

The time deviation table for the above jobs is specified as follows

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 | J6 |
| M1 | (5, 3) | (0, 0) | (1, 0) | (4, 7) | (0, 0) |
| M2 | (1, 2) | (2, 4) | (3, 5) | (0, 6) | (1, 4) |
| M3 | (5, 0) | (4, 1) | (6, 2) | (0, 0) | (5, 2) |

The jobs J2, J6 in machine 1 and J4 in machine 3 have both the vectors zero and so they are arranged as follows

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| J5 | J6 | J2 |  |  | J4 | J7 |

The time duration table for the remaining jobs is given as follows

|  |  |  |
| --- | --- | --- |
| Jobs/Machines | J1 | J3 |
| M1 | 3 | 7 |
| M2 | 4 | 2 |
| M3 | 6 | 5 |

The time deviation table for the above two jobs are given as follows

|  |  |  |
| --- | --- | --- |
| Jobs/Machines | J1 | J3 |
| M1 | (4, 3) | (0, 0) |
| M2 | (0, 2) | (2, 5) |
| M3 | (0, 0) | (1, 2) |

The job J3 in machine 1 and the job J1 in machine 3 are then assigned to the sequence as follows

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| J5 | J6 | J2 | J3 | J1 | J4 | J7 |

This sequence is then arranged in the reverse order from last obtained job to the machine 1 jobs and machine 2 jobs. It is represented as follows

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| J1 | J3 | J2 | J6 | J5 | J7 | J4 |

The minimum total elapsed time is calculated for the obtained sequence as follows

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Job sequence | Machine 1Time-in Time- out | Machine 2Time-in Time- out | Machine Time-inout | 3Time- |
| 1 | 0 | 3 | 3 | 7 | 7 | 13 |
| 3 | 3 | 10 | 7 | 9 | 13 | 18 |
| 2 | 10 | 18 | 9 | 12 | 18 | 25 |
| 6 | 18 | 26 | 12 | 16 | 25 | 31 |
| 5 | 26 | 35 | 16 | 17 | 31 | 36 |
| 7 | 35 | 42 | 17 | 20 | 36 | 48 |
| 4 | 42 | 46 | 20 | 25 | 48 | 59 |

Thus the minimum total elapsed time for the given sequence is 59 hours.

# SEQUENCING N JOBS IN M MACHINES

The N jobs can be sequenced in M machines by the following steps

* + - The M machine problem is first converted in to the two machine problem by either of the following conditions

Minimum of M1 ≥ Maximum of (M2, M3 … Mm-1) (3)

Minimum of Mm ≥ Maximum of (M2, M3 … Mm-1) (4) Or both hold.

* + - The required sequence is then obtained by applying the time deviation method as done in two machine problem previously.

**Example:** Sequencing of N jobs in M machines can be given by the following problem

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 |
| M1 | 7 | 6 | 5 | 8 |
| M2 | 5 | 6 | 4 | 3 |
| M3 | 2 | 4 | 5 | 3 |
| M4 | 3 | 5 | 6 | 2 |
| M5 | 9 | 10 | 8 | 6 |

The M machine problem is converted into two machine problem by the conditions (3) and (4). The converted two machine problem is given as follows

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Jobs/Machines | J1 | J2 | J3 | J4 |
| G | 17 | 21 | 20 | 16 |
| H | 19 | 25 | 23 | 14 |

The required job sequence is then obtained by the procedure that is normally applied for the two machine problem as explained by the above example.