HARVESTING ECONOMICS

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It is the purpose of this paper to present and apply some of the economic concepts that influence critical harvesting decisions. Typical decisions that are significantly shaped by economic considerations are: 1) specification of road design standards; 2) selection of logging systems, and, 3) targeted amount of road construction within an area. It is hoped that a better understanding of these particular economic forces by peripheral participants in the decision making process will enable them to use these concepts in explaining and achieving their individual goals.

The first step will be to present a simple but useful graphical model of the costs involved in timber harvesting. This model will provide insight to these economic factors and their role in the decision making process. Some of the economic trade-offs that are being made in this process will become obvious. Subsequently, a modification will be made in this harvesting cost model which will assist in applying the model to some other harvesting decisions.

The Harvesting Cost Model

The timber harvesting process can be viewed as the movement of logs from the stump to the mill. This transportation process may be conveniently divided into two stages for a typical western logging operation. During the first stage logs are moved (skidded) from the stump to a roadside loading area (landing). The second stage consists of hauling the logs from the landing to the mill. The model to be presented here will focus on the first stage of this transportation process.

Integral to the transportation process is the development of a system of truck roads. This truck road system may be conceptualized as consisting of many, relatively short, secondary roads feeding into a much longer and higher standard primary road.

(The higher standard for the primary road is justified by its much heavier volume of traffic.) It is precisely the development of secondary roads, their design standard, location, construction and density (miles of road per section*harvested), that is of fundamental economic concern to the harvest planner. However before road development decisions can be made an objective must be specified.

From the perspective of the harvest planner a given area of forest land at any point in time has a known volume of timber worth a fixed amount when delivered to the mill. In order to obtain the highest possible return on this timber he will attempt to move it from the stump to the mill at the lowest attainable cost.[1] The objective of the harvest planner then is to minimize the total harvesting cost for the given area subject to any applicable constraints such as those on safety and environmental protection.

A key decision facing the planner is the amount of secondary road that should be built (please refer to figure 1). A decision to build only limited mileage of secondary road (case I) means that total road construction cost per total volume of timber removed will be kept very low. However, because logs on the average will have to be yarded a considerable distance, logging cost, which includes yarding cost, will be very high (see figure 2, case I). The other extreme is a decision to have a very dense system of secondary roads (figure 1, case II). This decision will reduce logging cost but road construction cost will be very high (figure 2, case II). The planner seeks that intermediate road density which minimizes the total cost of both roading and logging the given area.

The perceptive reader may interject at this point that the hauling cost has not yet been included in the model. In fact it has not been included because for all practical purposes truck hauling cost does not significantly change over the range of road density from case I to case II. Hauling cost is primarily a function of road standard and haul distance. In case I and case II most of the haul is over primary

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1. This is true whether the timber owner logs the area himself or decides to sell the standing timber (stumpage) to someone else.

* one square mile of land.

road, which is the same length and standard in both cases. There may be some difference in secondary road haul distances between case I and case II, but the difference is minor and, additionally, the secondary road standard is assumed to be the same in both cases. If this constant truck hauling cost is everywhere added to the "Total Timber Harvesting Cost" curve of figure 2 its effect is to raise every portion of the curve the same amount on the vertical scale. Quite clearly under these conditions the "best" road density point will not be shifted from its current position. Therefore hauling cost will not influence the decision about best secondary road density.

Two Assumptions. Two important assumptions have been made in the development of the graphical model shown in figure 2. The first of these assumptions is that neither the road standard nor the logging system change over the range of decisions (from case I to case II). For example, it may have been decided to log an area using crawler tractors and to build a system of single lane unsurfaced roads throughout the area. Having made these prior decisions the harvest planner is searching for the spacing between roads (road density) that minimizes total harvesting cost. He trades off the increased cost of building additional road with the corresponding reduction in logging cost. It is unlikely that a planner would be so restricted by prior decisions in this regard and a key point in further analysis and understanding of the decision process involves relaxing this assumption.

Changes in roading and logging methods can significantly shift the economic optimum road density[2] and may simultaneously raise or lower the minimum total harvesting cost (please refer to figure 3). Changes in cost of road construction per unit length of road will shift optimum road density to the left or right depending on whether the cost is increased or decreased respectively (figure 3a). Logging costs which are

2. The technical appendix develops this idea in a more rigorous fashion for those who are interested.

proportionately reduced from previous levels will shift the optimum toward lower road density (figure 3b). A shift in the opposite direction for the optimum will occur if logging costs increase. By way of example refer back to the crawler tractor/unsurfaced road harvesting system. A decision in that case to ballast and surface the roads would have a tendency to push the planner toward selection of a lower road density since the optimum has shifted in that direction. Total harvesting cost would increase unless offset by a reduction in haul cost over the secondary road system.

Continuing with that example, a decision to utilize rubber tired skidders rather than crawler tractors would in most cases reduce logging cost and would also lead to selection of a lower road density. On balance these two changes would both tend to reduce road density, but whether they would result in a lower or higher total harvesting cost cannot be determined without more specific data because of their potential off-setting effects on total cost.

A second assumption of the graphical model is technological and economic efficiency. It is assumed that given the selected road construction and logging processes the planner will integrate these two activities in such a way that at any given road density no significantly more efficient harvest plan might be devised. The best utilization of the roading and logging processes means that roads are built to take advantage of the ground and the unique characteristics of the selected logging process. No road(s) or landing(s) could be relocated (assumed to be done without a significant increase in total road mileage) from what is planned obtaining thereby a reduction in total harvesting cost. The best possible match between road system and logging system has been found for the selected road density.

It is of course recognized throughout this discussion that road and landing locations which violate safety and environmental constraints are not considered even though their use might reduce total harvesting cost. Thus some environmental costs have been indirectly brought into the model. Observance of statutory constraints on roading and logging activities restrict the harvest planner's options. These restrictions, to the extent that they ruled out some financially attractive but socially expensive practices, have increased total harvesting cost in those applicable situations.

Model Application

Consider two possible charges that might be advanced against decisions reached by the harvest planner with regard to the road system he has proposed: 1) the planner has excluded or overlooked some major costs associated with the road system, and, 2) the planner has failed to select the most efficient harvesting plan. These two issues, alone or in combination, may be relevant in any given area. The harvesting cost model can provide a context within which to develop and examine supporting arguments.

Major Excluded Costs. Some of the costs which may have been excluded[3] are reduced water quality, degradation of esthetic value, less valuable wildlife habitat and reduced forest productivity due to land conversion to permanent road. Most of these factors, when operative, make the forest road system proportionately more expensive. Inclusion of these costs into the graphical model moves the road construction cost curve counterclockwise. The optimal road density is reduced. Convincing the planner to include these costs may, in the case of a public agency, only require that their relative importance be identified by the affected public. It is not always necessary that the actual costs be identified in order to sway a responsible planner - in fact these costs are often very hard to quantify. Consider for example the development of

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3. These costs, as discussed here, would represent a severity of potential impact on the public interest well beyond that envisioned by the framers of any applicable (and planner observed) statutory regulation of forest practices.

a harvesting plan for an area which is similar to nearby areas that have been logged but unlike them has very unstable soils. A strong case might be made under these circumstances that minimization of total harvesting cost (including the costs of reduced water quality and higher road maintenance) should lead to a significantly lower road density in this area relative to the other areas. Failure to observe lower road densities in such sensitive areas, in the absence of meaningful counter considerations, would be prima facie evidence of inadequate or incompetent planning.

Inefficient Harvest Planning. Selection of the most efficient harvesting plan requires that the planner select roading and logging processes which when combined in the most efficient manner at the best road density will yield the lowest feasible harvesting cost. Weakness in any of these matters leads to higher than necessary cost. Roading and logging processes can be changed not only through use of different equipment or employment of standard equipment in innovative ways but also through thoughtful re-specification of the desired process output; e.g., road design standards and log utilization standards. A good knowledge of the fundamentals of roading and logging practice and an understanding and appreciation of their crucial interdependence at the practical level is absolutely essential to development of efficient or even feasible harvesting plans.

Planning deficiencies at any stage in this process mean that actual harvesting costs may be far above those which could be realized through competent planning. The persistent occurrence of deficit sales (or unsold sales) in areas interspersed with financially and environmentally sound private and state forestry operations may be one symptom of this problem.

Technological Opportunities

Technological advances make possible a wider range of harvesting alternatives and also the means by which to evaluate and use them to best advantage. Medium sized yarding cranes with interlocks, fast track skidders, steep ground feller-bunchers, hydraulic backhoes, and full tree merchandizing processors are widening our opportunities. Programmable calculators and micro-computers used with roading and logging software let the planner examine many more alternatives at lower cost. Laser terrain mapping and automated collection of equipment performance data will improve our estimates and evaluation of alternative harvesting systems.

Technology often allows us to achieve not only lower harvesting costs but also lower concomitant environmental costs - especially if adequate planning is done. Examples are the growing use of excavators with or in place of bulldozers for road construction, and the use of skyline rather than highlead cable yarding. For these systems to be environmentally and economically advantageous however harvest planners will have to recognize and integrate the unique requirements and abilities of these systems. Economic and environmentally sound use of forest resources is only going to be consistently achieved by planners who have training and practical experience in forest resources, timber harvesting and road engineering. The opportunities are there but it will take the right people to appreciate and apply them correctly.

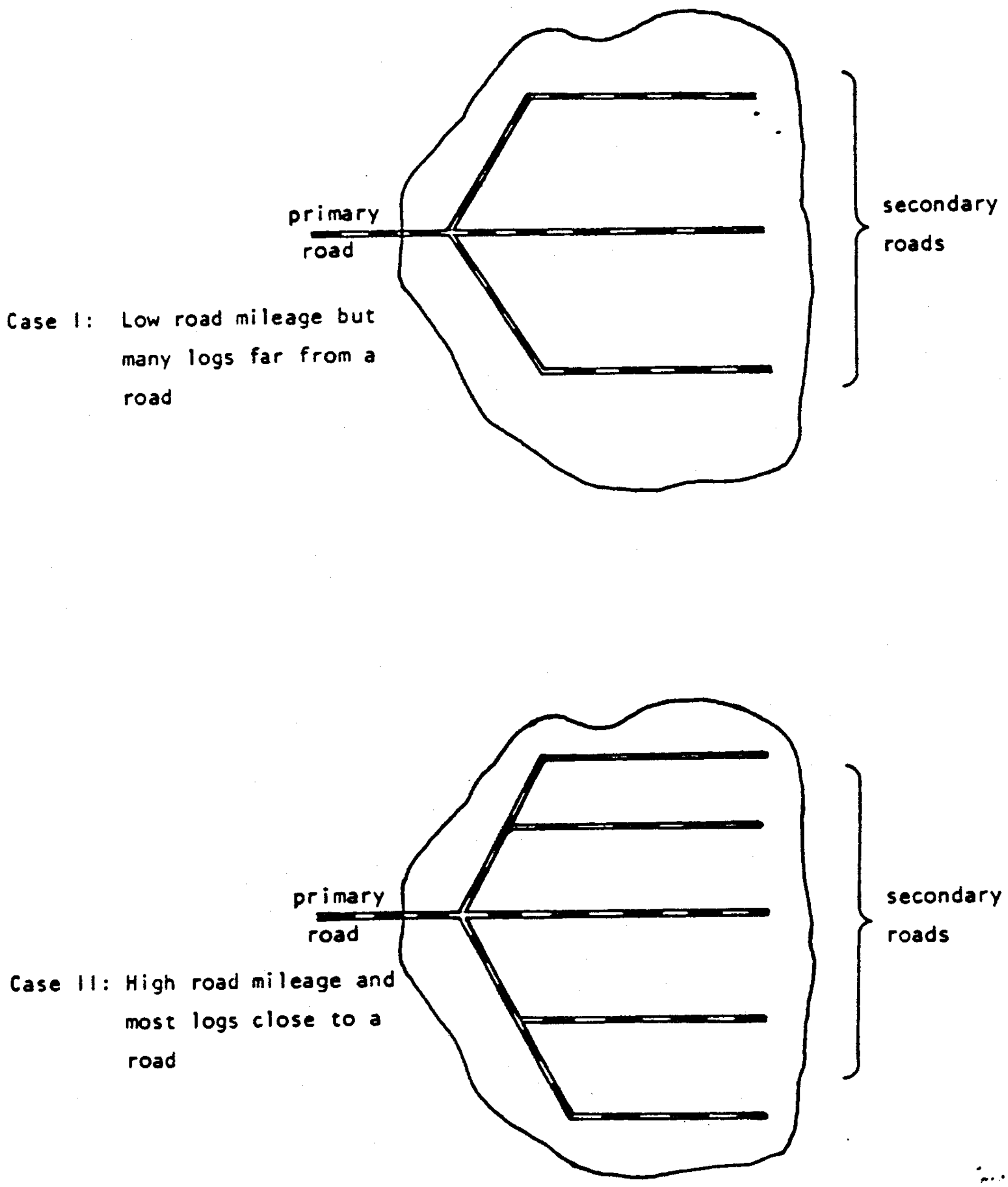


FIGURE 1. Two, of many, possible alternative road densities in a given harvest planning unit.

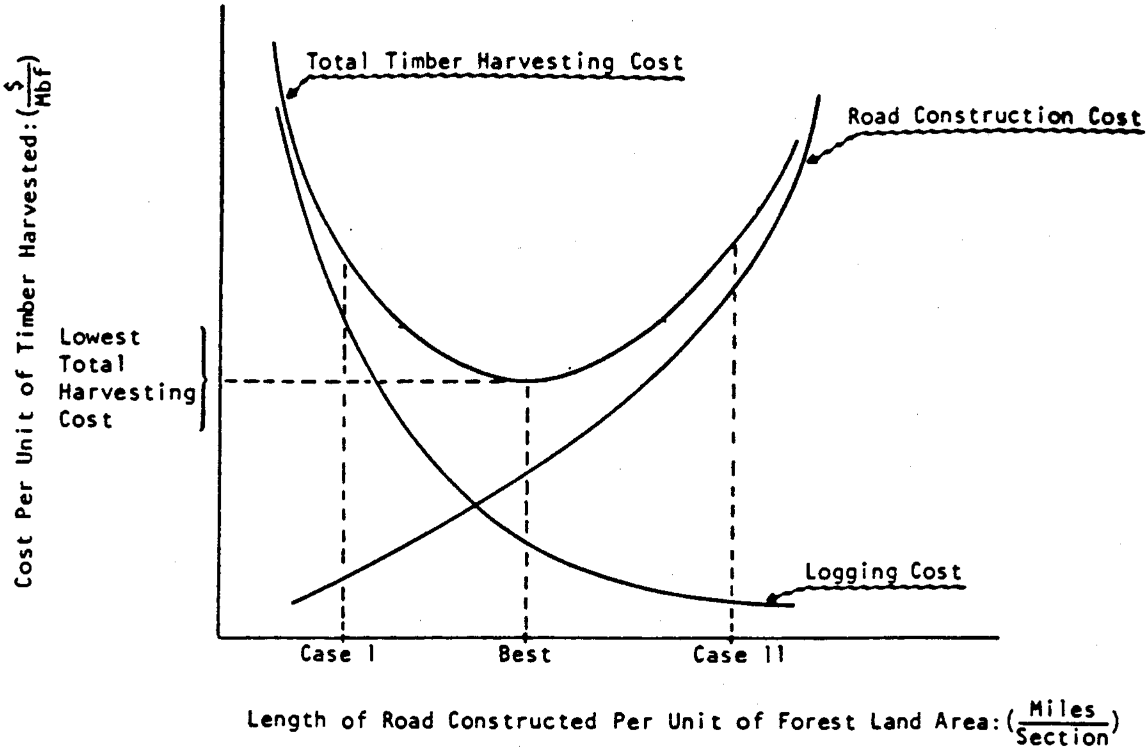
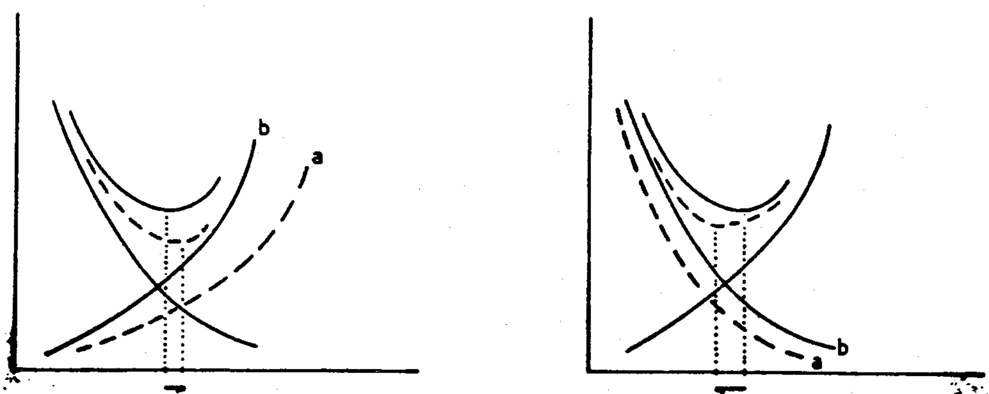


FIGURE 2. Graphical representation of the most economical road density - the goal in harvest planning.



Proportionately less expensive road construction (e.g., unsurfaced road,"a", rather than ballasted & surfaced,"b") shifts the economic optimum to the right and down

Proportionately less expensive logging (e.g., rubber tired skidder,"a", rather than crawler tractor,"b") shifts the economic optimum to the left and down

FIGURES 3a&b. Changes in roading or logging procedures can shift the economic optimum.

Technical Appendix

Logging cost, L, and roading cost, R, are both functions of road density, w:

$$L = f(w) \qquad 1.$$

$$R = g(w) \qquad 2.$$

and over the range of road densities of practical interest it may be convincingly argued that the logging cost decreases at a decreasing rate with increased road density, and that the roading cost increases at an increasing rate:

$$f'(w) < 0 \qquad 3a.$$

$$f''(w) > 0 \qquad 3b.$$

$$g'(w) > 0 \qquad 4a.$$

$$g''(w) > 0 \qquad 4b.$$

for

$$w_{min} \leq w \leq w_{max} \qquad 5.$$

Total harvesting cost, T, is the sum of logging and roading costs:

$$T = f(w) + g(w) \qquad 6.$$

Assume that a change is proposed in the road construction process that will proportionately[1] change the cost of road building:

$$R_{new} = p\, R_{old} \qquad 7.$$

with

$$p > 0 \qquad 8.$$

and for all densities within the range

$$w_{min} \leq w \leq w_{max} \qquad 9.$$

so that total cost will now be:

$$T = f(w) + p\, g(w) \qquad 10.$$

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1. If not exactly proportional, at least to a reasonable approximation. It is left to the inquisitive reader to show that such restrictions on the nature of the cost change are necessary - it is possible to show examples where a general reduction in road construction cost may actually move the optimal road density toward less, not more, road per unit area harvested.

In order to find the optimal road density the derivative of "T" with respect to "W" is set equal to zero (first order condition):

$$\frac{dT}{dw} = f'(w) + p\ g'(w) = 0 \qquad 11.$$

If there is a solution to this equation[2], say w*, such that

$$w_{min} \leq w^* \leq w_{max} \qquad 12.$$

then a check of the second order condition

$$\frac{d^2T}{dw^2} = f''(w) + p\ g''(w) \qquad 13.$$

shows that it must necessarily be a minimum point since

$$f''(w) + p\ g''(w) > 0 \qquad 14.$$

for all "w" within the range of interest, a result that follows immediately from conditions 3b, 4b and 8.

Now assume that "p" is originally equal to one and that the introduction of a new road construction practice changes it to something more than one; i.e., the new practice makes it more expensive to build each mile of proposed road. Changing "p" from its original value is probably going to cause the optimal road density, w*, to change also - the question is, will the new optimal road density be found to be higher or lower than the old after this increase in "p". In order to answer this question the derivative of "w*" with respect to "p" is taken using implicit differentiation on the first order condition[3]:

$$\frac{df'(w^*)}{dw^*} \cdot \frac{dw^*}{dp} + g'(w^*) + p\ \frac{dg'(w^*)}{dw^*} \cdot \frac{dw^*}{dp} = 0 \qquad 15.$$

following simplification and isolation of dw*/dp

$$\frac{dw^*}{dp} = \frac{-g'(w^*)}{f''(w^*) + p\ g''(w^*)} \qquad 16.$$

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2. Corner solutions will not be considered here.

3. w* is now being treated as a variable that depends on the value assigned to p.

but since

$$g'(w^*) > 0 \qquad 17.$$

and

$$f''(w^*) + p\, g''(w^*) > 0 \qquad 18.$$

It follows that dw^*/dp must be negative; i.e., increasing p will reduce w^* and conversely decreasing p will increase w^*.

It is concluded then that, ceteris paribus, the introduction of alternative roading practices that proportionately increase (decrease) roading cost from previous levels will create economic forces pushing toward less (more) road construction. A similar mathematical argument can be made for a similar effect in the case of proportionate changes in logging cost.

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