PLANEX: A System to Identify Landing Locations and Access

Rafael Epstein, Andrés Weintraub, *University of Chile*

John Sessions, Bren Sessions, Oregon State University

Pedro Sapunar, Enrique Nieto, *Forestal Arauco*

Fernando Bustamante, *Forestal Bio-Bio*

Hugo Musante, *Forestal Mininco*

ABSTRACT - PLANEX is a system that solves the road network construction together with the location of harvesting machinery, skidders and towers, in planning the habilitation of up to a thousand hectares of terrain to harvest. The system is fed from digitalized information stored in geographic databases. This graphic tool automatically designs the road network, which is the third most important operational cost, after transport and harvest.

Before harvesting a forest area it is necessary to enable it for this purpose. This means to build a road network and landing areas that allow the access to the harvest machinery and store the logs. To solve this problem in an adequate manner it is advisable to analyze the problem as a whole, including the location of harvesting machinery and the construction of the road network. This problem turns to be complex and few analytic solutions are possible to analyze in practice, which limits the quality of the obtained solutions.

Harvesting in flat areas is done with skidders, which move the logs to road borders, where they are loaded over trucks. When the forest has too steep slopes, the logs must be pulled uphill or downhill using an aerial cable system that moves them to landing areas close to roads.

Furthermore, roads must fulfill some technical constraints, such as the following:

1. a maximum slope for loaded trucks, and

2. the turn radius of the road must be wide enough to enable the trucks to turn the curve safely.

The cost of carrying the logs to the road borders using skidders and towers depends mainly of the distance between the timber and the road. A very dense road network will produce smaller harvesting costs. Nevertheless, road construction is expensive, and it also negatively affects the environment. Therefore, finding the best technical and economical combination among the location of skidders, aerial cables and the road network design is a difficult problem to solve. The resulting problem is a combination of two NP-hard problems: a plant location problem and road construction problem in huge configuration with a network represented with hundreds of thousands of nodes and millions of arcs, as we explain later in this paper.

The main decisions are:

1. ¿Which areas must be harvested with skidders and with towers?

2. ¿Where must the landing areas for unloading the work of towers be located?

3. ¿Which surface must be harvested with each of the specific towers?

4. ¿Which roads must be built in order to transport the harvested volume?

Given the large-scale nature of the mathematical model behind the problem, it is not solvable in practice with present state of art optimization software technology. We discuss this issue in detail later.

Modeling the problem requires topographic information of the harvesting areas and timber inventory in digital format, typically obtained through a Geographic Information System (GIS). PLANEX solves the problem using this information together with technical parameters and costs of harvesting and road construction.

PLANEX interacts with a GIS, obtaining topological information and timber volumes. A visual solution includes location of towers, harvesting areas of each equipment, non-harvested or unreachable areas, existing roads used and new roads to be built. It allows the user to modify several of these elements. The system also gives as output several reports that specify the location of towers in coordinates harvested volumes, average harvesting cost, and cost of road building and timber transport.

We now describe the general scheme in which the system operates. First, we divide the study area in small cells of 10x10 square meters, which establish the basic unit of analysis. A typical problem has about 50 thousand cells.

For each potential location of towers or skidders, the system identifies all the cells reachable (possible to harvest) from that location.

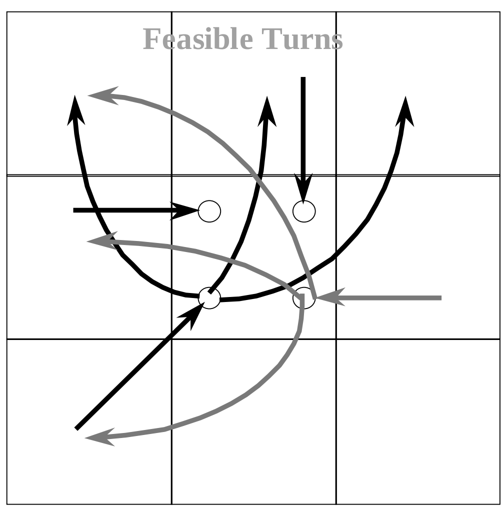

Figure 1. Connection of a cell with the existent road network.

As illustrated in Figure 1, to calculate the best way of connecting a machine with the existent road network, we build a set of potential roads to be analyzed. For each cell we evaluate the technical feasibility of building a road segment that links this cell with its adjacent cells. The road network is huge and grows even further when the technical constraints for road building (the turning radius, specifically) are incorporated. This implies the addition of several nodes on each cell to identify the direction in which the cell is accessed. This way, it is possible to identify every feasible turn by eliminating the arcs that produce very close curves. Thus, for a given location, the shortest path between this point and the existent network represent the cost of connection.

We implemented a heuristic of two phases. The first phase basically installs, on each iteration, the equipment with the cheapest total harvesting cost per cubic meter of timber volume. This includes the cost of machinery, road building and local transport. The second phase considers local exchanges of locations of harvesting machinery and reoptimization of the road network.

Figure 2 illustrates a solution of an example problem. Darker areas are allocated to skidders while lighter areas are allocated to towers, which are represented by dark spots. The road network is shown in white.

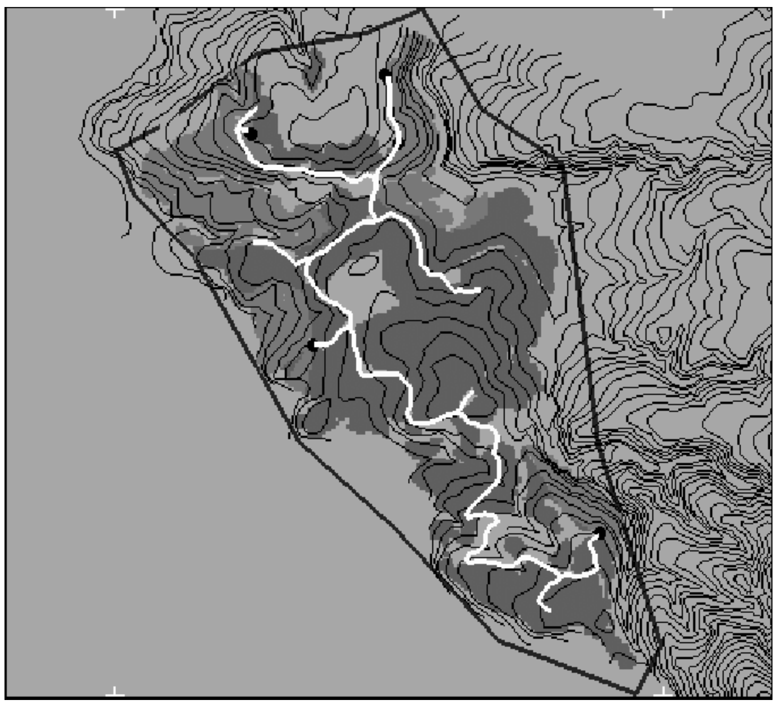

Figure 2. Graphical solution generated by PLANEX

PLANEX is used each time the forest firms decide to harvest an area and require its habilitation. The system is usually operated by forest engineers, who have significantly reduced the cost of harvesting and road building. PLANEX system runs in a PC and takes 15 minutes to solve instances of 1000 hectares. The system also allows the optimization of a fraction of the problem after it has been altered, enabling the planner to test several scenarios and concentrate his effort more in analysis than in map generation.

REFERENCES

Epstein, R., Serón, J., Weintraub, A., 1999, "Un Caso Exitoso: Sistemas de Optimización en la Industria Forestal Chilena", *Revista de Ingeniería de Sistemas*, Vol. XIII, Nº 1, pp. 5-32.

Epstein, R., Morales, R., Serón, J., Weintraub, A., 1999, “Use of OR Systems in the Chilean Forest Industries”, *Interfaces,* Vol. 29, Number 1, pp. 7-29, January-February.

Epstein, R., Weintraub, A., Sapunar, P., Nieto, E., Sessions, B., Sessions, J., 1995, “PLANEX: Un sistema para la Optima Habilitación de Maquinaria de Cosecha”, *Actas V Taller de Producción Foresta*l, Concepción, Noviembre.

Kirby, M.W., W. Hager, y P. Wong, 1986, “Simultaneous Planning and Wildland Transportation Alternatives,” *TIMS Studies in the Management Sciences*, Vol. 21, Elsevier Science Publishers, New York, pp. 371-387.

Meacham, M.L. y M.W. Kirby, 1994, “A Heuristic System to Solve Mixed-Integer Forest Planning Models,” *Operations Research*, Vol. 42, pp. 1010-1024.

Twito, R.H., S.E. Reutebuch, R.J. McGaughey, y C.N. Mann, 1987, “Preliminary Logging Analysis System (PLANS): Overview,” *Technical Report, USDA Forest Service*, PNW-199, Portland, Oregon.

Weintraub, A. y B. Bare, 1996 “New Issues in Forest Land Management from an Operations Research Perspective,” *Interfaces*, Vol. 26, Nº5, pp. 9-25.

Weintraub, A., Epstein, R., Morales, R., Serón, J., 1994, “OR/MS Boosts Productivity on Chile’s Timber Industry”, *OR/MS Today*, pp. 40-42, October.