Session 2
Paper (a)

PLANNING PACKAGES: WILL THE COMPUTER DO IT ALL?

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A valid question for forest planners is the following: Are mathematical models and computational systems useful to support decision making at different levels of forest firms?. We will try to deal with this question and show what systems have been developed for forest firms in Chile and what has been their impact.
A first point to define is how to measure usefulness. You could argue that one measure is to analyze if systems are being used and lead to better decisions, measured in terms of

- Better utilization of the forest.
- More efficient use of harvesting equipment and trucks.
- Improved net revenues.
- Better compliance with contracts to supply demand.

Systems also give an impulse to a more orderly operation through requiring accurate information and good communications.

Typically models are needed for complex decisions, where many combinations are possible and experience and good judgement alone are not sufficient to choose a best combination of decisions among thousands or even millions of possible ones.

There are requirement needed in order to implement computational systems, such as:

- Existence of reliable information, for example in growth simulators
- The possibility of modelling complex reality in a reasonable approximation.
- Control over operations, to guarantee an adequate implementation of decisions.
- Existance of staff members with adequate background and equipment to develop and run models and systems.

Two aspects that have given an important impulse to the use of models are on the one hand the opening of global competitive markets, which give an impulse to firms towards higher levels of productivity. The second one is technological advance, with the introduction of PC's, very efficient commercial mathematical packages to solve models, and improved data bases (like Geographical Information Systems).

We will show models that are being used successfully in Chilean forestry firms for decisions that go from long range, strategic level to short term operations.

These models have been developed through the coordination of Fundacion Chile and the direct participation of the forestry firms in the development of the systems.

MEDFOR, a model for long range, strategic decisions.

These decisions correspond to basic silvicultural options or mayor investments. In this case we take an approximate general view rather than a detailed analysis. Individual stands are grouped into macro-stands. The grouping is done based on similarities of species (pine or eucalyptus in our case), site quality, tree age, location. Timber production is also aggregated into major categories: sawtimber, pulp wood, export as logs.

Main decisions at this level are.

- Optimal sustainable rates of timber production, consistent with demands at plants.
- Levels of production for each aggregate timber category per period.
- Aggregate silvicultural management options.
- Possible investments in new plants or land acquisition.

Typical planning horizons are from 35 to 70 years, divided in periods of 3 to 5 years.

This problem has been modelled as a Linear Programming model of moderate size, which runs on a PC 486 in a few minutes. It is currently being used on a regular basis by three forest companies in Chile (Bio-Bio, Cholguan and Millalemu).

The model maximizes net present value of the firm by considering revenues due to timber sales for export plants and sawmills minus costs of silvicultural management and harvesting, and land acquisition. The present value of standing timber at the horizon is also included.

Decisions are constrained by land availability, aggregate demands for timber required for exports, for existing and new pulp plants and for sawmills.

The model requires as inputs adequate timber growth proyections, estimates of relevant costs and timber prices through the horizon.

One typical use is in evaluating a possible investment in a new pulp plant. To evaluate this investment, the new plant is introduced, with its capacity and operational costs into the model. The model gives an optimal solution including this new plant. The difference between the solution with and without the new plant is compared with the investment cost of the plant to determine the convenience of the investment.

A new system is presently being developed where two models are designed separately. One is similar to the forestry model just presented. The other is an explicit model for investments in industrial installations. The model includes decisions on investments along time on pulp plants with possible expansions, sawmills and other industrial plants. Typical horizon for this model is 10 to 15 years. The two models are linked to account for the interaction of timber production and demand at industrial plants.

OPTIMED, A System for Medium range Decisions

These decisions correspond to a tactical level, in coordination with long range decisions given by the strategic level. In this case we are looking at a horizon of 3 to 5 years, semesters are considered to take into account summer and winter seasons. Real stands are considered now rather than aggregate ones. Main decisions at this level are:

- Stands to be harvested, by time period.
- Volume of timber to be obtained, divided into a few categories, such as export as logs, sawtimber, pulp wood.
- Roads to built for access. In Chile roads built by forest firms are either dirt or gravel. Paved roads are public highways. Dirt roads can only be used in summer. Stocking yards allow to store timber from summer to cover winter demand. In a few cases, there exist sand roads, to be used in winter.
- Number of trucks, towers (cable logging) and skidders to be used in each period.

The model requires information on future timber yields, demand estimates per period (ranges), production yields of machinery, existing roads and roads that could be potentially built, plus estimates of sale prices and costs of harvesting, road building, transportation to markets or plants, and stocking.

The model maximizes net present value. Income is derived from timber sales, and costs are due to harvesting, road building, and transportation.

Decisions are constrained by existing timber land, demand for aggregate products, flow conservation to assure that production at origin sites flows to destinations through the road network. Some roads need to be built to provide for access. Since dirt roads can only be used in summer, stocking yards are defined to hold timber for the winter season. The model allows for degrading of timber if needed. For example, sawmill quality timber may be used for the pulp plant if needed. The model will try to minimize these losses.

The resulting model will indicate an optimal strategy for choosing a sequence of coordinated stands to harvest, with the corresponding road network and volumes to harvest in each stand and period to cover demands of timber for exports, sawmills and pulp plants.

One interesting use of the model is to evaluate the purchase of the right to harvest standing timber. The model is run including and excluding this possible purchase. The difference in value between the two solutions indicates the value to the firm of this right. Note for example that what might look like an excellent timber purchase, may be less valuable in the context of a particular firm if long distance hauling or road building is involved or if the particular timber supply does not integrate well with the firm's existing supply to match the demand.

This system is presently being used at Forestal Millalemu. The system is based on a Linear Programming model with 0-1 variables. The integer variables are needed to define road building decisions (roads are built or not) and to consider that if an area is harvested it is worthwhile only if a minimum number of hectares is cut.

The model is run using a commercial package on a PC 486 and takes about 20 minutes to run. This time includes heuristic rules to obtain an approximately optimal all integer solution.

A Geographic Information Systems can be used to help input the data. This is currently done with a Windows interface.

OPTICORT: A Short Term Harvesting System

This system is linked to tactical decisions. In this case the horizon is about three months. Decisions involve detailed harvesting, with instructions that can be carried out in the field, and definition of products by length, diameters and average diameter in some cases (sawmills, exports).

An accurate inventory simulator is needed for information on standing timber.

The main decisions involved are:

- What stands to harvest among those mature and with road access.
- What harvesting machinery to use each week. Tower or cable logging are programmed for steep terrains, skidders for flat areas.
- What volumes should be harvested of each product, each week in order to satisfy demand.
- What bucking patterns to use.

Product requirement are detailed for sawmills and export in terms of lengths, diameters and average diameter. A typical bucking pattern which corresponds to instructions for field people can be 12^{10} meters in length, minimum diameter 26 cm. (export) 8.10 meters in length, minimum diameter 24 cm. (sawmill), 4^{10} meters in length, minimum diameter 22 cm. (sawmill), 4^{10} meters in length, 16 cm. in diameter (pulp). Export and sawmill sales will also have average diameter requirements.

The system is based on a linear programming model. The objective is to maximize net revenues derived from sales of products at known prices minus costs for harvest operations and transportation.

The model considers constraints for

- Production limited by timber availability and capacity of harvesting machinery.
- Timber harvested is sent to destinations to satisfy demand for each product.
- Timber transport is limited by the truck fleet available.
- Average diameter constraints for exports and sawmills.

Additional operational constraints relate to harvesting policies. Once a tower is installed, it will harvest all the area it reaches. If a stand is intervened, a minimum area in it must be harvested.
In addition, a value is given to the standing timber, its oportunity cost or market value to prevent the model from downgrading timber unnecesarily.

A typical LP model has about 4000 constraints and 12000 variables and runs in 5 minutes on a PC 486. It is run every one or two weeks and has provided benefits in terms of:

- Aiding in the organization of the harvest operation. The system requires making explicit estimates of yields, costs, revenues, productivity of machinery.
- Providing an efficient match between demand for specific products in lengths and diameters and the timber supply, so that timber downgrading is minimized.
- Reducing operating costs. in particular in transportation.
- Evaluation the purchase of timber production

The system is presently used at Bosques

Arauco, Forestal Chile, Forestal Bío Bío, and Forestal Mininco.

ASIPRO: A Daily Harvesting System

This system, presently being introduced by Bosques Arauco, programs daily harvesting operations. It deals in high detail with bucking patterns, production of each product, directly to demand points or through stocking yards, and bucking patterns. Inventory simulation information at local level is needed here.

The system is based on an LP model of moderate size.

PLANEX: A System to Optimize Equipment Use in Harvesting

This problem is linked to short term harvesting. Once there is a decision to harvest an area of say 200 Hectares, a decision has to be made in terms of how to deploy the harvesting machinery. Steep areas need cable logging or towers while flat areas are harvested with skidders.

The main decisions involved here are in terms of location of towers, use of skidders, roads built and volumes harvested.
The system is based on information provided by a Geographic Information System for topography, timber existence, roads. A heuristic algorithm finds an approximately optimal solution.

A graphic user interphase provides an easy way to view and modify solutions.

The system is presently being used by Bosques Arauco and Forestal Chile.
More details on this system are given in another paper presented at this meeting.

ASICAM: A System for Scheduling Daily Transportation.

A typical problem timber companies face is daily hauling of timber products from origins in the forest where harvesting is carried out to destinations such as pulp plants, sawmills, stocking yards and port for exports. In most cases truck fleets are subcontracted and paid through formulas based on the cubic meters-kilometer transported.

The main decisions involved are:

- From which origin should each demand for products be supplied.
- The requirements in terms of truck fleet and cranes needed at origins and destinations.
- The work schedule for each truck and crane.

The basic objective is to satisfy demand of different products at destinations with given priorities using the timber produced or stocked at origins, while minimizing transportation costs, within technical, policy and labor constraints.

In some destinations regularity of arrivals is important to synchronize with dowstream operations. This allows to unload directly on a conveyor belt for example.

Firms will operate with about 10 to 90 origins, 5 to 30 destinations, 50 to 300 trucks. Depending on the distances involved, each truck will make between 1 and 4 trips per day.

Since transportation costs account for about 40% of total operating costs, important, savings can be derived by an efficient scheduling.

Traditionally, firms operated without

rigorous truck schedules. Each truck would be assigned a specific origin-destination task for the day to do as many trips as he could, with no specific time schedules. This led to several inefficiencies in the use of equipment, long queueing times, and excessive need for trucks and cranes. It was typical for example to be at an origin which was empty for 30 minutes, and then three trucks would arrive almost simultaneously, leading to queueing.

ASICAM involves a centralized transportation center, which schedules and controls truck trips. The trips are scheduled using a simulation model based on heuristic rules.

The system has been operating very successfully for about 5 years in different forest firms in Chile and also 2 firms in South Africa. It has produced significant savings in terms of

a) Reduced need for trucks.
   For example after introducing ASICAM, FORVESA went from 120 to 80 trucks, Forestal Millalemu reduced from 80 to 45 and Forestal Bío Bío from 80 to 60.

   In Bosques Arauco, with the introduction of a new pulp plant, the number of trucks went from 125 to 300 overnight. This could be controlled with ASICAM causing no problems.

b) Overall transportation costs were reduced between 15% to 25% through reduced capital and operational costs, as the trips carried out were more efficient.

3. Queueing time was reduced significantly. In one typical firm from 4.5 hours daily per truck to half an hour per day. Also daily working hours were reduced as wasted time was decreased.

4. Regularity for deliveries at destinations improved, as well as the ability to control stocks to avoid losses or theft.

The system runs on a PC 486, and takes about 3 minutes to run for the large problems (250 trucks). It is run daily in the afternoon and computer printed instructions for the next day are given to each truck driver and crane operator. Disruptions during the day, such as a crane failure are handled at the moment manually through the use of radios.

References

Weintraub A., Epstein R., Morales R., Serón J., Traverso P., 1995. "A Truck Scheduling System Improves Efficiency in the Forest Industries". To appear in Interfaces.

Weintraub A., Morales R., 1991 "A Model for Strategic Planning in the Management of Pine Forest Industries". Annals Symposium Systems Analysis in Forest Resources, Charleston, EE.UU. pp. 114-117.

Weintraub A., Morales R., Serón J., Epstein R., 1991 "Managing Operation in Pine Forest Industries". Annals Systems Analysis in Forest Resources, Charleston, EE.UU. pp. 31-34.

Weintraub A. and Cholacky A. 1991 "A Hierarchical Approach to Forest Planning". Forest Science, Vol. 39 N°5, pp.439-460.

Weintraub, A., Jones, G., Magendzo, A. Meacham, M. Kirby M. 1994 "Heuristic System to Solve Mixed Integer Forest Planning Models", Operations Research. Vol. 42, N°6, pp.1010-1024.

Weintraub A., Epstein R., Morales R., Serón J. 1994 "OR/MS Boosts Productivity in Chile's Timber Industry" OR/MS Today, pp. 40-42.

Weintraub, A. and B. Bare, 1995 "New Issues in Forest Management from an Operations Research Perspective", to appear in Interfaces.

Weintraub, A., Jones, G., Meacham, M., Magendzo, A., Malchuk, D., 1995. "Heuristic Procedures for Solving Mixed-Integer Harvest Scheduling Transportation Planning Models". To appear in Canadian Journal of Forest Research.

Epstein, R., Weintraub, A., Sapunar, P., Nieto, E., Sessions J., B. Sessions. 1995 "PLANEX : A System for Optimal Assignment of Harvesting Machinery". Annals of the LIRO Harvest Planning Conference. Nelson, New Zealand.

Weintraub, A., Wainer, A., Magendzo,A. 1993 "Un Sistema de Decisiones de Cosecha y Acceso Optimed". Anales 4 Taller de Producción Forestal, Concepción, Noviembre.

Weintraub, A., Guignard, M., Epstein, R., 1995, "Exact and Approximate Algorithms for Forest Management Problems, Annals Symposium on Systems Analysis in Forestry, Asilomar EE.UU, In press.