New Look at Optimum Road Density for Gentle Topography

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Past forest transportation planning techniques and trends were reviewed. The needs of the Chequamegon National Forest located in northern Wisconsin were analyzed. The most applicable method was then adapted to the Chequamegon. It was found that road-spacing equations fit the needs as much as any other available technique. The equations were modified to include log-hauling costs and two separate road standards. The equations were then solved for typical conditions found on the Chequamegon. Roads could be built at a 20 percent greater density on the Chequamegon. This increase would result in lower total costs. The 750 000 timber-production acres will require an additional 5100 miles of road at a cost of about $42 000 000. This information will be combined with timber-harvest data in the preparation of a Chequamegon National Forest plan to develop a timber harvest and roading schedule.

Throughout the history of transportation planning in the logging industry, many attempts have been made to determine the optimum logging-road density. In 1942, Matthews dealt with this problem in Cost Control in the Logging Industry (1). He proposed a method for optimization of logging and road construction costs with respect to distance to minimize costs and maximize profits. Matthews, however, did not include haul cost in his attempt to define optimum road spacing. This paper expands his work by adding another set of terms, which allows two road standards, and applying them to a new set of equations where haul is a factor.

Several applications of the road-spacing theory can be observed as a result of these equations. For example, timber sales are usually irregular in shape. We can simulate the shapes as rectangles or squares, and the road densities (miles of road divided by the number of square miles) can then be calculated by using the equations. An actual area can be selected and measured for road density. This value can then be compared with the theoretical value, and conclusions regarding current densities can be made (i.e., too few roads, too many roads).

This system's main applicability will be related directly to gentle slope terrain due to the assumption that the effect of slopes on haul and skid costs will be minor. The small magnitude of vertical relief in this region makes this assumption valid. Use of this system in a mountainous region would entail the formulation of new and additional terms or, at the very least, a cost for haul, skid, and construction that reflects the increase created by the slopes encountered during road building and logging.

The new equations give the land manager a clear view of the cost of land development options that can then be used to compare environmental consequences. As a result, valid and rational land management planning decisions can be made.

PURPOSE AND SCOPE

The purposes of this investigation were to study the transportation needs of the Chequamegon National Forest in northern Wisconsin, to review past forest transportation planning techniques in relation to these needs, and to adapt the most applicable method to the conditions on the Chequamegon.

The investigation was carried out in four phases. The first phase consisted of reviewing the key forest transportation planning techniques used from 1900 to the present. During the second phase, the critical features of the Chequamegon National Forest related to planning forest road and logging systems were identified. In the third phase, the most applicable method was adapted to the precise conditions found on the 847 000-acre Chequamegon National Forest. The last phase developed the adapted method to determine the quantity and cost of roads needed for the optimum road and logging system development on the forest.

In all phases, the suitability of the methods was tested for the conditions found on the Chequamegon National Forest. The results are applicable to areas that have gentle terrain and use multiple road standards. It is quite possible that the methods developed could be used for other natural resource and agricultural applications where the activities are spread fairly evenly over a large area.

REVIEW OF PAST PRACTICES

In the early years of forest transportation planning, it was common practice to focus on an intended activity such as building a campground, harvesting a stand of older timber, or accessing a high forest-fire activity area, and then project the roads to these sites. Road standards and routes were sometimes determined by estimating some combination of probable traffic, perhaps considering travel time, road costs, engineering economics, road impact, and budget priorities. Most often, standards and routes were determined by past practices or by the "gut" feelings of engineers or forest managers.

In 1942, Matthews (1) recognized the need for a more systematic method of planning logging and roading costs. He developed formulas for balancing the cost of hauling or skidding logs to forest roads, the cost of building roads, and the density of the timber. He considered the cost of prehauling (yarding or skidding), the volume per acre, and the cost of road construction. Matthews pointed out that the standard of main roads might change as the roads penetrated deeper into the forest because of the diminished volume being hauled. He stated that higher standards should be justified by the reduced cost of haul.

Later, in 1947, the Forest Service published the Cost of Hauling Logs by Motor Truck and Trailer (2). For many years, this authoritative work was the basis for calculating the cost of log haul in the western United States. This excellent work lacked a precise means of calculating road construction, road maintenance, and logging costs. The 1960 revision, called the Logging Road Handbook (3), included updated costs and hauling costs for the eastern United States. Another significant addition to forest transportation planning was the Forest Engineering Handbook (4) published in 1961 by the Bureau of Land Management, U.S. Department of the Interior. The handbook outlined a systematic method for planning road and logging systems. A good transportation plan, the handbook pointed out, is the result of concurrent consideration of the physical requirements of logging methods; the economics of yarding, roading, and trucking; the silvicultural system; cutting priorities; protection of soil, water, and the uncut stand; and the safety of the entire operation. The final plan should be the compromise reached after weighing all these factors. The necessity for on-the-ground reconnaissance to identify elements that do not show up on photographs or maps was also pointed out. The fact that the planner cannot avoid field work was emphasized.

Team transportation planning became somewhat popular in the late 1960s. A group of engineers and foresters on the Olympic National Forest became one of the first teams. It was felt that the participation of other specialists in the development of the forest transportation plan would result in a more effective plan. Through this approach, the Olympic found that an adequate transportation plan required a complete logging plan and field verification. Haul costs were found to be relevant in few instances in the steep, mountainous terrain of that forest. The best plan was often the location that had the least impact on the land while providing a logging system that could log a maximum amount of land. One result of the Olympic's efforts was one of the first systematic, planned skyline logging programs.

In the late 1960s, the public's image of government changed. The feeling that the government was not responsive to their needs prevailed. A.W. Greely, associate chief, Forest Service, in his address at the 1970 Intermountain Logging Conference (Spokane, Washington, April 2, 1970), felt that the Forest Service would become a target of the public's dissatisfaction. He recognized the trend toward direct confrontation with public agencies and demands for change. He also warned that increased accountability and satisfaction of public needs would be essential in future management activities.

The controversy on the Bitterroot National Forest was evidence of Greely's concerns. The Bitterroot (5) was accused of having too many poorly located and improperly constructed roads, which were reducing the natural beauty and causing sedimentation. After examining these issues, the Forest Service found some of the concerns to be real. It was suggested that a coordinated transportation plan is essential to the orderly development and management of the many resources on any national forest. The interrelation between the resource base, the transportation system, the silvicultural systems, and the logging system must be thoroughly known and analyzed to achieve the objective of quality land management. One obvious solution was to require longer yarding distances with existing logging systems to eliminate some roads.

By the end of the 1960s, the complexities of transportation planning demanded a computerized method for analyzing the myriad combinations of road possibilities. In 1965, the Forest Service established the Transportation System Planning Project at Berkeley (6) and an Advanced Logging Systems Program at Seattle (7). The main emphasis of the Berkeley project was to adapt newer urban transportation planning techniques to the national forest transportation system. The main focus of the project was a computer program called the Timber Transport Model. The model converted earlier manual network methods to computer format, thereby making it easier to analyze some forest roading problems. The Seattle project was mainly directed at getting design data for advanced logging systems, including skylines, helicopter, and balloon.

The tools of forest transportation planners have become more complex, and the need for more precise forest road and logging system techiques more pressing. At the same time, the public has shown more awareness and concern over the environmental effects of logging and road building and the trade-offs between the costs and benefits of building these road systems. Improved methods of planning are needed to determine the number of roads and their dollar and environmental cost so that forest managers and the public can understand what is being analyzed, why the transportation decisions are important, and what the total transportation system might look like.

TRANSPORTATION PROBLEM

Log transportation starts after the trees are first cut, limbed, and left in tree lengths or sawed into log lengths. A tractor is used to skid the trees or logs to a landing area that is accessible by an 80 000-lb gross-vehicle-weight truck. The landing can be a clearing adjacent to a main road, along a low-standard road, or anyplace on or adjacent to an extremely-low-standard road (Figure 1). Landing areas usually are accessed by extremely-low-standard roads because those roads are adjacent to the greater timber area. These extremely-low-standard roads are such that logging trucks can barely travel on them. Truck speeds are usually less than 5 mph. Rocks 1.5 ft in diamter, ruts 1 ft deep, and large roots usually make these roads impassable to passenger cars. Recreationists, loggers, hunters, and other forest users must use light trucks or four-wheel-drive vehicles to use these extremely-low-standard roads.

Low-standard roads are the next higher order of roads. Curves are not geometric but are greater than a 100-ft radius. Maximum grade is 15 percent, truck speeds are about 15 mph, and selected gravels are used to reinforce weak areas. The road surface is 12 ft wide, with a 25- to 30-ft clearing width. In some cases, crushed gravel will be used if it is most economical. Passenger cars can use these low-standard roads during most of the year.

The main trunk roads are 18-24 ft wide. Truck speeds are about 35 mph. Passenger cars can use these roads from early spring to late fall. The minimum curve has a radius greater than 400 ft and grades are less than 8 percent. About 90 percent of these roads have a crushed-gravel surface.

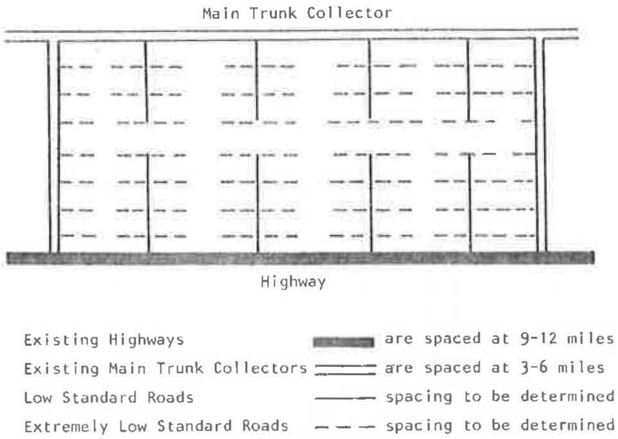
The highways that access the forest have a 24-ft-wide paved surface. Speeds of 50 mph or greater are common for logging trucks.

In mountainous regions, the problem of planning a transportation system is often simplified because of the limited choice of logging equipment. A particular type of cable logging equipment may have a maximum of 1000 ft of an appropriate size cable. This fact limits the maximum road spacing to a 1000-ft slope distance. The 1000-ft maximum distance may not be optimum, but it does limit the number of practical possibilities that need to be considered. Two or more logging systems, with quite different characteristics and costs, often need to be considered for the same area.

In flat areas, by contrast, logs are pulled with large-tracked or rubber-tired tractors. There is no fixed distance that determines the needed spacing of roads. Under these conditions, road spacing should be determined from a study of the break-even cost of skidding logs to roads with the cost of building more roads. It is the interaction of the cost of logging and the cost of road building that determines the amount of road needed and the amount of money spent on roads.

As more and more low-standard roads are connected, the increased traffic will, at some point, demand a higher-standard main road. In the western mountains, the main road location is often dictated by topographic features such as a major valley, ridge, or pass. Techniques such as network analysis are highly effective in these locations. A break-even analysis, however, is more useful in areas with

Figure 1. Idealized road layout on Chequamegon National Forest.



gentle topography. This analysis consists of calculating the point where increased road construction will be offset by lower haul costs. Traffic is then estimated to see what the most efficient road standard will be. The question to be answered is not, Which road is the best?; it is, How many roads of what standard is most efficient? When considering the lowest possible road standard, care should be taken not to select a standard that is too low. In some cases, increased truck-hauling costs more than offset the savings in road construction. The cost of roads is often looked at as an independent cost element that should be minimized. Care should be taken to consider all the elements of transportation rather than just one or two. Skidding, road construction, and road maintenance, as well as hauling, must be considered in order to optimize the cost of log transportation.

Timber on the Chequamegon is sold by sealed bid auction. In order for national forest timber to be competitive, the cost of logging must be favorable when compared with other potential sources near northern Wisconsin. These sources include other government forests such as state, county, and town forest lands; small private landowners; and forests in northern Michigan, Wisconsin, and around the Great Lakes in Canada.

Roads on the Chequamegon must also compete with roads on other national forests. Only those roads that return the greatest amount of money along with other considerations are normally built on the national forests. The roads on the Chequamegon must be highly cost effective in order to be funded.

In order for timber to sell, an adequate road density should be available so that the combination of skidding and roading costs are minimized.

METHOD SELECTED

Matthews' method seemed to fit the conditions of gentle topography, evenly dispersed timber, and small variation of road-building costs from one area to another. The difference in the road costs of one location, as compared with another, is often insignificant in flat areas. Haul-cost differences can also be small. One approach to this situation is a road-spacing-standards analysis that results in approximate road spacing for the road standards being considered. Matthews developed a road-spacing equation that can be used to develop a guide for road spacing in areas where road locations are not sensitive to cost [Figure 2 (1)]:

$$S=\sqrt{17.4R/VC} \quad (1)$$

where

S = road spacing in units of 100 ft,
R = road cost per 100 ft of road,
V = volume of timber to be removed per acre, and
C = cost of skidding logs per 100 ft of round trip.

Truck-hauling costs were not included in Matthews' equation because he found them insignificant. This was tested for extraordinarily-low-standard roads where maximum truck speeds are 5 mph or less. It was found that, for very low road-building costs ($5700/mile) and very high hauling costs [$5.15/units of 100 ft^3 of timber (Ccf)/mile], optimum spacing changes from 840 to 890 ft. When considering a large number of these extremely-low-standard roads, this difference in spacing may be significant.

Although Matthews' equation gives some very good general direction for road spacing on gentle topography with timber evenly spaced on the land, it does not fit the most common situation found on the Chequamegon National Forest. Rather than one standard of road, the most common condition is extremely-low-standard roads used in combination with low-standard roads. The cost of the extremely-low-standard road is often less than half that of the low-standard road. Adding another layer of roads greatly increases the complexity of a mathematical analysis.

In considering solutions to this problem, both mathematical and computer analyses presented themselves as possibilities. A computer program could be useful in developing total costs and in solving the program for some of the variables to see how they affect total costs. Unfortunately, successful use of such a program is predicted on the user's understanding of the mutual interdependency of the variables. It was decided that a mathematical solution would be more systematic and would result in more consistent findings that could be clearly presented to the decisionmakers.

NEW EQUATIONS

We decided to modify Matthews' equations so that multiple road standards and haul costs would be considered. Our goal was to develop an equation that reflected total costs of road building and hauling for two road standards and logging costs for various timber densities. Road maintenance also needed to be considered. To simplify the equations, road construction costs were increased by the present value of 20 years of road maintenance.

First, each cost element was identified (Figure 3):

$$\text{Extremely-low-standard-road cost} = (Re/52.8) \times Le \times Ne \quad (2)$$

where

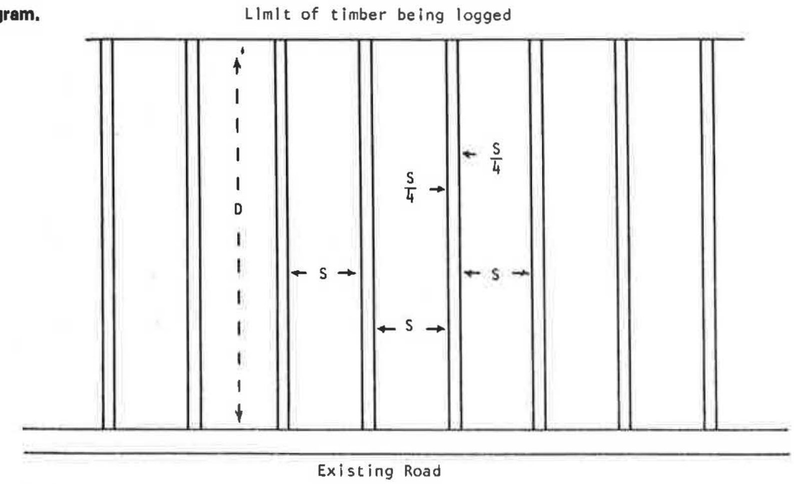
Re = cost of extremely-low-standard road ($/mile),
Le = length of extremely-low-standard road (units of 100 ft),
Ne = number of extremely-low-standard roads in the study area, and
52.8 = coversion of miles to units of 100 ft.

$$\text{Low-standard-road cost} = (R/52.8) \times L \times N \quad (3)$$

where

R = cost of low-standard road ($/mile)
L = length of low-standard road (units per 100 ft), and

Figure 2. Problem diagram.

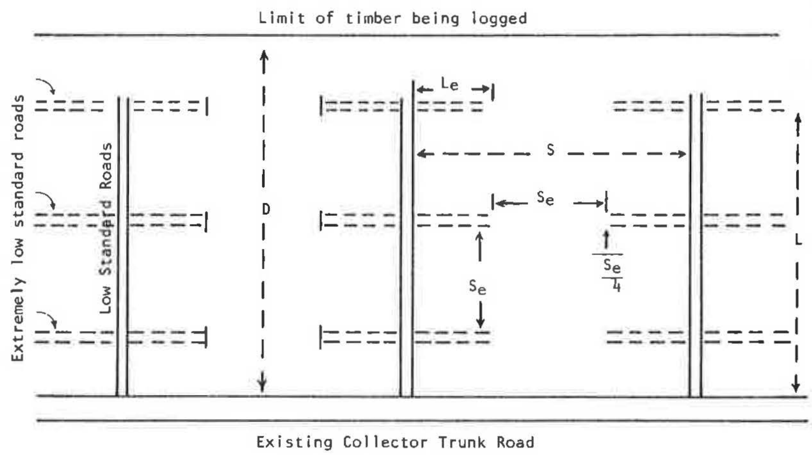


D = Depth of Timberbelt

S = Road Spacing of Branch Roads

$\frac{S}{4}$ = Average Prehauling or Skidding Distance

Figure 3. Chequamegon National Forest problem diagram.



D = Depth of timberbelt

S = Road spacing of low standard roads

L = Length of low standard roads

S_e = Road spacing of extremely low standard roads

L_e = Length of extremely low standard roads

$\frac{S_e}{4}$ = Approximate average skidding distance

N = number of low-standard roads in the study area.

$$\text{Haul on extremely-low-standard road} = (He/52.8) \times (Le/2) \times V \quad (4)$$

where He is the haul cost on extremely-low-standard roads ($/mile/Ccf) and V is the total timber volume in the study area (Ccf).

$$\text{Haul on low-standard road} = (H/52.8) \times (L/2) \times V \quad (5)$$

where H is the haul cost on low-standard roads ($/mile/Ccf).

$$\text{Haul on collector truck road} = (Hh/52.8) \times (L/2) \times V \quad (6)$$

where Hh is the haul cost on the collector trunk road ($/Ccf/mile).

$$\text{Skidding costs} = C \times (Se/4) \times V \quad (7)$$

where C is the skidding cost ($/unit of 100 ft/Ccf/round trip) and Se is the spacing of extremely-low-standard roads (units of 100 ft).

The total cost is equal to the sum of the factors above; i.e., total cost equals skidding cost plus haul cost over the various road standards plus road construction costs. The unknowns were replaced with terms that resulted in only one unknown factor.

All the individual terms were placed into a single total-cost equation (the full equation derivation is available from the authors):

$$\begin{aligned}\text{Total cost} = {} & (CSeV/4) + (HeV/211.2)(S - Se) + (HhLeV/105.6) \\ & + (HLV/105.6) + (2ReL^2/105.6S_eS) \times (S - S_e) \\ & + (RL^2/52.85)\end{aligned} \quad (8)$$

The first partial derivative with respect to spacing of the low-standard roads (S) was taken and the derivative was set to zero and solved for S:

$$S = \sqrt{4(RL^2 - 2ReL)HeV} \quad (9)$$

The first partial with respect to the spacing of the extremely-low-standard road (Se) was taken, set equal to zero, and solved for Se, which resulted in the following equation:

$$Se = \sqrt{2ReL^2/\{13.2V[(C - He)/52.8]\}} \quad (10)$$

In the total-cost equation, the spacing of the extremely-low-standard roads must be less than the spacing of the low-standard roads or negative values will result. Empirically, the spacing of the higher-cost roads would always be greater than for lower-cost roads; when using Matthews' equations, this is always true. We feel this assumption is safe.

A defined area was used to solve the equations in order to make L and Le constants. An area 20 000 x 20 000 ft was used to develop the relations. This was checked by using an area 200 000 x 200 000 ft. The spacing checked out to within 0.02 ft of the values for the smaller area.

To verify that the equations were realistic, the total-cost equation was solved on a programmable calculator for various values of road spacing and road costs. The results were graphed for extremely-low-standard-road spacings of 500, 1000, and 1500 ft. The minimum points on the curves correlate well with the calculated optimum values. When both the low-standard-road spacing and the extremely-low-standard-road spacing are near optimum, the total cost is at a minimum. A further check of the equations was made for a rectangular area that had a depth of 8000 ft. This is a representation of the actual conditions found on the Chequamegon National Forest because the main trunk roads are spaced about three miles apart. The results are very close to the equations developed for a square area.

RESULTS

To study the effects of the new equations, skidding costs were changed while all other elements were fixed. The results were calculated for a variety of road spacings. We found that skidding cost will not significantly change the optimum road spacing for low-standard roads even though it has a large effect on total cost.

Timber volume had a substantial effect of road spacing (Figures 4 and 5). For a situation where low-standard roads cost \$11 000/mile, extremely-low-standard roads cost \$5700/mile, and the skidding costs \$1.74/Ccf, the optimum spacing would be as follows:

Volume	Optimum Spacing (ft) at 5 Ccf per Acre	10 Ccf per Acre	15 Ccf per Acre
Low-standard roads	8570	6060	4950
Extremely-low-standard roads	1460	1030	842

Figure 4. Cost versus spacing for an extremely-low-standard road.

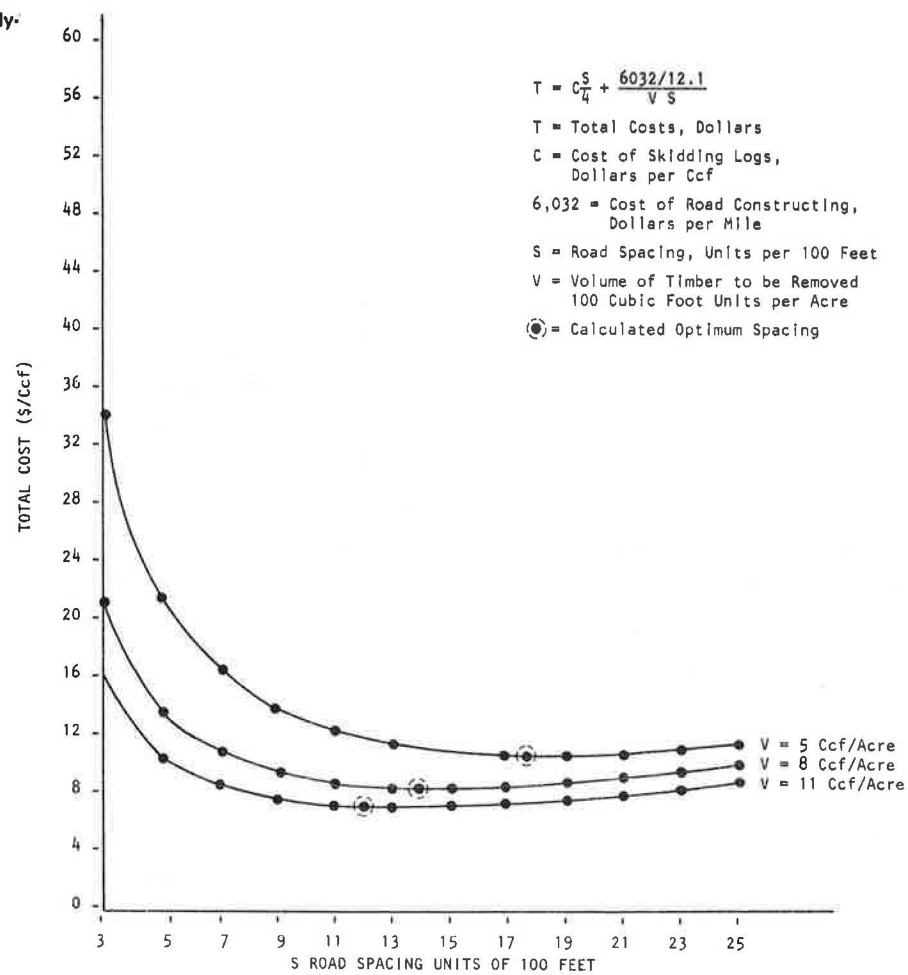
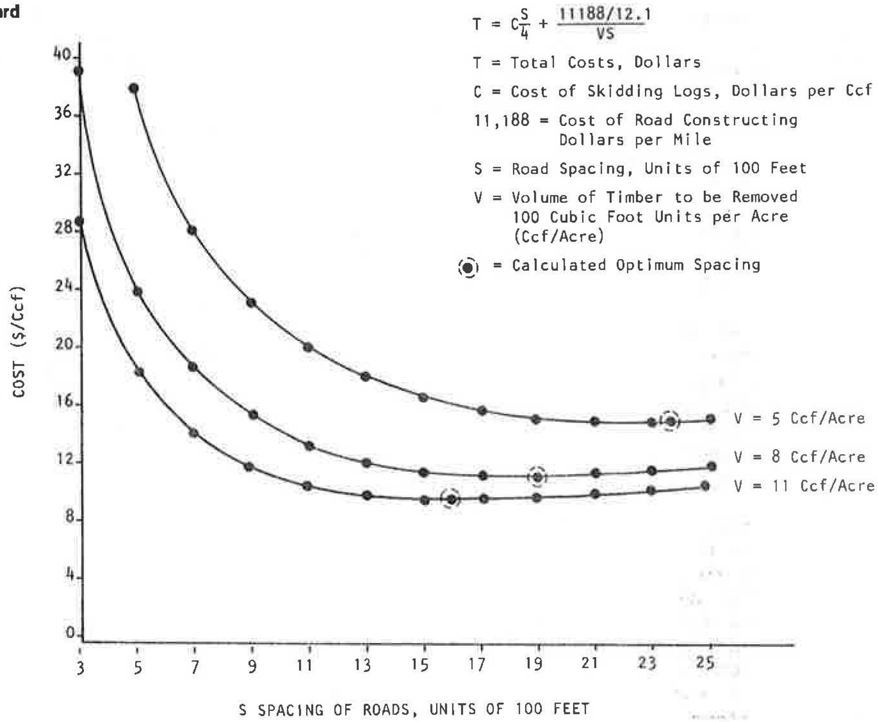


Figure 5. Cost versus spacing for a low-standard road.



Skidding costs had a substantial effect of the spacing of extremely-low-standard roads. The total-cost curve for road spacing of extremely-low-standard roads does not have the broad, flat character of the curves of total-cost curves compared with spacing of low-standard roads. This indicates that the spacing of the extremely-low-standard roads is more critical and has a narrower range of acceptable values (Figures 4 and 5).

The values of road length needed must be adjusted from the perfectly shaped geometric model to allow for road locations that fit the topography, soils, or other important features. This was accomplished by comparing the effective straight-line length with their actual length. A number of existing roads that have the same standards as the proposed roads were studied. It was found that the actual distance exceeds the theoretical distance by 12 percent. This indicates that the theoretical road lengths should be increased by 12 percent so that on-the-ground conditions will be allowed for. Road construction costs should be increased by 12 percent so that the equations are correct for actual conditions.

The effect of nonproductive land was also considered. Such nonproductive areas as small open marshes, wildlife meadows, peat bogs, and other features are found throughout the Chequamegon National Forest. These non-timber-producing areas have few or no roads. A study of the forest found that non-timber-producing land ranged from about 0.5 to about 3.3 percent of otherwise timbered land. A study of the road layout for logging around these small non-timber areas showed that they had little effect on optimum road density.

A question that seemed important was, How do current road densities compare with theoretical optimum road densities? To answer this question, several areas of different timber types were selected. A complete road system was projected by using current techniques of projecting a normal road density that considered timber, soils, streams, etc. This projected road density was compared with the calculated optimum road density. It was found that the actual road density ranged from 79 to 82 percent of the optimum calculated density. This indicated that about 20 percent more roads could be constructed and would result in a lower total cost of timber production. The lower cost would be about \$1.50/Ccf or about \$180 000/year.

The road-density calculations allow us to estimate total road needs for the Chequamegon National Forest. There are about 847 000 acres of national forest land on the Chequamegon. Of this, about 18 000 acres are open water and 64 000 acres are open or non-timber-productive brush fields. Another 15 000 acres are reserved for uses other than growing timber, including recreation. Because recreation roads are usually also used for timber production, they do not substantially affect the total mileage. Considering these deletions, 750 000 acres (about 1172 mile^2) are available for timber production.

Assuming an average yield of 15 Ccf/acre and an optimum road density of 6.5 miles/mile^2, the total road needs for the Chequamegon National Forest are 7600 miles. There are currently 2274 miles of forest roads and 231 miles of highways under state or county jurisdiction. This shows that there are an additional 5100 miles of roads needed to log timber at an optimum least cost on the forest. The estimate record is that a total of 3500 miles of road are needed on the Chequamegon. This would mean that only 1000 more miles are needed. About 50 miles are constructed on the Chequamegon each year. It is apparent from the progress being made that the additional 1000 miles needed is quite low. Of the 5100 miles needed, about half will be low-standard roads and half will be extremely-low-standard roads. The total cost will be about \$42 000 000.

Road-density calculations have direct application to the type and age of timber stands. Most of the timber stands on the Chequamegon are now 40-90 years old. Some species such as aspen and jack pine have a rotation of 35-45 years. These species are now being clearcut. Other species have a rotation of 120 years. These stands will undergo commercial thinnings beginning near age 35 and periodical thinnings until age 90. Road-density calculations will be modified by discounting future costs for these stands to allow for the reduced early yield and still consider the much heavier final cut.

A forest plan is currently being developed for the Chequamegon National Forest. This plan considers public opinion and data about the natural resources found on the forest. The analysis portion of the plan will include calculations to determine the optimum time to cut the various timber stands while maintaining an even, sustained yield of timber and other resources from the forest. The road-density calculations will be matched with the harvest plans to develop the miles of road needed for timber harvest for the first 10 years of the plan. The construction cost by year, and the cost of road maintenance, will be a part of the plan and will be used to develop the forest budget.

CONCLUSIONS

The road-spacing equations work well for gentle topography. Optimum road spacing is fairly easy to calculate for different road and haul costs for two road standards, skidding costs, and timber densities. The minimum total cost of logging and hauling timber will be achieved at the optimum road spacing.

Roads are not laid out in straight lines. They curve around obstructions, which increase construction cost. The theoretical values can be compared with actual situations so that the true road lengths can be estimated.

The Chequamegon National Forest will need an additional 5100 miles of road to remove timber at an optimum least cost. These additional roads will cost about $42 000 000. Having a greater road density should save $180 000/year.

The optimum road-spacing equations, in conjunction with timber stand production data, will form the transportation planning portion of the Chequamegon's forest plan. The road-spacing, road, and road maintenance costs will be calculated for various planned timber harvests so that a firm budget can be developed.

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Classification of Unpaved Roads in Ontario

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Unpaved roads constitute a large portion of the total road network in Ontario. Currently, there is no program available to the municipalities that will enable them to classify their unpaved-road network and apportion their existing maintenance funds across the road system in a cost-effective manner. This paper outlines a simple but rational approach to classifying unpaved roads into three distinct classes by using four quality-of-service characteristics. A formula was developed that permits the existing maintenance expenditures to be apportioned over the three classes of unpaved roads. The conclusion is that classification of the unpaved roads in Ontario will permit the unpaved-road network to be elevated to the level of maintenance management now practiced on paved and surface-treated roads. Such a program will enhance the task of the roads manager and aid the taxpayer, traveler, and those who strive to conserve our natural resources for future generations.

Unpaved or aggregate-surfaced roads have been an integral part of the road and street network in Canada for the better part of a century. As the nation has grown, so has the road system, giving ever greater access to the frontier areas of Canada. Initially, roads were hewn out of the forests, and the existing soil formed the road surface. Maintenance requirements were nominal.

The development of the motorized carriage triggered a new era, and along with this industrial development came a need for improved roads. Industry and the engineering community responded, and today we have a great network of roads. In the Province of Ontario, there are 75 000 km of unpaved roads, of which 72 000 km are maintained by individual municipal governments. The responsibility for maintaining the unpaved-road network may be the county; the individual township within a county; the individual city, town, or village within a township; or the provincial body--the Ministry of Transportation and Communication (MTC). The greatest percentage of unpaved roads is under the jurisdiction of the township governments, as shown in Table 1 (from 1980 MTC data).

The network of roads continues to expand as the population grows and its needs increase. It is not practical to transform all of these unpaved surfaces into hardtop surfaces and, as a result, unpaved roads will continue to form an integral part of the total road network for the foreseeable future.

The costs for maintaining the road system have escalated dramatically since the mid-1970s and, in recent years, the municipalities have not been able to raise these increased costs from the ratepayers. As a result, there have been arbitrary cuts in some road programs to offset escalating costs in other