1. Introduction to scheduling

1.1 Definition

Scheduling problems are encountered in all types of systems, since it is necessary to organise and/or distribute the work between many entities. We find in every book in the literature a definition of a scheduling problem as well as its principal components. Among these definitions we can quote the following one [Carlier and Chrétienne, 1988]:
"Scheduling is to forecast the processing of a work by assigning resources to tasks and fixing their start times. [...] The different components of a scheduling problem are the tasks, the potential constraints, the resources and the objective function.[...] The tasks must be programmed to optimise a specific objective [...] Of course, often it will be more realistic in practice to consider several criteria."

Another definition has been put forward by [Pinedo, 1995]:
"Scheduling concerns the allocation of limited resources to tasks over time. It is a decision-making process that has as a goal the optimization of one or more objectives."

A statement of scheduling problems can be found in [Gotha, 1993]. This article sets out the resolution approaches and the traditional scheduling problems. We can find in [Lee et al., 1997] a presentation of the current problems as well as more recent resolution methods.

In the above definitions, the task (or operation) is the entity to schedule. In this book we deal with *jobs* to schedule, each job is broken down into a series of operations. When all the jobs contain only a single operation we speak of a *mono-operation* problem. By contrast, we speak of a *multi-operation* problem. The operations of a job may be connected by precedence constraints. In this case the set of operations of a job and their precedence constraints define the *routing* of this job.
We are also dealing with the *resource* or *machine* (this latter term is more often used in the context of shop scheduling). We consider generally that the resources are of two types: renewable or consumable. Renewable resources become available again after use (machine, file, proces-

sor, personel, *etc.*), whereas non renewable resources disappear after use (money, raw materials, *etc.*). Among the renewable resources we can distinguish between the disjunctive resources, which can only perform one operation at a time and the cumulative resources which can process a limited number of operations simultaneously. The case of cumulative resources is being studied more and more as for example in shop scheduling problems [Carlier and Latapie, 1991], in project scheduling problems and in batch scheduling problems ([Potts and Kovalyov, 2000]).
Frequently, to solve a scheduling problem, we are also caused to solve an *assignment* problem, where it concerns in addition specifying the resources to process the operations.

We can separate the criteria to optimise into two types: those relating to completion time and those relating to costs. In the category of completion time related criteria we find for example those which measure the completion time of the whole schedule and those which measure tardiness of jobs in relation to their due date. In the category of cost related criteria we may cite those which represent cost of machine use and those which represent cost allied to waiting time of operations before and/or after they are processed.

1.2 Some areas of application

Scheduling problems are encountered at all levels and in all sectors of activity. Generally, we can distinguish between those of manufacturing production and those in computer systems or project management.

1.2.1 Problems related to production

We encounter scheduling problems in **Flexible Manufacturing Systems** (FMS). Numerous definitions of an FMS are found in the literature. For [Liu and MacCarthy, 1996]: "*An FMS comprises three principal elements: computer controlled machine tools; an automated transport system and a computer control system.*" These problems are broadly covered in the literature and most often in a well defined application class. Besides, this very broad problem encompasses other problems related to *Robotic Cell Scheduling* and *Scheduling of Automated Guided Vehicles* (AGV).

Equally, **electroplating and chemical shops** have their peculiarities in scheduling problems. The latter are also called Hoist Scheduling Problems. These shops are characterised by the presence of one or more travelling cranes sharing the same physical area and which are ordered to transport the products for treatment in tanks. In general, the soaking time in a tank is bounded by a minimum and a maximum (*the interval processing time*), transport time