AIMMS Tutorial for Professionals - Problem Description

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Chapter 2

Problem Description

This chapter

In this chapter you will find a description of the problem to be translated into an optimization model. The problem statement covers several pages, typical for a professional application in the field of planning and scheduling. The overall goal in this problem is to obtain a production and maintenance plan on a weekly basis for a total planning horizon of one year. The corresponding mathematical model is provided in Chapter **??**.

2.1 Initial problem components

Planning horizon

The application discussed in this tutorial considers a planning horizon of one year and individual planning periods of one week. The overall goal of the application will be to develop a robust production and maintenance schedule.

Production and distribution

Consider the production and distribution of a specific soft drink on a weekly basis. There are 3 factories and 22 distribution centers, all located in the Netherlands (see Figure 2.1). Every week, truckloads of soft drinks are distributed from the factories to the distribution centers. There is an upper bound on the number of truck loads that can be moved from a particular factory during a single week.

Production lines

Each factory has several production lines each with a fixed production level measured in terms of hectoliters per day. During any particular week, a production line is either operational at a fixed production level, or does not produce at all.

Mode switches

The term *mode switch* of a production line refers to an on/off change in production. Thus a mode switch occurs when a production line becomes operational during a particular week if it was not operational during the previous week, and vice versa.

Figure 2.1: The Netherlands

Storage

There are storage facilities at both factories and distribution centers. Stock, like production, is measured in hectoliters. There is a reserve stock at each location, and storage is limited.

Cost components

Total cost, measured in terms of dollars, is made up of several cost components related to production, distribution, storage, and mode switches. The first three of these components are self-explanatory, but the final component deserves some explanation. In this application some of the workers employed to work on the production line are temporary workers, but it is assumed that frequent hiring and layoffs are undesirable. Therefore, an extra artificial cost term is introduced to penalize mode switches.

2.2 Maintenance and vacation planning

Maintenance requirement . . .

Production lines need to be maintained on a regular basis dependent on their associated deterioration rate. It is assumed that when a production line has been in full use for a period of 16 weeks, then shortly thereafter it must be closed for a week of maintenance which will be performed by the crew previously working on that line. If a production line has not been in use for more than 64 weeks, then it must have maintenance in the week prior to becoming operational. If the line has been in and out of use over a period of weeks, then every week of non-use increases the deterioration level by an amount equal to one quarter of a week of use.

. . . causes no mode switches

The workers on a production line also perform the line maintenance. Therefore, the mode switch penalty, described in the previous section, does not apply when production comes to a halt or starts again as a result of maintenance.

. . . and preserves continuity

To guarantee continuity of production in each factory, there exists an additional requirement that only one production line per factory can be maintained at the same time.

Inactive days

The production lines in the factories are closed during weekends and official holidays. In addition, there is no distribution of soft drinks from the factories to the distribution centers on these particular days. As a result, a production week always consists of five or less working days.

Vacation periods

In addition to the official holidays, there are whole periods reserved when workers have the opportunity to take a vacation. For planning purposes, it is assumed that not every worker will be on vacation, and that the level of production for all the lines in use will drop by a particular percentage during such a vacation period. The mode switch penalty does not apply when such a drop or subsequent increase in production takes place.

2.3 Multiple demand scenarios

Demand is uncertain

The weekly demand for soft drinks to be supplied by the distribution centers to customers is not exactly known. Variations over the years have been observed, which is why there is a reserve stock. Nevertheless, when building a model with demand as a parameter, demand values for the weeks to come must be chosen. Such a set of demand values is referred to as a *demand scenario*.

Three scenarios

Instead of selecting a single demand scenario, the use of three demand scenarios is proposed in order to obtain a more robust production and maintenance plan. These scenarios reflect an expected, a somewhat pessimistic and a somewhat optimistic demand, thereby capturing overall demand behavior over the previous several years.

Robust planning

The key idea of robust planning is to make a single production and maintenance plan that is feasible for all three demand scenarios. The only decisions that are allowed to be different with each demand scenario are those related to distribution and storage. For more details on scenario-based optimization you may want to consult Chapters 16 and 17 of AIMMS, *Optimization Modeling*.

2.4 Planning objective

Overall goal

The overall goal of the company is to obtain a production and maintenance plan on a weekly basis for a total planning horizon of one year. The resulting plan should be in the form of a Gantt chart (see Figure 2.2) at the level of the individual production lines at each of the three factories. Such a plan provides insight into the use of capacity, the build up of inventories, and the need to make arrangements for temporary workers to be hired in each of the factories.

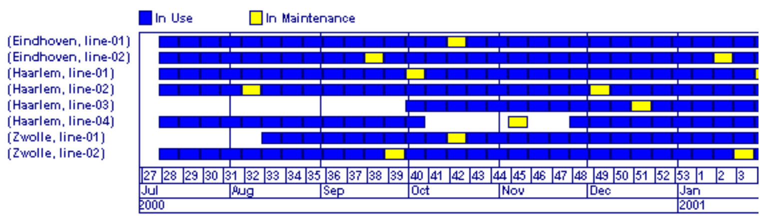

Figure 2.2: Selected portion of a Gantt chart

Specific goal

The specific objective of the mathematical programming model to be built is to minimize total cost over the planning horizon. It is straightforward to specify the individual cost components related to production and mode switches. The cost components related to storage and distribution, however, are scenario-dependent and thus should be weighted in the objective with the scenario probabilities. In this application, the assumption has been made that the probabilities of the pessimistic and optimistic scenarios are each equal to 0.25.

2.5 A rolling horizon approach

Size problematic

In practical applications of the type described in this chapter the number of factories and distribution centers is usually much larger than the few locations specified here. In addition, most applications have more than one product. With the one-year planning horizon, on a weekly basis, the mathematical program as built in this tutorial is likely to be too large to be solved all at once in a real life situation.

Restrict horizon

One remedy would be to consider a shorter planning horizon. The effect on the number of decision variables is immediate, as all of them are indexed with weeks. The disadvantage of this approach is clear: it does not satisfy the management requirement to plan for a full year.

Rolling horizon

The approach followed in this application is to run a sequence of mathematical programs each with a planning horizon for intervals of 8 weeks. Once the first program is solved for week one, all decisions concerning this first week are considered to be final. The subsequent mathematical program then starts at week two, and again, all production and maintenance decisions concerning this second week are fixed. This process continues until the mathematical program covers the last 8 weeks of the full year planning horizon.

Dependency on future data

Rolling horizon models are a compromise between speed and accuracy. If the planning interval is long, the solution should be more optimized. The corresponding mathematical program is however larger in size, and could take up a considerable amount of computational time. The length of the planning interval should certainly reflect the insensitivity of future data to first-period decisions. This choice is application dependent. A planning interval of 8 weeks was adequate for the problem in this tutorial.

Maintenance external

An advantage of this rolling horizon approach is that maintenance planning can, for the most part, be placed outside the mathematical program. Every time the decisions corresponding to a first week are committed, their effect on maintenance can be registered by adjusting a deterioration parameter for each production line. Once maintenance for a particular production line is due within the next horizon of 8 weeks, the level of production during the corresponding estimated maintenance period is set to zero. The specific implementation details are discussed later.

Evaluation

From the point of view of a tutorial, it is an interesting exercise to work with time and a rolling horizon. In practical applications, however, caution is needed: a short planning horizon may not be sufficient to take the relevant future into account. In this example, a planning horizon of 8 weeks was considered sufficiently large because demand fluctuations are not drastic, and storage safety buffers at the locations are of a reasonable size.