WOOD ROADS

THEIR LOCATION, SPACING AND STAND-
ARDS

Joseph J. Mendel
1942

BF in 1941
MF incomplete

WOODS ROADS

THEIR LOCATION, SPACING AND STANDARDS

by

Joseph J. Mendel

School of Forestry and Conservation
University of Michigan
Ann Arbor, Michigan
January 27, 1942

CONTENTS

INTRODUCTION

In spite of good progress being made in construction of woods roads, the standards and practices in selection of their location frequently are still inadequate. Although much valuable information has been obtained from aerial photography, more time and care should be given to detailed determination on the ground of the best route in relation to the cost of road construction, maintenance and particularly, of transportation.

In the case of main woods roads, such as for heavy trucking during fairly long periods, the total expenditure on transportation often will be at least $5000 and sometimes over $10,000 per mile. However, the cost of ground work in location of such roads frequently is under $25 per mile, ie. merely a fraction of 1% of the total investment in transportation. That is usually not nearly for the best economy in the end.

There is no doubt that this statement is true, as many miles of truck road have been constructed without sufficient effort having been spent on location. The final location of the center line of the road is where savings in construction, maintenance and subsequent trucking costs can be effected.

There are many factors to be considered before the center pickets can be finally set and construction started. This preamble gives sufficient justification for the forthcoming discussion.

LOCATION OF WOODS ROADS

The road location program is in its briefest form that of providing a road between two given points with the possible addition of one or more points in between where it has previously been decide to place depots or other headquarters.

When a Road is Well Located:

There is a great deal of difference between the best possible road location as it may be visualized and the best possible location that the country affords. It is easy to form the opinion, after the road has been built, that certain hill, bridge location, swamp crossings, etc. is not all that is to be desired. However, it may be the very best the region affords. There is only one way to competently judge a location and that is to travel over all other possible locations that might have been used. The question, "Is this the best location?" has often been asked. Unfortunately, satisfactory answers are difficult to give. A road is well located when it meets two requirements. First, when it avoids the criticism of the executive concerned, and secondly and most important, when it is in the most ideal situation for cheap construction, maintenance, and transportation.

Policy in Road Location:

Before construction of a road starts there should be a definition of policy by the executive of the company. A truck road is one improvement that immediately becomes easily accessible as soon as completed. The point here is that every individual, who is going to judge with authority the finished road, should express an opinion of what type of road he will expect to see when he inspects the finished project. By type of road is meant allowable grades, directness of routes, type of culvert and bridges, width of right-of-way, width of crown, ditches, etc.

It is during the consideration of policy that the question of the probable life of the road should be considered. Knowing the life of the road it is then possible to arrive at the likely transportation cost that will be expended. As suggested in the introduction, this figure may exceed $10,000 per mile. There is then a definite basis available from which it is possible to determine a justifiable construction and location cost. By following this type of reasoning, location costs up to $250 per mile are allowable. This sum of money will do an immense amount of location work.

The person making the location should be well informed on all these questions of policy so that he may properly make dissensions between alternate locations.

Though policy is not directly related to the actual engineering problem, it is worthy of consideration because by its interjection may bring about more serious thought for better woods roads.

Procedure For Locating Woods Roads:

1. General Location: Aerial photographs are definitely the best means of making the first general location. If pictures are already available so much the better. If they must be taken for the particular purpose in hand, they should be flown in the general direction of the proposed route and include a strip wide enough to cover all possible routes. From one to two miles should in most cases be ample. A scale in the vicinity of 1000 feet to the inch will serve, although there are factors to determine the most desirable scale which do not require discussion here.

Starting at the point of origin for the road, the pictures are studied stereoscopically. Abo't three alternate locations are made on the pictures, different colored pencils being used to differentiate between locations. The colors indicate in sequence which is the most desirable route, and serve the additional purpose of making it easy to follow each location from one overlap to another.

The next step is to explore in the field all possible routes and determine the most desirable. This work should be carried out by the person responsible for the location. The pictures are used constantly during the field work and a portable stereoscope is indispensable.

2. Running the Tangents: With the completion of the preliminary location it is then desirable to terminate field work for a time. The individual responsible for the location should now discuss the situation with his Manager. This is necessary as there are always numerous alternates that require discussion from a policy point of

view.

With these points settled, the next step is to lay out the entire road as a series of tangents, on the photographs. This layout is accomplished under the stereoscope. The point of origin and termination of each tangent are carefully located features which can be identified on the photographs and on the ground. By features are meant creek crossings, marshes, small clearings, definite changes of timber types, etc., which are not difficult to find.

The bearing and distance is computed on the photographs for each course. A field party is now organized to run and blaze the tangents in the field, but the person responsible for the location need not do this work. This location of the tangents also provide a final map of the road.

Excessive grades are measured with hand levels while bridge locations are measured for length of span, and all this information is recorded on the margin of the photograph. There are obvious advantages in having information relative to the location, on the photographs, so as to be readily available whether pictures are functioning as a map or being studied under the stereoscope.

3. Final Location: With the tangents blazed, the final location is made by the person responsible for the work. If it is at all practicable, the person making the location should also be in charge of construction.

The final location work consists of picketing the centerline of the road. It is absolutely unnecessary to do any transit work, as tangents are kept straight by linning up three pickets. Before the location is finally accepted as the best, the route must be travelled and re-travelled to make absolutely certain that there is no better situation.

It is in this final location work that money is saved or wasted in construction. A few feet to one side or the other may effect appreciable savings in construction costs.

During the final location work curves are staked out. It will be borne in mind that no previous picketing of curves has been done nor is it necessary before this final operation. Although instrument work is not necessary on curves it is advisable to get smooth curves with as large a central angle as possible. Diagrams of middle ordinates, tangent offsets or deflection angles are helpful, used in conjunction with a tape and the trail and error use of your eyes as an instrument. With a little practice very accurate work can be executed by this procedure (2).

SPACING OF WOODS ROADS

It is evident to timber operators who are planning road layouts that the cost of their roads must eventually appear as a part of their logging roads per thousand board feet. Usually however, their cost is origionally dealth with in terms of a distance unit such as the station, the chain or the mile. This cost is transferred to a cost per thousand board feet or per cord by spreading it against the volume moved over the road. The total volume available per unit distance will depend first upon the volume per acre, and second upon the area served by the road, and this in turn varies directly with spacing.

Probably all operators take these factors into account to some extent. The fact that the prehaul operation in combination with the cost of the transport system commonly makes up 50% or more of the total logging costs exclusive of the supervision, justifies careful attention to the correct planning of the road system with constant adjustment of spacing to changes in conditions.

Determination of Formula for Spacing of Roads:

A formula for total cost of skidding and road construction when the spacing of roads has not been predetermined reads:

$$X = C\frac{S}{4} + \frac{R}{VS}$$

In this formula S = spacing between roads running into woods from the highway. Logs would be skidded a maximum distance of one-half the spacing and the average skidding distance would be one-half this distance, hence the expression S/4 for the average skidding distance. As C = cost of skidding per unit distance such as 100 feet then average cost of skidding is $C\frac{S}{4}$ when the distance S is expressed in units of 100 feet. R represents the cost of road construction per acre on some assumed unit spacing of roads. V represents volume per acre.

If the spacing unit chosen is 100 feet and R is determined in the first instance as cost per mile, then as a road spaced every 100 feet serves 12.1 acres, the cost of the road per acre would be R divided by 12.1 acres. The formula can therefore be rewritten as follows:

$$X = C\,\frac{S}{4} + \frac{R/12.1}{VS}$$

In this equation the skidding cost component $C\,\frac{S}{4}$ varies directly with the spacing, whereas the road cost component varies inversely. In such cases minimum costs are achieved when these two components are equal. Therefore we may equate the two right hand components of the above equation and solve for the quantity of the changing value of S which will result in minimum cost:

$$C\,\frac{S}{4} = \frac{R/12.1}{VS} \qquad \text{Multiply by 4S}$$

$$CS^2 = \frac{.33R}{V} \qquad \text{Divide by C}$$

$$S^2 = \frac{.33R}{VC}$$

$$S = \sqrt{\frac{.33R}{VC}}$$

Application of Formula for Road Spacing:

Problem: A tract of pulpwood averaging 10 cords per acre is to be logged by building in a main logging road from which haul roads will branch off as feeders. These roads are estimated to cost $200 per mile to construct. Pulpwood will be skidded to these haul roads and there loaded on trucks. Skidding is estimated to cost 12¢ per cord per 100 feet round trip distance. How far apart should these branch haul roads be spaced?

The values for insertion in the road spacing formula are:

V - volume per acre - 10 cords

R - cost of road construction $200 per mile

C - cost of skidding - 12¢ per cord per 100 feet

Substituting in the formula we have:

$$S = \frac{.33 \times 20000}{10 \times 12} \quad \text{or} \quad 55 \quad = \quad 7.41$$

Therefore roads should be spaced about 740 feet apart, thus obtaining the most economical spacing. (6)

STANDARDS OF WOODS ROADS

On the majority of forest properties that are financed by private means, roads will be constructed for the sole purpose of facilitating the transportation system of forest products. The utility of these roads for general use or as an addition to the fire protection system will not ordinarily be estimated or allowed for, and the cost of construction will be charged off against the timber products that are to be moved over the road system. The following discussion will assume, however, that the objective in road planning is to acheive a minimum total for the sum of road construction, hauling and prehauling costs.

Classes of Roads Considered:

Bruce Spike, of George Banzhaf & Co., Milwaukee, Wisconsin, has made a study of trucking costs in Northern Michigan for his firm, which operates both as a producer and a consultant on forest industry costs. He first classified the roads over which trucks operated in the region and then determined average speeds and fuel consumption on each class of road. His road classification is as follows:

I. Strip roads - Brushed out, stumps cut low, little or no grading, rough, no alignment, creeper gear. Made by piece cutter or trucker.

II. Poor haul roads - Brushed out, stumps cut low, hand-graded with shovel or grubhoe, rough or not smooth, more or less contour alignment, creeper and first gear.

III. Fair haul roads - Hand or machine graded, more or less contour alignment, gradient changing but more favorable, fairly smooth if properly maintained, considerable first and second gear.

IV. Good haul roads - Machine graded, drainage provided for, usually dirt surface, fair alignment, fairly smooth.

Public Roads

V. Dirt and poor gravel - Fair alignment and gradient, about 20% first and second gear, smooth surface or rough, depending on maintenance.

VI. Good gravel and old macadam - Good alignments and gradients, surface more or less uneven, nearly equal to hard surface roads.

VII. Pavement and good macadam - First class alignment and long sustained gradients. Maximum performance and saftey.

Determination of Road Standards:

The information that is required in order to make a correct decision as to the standard to adopt for any road may be listed as follows:

1. Volume of timber that will be moved over the road.
2. Length of the road when subject to control - not essential in the case of exterior main-line roads.
3. Cost of construction to various standards per mile or other distance units.
4. Cost per round trip mile, or other distance units, of hauling the product over roads of various standards. Therefore speed will determine costs when the machine rate per hour for the transporting vehicle and the average load per trip are known.

Application of Road Standards to Logging:

Problem: A main logging will have to be constructed to tap 8000 M ft. b.m. of timber. Hauling will be by trucks, for which the machine rate has been calculated at $1.30 per hour. Trucks will carry an average load of 2 M ft. b.m. Fuel consumption is estimated at an average of 0.3 gal. per round trip mile, which, at $0.20 per gallon, places fuel cost at $0.60 per round trip truck mile. The cost comparisons to be given consideration are as follows:

road class	Ave round trip speed, m.p.h.	Hauling cost per mile per M ft. $\frac{130¢ \times 2}{\text{m.p.h.} \times 2M}$ $\frac{\text{fuel at } 6¢}{2M}$	Cost of road construction per mile	Cost of road construction per M per mile of road $\frac{\text{cost per mile}}{8000\ M}$	Total cost per M per mile of road for hauling plus road construction
II	4	32.5¢ 3¢ = 35.5	$200	2.5¢	38.0¢
III	7	18.5¢ 3¢ = 21.5	$400	5.0¢	26.5¢
IV	9	14.4¢ 3¢ = 17.4	$600	7.5¢	24.9¢
V	18	7.2¢ 3¢ = 10.2	$1400	17.5¢	27.7¢

It is evident from the foregoing comparison that a road of Class IV designation should be adopted. The actual differences seem small, but it is to be remembered that they are per M costs for a haul of only 1 mile. If the haul were 10 miles in length, the total cost difference between a Class III and a Class IV road would be (10 x 8000)($0.265 - $0.249) or $1,280.

As the volume to be moved falls below or rises above the 8000 M ft. b.m. assumed for this case, other classes of roads will come into equality with a Class IV road. The volume that will bring about equality of economy between any two classes of roads can be determined by a simple application of the break even point formula. This formula, which is normally written

$$N = \frac{F' - F}{V - V'}$$ can be rewritten to read

$$\text{Total volume to be hauled over road} = \frac{R' - R}{H - H'}$$

where R and R' are the costs of construction per mile for the two standards of roads being considered and H and H' are the hauling costs per volume unit per mile on roads built to these standards. If, in this case, the volume were less than 8000 M ft. b.m., it might be desirable to determine what volume less than 8000 M ft. b.m. would justify consideration of a Class III road. Letting R' = $600, and H' = $0.174, R = $400 and H = $0.215. The following break-even equation can be written:

$$\text{Volume in M ft. b.m.} = \frac{600 - 400}{0.215 - 0.174} \text{ or } \frac{200}{0.041} \text{ or } 4{,}875$$

This indicates that if the tract carries 4,875 M ft. b.m. either a Class III or a Class IV road may be constructed with equal economy. For volumes of more than this, a Class IV road should be constructed, and for lower volumes, a Class III road should be constructed.

This does not mean that either of these roads is the most economical that could be constructed for a volume of 4,875M ft. b.m. but merely that equality of economy exists for these two classes of roads on the basis of estimated costs when the volume to be removed is 4,875 M ft. b.m. (6)

This problem indicates one approach to the determination of the selection of the standard of woods road that should be built on the basis of factors affecting the cost of the road.

CONCLUSION

It has been the object of this paper to stress the importance of spending more time and effort on the determination of road location, spacing and standards. The ordinary timber operating company does not have enough road construction work to develop the proper skill and efficiency in road location and construction.

It would seem logical to suggest that a competent consulting organization might be better able to handle all the location and construction work. Each operator would then have at his disposal the experience gained on other roads built by this type of an organization. Until such an organization is founded or until the timber operator learns to use the factors affecting the cost of his roads, he is faced the use of high powered trucks on poor roads where it is impossible to obtain the greatest efficiency at the lowest cost.

BIBLIOGRAPHY

(1) Clar, C. R. A Method of Traversing Roads. Journal of Forestry. February, 1935. 33:139-141.

(2) Davis, R. E.; Foote, F. S.; and Rayner, W. H. 1934. Surveying, Theory and Practice. McGraw-Hill Book Company. New York.

(3) Federal Works Agency. Public Roads Administration. 1941. Specifications for Construction of Roads and Bridges in National Forests and National Parks.

(4) LeMay, P. V. July 15, 1937. Location and Construction of Portage Roads. 3 pp.

(5) Martin, J. P.; and Norcross, T. W. December, 1932. Method of Determining the Economic Value of a Forest Road. Journal of Forestry. 30:988-1003.

(6) Matthews, D. M. 1942. Cost Control in the Logging Industry. McGraw-Hill Book Company. New York.

(7) Morrel, F. November, 1927. Relation of Roads to Forest Management. Journal of Forestry. 25:818-834.

(8) Reynolds, R. December, 1940. Pulpwood and Log Production Costs As Affected by Type of Roads. Journal of Forestry. 38:925-932.

(9) United States Department of Agriculture, Forest Service. May, 1927. Handbook for Forest Development Roads and Minor Roads.

(10) __________. 1935. Forest Truck Trail Handbook.