Session 3
Paper (b)

ECONOMIC ANALYSIS OF SPUR ROAD EXTENSION

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INTRODUCTION

Within the field of logging economics, the evaluation of optimum roading density has received attention from many authors. LIRA, too, has had some involvement with this subject. The purpose of the study was to incorporate in the evaluation distinctive features of plantation forests, (New Zealand's plantation forestry in particular).

The investigation was first undertaken by C.D. Hutton, at the time an undergraduate at the School of Forestry, and employed for the summer vacation at LIRA. His B.For. Sc. dissertation (Hutton, 1984) describes the model which was developed.

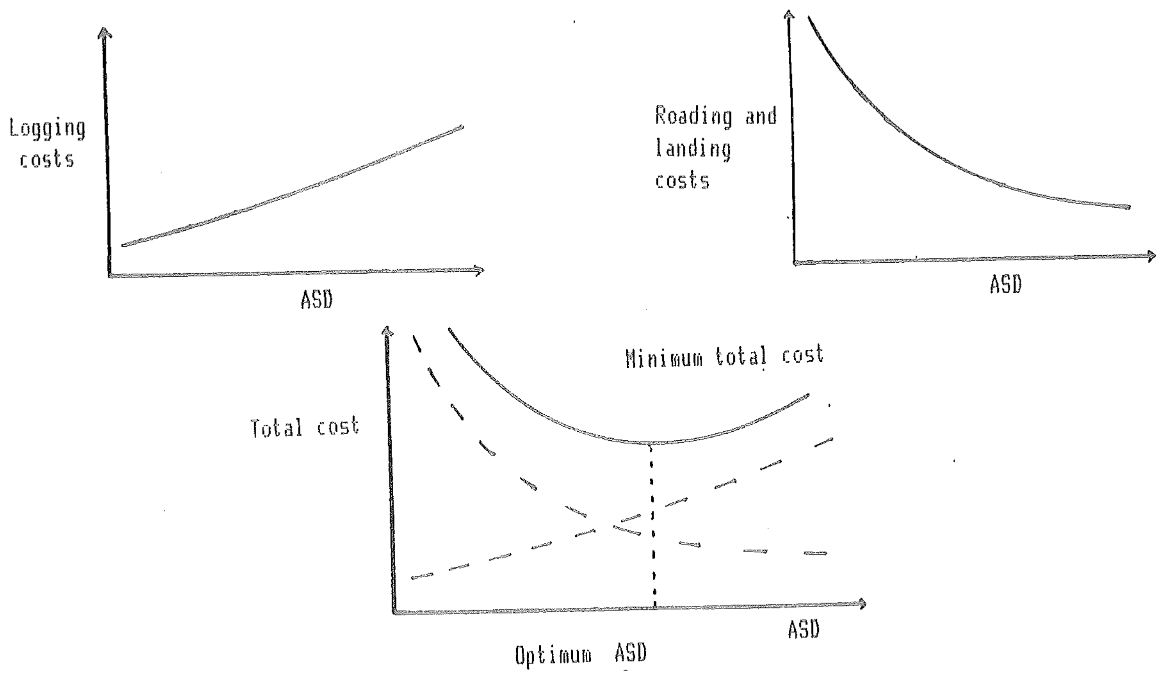
Since this first report the project has received only sporadic attention. More recently, the author has prepared a new computer model, introduced some refinements to recognise taxation and depreciation, and conducted a limited sensitivity analysis.

This paper describes the current status of the model.

BACKGROUND

The initial and popular treatment of optimising average skidding distance (and thereby roading density) was by D.M. Matthews in "Cost Control in the Logging Industry" (1942).

Matthews described how skidding costs generally may be expected to increase as the average skidding distance increases. Conversely, roading costs can be expected to fall as their spacing becomes wider. Graphically we have :



The average skidding distance at which the minimum total cost occurs is the optimum ASD. From this ASD the optimum spacing between roads and the landings on those roads can be calculated.

The graphical portrayal is the most suitable means of demonstrating the purpose of the analysis. In practice, provided that the relationship between logging cost and the ASD can be described by a linear function, then algebraic formulae can be used to arrive directly at the optimum skidding distance.

Matthews presented such formulae, and over the years other authors have progressively refined and adjusted these. Procedures for accurately determining Average Skidding Distance have also been thoroughly examined.

The ultimate demonstration of this algebraic approach is surely in the three pages of formulae prepared by Weller et al., included in the American Society of Foresters Handbook.

ACHIEVING THE OPTIMUM SOLUTION

The formulae for determining road and landing spacing assume, as a matter of course, that road and landing spacing can be infinitely varied. The flatter parts of Kaingaroa Forest, and some of the plantings on the Canterbury Plains are probably closest to this ideal. In general though, most logging planners know only too well that there are limited sites within the forest which are suitable for landings, and a limited range of feasible road routes to provide access to these. The more difficult the terrain, the more limited the suitable sites. Roading moreover can no longer proceed directly from landing to landing, but twists and turns markedly. The relationship between roading density and ASD becomes less predictable in broken country.

Under these circumstances it becomes more difficult to be comfortable with the solutions derived using the formulae, especially if trying to relate these to road and landing spacing.

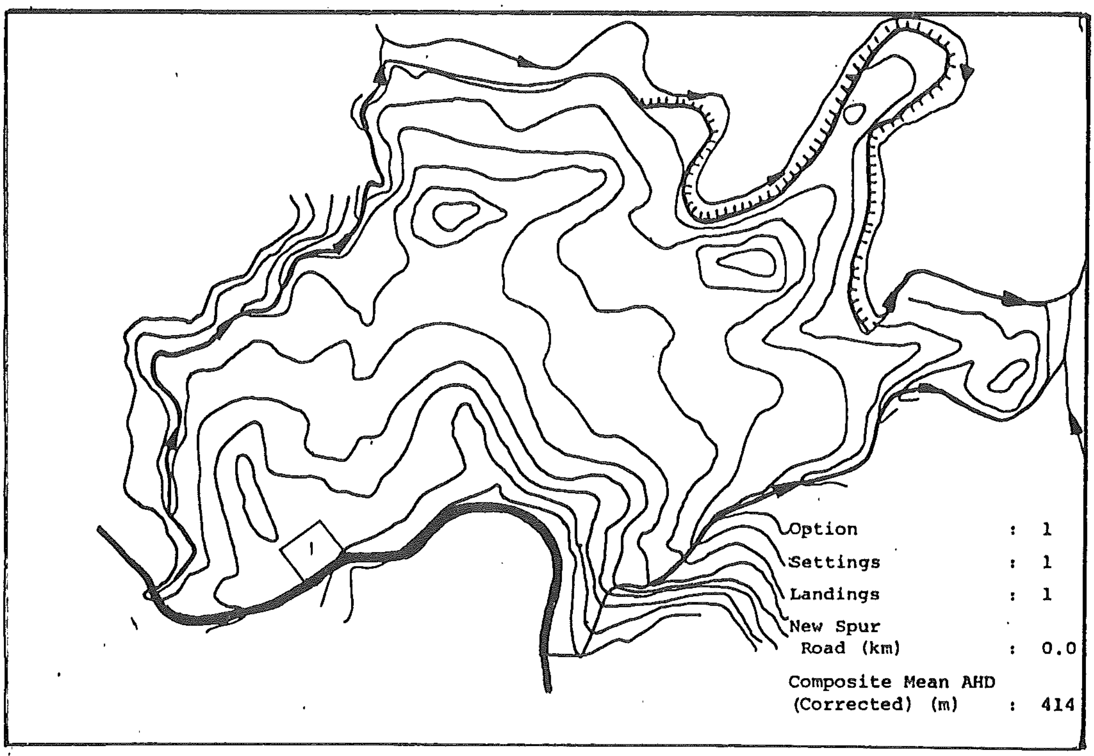
The response was to adopt a different approach, exploring a series of discrete options, rather than assuming that the possible range of alternate solutions was unlimited.

SPUR ROAD EXTENSION

The preferred system of analysis involved progressively introducing further settings within a forest compartment, and examining the resulting effect on total costs.

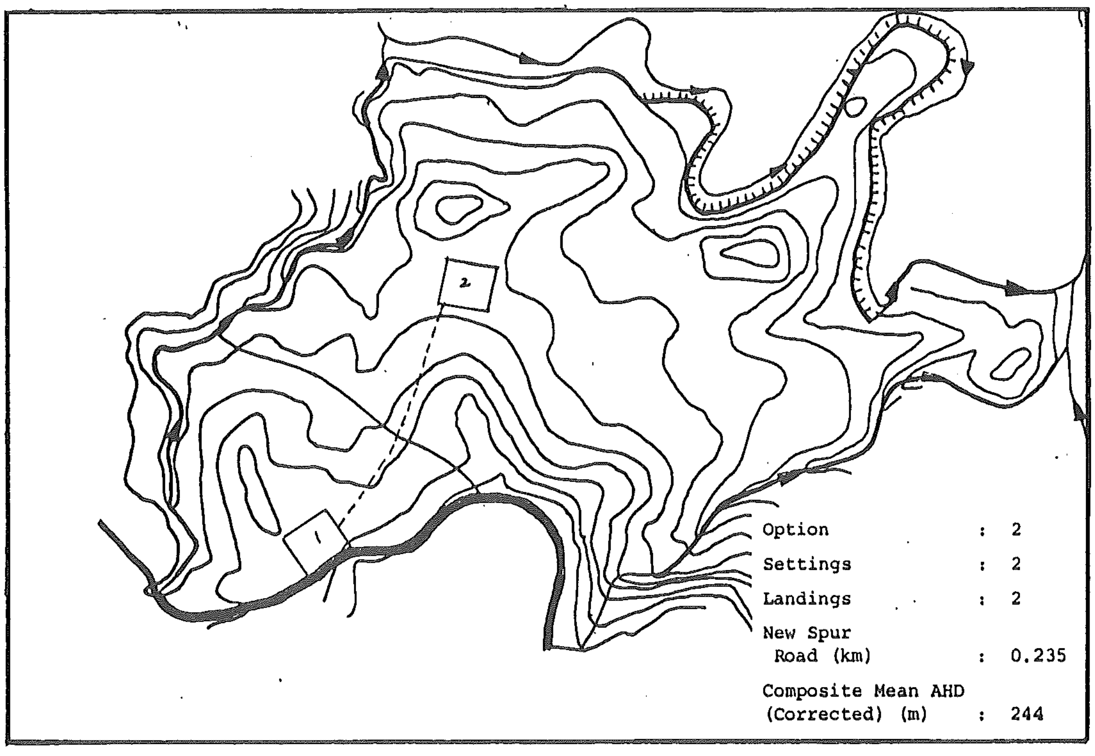
The method is demonstrated for an example compartment (Hutton, 1984) :

Figure 1



The compartment to be logged is indicated (Figure 1). A secondary road adjoins the lower edge. In this example the first option is to simply locate a landing directly adjacent to this road. Costs of new roading are nil. There is a large average skidding distance and hence logging costs are high.

Figure 2



In Option 2 the first landing has been retained (Figure 2), but a second landing, with the shortest practicable road link, has also been proposed. The settings associated with the two landings are of markedly different size. If logging costs are linearly related to ASD then the weighted average ASD for the two settings can be used to derive an overall logging cost. Otherwise it is necessary to consider the settings individually. (Sessions and Li Guangda (1986?) describe a means of doing this using finite element analysis.)

Similarly a third and further option can be described (see Figures 3, 4 and 5). In this analysis 10 possible options were examined. The maximum number of landings was 7, and three final options explored possible variations with 5, 4 and 3 landings.

Importantly the number of alternatives is considered finite : - landings are only located where it is sensible to put them, and the road routes likewise provide the most direct feasible connection.

Figure 3

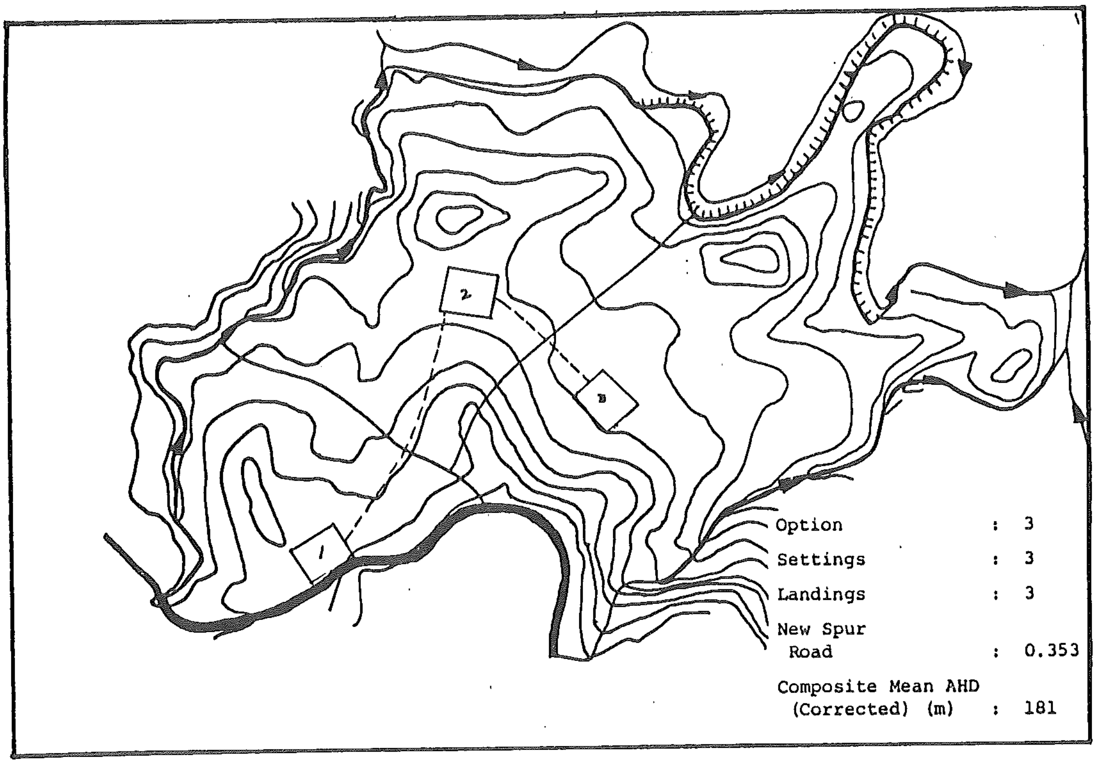


Figure 4

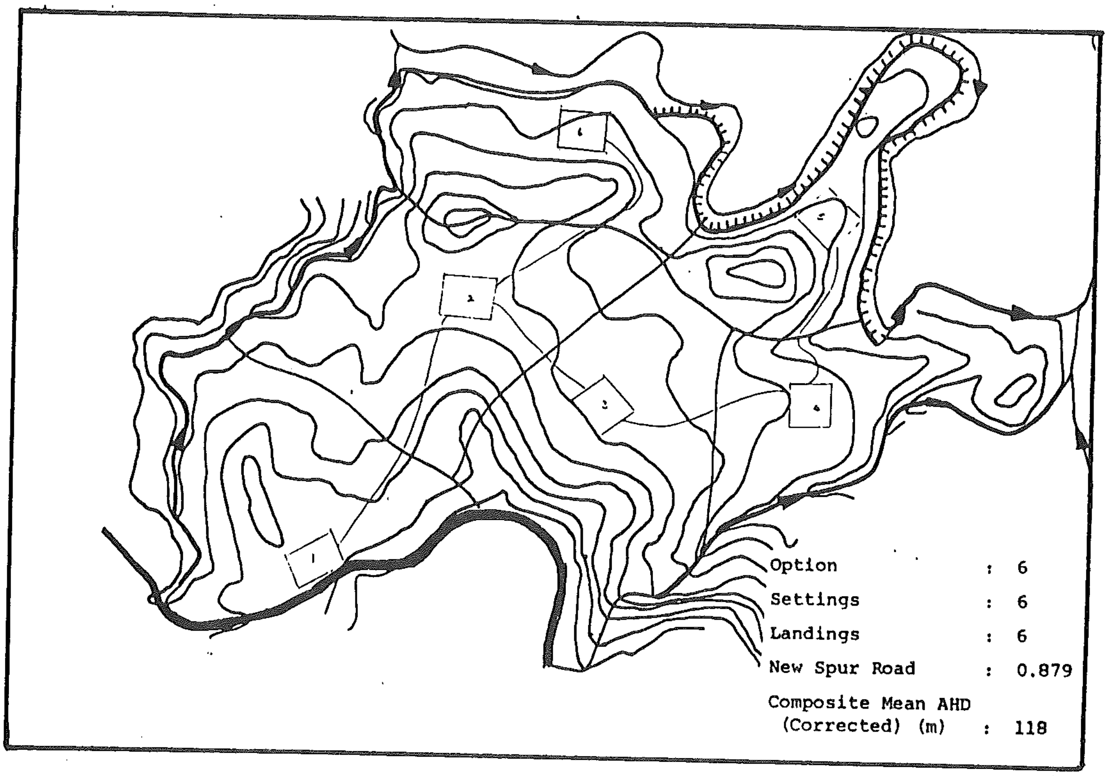
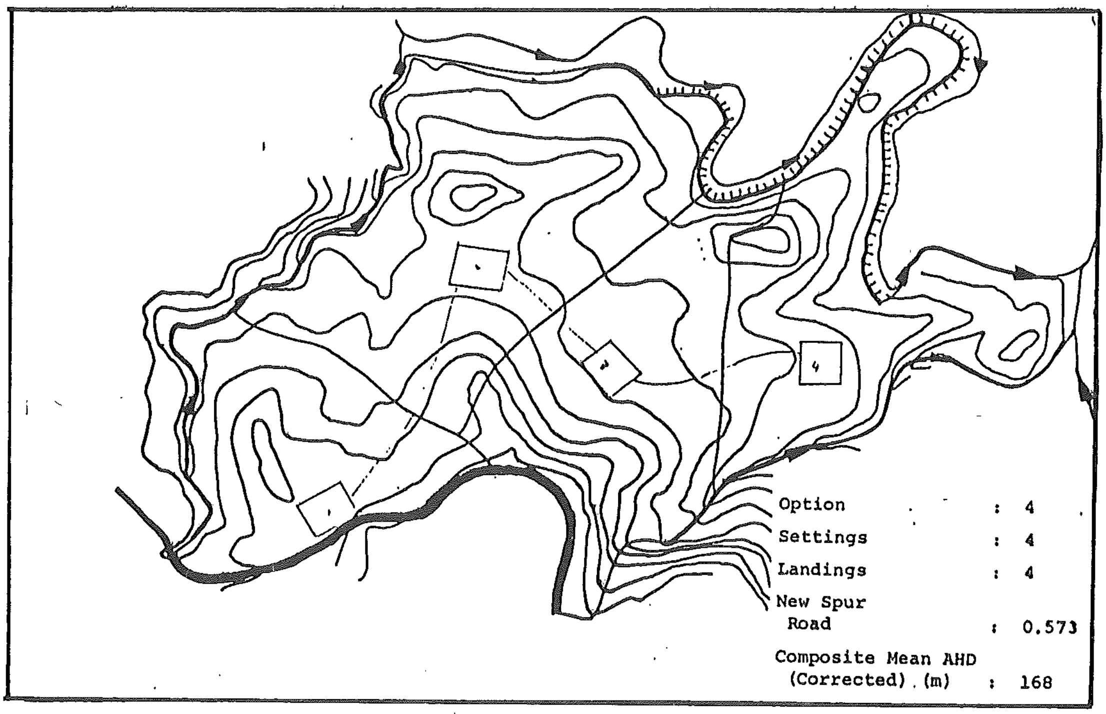


Figure 5



The process was originally described as one of "spur road extension". The intention was that for each new landing and associated road the marginal effect on total costs would be determined. Once total costs ceased declining then further extension would also stop, and the optimal solution would be assumed found. However this was an unduly simplistic approach, and might lead to insufficient options being tested. There is in fact the flexibility to test any number of possible layouts, and in any order. A rigid adherence to progressive extension is not necessary.

Calculating the unit logging costs, roading costs and landing costs on a per setting basis and overall would appear a daunting task but with computer assistance it can be handled quickly. The opportunities for computer involvement include :

- Determination of setting area, average skidding distance and road length.

  A digitiser tablet allows this to be completed quickly and very accurately. Suitable routines are available within the Cable Hauler Planning Package developed at FRI (Reutebuch and Evison, 1984). With a little more inconvenience, areas and average skid distance can be measured using a sheet of translucent graph paper and a computer routine based on that described by Donnelly (1978). (LIRA has such a program based on spreadsheet format - in effect a "poor man's digitiser").

- Determination of logging cost.

  Job costing programs such as COLCO (Gaskin, 1983) and PACE (Sessions and Sessions, 1985) are available on computer. Productivity functions based on piece size, ASD, and other relevant factors can readily be computerised.

- Determination of roading cost.

  Various programs allow for different degrees of complexity. In this particular example costs were simply allocated on a per kilometre basis.

- Calculation of overall cost.

  A program, written in PASCAL, was especially prepared for Hutton's original analysis by J. Green. A revised version based on spreadsheet software has been prepared by the author.

THE COSTING PROCESS

In the simplest case the analysis would include only the immediate costs of road and landing formation, and current logging costs. While these may indeed be the most significant costs a thorough costing procedure demands that other charges be included. Some of these assume more importance in plantation logging and New Zealand's plantation logging in particular. Logging costs are considered first, and then a variety of costs associated with roading.

1. **Logging Costs**

The relationship between unit logging cost and average skidding distance can become complex.

We recognise that :

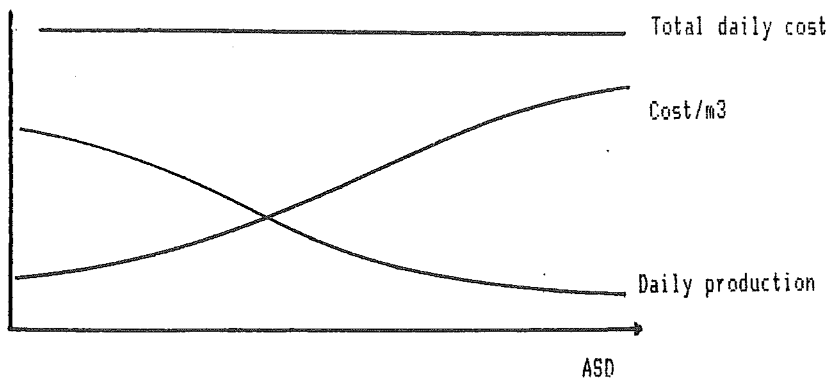
$$\text{logging cost/m3} = \frac{\text{daily cost of logging system}}{\text{daily productivity}}$$

Two simplified cases can be identified :

(a) The complement of men and machinery remains unchanged despite changes in the average skidding distance between different settings. This might well be the case where there are relatively frequent shifts between a variety of dissimilar settings.

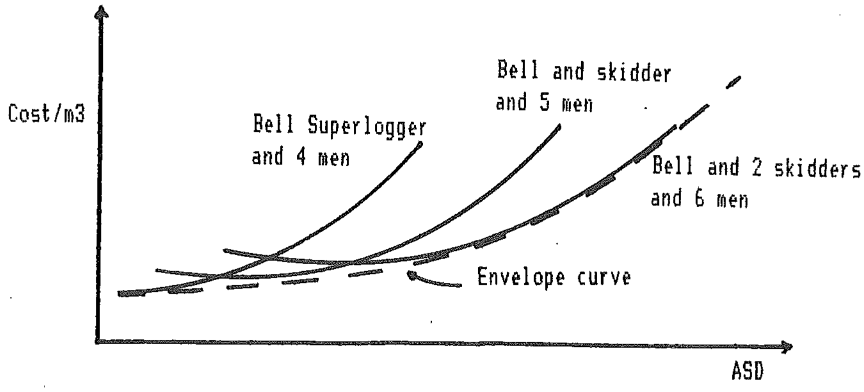
Daily productivity is influenced by interference effects on the cycle time of the principal machine. For instance if at short distances the machine is cycling too quickly, the fallers and skidworkers may not be able to keep up. Conversely, at very long skidding distances and cycle times these personnel may be underutilised.

Total daily cost for the crew remains relatively unchanged, and the cost curve is inversely proportional to the production function.



(b) In the second case the daily target remains unchanged and it is assumed that the logging gang can be modified to the most cost effective unit for producing that target at that particular skidding distance. Such changes may well be feasible over the longer term.

The unit logging cost vs ASD curve is then the envelope of a series of individual system curves, e.g.



Constrained gang production levels are an important feature of many forests in New Zealand.

In practice there may be inflexibility in both the gang complement, and its level of production.

At this stage the model provides no assistance in deriving the unit logging cost vs ASD relationship. This is left to the user who should consider the above points in his preparation.

2. **Timing of Roading**

It is widely recommended that logging roads should be constructed some time in advance of logging - a lead time of two years is often suggested. If this is the case, our analysis involves comparing roading costs and logging costs which are at different points in time. Discounted cash flow (DCF) analysis methods then become necessary for a proper evaluation.

Within this model the base year (year 0) for the analysis is the year of first logging road establishment. All future cash flows are discounted at a chosen rate of interest to this point.

3. **Road Maintenance and Reconstruction**

Maintenance costs of spur roads may be quite substantial in N.Z. plantation forests and this maintenance is not just confined to the road establishment lead time and duration of logging. Spur roads are increasingly being treated as long term assets of the forest.

The principal reasons are :

* The roads and landings have been expensive to establish. It may be [illegible] or economic practice to try to replant them.

* Soil compaction and disturbance on the roads and landings may result in [illegible] growth in the any case.

* The spur roads may offer improved access for management of the subsequent crop.

* If the subsequent crop is to be production thinned the roads and landings may be required for logging purposes in as little as another ten years.

Various strategies may be available for maintaining the roads and these are readily demonstrated using time lines, e.g.

Rotation age		Road maint. as % of construction						
23	Base yr	10	23		10	23		10
		10			10			10
25	Clearfell	15	25	Clearfell	15	25		15
	Replant	5			5			5
		5			1			5
		2			1			2
		2			1			2
5	Prune/thin	2	5	Prune etc	1	5		2
		2			1		Silvi-	2
7	Prune	2	7	Prune	1	7	-culture	2
		2			1			2
9	Prune,thin	2	9	Prune,thin	1	9		2
	to waste				1		Prod. thin	15
					1			10
					1			2
					1			1
		No			1			1
		Maint.			etc			1
					1			1
					1			1
23	Road recon.	40% of	23	No recon	10	23		10
		orig. cost		required	10			10
25	Clearfell 2nd rotation		25	2nd c/fell	15	25		15

Discounted cash flow analysis enables all such strategies to be brought to a common point in time for comparison. The computer model as currently set up will, if required, repeat the nominated rotation up to 100 years hence. As DCF analysis commonly shows costs and sales beyond three rotations hence rarely have any significant impact on the result.

4. Taxation

The model will evaluate the roading options on either a pre-tax or post-tax basis, depending on the user's requirements. Not all of the inputs are immediately tax-deductible against revenue. Although the cost of temporary roads, constructed purely for logging purposes, is tax-deductible in full from log sales revenue, if the road is a long term asset it is regarded as capital. The only way of offsetting the cost against income is then through depreciation.

The newly announced provisions for forestry costs will allow a depreciation rate of 5% (Declining Value) for "the construction of access roads to or on the land" (new Thirteenth Schedule to Income Tax Act 1976). Phase-out provisions on previous regulations will apply until 1991, but these have been ignored in this analysis.

By comparison maintenance expenditure on roading will continue to be tax-deductible in the year that it is incurred.

We might assume that the organisation undertaking the roading is paying tax on its profits at the company tax rate of 48%. In effect any expenditure which is tax deductible only costs 52% of its face value. (Had the company not spent the funds it would only have received 52c of each dollar of the resulting extra income.)

Were all expenditure immediately tax deductible there would be no requirement for a post-tax evaluation - the pre-tax analysis would suffice. Because capital expenditure only becomes deductible through depreciation the evaluation becomes rather more involved, and the model treats it as follows :

- Capital expenditure is included in full in the DCF analysis in the year it is incurred.

- The depreciation allowances in subsequent years reduce the assessable income and yet they are only notional expenses, not actual cash outflows. Because they reduce the taxable income without reducing the actual income they are, in effect, a "tax credit". The model recognises 48% of each depreciation expense as tax credits.

To complicate matters more there is the insidious effect of inflation. We assume, for convenience, (and as in most foresty investment analyses), that all costs and returns within the model will rise with time in more or less equal porportion. Provided that we then work with "real" rather than "nominal" interest rates in the DCF analysis then our model is mostly independent of inflation. Depreciation though is not so amenable to this simplification. Because it is assessed on historical values its effective value is eroded with inflation, and an adjustment must be made. At 15% inflation, for instance, a depreciation tax credit with a nominal value of $1.00 is worth only $1/1.15 in current dollar terms one year from now, and $\$1/(1.15)^2$, 2 years from now.

The computer model will accept the user's own values for the taxation rate, inflation rate, and depreciation rate should he wish to vary these.

5. **Sub-optimum rotation length**

The standpoint adopted from the outset by the model was that all new roading would be formed through planted standing forest. Most applications of the model to date, for instance, have considered spur road formation in year 23 of a 25 year rotation.

"Why", we need ask, "is the rotation age 25 years?" Ideally it is because 25 years represents the optimum economic rotation length. (In practice other management considerations may be more important.) If 25 years is indeed the optimum then the 23 year rotation of that part of the forest extracted in roadline formation will to some degree be sub-optimal.

The "opportunity cost" of the shortened rotation can be calculated as follows :

(a) Calculate the gross revenue which would be available from the sale of the roadline forest if it were allowed to reach optimum rotation length, i.e volume/ha at age 25 x value/m3 at 25.

(b) Calculate the gross revenue which is available from the sale of the roadline forest now, at the time of road formation, i.e. volume/ha x value per m3 at age 23.

(c) Discount (a) to the present.

(d) (a)-(b) is the opportunity cost of the less than optimum rotation length of the roadline forest.

Obviously if the roadline forest is extracted only one or two years prior to clearfelling then the opportunity cost may only be small. If, though, the road is established sufficiently far ahead that the salvaged volume is much lower in both quantity and quality then the foregone revenue may be much more significant.

6. **Roadline Logging Cost**

This cost is distinct from both the roadline sub-optimum rotation cost and the clearfelling logging cost. It is more correctly associated with road formation cost.

Roadline logging may be more expensive than clearfelling logging because although haul distances may be shorter, there are spatial constraints on falling, machine movement, stack placement etc.

7. **Transport Cost**

A rigorous analysis must recognise that if there is extra roading within the compartment then there will also be an extra transport cost. Not unexpectedly this appears to be one of the least significant costs in the analyses which have been run.

8. **Land Rental**

Plantation foresty in New Zealand has always had to justify itself economically against other competing land uses. If the land under plantation forestry must provide an adequate commercial return, so too must the land occupied by permanent forest roads and landings.

One means of including the land use cost in the analysis is as an annual rental charge. It is assumed in the model that the rent is calculated as :

current value of the land x interest rate used for DCF

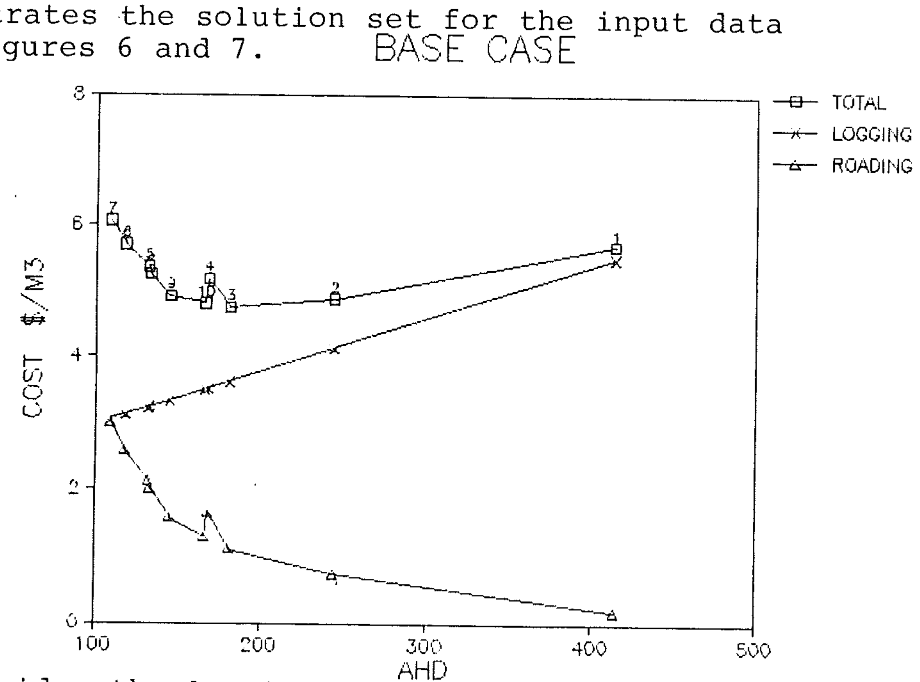
Where the period of analysis is long the present net worth of such a series of annual payments is approximately the land value itself. In effect the land is "purchased" from the forest to be used for roading.

THE COMPUTER MODEL

Example input data and output from the computer model are shown in Figures 6 and 7. These include all of the cost components described in the previous section.

COMPUTER SOLUTION

Figure 8 illustrates the solution set for the input data described in Figures 6 and 7.



Note that :

- Option 3 provides the least cost solution. It involves only three of the seven possible landing sites identified.

- With the exception of option 4, the total cost curve is comparatively flat between ASD's of 150 and 250 m. The best option, 3, is cheaper than the next best by $0.06 (post-tax)

Figure 6

SPUR ROAD ANALYSIS PROGRAM

OPTION NUMBER	1	2	3
PHYSICAL DATA			
Area to be logged (ha)	25		
Number of landings	1	2	3
Average landing area(ha)	.14		
Length of spur roads(km)	0	.235	.353
Width of spur roads(m)	6		
Average skidding distance(m)	414	244	181
FOREST DATA			
Length of rotation(20-38yrs)	25		
Volume/ha at road formation	480		
Volume /ha at rotation age	510		
Crop age at road formation	23		
FINANCIAL DATA			
Base year for analysis	23		
Stumpage at rotation age	23.00		
Stumpage at road formation	18.00		
Average cost per landing	2000		
Roading cost- formation	8000		
-culverts	1200		
-metal + grading	5000		
Logging cost (full rotation)	$10.52	7.9	6.93
Logging cost(roadlining)	$9.40		
Cartage cost($/tonne-km)	$.25		
Land value	700		
% of road requiring rebuilding	40		
Interest rate for discounting	8		
Average tax rate(%)	48		
D.V. depreciation rate (IRD)	5		
Inflation rate(15)	15		
Number of future rotations	2		
IRR of forest investment	7		
% of landing requiring rebuild	40		

Figure 7

OPTION NUMBER	1	
ROAD CONSTRUCTION	0	
RECONSTRUCTION	0	
LANDING FORM & REFORM.	.1577461	
LESS: TAX CREDIT	-.016762	
TOTAL CONSTRUCTION	.1409840	2.48%
ROAD MAINTENANCE	0	.00%
ROADLINE LOGGING	.0259077	.46%
LOGGING	5.491893	96.77%
TRANSPORT	0	.00%
LAND RENT	.0073014	.13%
STUMPAGE FOREGONE	.0092183	.16%
TOTAL	5.675304	100.00%

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OPTION NUMBER	2	
ROAD CONSTRUCTION	.2662084	
RECONSTRUCTION	.0181503	
LANDING FORM & REFORM.	.3408556	
LESS: TAX CREDIT	-.063745	
TOTAL CONSTRUCTION	.5614691	11.54%
ROAD MAINTENANCE	.0359873	.74%
ROADLINE LOGGING	.0787989	1.62%
LOGGING	4.124140	84.75%
TRANSPORT	.0153350	.32%
LAND RENT	.0222072	.46%
STUMPAGE FOREGONE	.0280378	.58%
TOTAL	4.865975	100.00%

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OPTION NUMBER	3	
ROAD CONSTRUCTION	.4033383	
RECONSTRUCTION	.0275000	
LANDING FORM & REFORM.	.5157063	
LESS: TAX CREDIT	-.096507	
TOTAL CONSTRUCTION	.8500373	17.93%
ROAD MAINTENANCE	.0545251	1.15%
ROADLINE LOGGING	.1192775	2.52%
LOGGING	3.617758	76.31%
TRANSPORT	.0230351	.49%
LAND RENT	.0336150	.71%
STUMPAGE FOREGONE	.0424407	.90%
TOTAL	4.740689	100.00%

per cubic metre. The best four options are separated by $0.16 per cubic metre.

- Option 4 appears a real odd man out. A return to the map for this option is necessary to see why. As Figure 5 shows, although option 4 splits one of option 3's settings by providing an extra landing, there is very little reduction in ASD achieved.

SENSITIVITY ANALYSIS

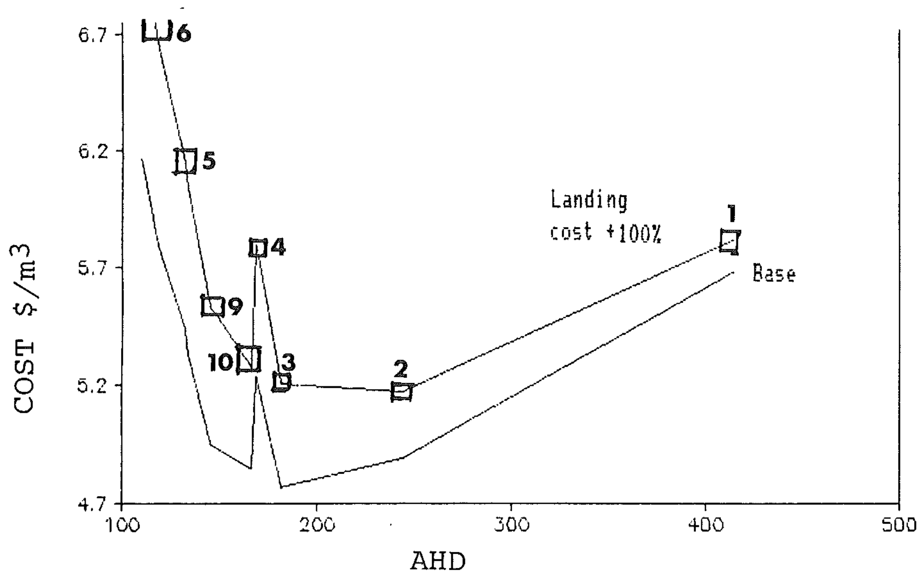
The great advantage with a computer based model is that iterations can be performed quickly and reliably making sensitivity analysis feasible.

Increases in Landing Cost :

An obvious place to begin making changes is with the major cost components. Figure 9 illustrates the effect of doubling the landing cost, (not an unrealistic assumption if there was a choice whether or not to surface the landing).

The whole total cost curve has been elevated, but more significantly its shape has changed so that option 2 (two landings) is now the optimal solution. Option 9, with four landings, is now much less favourable than option 2.

Figure 9

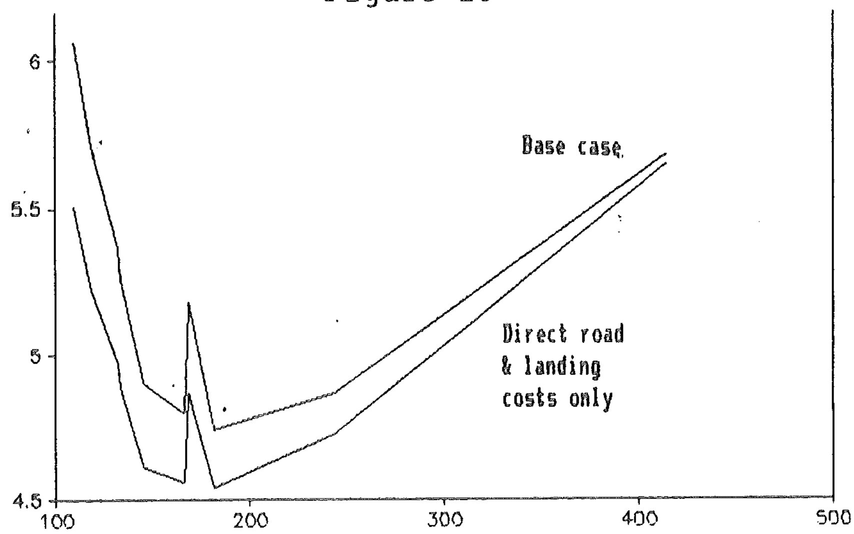


Deletion of Costing "Refinements" :

The various refinements to the costing procedure which have been described may well have some academic appeal, but are they of any practical significance in selecting the optimal solution?

Figure 10 illustrates the effect of ignoring all but the direct road and landing construction costs.

Figure 10



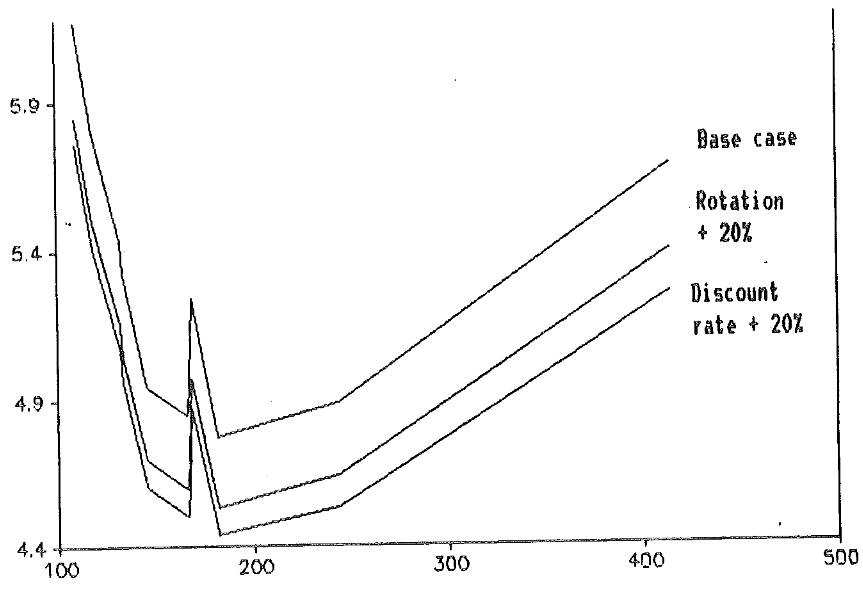
In this particular case the optimal solution remains option 3. The shape of the curve has altered slightly though and would favour smaller ASD's. The third best solution has changed from option 2 to option 9.

Adjustment to Discounted Cash Flow Parameters :

The two most important parameters in a discounted cash flow analysis are the discount rate and the period of discounting. Figure 11 illustrates the effect of increasing the discount rate and rotation lengths by 20%.

In this case the curves remain essentially parallel. Determination of the optimum solution, in this case at least, appears to be reasonably indifferent to the discounting rate used.

Figure 11

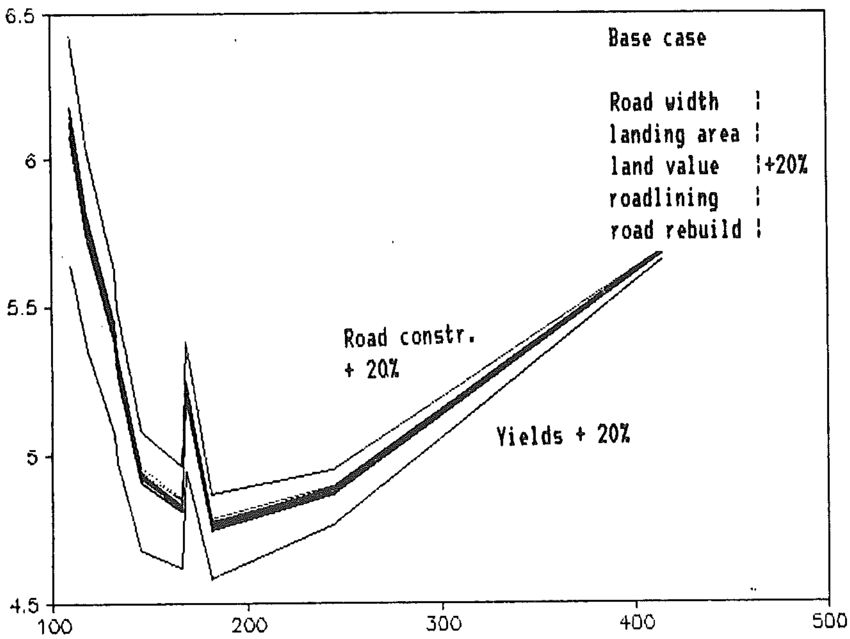


Adjustment of Minor Road Cost Elements :

The effect of deleting the costing "refinements" altogether has already been examined. We can also explore the effect of changing some of the parameters that these relate to, as shown in Figure 12.

Road construction costs and available yields are not minor elements but have been shown for comparison.

Figure 12



Increasing by 20% road width, landing area, land value, roadline logging cost or road and landing rebuild costs clearly makes very little change from the base case.

Increasing the initial road construction cost by the same proportion has a more marked effect, and as expected tilts the curve in favour of longer ASD's. Increasing the available volume has the reverse effect, because while logging costs remain the same per cubic metre, road and landing costs become less.

CONCLUSION

This paper has described the preparation of an economic model for determining optimum spur road density. Significant features of the model are :

- it compares a limited set of possible alternatives, rather than assuming that the location of roads and landings can be infinitely varied.

- the user must derive beforehand a suitable logging cost function. He must also determine setting areas, ASD's and road lengths as input to the model.

- the model recognises several important aspects of plantation forestry which include :

    * Roads and landings are assumed to become permanent assets of the forest, and will be subject to ongoing maintenance.

    * In common with other forestry investment evaluation a means of bringing costs and returns to some common point in time is necessary. DCF analysis is the method used in the model.

    * Taxation regulations make it important to distinguish between capital investment and maintenance expenditure. Depreciation is a means of offsetting capital costs against income, but it may be eroded by inflation.

    * Logging the forest at other than its optimum rotation age implies some opportunity cost.

    * Plantation forestry is one alternative land use. Roading and landings are another. Any such use must be able to provide a return on the land investment.

To date more time has been spent on preparing the model than actually running it. The limited sensitivity analysis which has been performed around the one example case examined to date has been described. In this example including the costing refinements has a small though discernible impact on the shape of the total cost curve.

A wider range of examples should be evaluated with the model before any conclusion can be made on the significance of the costing refinements on the decision making process.

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