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Applications

The present chapter is concerned with applications of the concepts developed in Chapters 1 to 5 to production planning problems in the manufacturing and process industries, to the evaluation of investment projects, and to resource allocation problems that are subject to different kinds of uncertainty.

In Section 6.1 we discuss how scheduling problems arising in make-to-order assembly environments can be modelled as resource-constrained project scheduling problems. For different product structures, we consider the definition of appropriate minimum and maximum time lags ensuring a non-preemptive execution of overlapping operations.

Section 6.2 is devoted to a hierarchical three-stage approach to small-batch production planning using resource allocation methods from project management. The approach comprises the master production scheduling, multi-level lot sizing, and temporal plus capacity planning stages. At all levels, the scarcity of resources is taken into account, which differentiates this approach from most production planning and control systems used in practice. The lacking integration of capacity aspects is the essential reason for the generally poor performance of the latter systems.

When scheduling batch plants in the process industries, a variety of technological peculiarities have to be taken into account. In contrast to manufacturing, the batch processing times are mostly independent of the batch size and the intermediate products must be stocked in dedicated storage facilities. In addition, intermediate products may be perishable and to guarantee the purity of output products, the processing units have to be cleaned between the execution of certain operations. In Section 6.3 we deal with a two-phase method for production scheduling in the process industries, which decomposes the problem into a batching and a batch scheduling problem. For given primary requirements, the batching phase provides the numbers and sizes of the batches to be produced. Subsequently, the batches are scheduled on the processing units in the batch scheduling phase. The batching problem can be formulated as a mixed-integer linear program of polynomial size. By using the concepts of renewable and cumulative resources in combination with the

supplements from Chapter 5, the batch scheduling problem can be modelled as a resource-constrained project scheduling problem.

In practice, it is customary to evaluate investment projects based on the net present value criterion. The maximum net present value of a time-constrained investment project can, e.g., be computed by using the steepest descent method for convexifiable objective functions discussed in Chapter 3. In literature, however, it is commonly accepted that often the discount rate to be applied (i.e., the required rate of return) cannot be determined with sufficient accuracy. Moreover, the project deadline may be subject to negotiations between the investor and his customers. In Section 6.4 we show how using the steepest descent approach, the project net present value can be represented as a function of the discount rate and project deadline. On the basis of this function, investment projects with uncertain discount rate can be evaluated for a variable project deadline.

Throughout our previous discussion we have supposed that data such as activity durations, time lags, and resource requirements are deterministic quantities. Clearly, this is a simplifying assumption, which nevertheless is justified in many cases when the project data can be forecast reliably and small deviations from schedule do not seriously affect the execution of the project. Sometimes, however, the latter conditions are not met, in particular when coping with long-term projects like in the building industry or with production scheduling problems where machines and equipment may be subject to disruption. It is then expedient to take uncertainty into account already when scheduling the project or to adapt the schedule in a suitable fashion during its implementation. In Section 6.5 we propose two deterministic strategies for coping with uncertainty in project management. The anticipative approach consists in scheduling the project in a way that the impact of perturbations is minimized. Alternatively or additionally, one may use a reactive approach, where the project is rescheduled after each disruption and the objective is to minimize the changes with respect to the previous schedule.

6.1 Make-to-Order Production Scheduling

We consider the processing of a given set of customer orders in a multi-level make-to-order manufacturing environment, where no inventories are built up for future sale. At first, we recall some basic concepts from materials requirements planning (see, e.g., Nahmias 1997, Sect. 6.1). We assume that each final product consists of several subassemblies, which in turn may contain several components from lower production levels. Let P^f be the set of all final products ordered and let P be the set of all (intermediate or final) products l under consideration. Generally speaking, the product structure of a firm can be represented as a *gozinto graph* $G = (P, A, a)$ with node set P. Arc set A contains an arc (l, l') weighted by *input coefficient* $a_{ll'} \in \mathbb{N}$ if $a_{ll'}$ units of