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A DECISION SUPPORT MODEL FOR PREDICTING NET REVENUE OF HARVESTING COASTAL SECOND-GROWTH FORESTS

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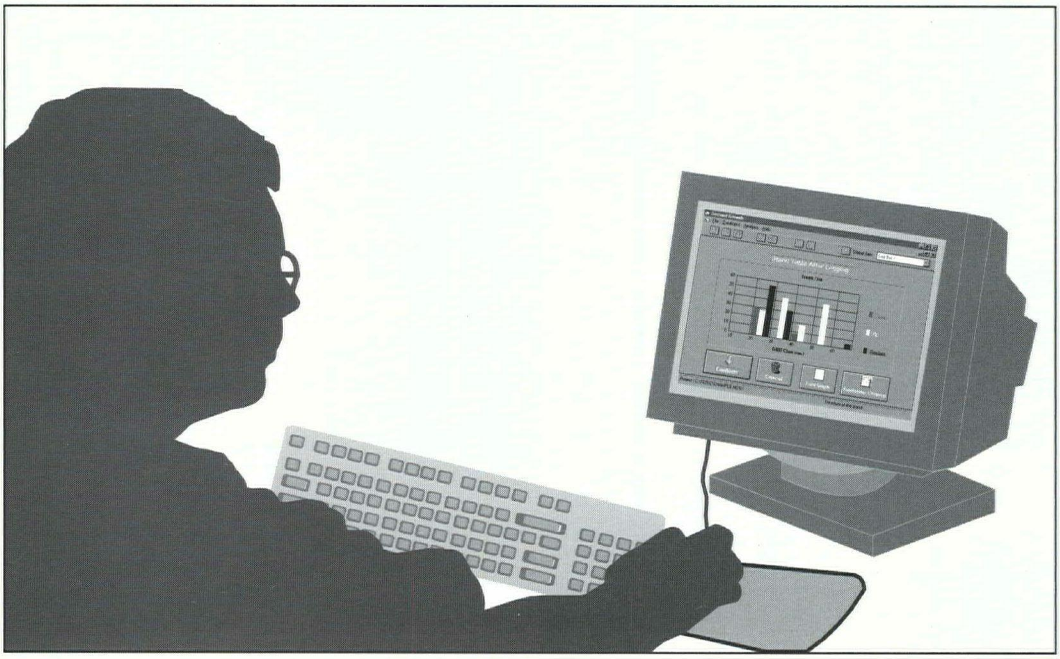
March 1999



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Abstract

The Forest Engineering Research Institute of Canada (FERIC) and the Faculty of Forestry at the University of British Columbia (UBC) developed a computer model, for use at the cutblock level, to predict the net revenue of coastal second-growth stands that are to be clear-cut or partial cut. Cruise data and company sort descriptions are used to predict volume by sort and timber value. Productivity and cost data from within the model, or as defined by the user, determine the total harvesting cost for an operation. Net revenue is obtained by subtracting the harvesting cost from the timber value. At two harvesting sites near Powell River, B.C., the predicted total volumes and timber values were within 5% and 3% of scaled volumes and actual values, respectively.

Authors

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Disclaimer

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Summary

As harvesting shifts from old-growth to second-growth stands, profitability is becoming an important issue. The Forest Engineering Research Institute of Canada (FERIC) and the University of British Columbia (UBC) developed a model to predict the economics of harvesting second-growth stands (clearcuts and partial cuts). The objective of this model is to assist forest planners make medium-term management decisions.

The model is a Windows-based program and was written in Visual Basic. It ships on two diskettes with a set-up kit.

The model calculates the net revenue produced when logging second-growth stands that are to be clear-cut or partial cut. This is computed as a function of stand characteristics, company product requirements, and harvest equipment used. Additional results computed by the model are total volume, distribution of volume by species and by sort, and estimate of time required to harvest a block.

Testing of the model was done at two second-growth sites near Powell River, B.C. The model compiled input data and calculated the volume by log sort and timber value as intended. Results obtained with respect to volume and value were very good in both tests. The total volume and timber value predicted by the model for each of the two test sites were within 5% of the scaled volume and 3% of the actual value, respectively. The model is more likely to overestimate the volume and value of the stands, as there is currently no allowance built into the model for internal tree defects and operational factors that cause stems to be bucked suboptimally from a value viewpoint.

The model should be a helpful tool for predicting cost and revenue of harvesting operations in coastal second-growth forests, and can be easily improved to analyze and display more information.

Sommaire

À mesure que la récolte forestière passe des vieilles forêts aux peuplements de seconde venue, la rentabilité devient un enjeu important. L'Institut canadien de recherches en génie forestier (FERIC) et l'Université de Colombie-Britannique (UBC) ont développé un modèle pour prévoir les paramètres économiques de la récolte de peuplements de seconde venue (coupes à blanc et coupes partielles). L'objectif de ce modèle est d'aider les planificateurs forestiers à prendre des décisions de gestion à moyen terme.

Le modèle est un programme fonctionnant dans un environnement Windows et il a été écrit en Visual Basic. Il se présente sur deux disquettes avec programme d'installation.

Le modèle calcule le revenu net produit lors de la récolte de peuplements de seconde venue qui doivent être coupés à blanc ou partiellement. Les calculs sont faits en fonction des caractéristiques du peuplement, des produits requis par la compagnie et de l'équipement de récolte utilisé. En plus de ces résultats, le modèle calcule le volume total, la répartition du volume par essence et par classe de qualité, ainsi qu'une estimation du temps requis pour récolter un bloc.

Le modèle a été vérifié sur deux sites de seconde venue près de Powell River, C.-B. Il a compilé les données d'entrée et calculé le volume par classe de qualité des billes et valeur des bois selon l'utilisation désirée. Les résultats obtenus en fait de volume et de valeur étaient très bons dans les deux essais. Le volume total et la valeur totale prévus par le modèle pour chacun des deux sites d'essai étaient à moins de 5 % du volume mesuré et à moins de 3 % de la valeur réelle, respectivement. Le modèle est davantage susceptible de surestimer le volume et la valeur des peuplements puisque, actuellement, il ne comporte aucune déduction pour tenir compte des défauts internes des arbres et des facteurs opérationnels qui font qu'une bille est tronçonnée de façon sous-optimale au point de vue valeur.

Le modèle devrait se révéler un outil utile pour déterminer le coût et le revenu d'opérations de récolte dans les forêts côtières de seconde venue et il peut facilement être amélioré pour analyser et afficher plus d'information.

INTRODUCTION

The ongoing shift from old-growth to second-growth harvesting, combined with high costs of wood fibre, increasing global competition, and fluctuating world market prices for wood and paper products, provides both challenges and opportunities for the forest industry in coastal B.C. To meet these challenges and opportunities, the industry must be able to assess the profitability of harvesting individual cutblocks using different harvesting systems. This requires reliable information on harvesting productivities and costs for different harvesting methods and stand conditions, as well as the volumes and revenues that can be obtained from the cutblocks. Making sound economic decisions involves analyzing several different harvesting options. This process can be facilitated by interactive computer-assisted decision models.

In order to provide the forest industry in British Columbia with information on second-growth harvesting and a tool for analyzing different harvesting options, the Forest Engineering Research Institute of Canada (FERIC) and the Faculty of Forestry at the University of British Columbia (UBC) initiated two consecutive projects beginning in 1991. The first project studied harvesting operations in coastal second-growth stands, and developed productivity functions and cost data for various harvesting systems (Andersson and Young 1998). The second project designed and tested an interactive computer model for use at the cutblock level to predict timber value and harvesting costs in coastal second-growth forests that are to be clear-cut or partial cut. The overall objective of the model is to assist forest planners make medium-term management decisions. Funding for the projects was obtained through the Industry, Trade and Economics Program of the Canadian Forest Service under the Canada–British Columbia Forest Resource Development Agreement (FRDA II).

This report briefly describes the computer model and presents the results of the validation test. Detailed information on the model and its use can be found in the User Manual accompanying the software (Pavel et al. 1997), and in a UBC Master's thesis (Pavel 1997).

MODEL DESIGN AND FUNCTIONS

Because coastal second-growth stands have few defects, attempting to predict the value of these stands seemed reasonable. This is in contrast with old-growth stands, where the presence of many defects and the imprecision of correlating them with loss in wood volume can make the prediction less accurate. Sets of log sorts used by some coastal B.C. companies were analyzed; the most important criteria used when describing a sort were dimensions (diameters at one or both ends, and length) and presence of knots. Consequently, one of the objectives of this study was to develop a function to predict distribution of knots (knot sizes existing at different heights) on trees cruised, to facilitate computation of volume by species and by sort for the cutblock analyzed.

Some loss in volume and value during a harvest occur because of breakage. Copithorne and Young (1994) showed that the majority of breakage occurs during falling. Loss due to breakage during subsequent primary transportation phases is about 0.2% of volume, and in this project was considered negligible. Previous FERIC studies suggest that stem breakage differs between falling methods (Andersson 1997; Young 1998). To account for this, a frequency function that predicts the height of break point relative to total height was developed as part of this project. Also, portions of the stem lost because of breakage (shatter) were measured and the impact of this on volume and value recovery was estimated.

The model developed in this study is a stand-alone software program written in Visual Basic, and runs under the Windows operating system (version 3.1 or later).[1] It ships on two diskettes with a set-up kit. The minimum machine configuration is a 486 microprocessor with 8 MB RAM, 4 MB of hard disk space, a 3.5-inch floppy disk drive, and a mouse.

The model consists of two parts. The first part determines the volume and value of timber in the cutblock, and the second part estimates machine productivity, harvesting costs, and net revenue (Figure 1).

Volume and Value Predictions

Estimation of volume by sort and value of timber is based on operational cruise data for the cutblock, and sort specification criteria defined by the user. The compilation process uses dynamic programming techniques and a stem taper equation developed by Kozak (1988). The taper equation allows the model to calculate the diameter (inside bark) at any height of a tree. For each tree in the cruise, the model determines the combination of sorts and log lengths that will give the highest value from the tree.

[1] Visual Basic is a registered trademark and Windows is a trademark of the Microsoft Corporation.

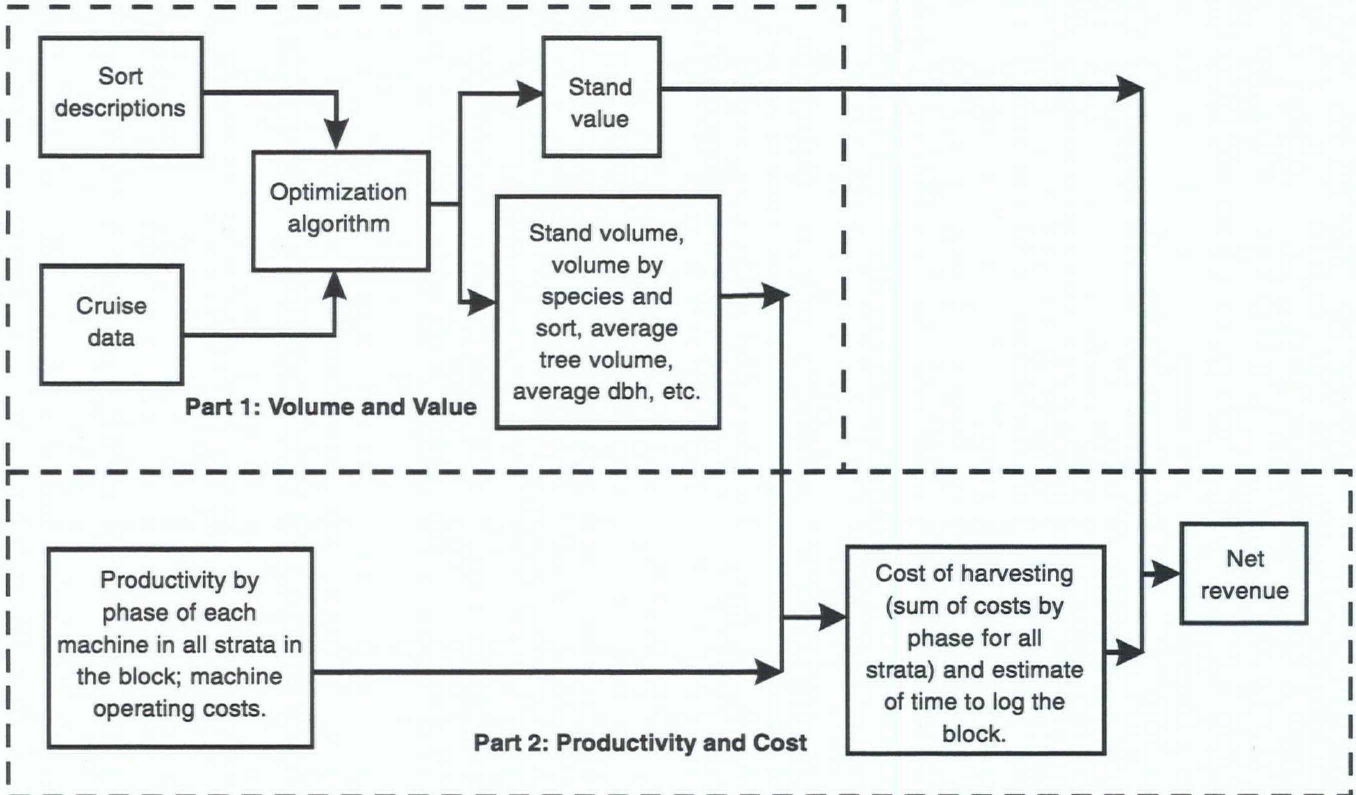

Figure 1. Diagram of the model.

Because of project time constraints, the current version of the model is programmed only to handle data for Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and western red cedar (*Thuja plicata* Donn).

In the Cruise Data screen, cruise data are input into the model by the user in the format specified by the British Columbia Ministry of Forests' Cruising Manual (1998) for variable-area cruise plots (Figure 2). The only exception is the Basal Area Factor (BAF); the user must specify the BAF of the prism used at each plot. This allows the model to combine plots (in the cruise data file) cruised with different BAFs. As the model was not designed to account for internal defects of trees cruised, only information on "fork or crook", "dead or broken top", and "sweep" are used by the algorithm that calculates the best combination of sorts for each tree. All the other data existing in the cruise are used as criteria for modelling partial cuts.

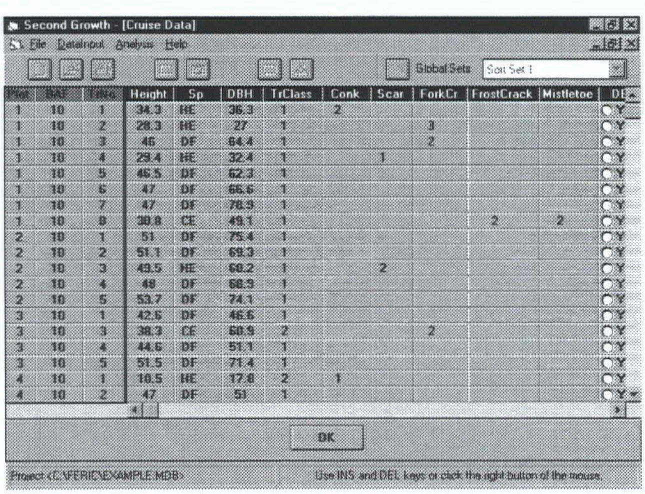

Figure 2. Cruise Data screen.

Sort description data are input by the user in the Sort Descriptions screen, stored by the model and retrieved as required (Figure 3). The user can create several sets of sort descriptions to accommodate different log markets. Each set contains information on log dimensions, unacceptable defects and knot sizes, and market log values.

In the Block Details screen, the silvicultural system and falling method can be selected (Figure 4). The user can also choose between a quick or detailed analysis option. The quick one is less accurate and therefore suitable for preliminary analysis, while the detailed option is recommended for final analysis. Based on the falling method selected, the model uses one of two "frequency of occurrence and location of breakage" tables. Other input required at this stage include area of the block,

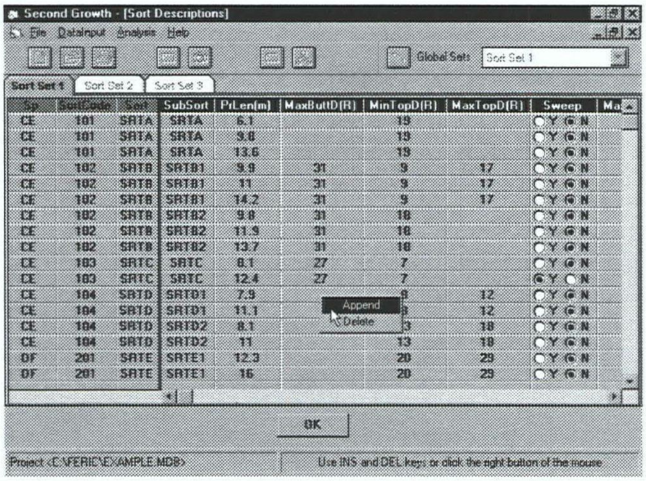

Figure 3. Sort Descriptions screen.

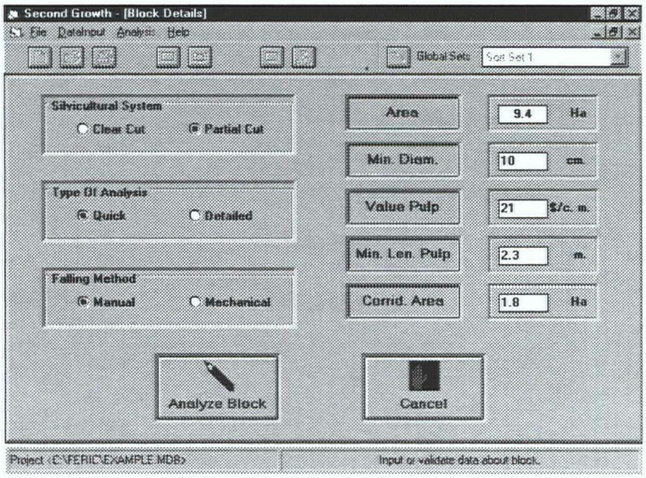

Figure 4. Block Details screen.

minimum diameter to be recovered, value of pulpwood, and minimum length of pulpwood.

For clear-cutting operations, no additional input data are required for the volume and value calculations. For partial cutting operations, the user must input the area of the skidding (or yarding) corridors and specify the selection criteria for trees to be removed between the skidding corridors. This process begins with a graph showing the pre-harvest stand table (Figure 5). Next, the model displays the Partial Cut Specifications screen, which lists tree features and diameter classes, by species, from which the user selects the type and/or size of trees to be harvested between the corridors (Figure 6). Finally, the model displays a graph (similar to Figure 5) of the predicted post-harvest stand table. If unsatisfied with the predicted results, the user can switch back to the Partial Cut Specificatons screen, change the selection criteria, and view the new post-harvest stand table.

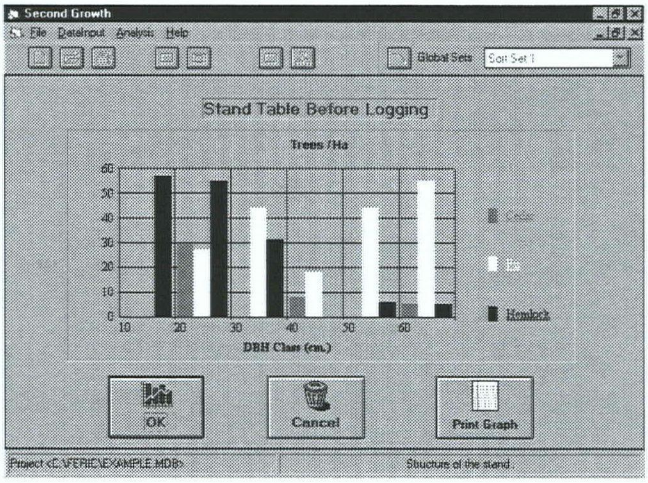

Figure 5. Graph of pre-harvest stand table.

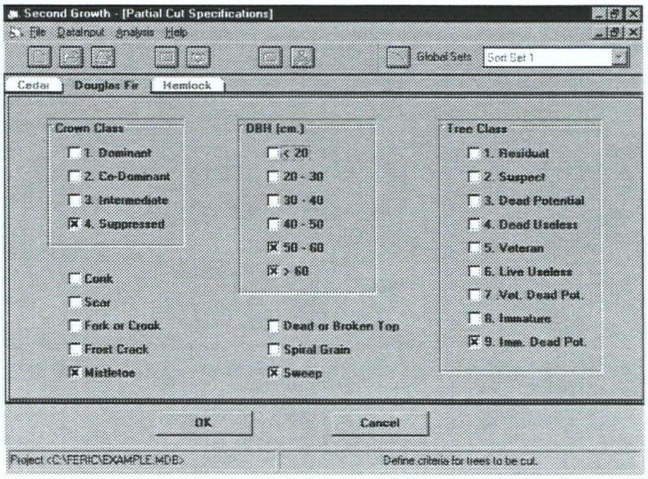

Figure 6. Partial Cut Specifications screen.

Once the necessary data have been input, the model calculates the predicted volume by sort and the timber value from the stand. The final results displayed by the model show volume and value by sort for each species, on a per hectare basis and total for the cutblock.

Harvesting Productivity and Cost Predictions

Following the completion of the volume and value analyses, the user proceeds with the harvesting productivity and cost analyses. First, the user defines the harvesting system by selecting the desired harvesting phases from the options presented by the model (Figure 7). The model allows the user up to five harvesting systems per cutblock, through stratification of the cutblock. Each stratum is assumed to have the same stand characteristics as the whole cutblock, and thus the size of each stratum is expressed as a percentage of total stand volume.

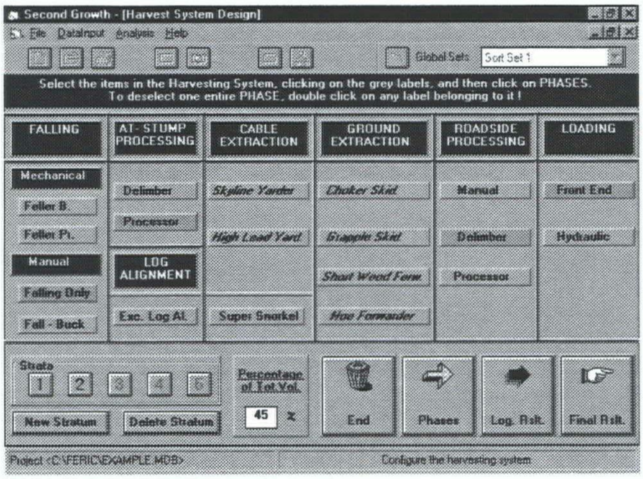

Figure 7. Harvest System Design screen.

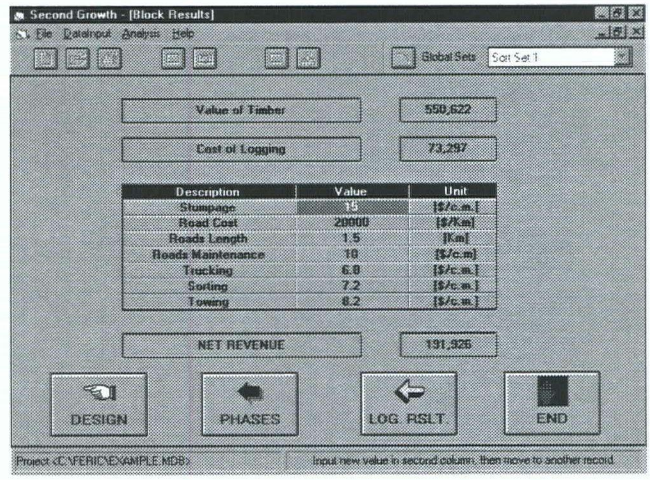

Figure 9. Block Results screen.

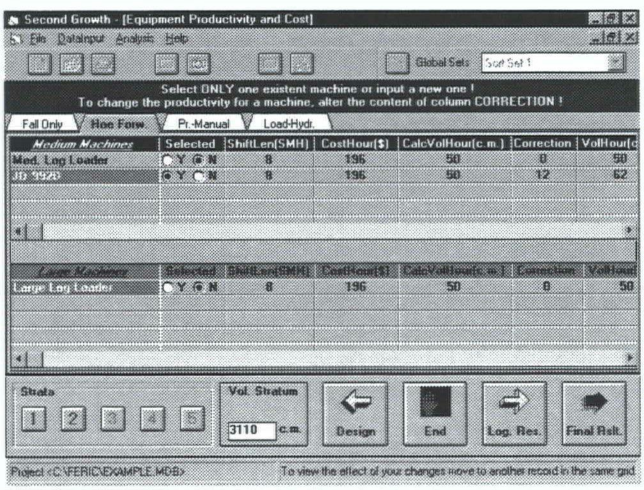

Figure 8. Equipment Productivity and Cost screen.

For each harvesting phase, the model displays one or two machine sizes (large and medium), and provides productivity and cost information (Figure 8). The default productivity and cost data are based on FERIC and other second-growth harvesting studies. The productivity data are integrated in the model either as regression equations linked to average tree size or extraction distance, or as averages.[2] The hourly machine costs are all averages, and calculated with FERIC's standard costing methodology, based on general assumptions of machine life, repair cost, annual use, and machine utilization.

The model allows the user to apply a correction factor to the default productivity or override the shift length and hourly machine cost displayed by the model, should these values appear non-representative of the current analysis. The user can also add new machines with their productivities and costs. Following the analysis, the model displays a summary of the harvesting costs. The user can input other costs, e.g., stumpage fee, road costs, and transportation costs, which the model includes in the final calculation of expected net revenue from the whole harvesting operation, displayed in the Block Results screen (Figure 9).

MODEL VALIDATION

The model was tested in the spring and summer of 1996 at two clearcutting operations situated on Crown land, near Powell River, B.C. The objectives were to test the model's compilation processes (i.e., logic), and determine if the model could predict realistic estimates of volume by sort and value.

Test Sites and Harvesting Methods

Site 1. Site 1 was a 40-ha cutblock offered by MacMillan Bloedel Limited, Stillwater Division. The cutblock was in a 60-year-old "thrifty mature" stand of Douglas-fir, western hemlock, western red cedar, and red alder (*Alnus rubra* Bong.). Based on operational cruise data, average tree size and gross stand volume of the conifer component of the stand were 1.31 m^3/tree and 602 m^3/ha, respectively (Table 1). The trees were hand-felled and bucked into prime log lengths. Logs within the road right-of-way were loaded directly onto trucks, while logs outside this area were extracted to roadside using two John Deere 690 loader-forwarders and a Madill 123 grapple yarder. The loader-forwarders operated on the flatter portion of the cutblock, while the grapple yarder worked on the steeper and more sensitive ground.

[2] The User Manual (Pavel et al. 1997) lists all productivity and cost values and regression equations incorporated as defaults in the model.

Table 1. Average Stand Characteristics of the Conifer Component of the Study Sites

	Site 1				Site 2			
	df [a]	hw [a]	cw [a]	All	df	hw	cw	df+hw
Tree dbh (cm)	54	26	28	33	30	26	33	29
Total height (m)	41	24	19	27	34	31	38	33
Trees/ha (no.)	104	275	80	459	529	347	110	876
Tree volume (m^3)	3.58	0.61	0.77	1.31	0.72	0.60	0.88	0.67
Cruise volume								
Gross (m^3/ha) [b]	374	167	61	602	383	208	96	591
Net (m^3/ha) [b]	348	157	57	562	367	198	90	565

[a] df = Douglas-fir, hw = western hemlock, cw = western red cedar.
[b] Differences due to rounding.

Site 2. The second site was offered by Granet Lake Logging Limited, and consisted of two separate cutblocks totalling 14.6 ha. Major species were Douglas-fir and western hemlock, with minor components of western red cedar and red alder. The stand characteristics varied considerably within the cutblocks, ranging from patches of dense small-diameter trees to patches of medium-sized second-growth trees, old-growth cedar snags, and windfalls. The cedar component included several dead old-growth trees with a high degree of decay, and was excluded from the study. Based on the BCMOF cruise information, average tree size and stand volume for the Douglas-fir and hemlock components of the stand were 0.67 m^3/tree and 591 m^3/ha, respectively.

Most trees were hand-felled, extracted in full-tree form by a Madill 122 skyline yarder, and processed into preferred log lengths at the landings, either mechanically by a Timbco/Keto 1000 processor, or manually by two buckers. Occasionally, large trees or trees near the block boundary were delimbed and bucked at the stump to simplify extraction. The logs were loaded and hauled to a dryland sortyard by self-loading log trucks. Some additional bucking and upgrading were done at the sortyard.[3]

Testing Procedure

Prior to falling, FERIC cruised the study sites at a plot density of 1 plot/ha using BCMOF cruising procedures. FERIC also recorded the height and length of all stem defects, as well as the size, location and distribution of knots.

Four special 20-m-radius cruise plots were established on Site 1 to collect data on prediction accuracy for taper equation, falling breakage, and actual bucking patterns. Two of the plots were located on flat ground (loader-forwarding area) and two on steeper ground (grapple yarding area). All trees were cruised and numbered prior to falling. Following falling and bucking, FERIC measured manufactured logs and broken pieces (length and diameter inside bark at both ends), located the breakage point(s) for each tree, and numbered all merchantable pieces. To compare actual bucking with that performed by the model for individual trees, marked logs were tracked to the sortyard where actual scaling and grading outcome were recorded. FERIC also measured the occurrence and location of the first break of 55 trees at Site 2 using a systematic sampling method.

Sort descriptions, log values, and scaled volumes by sort were obtained from the cooperating companies. The volumes by sort and the timber value of the cutblock were determined by the model, and compared with the scaled volumes. The model's response to information on stem defects, knot data, and falling breakage was tested by introducing these factors one by one into the model. The volumes by sort and value were recorded in each case.

RESULTS

By comparing diameters inside bark measured after falling, with those predicted by the taper equation, it was concluded that the taper equation predicted diameters very well in this study. Measurements performed in the 20-m-radius plots were used to develop frequency functions to estimate ratios of breakage, in terms of how many trees will break (by species and dbh class), and percentage of total height where breakage will occur. Also, the portion of the stem that has to be trimmed off after breakage was estimated according to the same criteria. Although not collected

[3] The processor generally did not buck the uppermost portion of each stem. Instead, the scaler/grader at the dryland sortyard determined the best use of these pieces to minimize wood waste.

as part of this study, data from another FERIC project (Young 1998) were used to analyze breakage that occurs during mechanical falling. For comparison of actual and theoretical bucking for individual trees, the number of logs retrieved at the sortyard was insufficient, and no definite conclusion could be drawn. Therefore, the final scale for the entire cutblock was used as the main criteria to test model performance.

The model responded as expected when information was added on stem damage, knots, and falling breakage, as it reduced the total volume and shifted some of the volume from higher quality to lower quality log sorts. Shifts occurring as a result of stem damage were proportional to the number of trees containing this damage. The most important shifts occurred as a result of breakage and, in particular, knots. These two factors contributed substantially to making the predicted distribution of volume approach the actual distribution. Based on these tests, information on knot distribution and breakage were programmed into the model. Therefore, future analyses with the model can be performed using regular cruises done according to BCMOF specifications and company log sort descriptions.

The total volumes predicted by the model for each of the sites were within 5% of the scaled volumes, while for individual species the differences between scaled and predicted volumes were more varied. The best prediction was for Douglas-fir, which was the dominant species on the two sites (Table 2).

The model's prediction of volume by sort was reasonably accurate, and there was no evidence of bias towards a particular sort (Figures 10 and 11). The lack of bias was also demonstrated by the predicted stand values, which were within 3% of the actual values (obtained from the cooperating companies) for each of the two sites.

A statistical analysis was performed for each sort, to test if the volumes produced by the model are different from the actual ones. The analysis proved that for both cutblocks, only four sorts were statistically different: cedar pulpwood, hemlock chip and saw, and utility sorts at Site 1; and hemlock gang at Site 2. Various factors could have produced this effect, but none of them could be clearly identified. One explanation could be that cedar and hemlock were less represented in the stand (on each site, they comprised about 35% of total volume). Therefore, the sampling intensity achieved for these species was lower than for Douglas-fir, which was the main species. Also, the non-uniform spread of these species across the cutblocks could also have affected the accuracy of prediction.

Table 2. Comparison Between Actual, Model-Predicted, and Cruise Volumes

	Volume (m^3/ha)		
	Actual	Model prediction	Cruise estimate
Site 1			
Douglas-fir	443	429	348
Western hemlock	130	172	157
Western red cedar	57	63	57
Total	630	664	562
Site 2			
Douglas-fir	492	503	367
Western hemlock	187	155	198
Total	679	658	565

DISCUSSION

During the development of this model, the following factors were identified as affecting the accuracy of prediction. The impact on prediction could be controlled for some factors but not all.

- Optimal bucking: the computer model produces optimal bucking for each tree in the cruise, whereas the actual bucking performed may be suboptimal. This factor will cause the model to overestimate the stand value.

- Hidden defects: since the model does not account for them, when present, hidden defects will cause the model to overestimate the stand value.

- Breakage and knot distribution: these were programmed in the model such that they compensate for the effects of the previous factors.

- Sampling error: as the prediction is based on the cruise, which is just a sample of the stand, the sampling error may act either way; its effect on prediction cannot be controlled.

- Crew skill: this factor may also contribute to higher or lower recovery levels from a block, but it cannot be controlled through the model.

Overall, the way these factors were accounted for worked well. Distribution of volume by species and sort, and total cutblock value predicted by the model, were close to the actual ones.

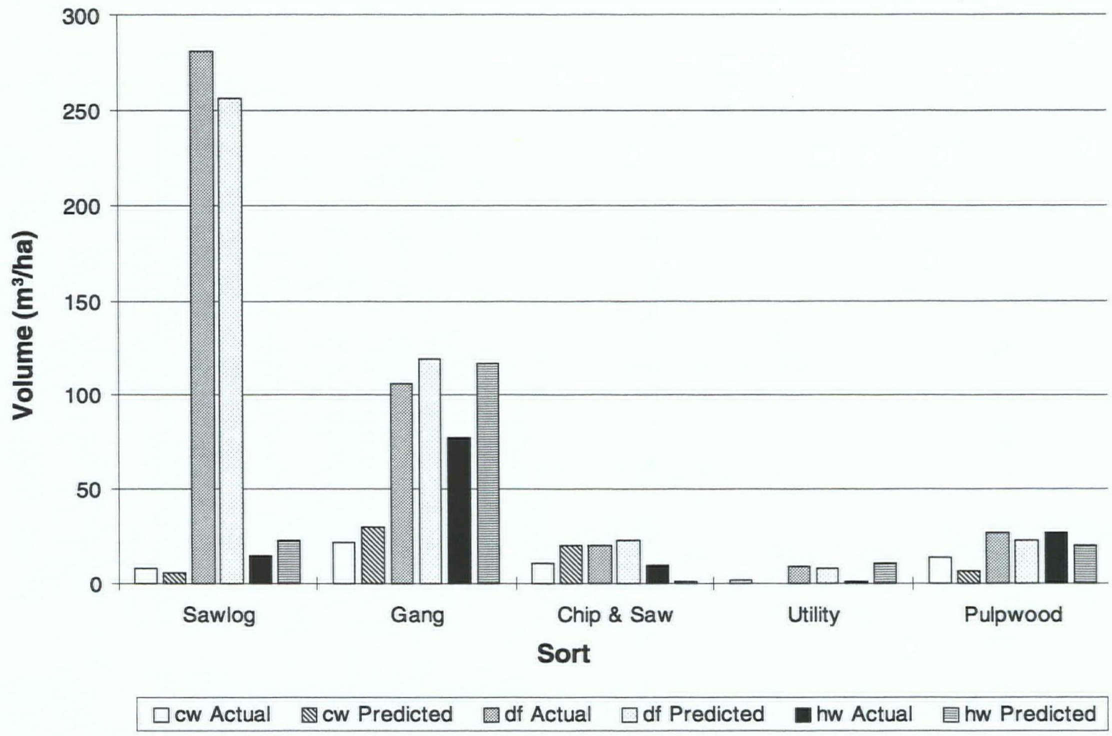

Figure 10. Predicted and actual results for Site 1.

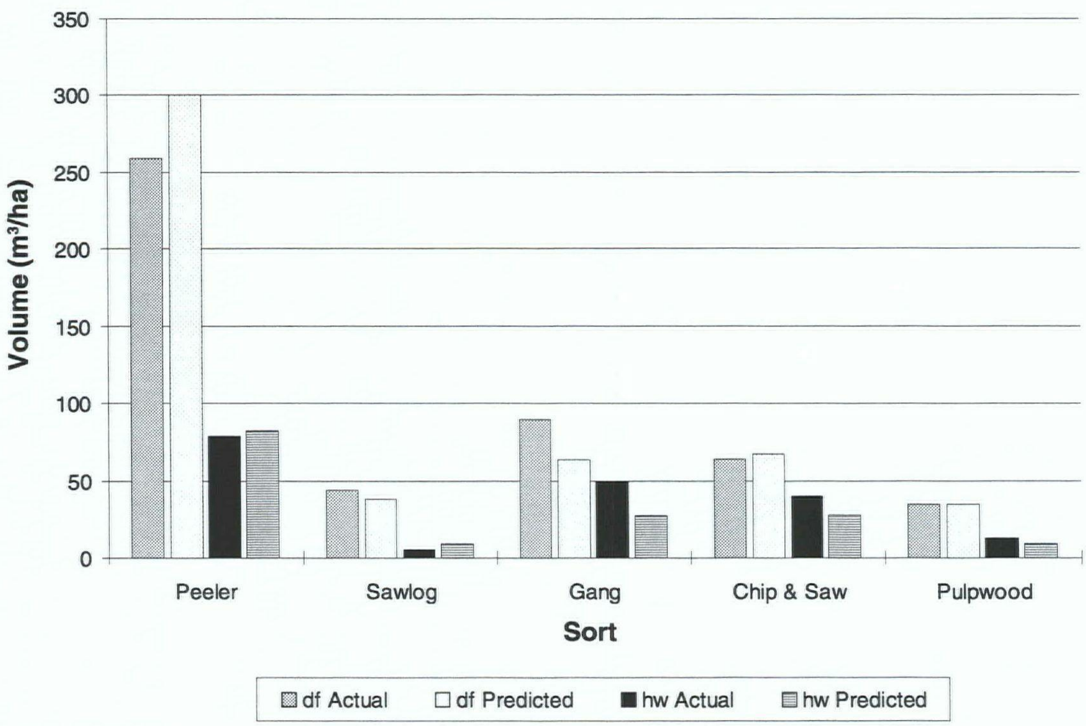

Figure 11. Predicted and actual results for Site 2.

FERIC has identified other factors that the user should recognize when assessing the model's predictions:

- Operational factors and harvesting policies (e.g., safety factors, minimizing wood waste) that are incompatible with value optimization will cause the model's predictions of the volume of high quality sorts and the total timber revenue to be overestimated.
- Incorrect assessment of the cutblock area will affect the model's total volume and value predictions, but should not affect the proportional volume distribution between log sorts and tree species.
- Poorly defined sort descriptions will adversely affect the model's prediction accuracy.

CONCLUSIONS

The model developed in this study compiled input data and calculated the volume by log sort and timber value as intended. The total volumes and timber values predicted by the model for each of the two test sites were within 5% of the scaled volumes and 3% of the actual values, respectively. The predictions for individual species were more varied. The best prediction of volume by species was for Douglas-fir, which was the dominant species in the cutblocks. The model responded as expected to the information on stem damage, knots, and falling breakage. These factors reduced the total volume and shifted some of the volume from higher quality to lower quality log sorts.

The model is more likely to overestimate the volume and value of the stands, as there is currently no allowance built into the model for internal tree defects and operational factors that cause stems to be bucked suboptimally from a value viewpoint.

Although the model was only tested on two clear-cut harvesting sites, it can be a helpful tool for predicting cost and revenue of harvesting operations in coastal second-growth forests. The model can be easily improved to analyze more species or to display additional information for better modelling of partial cutting operations (e.g., produce stock table and basal area table, handle user-input dbh classes, remove only a certain percentage from a dbh class). Also, as information becomes available (in a format usable by the model) on loss in volume when certain internal defects are present, the model can be improved to analyze both second- and old-growth stands with large amounts of defects.

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