

Optimal Control of Raw Timber Production Processes

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Abstract: This paper demonstrates the possibility of optimal planning and control of timber harvesting activities with mathematical optimization models.

The separate phases of timber harvesting are represented by coordinated models which can be used to select the optimal decision for the execution of any given phase. The models form a system whose components are connected and controlled by means of information flows.

A mathematical model is presented for the optimal planning of harvesting activities for the forest enterprise. The use of a mathematical model contributes to the balancing of supply and demand, to the coordination of forest management plans with other activities of the national economy, and finally, to the minimization of production costs.

INTRODUCTION

Planning in Czechoslovak forestry has a long tradition, and is highly developed. The present stage of development of the society imposes demands on the planning and control of production processes in the form of requirements for maximum utilization of production sources and for meeting the demands of the society. In the process of planning and control it is necessary to follow the efficiency principle which states that (a) the planned yield must be obtained at the lowest cost or effort, or conversely that (b) the highest yield is to be obtained from given resources.

This type of planning and control requires a well-elaborated information and decision system, and the use of advanced techniques for the transfer and processing of information.

PROBLEMS

In this paper I shall deal with the processes of decision in planning and control of harvesting, and point out the possibilities of utilizing the optimization models of operational research for the selection of the planning alternatives.

The harvesting of timber, in the context of Czechoslovak forestry, represents a complex system and requires the solution of several problems. Each country has its specific conditions and requires a different approach to the formulation of the task. Generally, it is necessary to recognize that mathematical models cannot be based upon the principles of maximum utilization of the forest for this would result in the decrease of its permanent production capacity and would simultaneously affect the biological balance adversely. With long-term planning models it is necessary to consider this principle in the formulation of the mathematical model. In short-term models, this principle is observed by insuring that the forest management plan (decennial plan) is constructed so as not to allow the decrease of the production potential of the forest.

The harvesting of timber is divided into felling, gathering at landings, primary conversion (production of wood assortments), and hauling of timber. The structure of the harvesting process is illustrated in figure 1. Each stage of timber production is represented by coordinated models leading to the selection of the optimal decision at a given stage.

The models form a system of components connected by information flow in such a way that the output from one model represents an input into a "lower" model. To date some of the mathematical models have been used in planning (e.g., optimal control of timber hauling); others have been theoretically validated or are in the process of being tested.

MODEL FOR SHORT-TERM PLANNING OF HARVESTING ACTIVITIES

The model solves the problem of optimal scheduling of quarterly harvesting activities, and of controlling the management of the "gravitational" areas of forest enterprises. "Gravitational" areas consist of a collection of stands which form a contiguous area and which have approximately the same production conditions. The annual tasks in each stand are given by the forest management plan, and the sum of these tasks represents the annual tasks for the gravitational area.

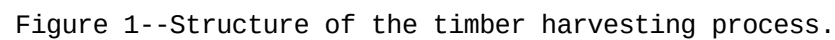
The mathematical model for short-term planning of cutting activities must fulfill the following conditions:

- Coordinate sustained harvesting activities with the demand for timber assortments as specified by contracts between supplier and customers

- Recognize the limited availability of labor

- Take into account the capacity of landings with respect to the logging techniques available for gathering timber at landings

- Concentrate as much as possible the harvesting and the silvicultural activities in each gravitational area



Elaborate quarterly plans which minimize the costs of harvesting and of other management activities.

This task can be formulated as a linear programming model:

$$\text{Minimize } z = \sum_{ijk} g_{ijk} \cdot x_{ijk} + \sum_{ijp} r_{ijp} \cdot y_{ijp} + \sum_{ijl} u_{ijl} \cdot z_{ijl}$$

$$\sum_i x_{ijk} = a_{jk} \quad \text{for } j = 1, 2, \dots, n; k = 1, 2, 3, 4$$

$$\sum_{ip} y_{ijp} = b_j \quad \text{for } j = 1, 2, \dots, n$$

$$\sum_i z_{ijl} = c_{jl} \quad \text{for } j = 1, 2, \dots, n; l = 1, 2, \dots, g$$

$$\sum_j f_{ijp} \cdot y_{ijp} \leq F_{ip} \quad \text{for } p = 1, 2, \dots, m; i = 1, 2, 3, 4$$

$$\sum_j x_{ijk} \geq s_{ik} \quad \text{for } i, k = 1, 2, 3, 4$$

$$x_{ijk}, y_{ijp}, z_{ijl} \geq 0$$

Additional relations determining the levels of y_{ijp} must be specified to represent the particular types of management practiced.

Notation:

x_{ijk} - volume harvested of assortment k , in period i , from area j

y_{ijp} - timber logged in m^3 with method p , during period i , in area j

z_{ijl} - silvicultural activities l carried out during period i , in area j , expressed in various units (ha, km, etc.)

a_{jk} - annual volume requirement in m^3 for assortment k from area j

b_j - annual target volume logged--by all methods--in area j

c_{jl} - annual target for silvicultural activity l on area j

i - quarter of the year, $i = 1, 2, 3, 4$

j - gravitational areas, $j = 1, 2, 3, \dots, n$

p - kind of logging method, $p = 1, 2, 3, \dots, m$

- k - combination of the type of harvest and species group (e.g., final-coniferous: $k = 1$, intermediate-coniferous: $k = 2$; etc.), $k = 1, 2, 3, 4$.
- l - kind of silvicultural activities, $l = 1, 2, \dots, g$
- F_{ip} - available inputs for logging with method p in period i
- f_{ijp} - quantity of input per m^3 required to log with method p in period i and area j
- s_{ik} - total volume required by the sale plan in quarter i for the k th combination of type of harvest and species group
- $g_{ijk}, r_{ijp}, u_{ijl}$ - coefficients of objective function, giving the costs for technical unit according to the kind of silvicultural activity

Because the planning problem has been specified as a linear program, it is relatively easy to solve it with a computer, in spite of the large dimension of the linear program required under real conditions.

The planning problem is specified as a deterministic model in spite of the stochastic characteristics of forest production. This shortcoming of the model may be compensated for by solving the model for various values of the coefficients of the LP matrix or of the objective function.

A mathematical model requires information which can be divided into technical and economic parameters. The technical parameters include the knowledge of possible technological alternatives for work procedures, available resources or capacities and scheduled means of production. Economic parameters represent data on costs which vary with the location of the activity and its technical characteristics.

To obtain all the necessary information for the model usually requires changes in the information system. Our present experience indicates that the information system must be developed concurrently with the mathematical model.

CONCLUSION

The use of this mathematical model contributes the following positive elements to planning:

- It balances the requirements of production and technical means and workers available

- It balances the sources of wood, with the wood assortment requirements of the national economy

- It coordinates the distributing of production over time with the requirements of national economy

It realizes the plan specification at minimum costs

The results which we have obtained establish the possibility of planning and controlling production in forestry. These results also indicate that by using operations research models, planning and control can be made more effective.