"Roads for Economic Timber Extraction."

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OVER £500,000,000 will be spent on the extraction of timber in the United Kingdom during the course of the next 40 years. The amount of profit, or loss, to the owner will depend largely on the existence and efficiency of a road system within the forest.

There is little doubt that roads are an answer to economic timber extraction.

In a questionnaire, recently sent to various authorities in twenty-eight different countries, and which asked for information and opinions, some of the questions were aimed at determining the importance of roads to timber extraction. Of the many replies received to date, it is almost unanimously agreed that roads are what are required—more roads and cheaper roads. In countries like Switzerland, with its mountains and aerial ropeways, and Norway, with its snow and skidding tracks, it was, nevertheless, advocated that money spent on roads and road construction research would be more remunerative than research on off-the-road haul methods.

Until quite recently, roads, like the notorious Working Plan, were either not required or not desired. Happily, now, roads are both required and desired. A surge of enthusiasm is apparent and the bulldozer is hard at work. As for the Working Plan, that is the "pigeon" of the Forest Officers, some of whom predict that the bird will, one day, escape from its pigeon hole and come home to roost. As an engineer, I humbly ask forest planners-at-large to remember that civil engineering construction and timber extraction cannot be carried out economically unless they are pre-planned and the programme adhered to.

Planning any forest road network starts with calculating the density of roads required, i.e. the most economic density. The cost of extraction is equal to the sum of the cost of roads plus the cost of off-the-road extraction. The ideal density, therefore, is when the sum of these two costs is a minimum.

A recent contributor to one of the British Forestry journals produced useful tables showing how much money could be spent on a road construction programme, based on the saving in cost on off-the-road haul. He assumed that the ideal road density in the United Kingdom to be 7 miles per sq. mile. The amount of money which could be spent on constructing the seven miles was equal to the sum saved by virtue of the shorter off-the-road haul. I do not, altogether, agree with the approach to the problem. For not only is the ideal road density not always 7 miles per sq. mile but also it would be very difficult to apply the figures taken from the tables. For instance, if it were found that, due to the reduction in short haul cost the money available to construct up to the advocated seven miles was, say, £400 per mile, what would be the answer if the estimated cost of road construction was, say, £2,000 per mile? I hold that the ideal density, based on short haul and road construction costs, must be first calculated and then applied.

I wish to present three graphs :—

(1) An ideal density graph for forest roads, which incorporates
(2) A unit short haul cost graph and
(3) A short term investment graph, which will be of more interest to those who are concerned with the practical rather than the ideal.

The ideal road density depends on three main factors, namely :—

(a) Off-the-road or short haul costs.
(b) Road construction costs.
(c) Yield.

As each of these vary from place to place it is necessary to devise a graph covering a wide range of conditions. In the United Kingdom an off-the-road haul cost will vary considerably, according to topographical and other conditions. The cost of road construction will vary from as little as £300 to as much as £7,000 per mile. Smaller and greater figures have been known but the former should not be believed and the latter never divulged! The following are some examples of average cost in the United Kingdom, though they may not necessarily apply to any district in particular.

Cost of road per mile	*Notes on type of construction*
£300—£600	A machine made earth road over easily drained soil and with no major constructional difficulties.
£1,000	A reasonably well drained sub-soil requiring a thin base coat of stone and with no major constructional difficulties.
£1,500	Same conditions as for a £1,000 road, except that some or all of the constructional work necessitates greater expense, e.g. weaker sub-soil calling for thicker base, greater excavation work or increased drainage difficulties.
£2,000	The average cost of the normal forest road. A base coat of stone on a machine excavated sub-soil with side drains and culverts.
£3,000—£5,000	A road constructed with one or more major difficulties such as a bridge (£12 per foot), very weak sub-soil necessitating a thick stone base, rafting or rock excavation (20/- per cu. yd.), etc.

A figure for yield can only be a long term estimate, as road planning policy will have to be decided and acted upon prior to the first thinning.

For the purposes of this calculation the figure of a total crop of 6,000 cu. ft. per acre, over a 60 year rotation, is selected. It is sufficiently accurate and represents an average for a new conifer plantation, which now forms a large proportion of our forest area.

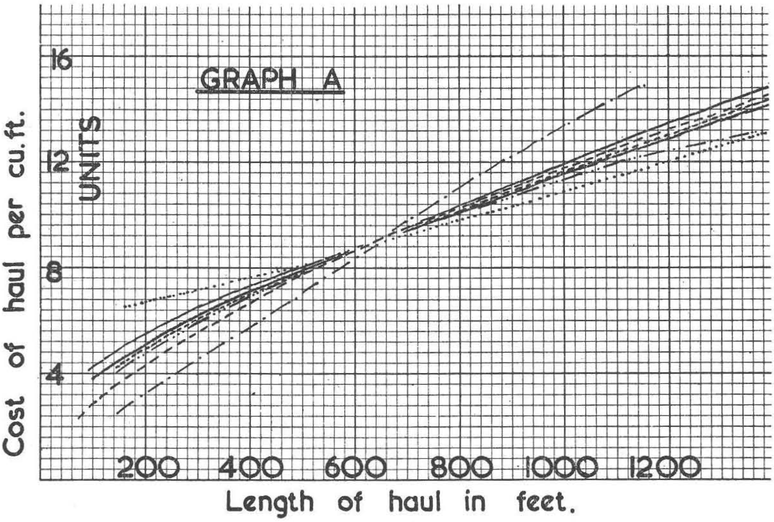
Assuming this yield, it can be determined what charge has to be carried by each cu. ft. of timber to be extracted throughout the rotation of the crop. This is done simply by dividing the total expenditure on roads, after accounting for compound interest, redemption of capital and maintenance etc. by the estimated total yield. Column 3 of the following table shows that figure in an example where the road construction cost is £2,000 per mile.

Road Density Mls./Sq. mile	Maximum Haul Feet	Cost of Road per cu. ft.	Cost of Short Haul per cu. ft.	Total Cost per cu. ft.
2	1,320	0.41d.	8.6d.	9.01d.
4	660	0.82d.	5.8d.	6.62d.
6	440	1.22d.	4.5d.	5.72d.
8	330	1.63d.	4.0d.	5.63d.
10	264	2.04d.	3.6d.	5.64d.
12	220	2.45d.	3.33d.	5.75d.
14	188	2.86d.	3.0d.	5.86d.
16	175	3.26d.	2.7d.	5.96d.

Some people may doubt the smallness of the figure to be borne by the timber due to road construction cost. They are the people who like to slap on 5 or 6% compound interest on to the capital for road construction and leave it there to accumulate until the final felling. Compound interest will strangle you if you will allow it. If one correctly starts to redeem the loan immediately after the first thinnings, similarly as a house owner gradually redeems a mortgage, then one obtains a much lower and realistic figure.

To revert to the main interest, it follows that the greater the cost of road construction and the larger the road density, the greater will be the amount which will have to be borne by each cu. ft. subsequently extracted.

It is next necessary to know how the cost of off-the-road haul varies according to the change in the length of haul. Graph A shows this relationship. The length of haul in feet is costed against the cost of haul in UNITS. This is a very useful graph and one which could form the basis for off-the-road economics. It has the big advantage of providing a figure for all off-the-road hauls, i.e. the cost per length of haul, without pegging a definite cost to any particular length haul. For

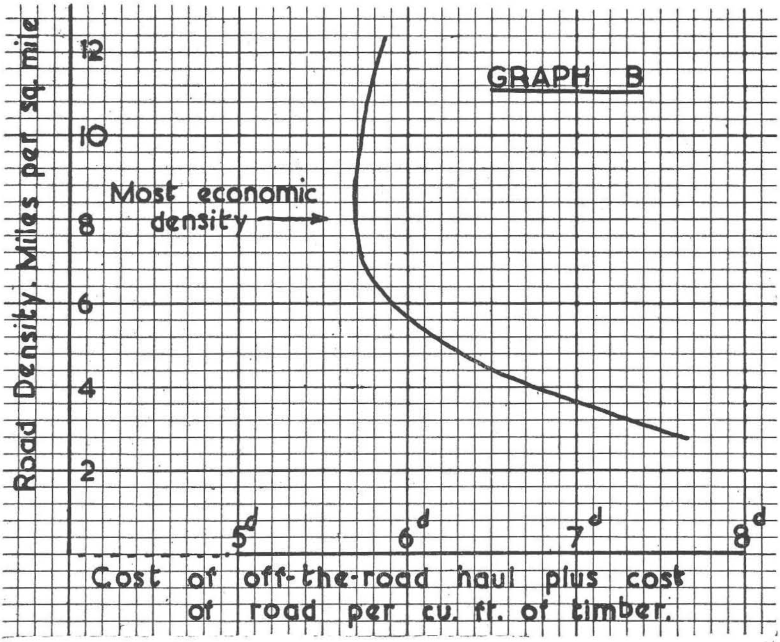


example, if the cost of, say, a 165 feet haul was known for a particular set of conditions, then the cost of other length hauls are readily obtained by reference to the graph and using simple proportion. In this way all length haul costs may be determined from one haul cost figure. As it is in the saving in cost, due to shorter haul, that we are at the moment interested, the graph will provide us with the data which we require.

Whence the graph? Does the cost actually rise to follow this fixed curve? I maintain that it does. On the graph are shown a number of lines, each of which is the result of figures gained from different authentic sources. These include the U.S. Dept. of Agriculture, Technical Bulletin No. 700 on logging Southern Pine, Matthew's "Cost Control in the Logging Industry" and other sources including many replies to the questionnaire already referred to. Indeed, not all of the replies agreed, but many did, and most of those which did not either were straight line graphs, indicating simple multiplication or else were incorrect in that they were acutely convex, instead of being concave. To reduce the scatter all figures were converted to represent 9 units of cost for a haul of 600 feet. Although the graph is presented here as a factor towards the solution of the ideal road density, I feel that it is a graph of importance in its own right.

To proceed with the density calculation, it is remembered that the ideal density is when the total cost of road construction per cu. ft. plus the cost of short haul is at a minimum.

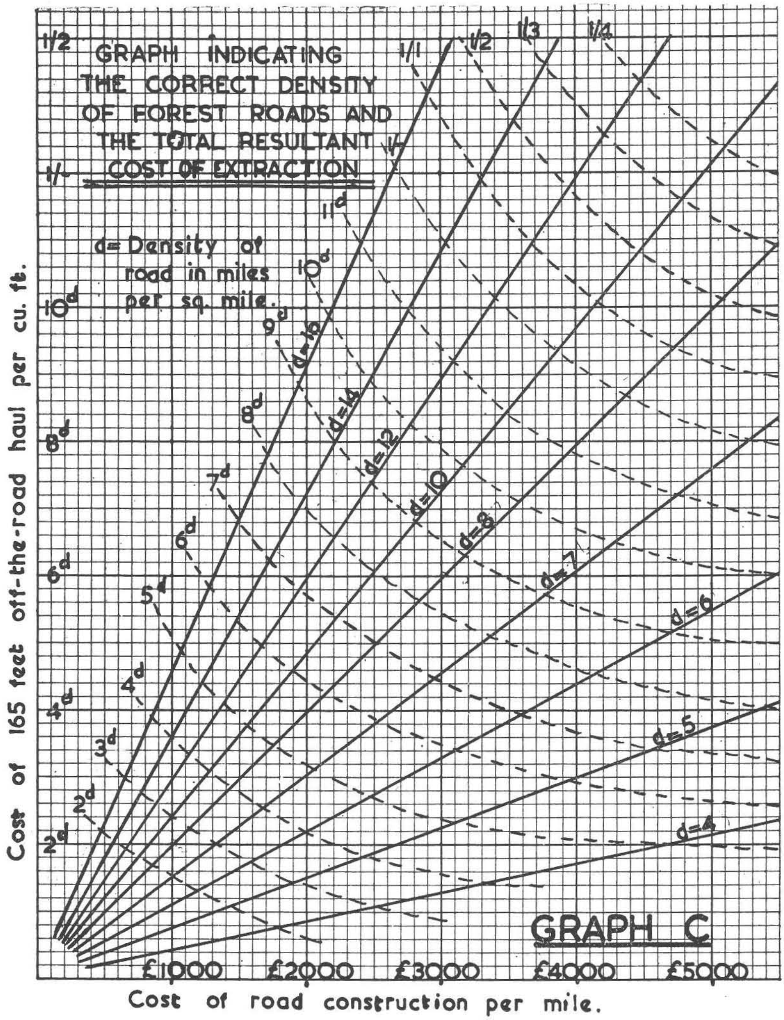
To take one particular example, if the cost of road construction was £2,000 per mile and the cost of a 165 feet haul was, say, 4d., then



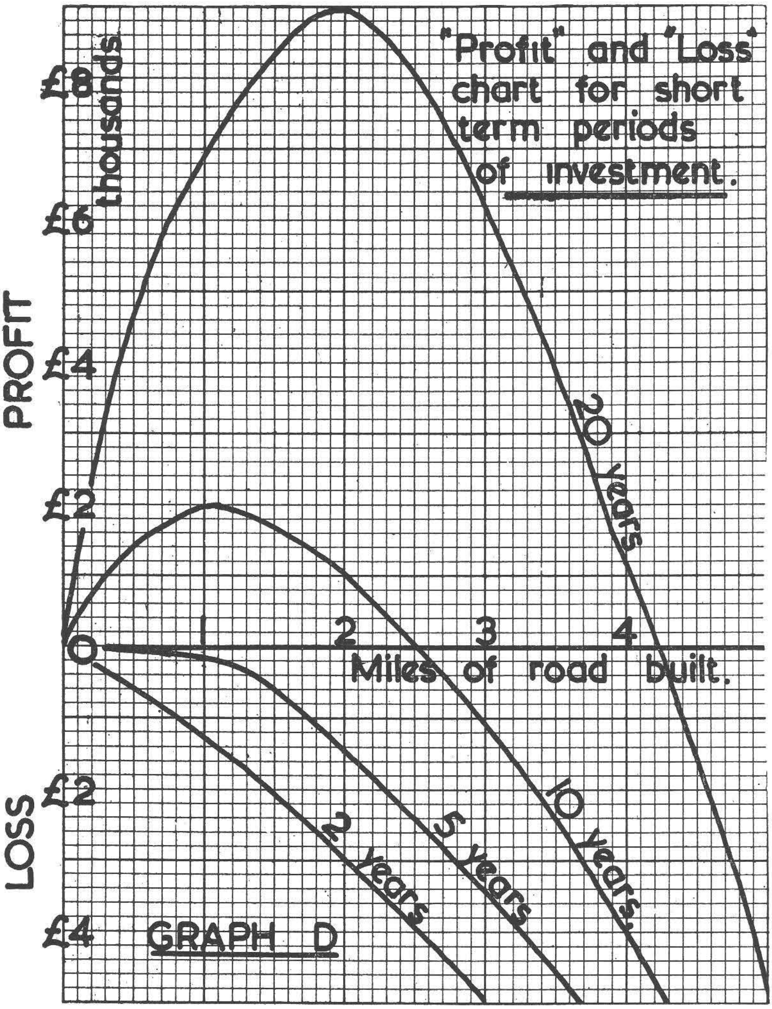
Graph B can be drawn. For those conditions, which are quite possible for the United Kingdom, it is seen that the most economic density is 8 miles per sq. mile, with a resultant total cost of extraction to be 5.7d. per cu. ft.

In this manner Graph C was compiled to cover all the possibilities between a road cost of £250 and £5,000 and a 165 feet off-the-road haul cost of between 2d. and 1s. 2d.

The ideal road density, depending, as it does, on short haul and road construction costs, cannot be a constant. If the cost of one rises in relation to the other the balance is upset with a change necessary in the road density. Prior to this century off-the-road timber haulage was extremely cheap relative to the cost of construction of either railroads or timber wagon roads and so the older plantations were covered with horse racks and narrow extraction rides. Now the trend is the other way and cheaper roads and more efficient transport justify higher densities. Graph B shows that to under-road a forest means expensive extraction. To over-road a forest does not account for a great loss but one would not, in this case, construct beyond a density of 8 miles per sq. mile as the availability of plant, labour and capital to construct roads is a major item to be considered.



It is generally only in the State forests that one is able and satisfied to invest over a long period in order to construct a large mileage of road. In the case of private forests it is more probable that the land-owner will wish to see a return of profit within a short period. I believe that many owners are under the impression that to invest in forest roads at all is merely to create a nest egg to be collected (if not poached) by the Chancellor of the Exchequer in years to come. That pessimistic view is not necessarily true, as the following example graph will show.



Taking as an example an area of one sq. mile, already covered by one mile of road and giving a sustained yield of 100 cu. ft. of timber and where roading costs £2,000 per mile to construct and a 165 feet short haul cost is equal to 4d. per cu. ft., graphs are drawn showing the profit and loss for various short term periods of investment, i.e. the cost of the road construction is written off within these periods. The profit or loss represents the amount of money gained or lost over and above the cost of the total extraction, should no roads be constructed.

The graph shows that, for investment over 2 or 5 years it would not pay to construct any roads beyond the one mile already assumed to exist. If the owner is willing to spread his investment over a period of 10 years, then he should construct one mile of road, in which case his extra profit would be £2,000. Over a 20 year period of investment he should build 2 miles of road and his gain would be equal to £9,000. Should he, like the State, be willing to invest over 60 or 70 years, then the ideal density figure of 8 miles, for these conditions, would apply and would produce a very substantial profit.

I apologize that this paper is mainly a mixture of compound interest, graphs and simple arithmetic but its purpose is to stress that the construction of roads is economically correct and that, for all forest areas, the effect of roads on the economics of the forest should be closely studied.