HARVESTING TECHNOLOGY WATCH

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Summary

TECHNOLOGY WATCH is a biannual report outlining research and technology developments that are occurring outside the FFR Harvesting Theme. This report summarises computer-based decision support tools available to help forest engineers balance the cost of harvesting and road construction with safety and environmental requirements to ensure the most acceptable harvest plan is derived. The potential usefulness of these tools for the New Zealand harvest planner is discussed. It is recommended that a co-development project for optimisation tools for harvest planning be incorporated into the FFR Harvesting Programme.

Spencer Hill, Scion

Optimisation in Harvest Planning

Developing harvest plans that deliver wood to customers at the lowest possible cost within safety and environmental management constraints is the role of the harvest planner. Role conflicts regarding conflicting management goals make the task more difficult [1].

For an area to be harvested there are typically many possible options for landing location, all of which result in different harvesting costs. The smaller the accepted landing sizes the more options there are for placement, but under current logging conditions in New Zealand the smaller the landing the higher the harvesting cost[2]. Cable harvesting costs average $35 per tonne[3]. Road construction costs vary hugely but are currently in the order of $8 - $10 per tonne, and transport costs are around $24 – 25 per tonne for 100 km lead distance. In-forest transportation accounts for around 30% of the transport cost for approximately only 10% of the distance. Therefore getting the right combination of road length, landing size and harvesting technique is crucial to achieving lowest delivered cost. Testing all possible options to ensure the lowest cost scenario is achieved is difficult without the aid of robust optimisation tools. Harvest planners tend to develop harvest plans for current systems rather than what might be the "best" option.

Optimisation support tools would allow comparison of different scenarios very quickly. Many computer-based decision support tools have been developed over the past three decades[4] all with the aim of aiding better harvest planning decision-making. Some of these programmes are listed below:

- CYANZ – Cable harvesting payload analysis
- CHPS – Cable harvesting payload analysis in the GIS environment
- CPLAN – Cable harvest layout design and harvest, road and transport costing
- FOCAS – Equipment costing
- FOREST – Road design
- FOROPERA – Harvest and road costing
- FRP – Harvesting costing
- Improved Road Network Design – Roading and Transport Costing
- LIRO Costing Model – Harvesting costing
- LOGGER-PC – Cable harvesting payload analysis
- NETWORK 2000 – Network analysis for transport planning
- PLANS – Preliminary Logging Analysis System for harvest and road cost
- PLANZ – Modified version of PLANS for harvest and road cost
- PLANEX – Harvesting, roading and transport Costing
- RoadEng – Road location and design
- SNAP for ArcGIS – Scheduling and Network Analysis Program

Developments in computing power and more accurate digital terrain models have allowed huge improvements in optimisation software. This report focuses on two more recent optimisation model developments, PLANEX and CPLAN.

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PLANEX

PLANEX was developed at the University of Chile in 2002 in conjunction with the Oregon State University (OSU) and a number of Chilean forest companies. The main design was achieved by Rafael Epstein and Andres Weintraub, with John and Julian Sessions [5].

PLANEX uses a heuristic approach to solving the harvest planner's problem of analysing many options to determine the lowest cost harvest plan, The heuristic approach used by Epstein *et al.* could be described as an approach to learning by trying, "trial and error", and without necessarily having a pre-determined goal, such as a set delivered cost of logs. When playing chess for example, players use a heuristic approach to determine the next move. The more combinations of moves and retaliatory moves a player considers the better the chances of winning.

PLANEX uses information directly from GIS systems, including existing roads, topography, stand boundaries, streams and rivers, protected areas etc., and therefore is fully integrated with GIS databases.

The planner must first select an area of forest to evaluate, and starts by defining the possible road entrances to the selected area. In Figure 1 the planner changed a number of parameters while running a demonstration. With the new parameters the new road in black was very different from the initial road layout shown in grey.

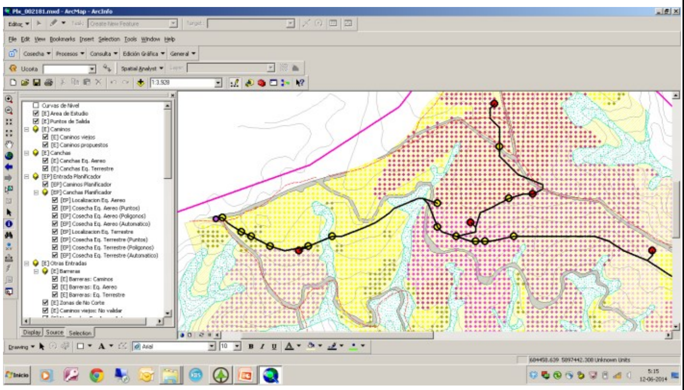

Figure 1: Road entrance selection

All the parameters that define acceptable limits (best practice) are then incorporated into the model. For harvesting, these include topography limits for systems, maximum haul distances, all possible landing locations, harvesting cost, special environmental conditions and any uphill or downhill restrictions. Roading parameters include maximum grade, corner radius, road width, batter angles, gravel cost including laying, construction cost, no spill zones, no road zones and end haul costs (Figure 2).

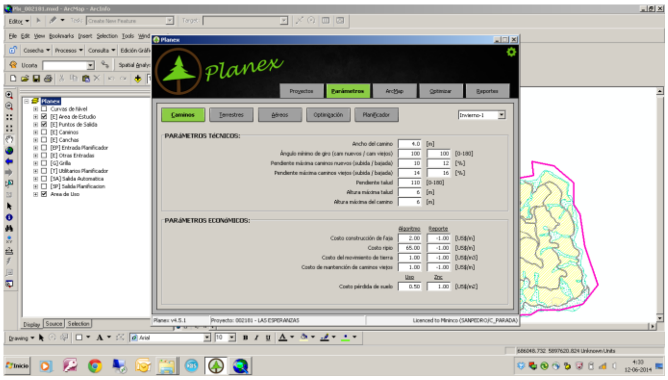

Figure 2: Roading (Camino) parameters, including width and maximum gradients

Transport costs are managed through designated speed zones from each landing to the exit point designated at the start of the modelling exercise. Once all the parameters have been set, the model has enough information to optimise the road location and choose which landings provide the best solution.

In the model the road network development works by breaking each part of the forest into small 10 m by 10 m-square cells. If LiDAR data are available this grid is 1 m by 1 m cells. From the DTM the position of each cell centre is known in terms of x, y and z coordinates. The height of the cell centre (z coordinate) is calculated as the weighted average height from eight projections from the cell centre to the nearest contour. The more precise the digital terrain model (using LiDAR data), the better the average cell height calculation. The slope (variable S) is then calculated by interpolating the heights with surrounding cells. These cell centres provide a path for potential

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roads. The slope at the cell centre is used to calculate the quantity of material required to be removed during road construction, which in turn will be used to calculate feasible road locations. The radius of possible road arcs between cell centres to achieve gradient restrictions will limit whether a road is feasible. The planner can manipulate the road position by imposing road restriction zones, or alternatively designating some roads as priority, forcing the model to use some road segments such as existing roads.

The road network will then join the location of the available landings, and select the landings based on the cost to get there, the cost of harvesting and then the cost of transporting the logs away.

Testing PLANEX

PLANEX is operational and many of the larger forest companies in Chile use PLANEX extensively. PLANEX was viewed in operation in Forestal Mininco in Chile in 2013. The harvest plan was developed using PLANEX and then checked on the ground by planning staff.

During this introduction to PLANEX it was apparent that one weakness of the system was in the area of the cost of harvesting and landings. PLANEX is able to generate an approximately optimal allocation of equipment and road network based on the heuristic algorithm. However, the system does not have the ability to analyse cableways with their topographic profiles, and some logging cost estimations do not vary with yarding distance and other cableway variables.

Forestal Mininco staff used only two logging rates, one for a haul distance less than 400 m, and a higher rate for greater than 400 m and less than 700 m.

A standard cost to construct a landing was also used, and a specific cost for each landing could not be entered in PLANEX. Considering that all logging contractors there used multi-span harvesting, generally uphill, the PLANEX solution seemed to result in minimising the cost of roading and extending the haul distance for logging. Staff at Forestal Mininco did very little cable analysis to determine allowable payloads, and this task was generally left to the contractor. In most cases the contractors were using LoggerPC, more to calculate the best position for intermediate supports than to calculate payloads.

Comparatively, in New Zealand the harvest planner is expected to do cable analysis to ensure the harvest plan is feasible from a harvesting perspective, given that harvesting accounts for 50% of the delivered wood cost.

From the brief investigation of PLANEX, it seemed it was also limited in terms of risk assessment. In the Mininco operation the planners made the decisions around environmental, safety and public acceptance concerns and managed this in PLANEX by manipulating where roads could or could not be built. It is recognised that it is often easier to decide where <u>not</u> to build roads than where to build them, and in the Mininco situation this management method appeared to be working well.

PLANEX could be further developed to include the following:

- calculated landing costs derived from LiDAR information;
- cable analysis to derive relative harvesting costs by setting;
- the calculation of risk between different options;
- incorporating an economic penalty system for higher risk harvest plan options; and
- LiDAR-based Digital Terrain Model (DTM) of the planning area.

If these developments were undertaken the result would make PLANEX a very powerful planning support tool and improve its usability and applicability.

The University of Chile has expressed an interest in collaborating with New Zealand harvesting researchers to develop PLANEX further, including translation into English from the current Spanish-only version.

CPLAN

Designing a timber harvest unit layout is one of the challenging tasks in forest operation planning. The task requires planners to identify logging equipment, landing sites, cable logging corridors, road locations, and transport routes. To undertake this task, CPLAN was developed in 2002 by Woodam Chung as a PhD dissertation [6, 7] at the Forest Engineering Department of Oregon State University. Understanding the current potential weaknesses of PLANEX, Chung incorporated cable payload analysis and logging costing into the development of CPLAN.

The input data required for CPLAN are described as follows:

- An accurate Digital Terrain Model (DTM) of a planning area;
- Harvest unit boundaries;
- Location and volume of timber to be harvested;
- Location of existing roads and fish-bearing streams;
- Location of candidate landings;
- Productivity data indicating the limitations and capabilities of the yarding system, and other system specifications for the ground profile analysis;
- Estimated construction costs of access roads and the effect of terrain on construction costs;
- Estimated construction costs for each candidate landing; and
- Areas which are subject to harvesting or road building restrictions due to expected environmental problems.

Road Network Development

A similar approach to PLANEX was taken to designing a road network where the forest was divided into small cells. One cell was linked to each adjacent cell with a road segment resulting in eight options for the location of the next road segment. Like PLANEX, parameters set in the model restrict where a road could be built based on user defined minimum standards set at the start of the modelling process.

The cost estimate for possible roads is calculated from the amount of material to shift during road construction, and the cost per cubic metre.

Landing Selection

The planner indicates on the DTM where possible landings could be built, and as with PLANEX the smaller the landing the more options there are. The cost to construct each landing selected is not calculated or derived from the volume of material required to be shifted times the unit cost. The size of the landing is not specified. For the purpose of the model a road can be designed to the landing from anywhere, which may not be feasible in reality.

Harvesting Cost

The addition of cable analysis in CPLAN makes CPLAN more robust than PLANEX. However CPLAN cable analysis was restricted to standing skyline uphill extraction with single or multiple spans. The cable analysis incorporated an automated multispan position system and tailhold positions. Once the location of the landing is selected the model locates the best position of the tower by analysing the net payload calculations within the area of the chosen landing. For each hauler location, 36 yarding corridors are projected in a "wheel-spoke" arrangement around the landing. Cable analysis takes into account partial suspension and full suspension requirements. From payload analysis the cost of logging is calculated for each landing and used in the balance of cost calculation.

Environmental considerations are managed in the model by adjusting operating costs for landings where there are higher risks. Multipliers or penalties are imposed to account for higher risk and in some cases penalise harvesting activities.

Testing CPLAN

Once development was completed Chung used a test case forest to test the model. A timber harvest unit layout was formulated as a network problem. Each grid cell containing timber volume to be harvested was identified as an individual entry node of the network. Mill locations or proposed

timber exit locations were identified as destinations. Each origin was then connected to one of the destinations through many alternative links representing alternative skyline cable corridors, different harvesting systems, landing locations, and truck road segments.

Forty landings with 2,880 yarding corridors from two logging system alternatives (a Koller 302 and a Madill 6150) were evaluated in the analyses. The heuristic algorithm for network programming was used for optimising the cable logging layout by solving the cost minimisation network problem. A total of 19 landings and 155 cable roads were selected to harvest 8,064 m3 of logs from 1,926 timber parcels over the planning area.

Overall yarding, roading and transportation costs for timber harvest in the planning area were provided. This case study indicated that the planning method is best used to provide a preliminary layout for the cable logging area, since modelling assumptions with respect to tail spar availability and unconstrained road alignments may require modification of the plan before implementation.

It was concluded that the model should be further tested and verified in the field. The outputs from the model could be compared with a paper cable logging plan produced by the conventional manual method for the same area. The efficiency of the method in terms of time required to develop a cable logging layout could also be compared with that of the conventional method.

Usefulness for New Zealand

CPLAN is yet to be used operationally but does address some of the potential shortcomings of PLANEX, and with further development would have a place in New Zealand harvest planning. While the cost of harvest planning ranges from a few cents per tonne to a few dollars per tonne the unknown cost of getting the plan wrong is much greater.

Harvest planners tend to stick with harvesting systems that are known or available, and it is difficult to develop harvest plans or even strategic plans when new options are not available. A system that could quickly test different scenarios based on pre-set criteria would be extremely valuable.

Both PLANEX and CPLAN can test sensitivities and “what if” scenarios by changing input parameters, with each result downloaded to Microsoft Excel and saved. Using the heuristic approach many options can be tested. CPLAN is an exciting development and has great potential.

Woodam Chung has been active in developing decision-support systems for forest transportation planning, forest operations design, and spatially-constrained harvest scheduling. Woodam Chung is now resident at Oregon State University (OSU) and continuing his work in this area.

Recommendation

Having spoken to Dr John Sessions at OSU it is apparent that OSU would be open to a collaboration to further develop the CPLAN decision support tool. The options for further development would include:

- more choice in systems for cable analysis;
- calculate landing costs incorporating end haul costs; and
- a more robust risk analysis tool.

Both OSU and University of Chile have expressed a keenness to further co-develop PLANEX and/or CPLAN for New Zealand. It is recommended that the FFR Harvesting Theme Technical Steering Team and the Programme Steering Group give serious consideration to this opportunity to collaborate for further development of optimisation in harvest planning.

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Other Useful Publications

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