PLANEX: A SYSTEM FOR OPTIMAL ASSIGNMENT OF HARVESTING

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Suppose you have already defined an area of say 400 Hectares which you plan to harvest in the next 3-6 months. One question to answer is how to allocate harvesting machinery in a most efficient way to carry out the harvesting operations. Cable logging or towers are used for steep areas and skidders for flat areas. So, first we wish to define which areas will be harvested with towers and with skidders. We also need to know at which points to assign towers, and what type for tower (range, typically, from 300 meters, to 1000 meters, and direction of pull, upwards or downwards). Finally we need to define the roads needed both to access tower landings, and so that skidders work close enough to roads. It is considered economical for skidders to work at distances no longer than 300 meters or so from roads. We present a system, PLANEX which provides support for these decisions. The system interacts with a Geographic Information System (GIS) which provides information on topography, volumes of standing timber, and roads. The system incorporates the information from the GIS, plus additional information provided by the user through a friendly graphic interactive interphase on possible location of towers and relevant costs.

The system designs an approximately optimal allocation of machinery based on a heuristic algorithm. The solution can be viewed graphically and modified by the user interactively to carry out analysis of alternatives. We describe use of the system in two Chilean forest firms, Bosques Arauco and Forestal Chile.

The Decision Process

The main objective of the system is to support decisions related to the location and operation of harvesting equipment in a specified area.

The main decisions involved are:

i) Areas to be harvested by skidders.
ii) Areas to be harvested by towers

iii) Location of landings for towers, and the area to be harvested by each tower.
iv) New roads to be built
v) Old roads to be repaired
vi) Volume of timber harvested and transported

The system must satisfy a set of technical constraints:

i) Locate the landing for towers in adequate locations, according to topographical conditions.
ii) Comply with the range of reach of each tower. This will depend on the type of tower, operating conditions (down hill, uphill, with or without haul back line) and the characteristics of the terrain (the reach of the cable for logging will be interrupted for example by a ravine).
iii) Satisfy technical and economical constraints for harvesting with skidders. Elements to consider here are forward and lateral slope, logging distance, length of winch and loading capacity.
iv) Characteristics of roads. In the design of the road network we must consider acceptable slope, minimum radius of turn, how to link new roads to existing roads.
These characteristics many change according to the type of road and season in question.
v) Availability of equipment.
The objective of the system is to harvest all of the volume that is profitable to harvest, while minimizing costs.

Basic costs considered are:

i) Costs of installing and operating towers.
ii) Costs of operating skidders
iii) Costs of road building
iv) Transportation costs. Since distances within the harvesting area are small, these costs are usually less significant

The Solution Approach

The system requires a large amount of information provided by a GIS. A raster format is used to divide the area in question into squares or poligons for analysis. The size of the squares are a parameter, defined usually as 10 x 10 meters. Information that comes from the GIS in vector format is transformed into raster format.

The GIS provides basic information on the area to be harvested, while the user provides additional information both manually and through a visual interactive interphase described in the next section.

The system has an internal heuristic algorithm which determines a solution based on the following steps.

i) The user defines the area under study and a set of points where towers could be located. This is done graphically with a mouse. We assume the user is familiar with the problem and can define possible locations of towers by examining the topographical altitude level curves and additional information at his disposal. The user can define any number of possible points to locate towers by a simple click of the mouse.

ii) With this information, the algorithm finds a solution.

Solution Algorithm.

a) First, based on slopes and distances it assigns areas to be harvested by towers or by skidders.

b) The methods then looks at all possible but not yet assigned tower locations and evaluates the net impact of installing a tower at each location. For this evaluation the following elements are considered.

- Volume harvested (m^3) by the tower in question. This is obtained through including all poligons not yet harvested which are within the reach of the tower.

- Road building costs. Based on the topography given by the GIS, a Shortest Path Algorithm looks at the least cost road to link the tower with some already existing road. Information from the GIS is necessary here to determine acceptable slopes and turning radious for the road.

- Timber production cost. The further a cell is from the tower, the more expensive it will be to harvest it, given the longer cable handling distance.

- Transportation costs on existing and newly built roads.

The tower location with least expensive total cost per m^3 harvested is chosen.

The assigned tower location is excluded from the set of possible locations for future iterations. The harvested polygons are excluded for future iterations.

c) When no new locations are chosen, which happens when there are not enough remaining polygons or timber volume to justify the costs involved, the tower allocation process is finished.

A similar approach is used to allocate skidders.

d) Once all tower and skidder allocations are carried out, these allocations are improved by carrying out some permutations to improve the global assignment. Then, the roads built in the process are eliminated, and the road network is reoptimized. A new road network that connects all chosen locations with existing roads at minimum cost is determined.

e) The user can also compel the building of new roads or the reutilization of olds roads. This allows to compare easily a solution obtained manually by the user with the solution obtained with PLANEX.

Input Information

The information required to run the system comes from two sources.

a) Information given by the GIS. This correspond to data related to:

- Topography, through altitude

level curves. Typically a curve will be defined for every 10 meters of altitude.

- Timber Volume. Information on cubic meters of timber available in each defined cell.

- Existing roads, indicating its location and characteristics.

- Topographic accidents, such as rivers or ravines.

b) Information provided directly by the user.
The amount of information in this case is relatively small, and is provided by the user in two forms. As basic data: costs for road building or road rehabilitation, transportation, harvesting. This is done with a user friendly graphic interactive interphase. In addition the user, with a mouse, defines all potential locations for towers. In addition all technical parameters required are included: maximum slopes allowed for trucks and harvesting equipment, logging distances and harvesting costs for different equipments.

Output information

The solution is presented in 3 forms.

a) On screen. A graphic menu shows on screen (VGA color) all relevant aspects of the solution.

Location of towers
Areas harvested by each tower
Areas harvested with skidders
Areas not habilitated or not harvested
New roads
Old roads that are used
Old roads not used
Boundery of stands

b) Conventional reports which indicate:
Location (coordinates x-y) of installed towers.
Volumes harvested
Average costs of harvesting (towers or skidders)
Road building
Transportation

c) Binary Files. These files contain all the information in a raster form at cell level. This allows to present the solution through a GIS.

Interactive Use of the System

The graphic interphase allows to analyze possible modifications to solutions. Using the mouse on the screen the user can for example choose towers that should be selected, or design a road that should be build. The system then optimizes the remaining part of the problem and presents a new global solution. This option allows the user to analyze different scenarios in a simple and visual way.

Computational Requirements

The system can run on a PC 486. Planex can help in improving in the planning of harvesting and reduce the habilitation costs. In particular, the planner can spend more time analizing different scenarios rather than generating maps. It requires 16 Megas of RAM memory.

A typical problem of 400 Hectares takes about 10-15 minutes to run for the first run. Additional runs with modifications take 3 to 5 minutes. Any number of possible locations of towers is allowed.

Computational Results

A real problem was run with the results shown in Tables 1 and 2. Table 1 is a comparison of time needed in a manual approach compared to PLANEX . It can be seen that PLANEX leads to a substancial reduction in time required, in particular for additional runs. Table 2 shows a comparison of results in terms of roads built, areas harvested and costs. Using PLANEX led in this case to a savings of about 6%.

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TABLE 1

COMPARISON OF TIMES SPENT IN EACH OPERATION, WITH AND WITH PLANEX

	WITH PLANEX		WITHOUT PLANEX
	FIRST RUN	ADDITIONAL RUNS	
Preparations of coveraje	2'	0	28'
Input of information	15'	3'	15'
Obtaining a solution	12'	3'	45'
Printing	14'	14'	20'
TOTAL	**43'**	**20'**	**108'**

TABLE 2
COMPARISON OF RESULTS CASE OF 228 HECTARES AND 70.500 m^3 TO BE HARVESTED

ITEM	WITH/PLANEX	WITHOUT/PLANEX	DIFFERENCE
Building new roads (km).	2,3	2,5	-0,2
Use of old roads (km)	2,8	3,3	-0,5
Number of landing selected	12	13	-1
Area harvested with tovers (has).	136,8	159,6	-22,8
Area harvested with skidders (has).	91,2	68,4	22,8
Harvesting cost (US$/m^3)	5,20	5,40	-0,20
Habilitation cost (US$/m^3)	2,67	2,98	-0,31