Μηχανουργική Τεχνολογία ΙΙ

“Προγραμματισμός Συστημάτων Παραγωγής”

Καθηγητής Γεώργιος Χρυσολούρης
Πολυτεχνική Σχολή
Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών

Manufacturing Processes II

"Scheduling in Manufacturing Systems"

Professor George Chryssolouris
School of Engineering
Dept. of Mechanical Engineering & Aeronautics

SCHEDULING IN MANUFACTURING SYSTEMS

- In process planning, the major issue is **how** to utilize the manufacturing system's resources to produce a part: how to operate the different manufacturing processes.

- In scheduling. The issue is **when** and in **what sequence** the different jobs should pass through the production facilities.

- A schedule must be compatible with the technological constraints established during process planning and should be optimal with respect to the performance criteria.

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- There is a wealth of literature related to scheduling problems, addressing both issues specific to manufacturing systems and aspects of scheduling in other areas.

- In manufacturing, the theoretical treatment of the scheduling problem makes assumptions related to the production facilities (the behavior of the different resources) and the job configuration (how the different jobs are structured, how flexible the technological constraints are, etc.).

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There are two major categories of scheduling problems:

- Static
- Dynamic or stochastic

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- In the case of **static scheduling problems**, the arrival and processing times for the different jobs are deterministic and known in advance.
- In the case of a **dynamic/stochastic scheduling** problem, the arrival times follow some distribution and the processing times vary and are often uncertain.
- In the case of a static problem, there is usually no resource breakdown – during the period of time one is scheduling, all of the resources can be either idle or working.
- In the case of a dynamic/stochastic problem, resource failures are allowed.
- In the case of a static job shop, moreover, there is no preemption – once a job has started working on a resource, it will be finished on that resource and the resource will be available for the next job.

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The production facilities of a manufacturing scheduling problem are usually assumed to be a **job shop** (see Chapter 5). To be more specific about the problems addressed in a static job shop, we will discuss some additional assumptions about the static job shop to help you understand the major scheduling issues.

- A job is an entity: it cannot be split and processed by two different resources simultaneously. This means that assembly operations are not addressed under this type of assumption.

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- Each job has m distinct operations, one on each resource/machine: there is no repetition on the same machine from the same job. For example, if one does a turning operation on a lathe, the part will not go back to the same lathe for a second operation.

- No cancellation: once a job has arrived, it cannot be cancelled.

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- Processing times are independent of the schedule: irrespective of which jobs are put on which machines, the processing times remain the same.

- In static jobs, an in-process inventory is allowed. Machines may be idle, and no machine may process more than one operation at a time.

- There is only one of each type of machine and they never break down, as discussed above.

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The general job shop problem is usually formulated as a problem in which one has *n* jobs, *m* machines, and an operation o_{ij} denotes the operation of job *i* by machine *j*. The technological constraints are represented in the order the jobs must follow while they are processed by the different machines. There are some further simplified variations of the problem when one refers, for example, to **flow shop** where all jobs share the same order.

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- A representation of the sequence the jobs must follow through a job shop is the **Gantt diagram**.

- r_i is the arrival/ready time of job J,
- O_{ij} is the operation of the i^{th} job by the j^{th} machine,
- p_{ij} is the processing time of the operation o_{ij}, di is the due date, ai is the allowance of that particular job,
- W_{ik} is the waiting time,
- W_i is the total waiting time for particular job,
- C_i is the completion time,
- F_i is the flow time,
- L_i is the lateness,
- T_i is the tardiness, and
- E_i is the earliness.

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- example of scheduling four machines to process four different jobs.
- The machines are M1, M2, M3, M4, and the jobs are indicated by A, B,C,D.
- Table 8.1 shows the technological constraints as well as when the jobs are released in the particular job shop with the four machines.

Table 8.1: Data for the Scheduling Examble

Job	Released at	Machining Order/Times (min.)			
A	8:30	M1(60)	M2(30)	M3(2)	M4(5)
B	8:45	M2(75)	M3(3)	M1(25)	M4(10)
C	8:45	M3(5)	M2(15)	M1(10)	M4(30)
D	9:30	M4(90)	M1(1)	M2(1)	M3(1)

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- A schedule is a sequence of jobs on each machine as indicated in Table 8.2.
- This same sequence is represented in the Gantt chart of Figure 8.2.
- One can see that all the jobs will be done by 11:51.

Table 8.2: An examble schedule

	1st	2nd	3rd	4th
M1	A	D	C	B
M2	B	C	A	D
M3	C	B	A	D
M4	D	A	C	B

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Table 8.3 presents an “infeasible” schedule, where the sequence suggested contradicts the technological constraints as stated in table 8.1. The infeasibility of this schedule can easily be documented by drawing a Gantt chart for this sequence and seeing that the technological constraints are violated.

Table 8.3: Infeasible Schedule

	1st	2nd	3rd	4th
M1	D	B	A	C
M2	D	C	B	A
M3	D	B	C	A
M4	A	D	C	B

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Table 8.4 presents a feasible schedule similar to that in Table 8.2. It is not only feasible, but it is better in that all the jobs are done by 11:45. In this table and corresponding Figure 8.3, one can see an even better improvement as far as the maximum completion time of all the jobs.

Table 8.4: A Feasible Schedule

	1st	**2nd**	**3rd**	**4th**
M1	A	B	C	D
M2	B	C	A	D
M3	C	B	A	D
M4	D	A	C	B

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A general formulation of the scheduling problem can be stated as n/m/A/B, where n is the number of jobs that will be scheduled on m machines, with A signifying the type of shop (F for flow shop or G for general job shop) and B indicating the performance measure to be optimized. A schedule for the general job shop problem consists of m permutations of the n jobs with each permutation giving a particular sequence of the jobs ion one machine. Since there are n! permutations of n objects and there are m different machines the number of all possible schedules is (n!)m.

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In the previous example, where n=4 and m=4, the total number of schedules is 4331,776. The purpose of the scheduling techniques and algorithms is to find a schedule, which optimizes a particular performance measure with no full enumeration of all possible schedules.

An important aspect of this process is which performance measures must be optimized. They can be grouped according to three different categories:

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- Based on completion times
  - o F_{max} : maximum flow time
  - o C_{max}: maximum completion time
  - o F_{av}: average flow time
  - o C_{av}: average completion time

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- Based on due dates
  - L_{av}: average lateness
  - L_{max}: maximum lateness
  - T_{av}: average tardiness
  - T_{max}: maximum tardiness

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- Based on inventory and utilization costs
  - Nw_{av}: average number of jobs waiting for machines
  - Nu_{av}: average number of unfinished jobs
  - Nnc_{av}: average number of completed jobs
  - Np_{av}: average number of jobs in process at any time
  - I_{av}: average machine idle time
  - I_{max}: maximum machine idle time

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These performance measures are often complex, conflicting, and sometimes overlapping. Performance measures based on completion times, are important in cases in which a set of jobs are to be worked through the manufacturing system, and the time the jobs will remain on the factory floor is important. The second category, performance measures based on due dates, is related more to "made-to-=order" production where particular deadlines must be met and penalties may be associated with the deadlines. The third category, criteria based on inventory and utilization costs, is particularly important in case sin which expensive materials are processed or capital-intensive facilities are used.

Figure 8.1: Gantt Diagram

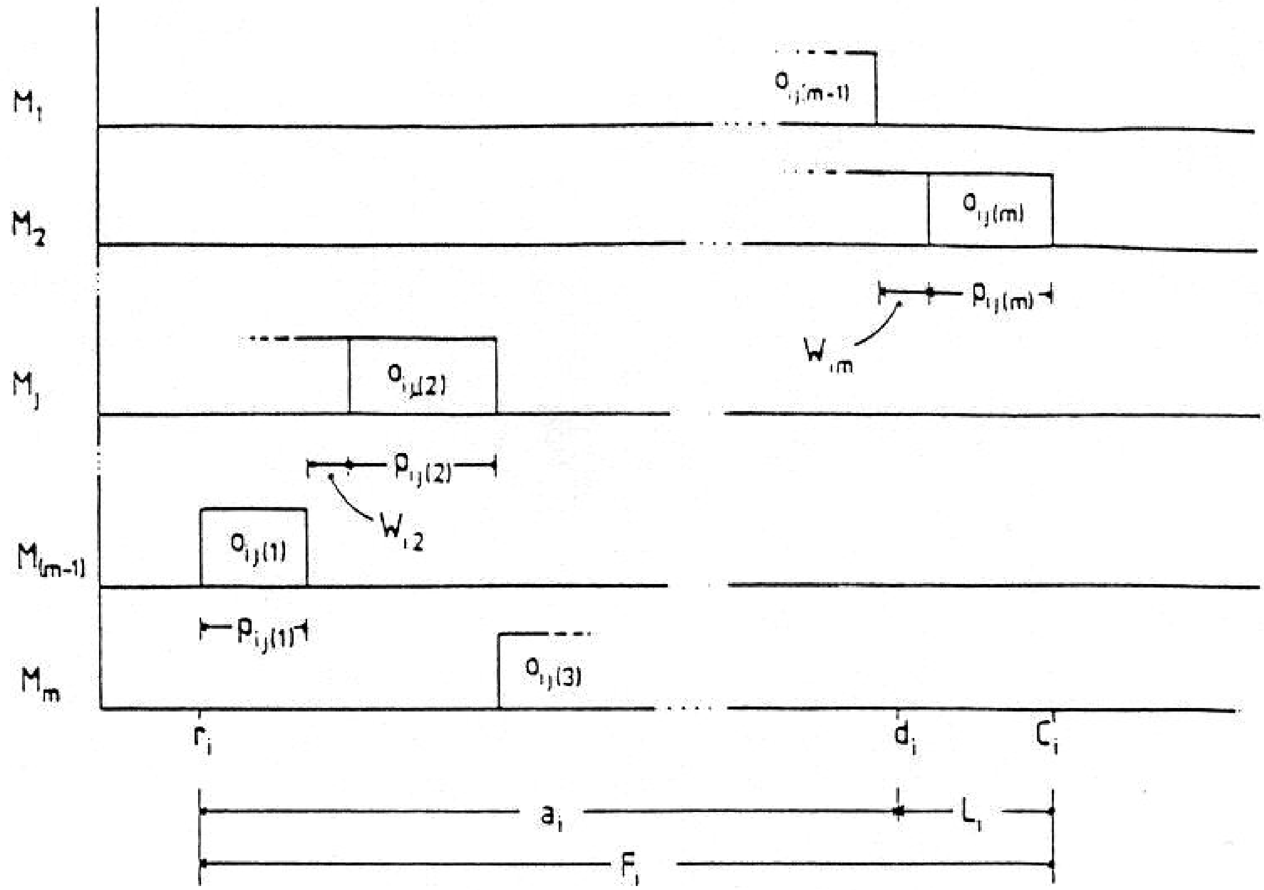


Figure 8.2: Gantt Diagram for the Schedule in Table 8.2

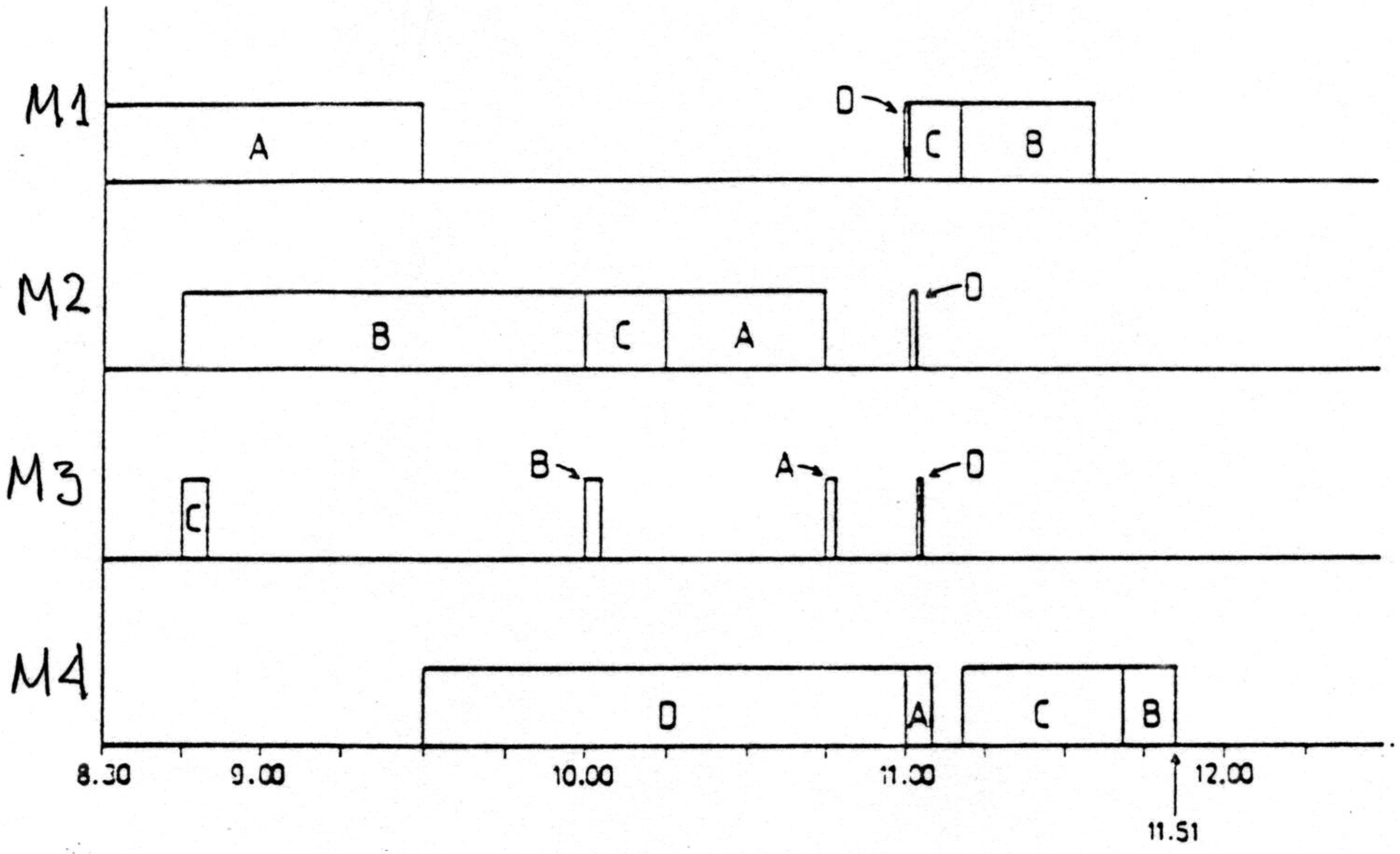
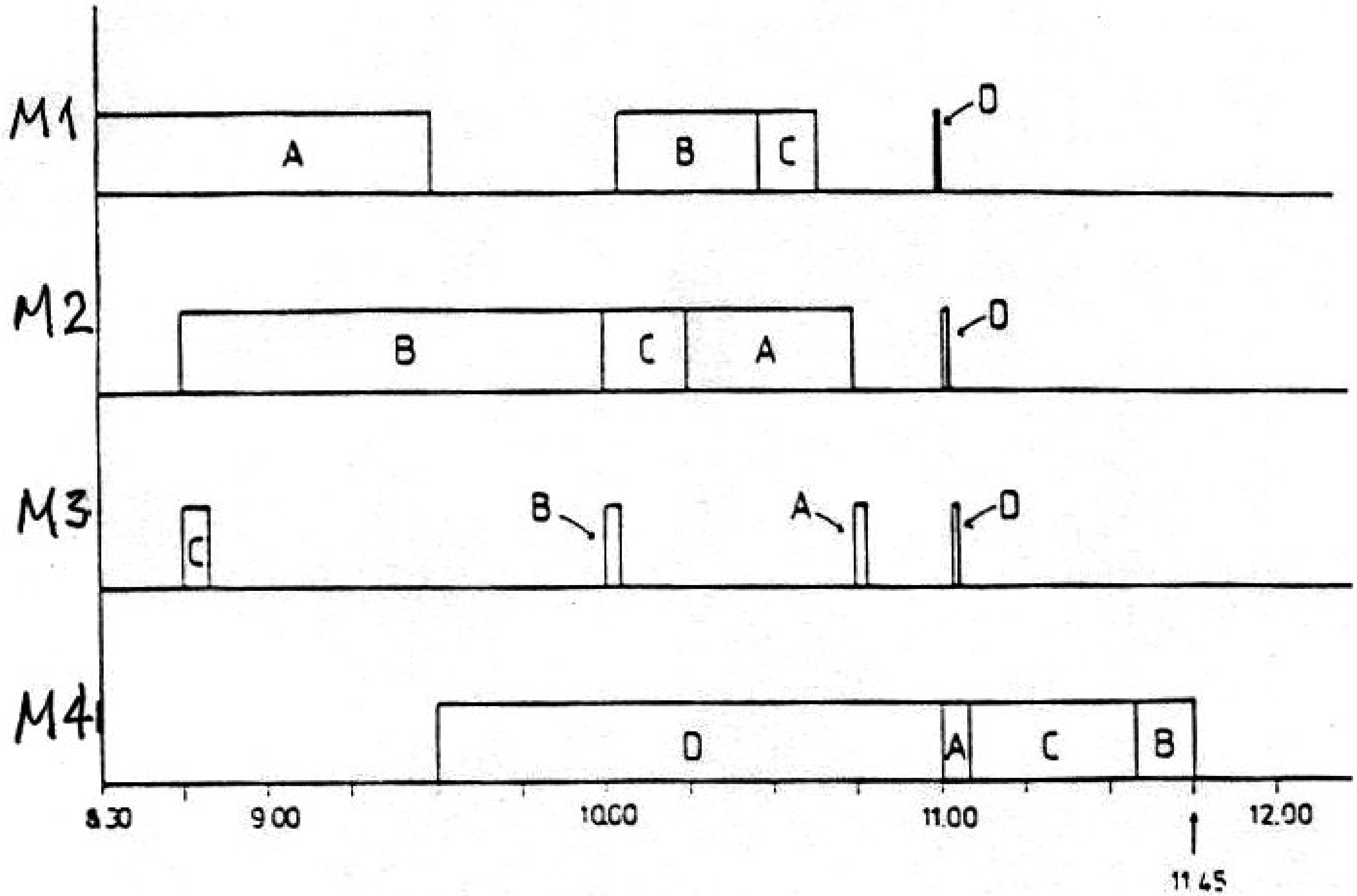


Figure 8.3: Gantt Diagram for the Schedule in Table 8.4



Funding

- This educational material has been developed in the teaching duties of the respective educator.
- The project «**Open Academic Courses at the University of Patras**» has funded only the reformation of the education material.
- The Project is implemented within the context of the Operational Programme "Education and Lifelong Learning" (EdLL) and is co-funded by the European Union (European Social Fund) and national resources.

Reference Note

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