Road Systems in Forestry

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ABSTRACT

The high costs of forest road construction, maintenance, and timber transportation warrant extensive planning of forest road network layout. Two factors have to be considered during this planning process: road density, which influences off-road transportation distances, and road class, which relates to trucking and road maintenance costs. In order to establish well planned forest roads, it is essential that the planning process involves the total network, not individual roads or road segments.

Current research, including computerised road location procedures, the use of geotextiles in road construction, and the development of a central tyre inflation concept, will have an important impact on the control of future harvest transportation costs.

INTRODUCTION

The management of timberlands requires easy access to the total production area, and the linkage of resources and processing locations. In general, roads form the major contributor in a forest transportation network. They are both the arteries and veins in the anatomy of the forest products industry. On the basis of ownership the overall road network can be divided into two parts: roads that are in public control, and roads in private control. Both the public and private roads are of critical concern to those involved in the management of forest resources.

Within the (private) forest lands a road network is needed to provide access to the stands of timber for management, protection and harvesting operations. These forest road networks commonly connect the forest area with the public road system, which in turn connects to the processing locations. In some situations, because of vehicle size and weight restrictions for the public road system, it is economically more attractive to expand the private road network all the way to the processing location. In that case it is possible to increase vehicle load size and to reduce transportation costs. If public roads make up part of the transport network from the forest to the processing location, it may still be economically interesting to use oversize vehicles, such as double trailers, on the private forest

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roads, and to adjust them to public road standards for the remainder of the journey (i.e. move one trailer at a time). However, in most cases a single vehicle configuration, restricted by the public road standards, will be used for the entire network.

ROAD CLASSIFICATION

Most private road networks are divided into classes according to owner policy (Murphy, 1985). The class of the road identifies the functional role of that road in the overall road system. Examples are: Class I=major haul road, primary transportation route; Class II=haul road, access to management units; Class III=operational road, to which the wood is yarded. Associated with each functions class is a list of minimum and/or maximum structural specifications. This list may include minimum and maximum up-hill and down-hill slopes, maximum curvature, minimum road width and right-of-way width, surface type, design speed, etc. Also included in the lists are specifications for related structures such as bridges and culverts. These specification lists are used during new road location and construction, and road maintenance and upgrading procedures. When locating a road of a given class, the location and design of the road are restricted by the structural specifications stated in the appropriate list. This will influence the final road location as well as the amount of construction work required. Maintenance and upgrading procedures should also take into account the class of the road and the required structural specifications. The specifications for each class should be chosen so that the overall cost of construction, maintenance and transportation will be minimised. For instance, in minimising construction costs, it is very likely that maintenance and transportation costs will be very high if the road is used intensively. It may be desirable to increase the construction costs, so that the maintenance and transportation costs will decrease.

ROAD DENSITY

A second major factor which determines the efficiency and effectiveness of a road system is quantity, expressed as road density or road length per unit area. For operational road classes, consisting of the roads to which the timber is yarded, the optimal density depends on the harvesting system used, stand parameters, and road (and landing) constructional costs. In the case of parallel operational roads, where the road sides are used as landing area and two-way extraction is possible, the formula for optimal road spacing is:

$$S = \sqrt{\frac{2R}{MVF}}$$

where S=optional parallel road spacing in 100 metre units,
R=road construction cost in pounds per 100 metres,
M=off-road movement cost in pounds per cubic metre per 100 metre roundtrip,
V=volume to be harvested in cubic metres per hectare, and
F= sinuosity or indirectness factor (=1), equal to the ratio of the actual over the straight-line extraction distance.

If both roads and landings have to be located, the mathematical relationships become much more complex and an iterative procedure is needed to determine the optimal road and optimal landing spacings simultaneously (corcoran, 1973). By shifting of landing locations on alternate roads it will be possible in certain cases to further reduce the total associated costs (Bryer, 1983).

The actual location of operational roads (and landings) in the forest should be performed according to the determined spacing(s), while taking into account the variability of local terrain conditions (Ashley et al., 1973). Special computer programmes have been developed which deal with various terrain conditions and yarding systems (Carson and Dijkstra, 1978; Hogan; Holman et al., 1976). But because of the almost permanent nature of most forest roads, and the changing harvesting systems and stand parameters, the use of constant road service zone widths in road location procedures has been increasing, especially in the case of operational road location.

The haul road densities are dependent on area configuration, harvest volumes, and road construction costs (Carter et al., 1973). The problem is to ascertain the combination of road classes (quality) and road density (quantity) which will minimise the sum of associated yarding, transportation, construction, and maintenance costs (Jonee et al., 1986). It has been claimed that the most valued real estate in forests, on a unit area basis, are the roads. Because of this high value, and also because of the high cost of transportation, the importance of ascertaining the right combination of road quality and quantity is essential for successful forest management.

ROAD NETWORK PANNING

Well planned and constructed roads are fundamental for carrying out harvesting and other operations economically. The planning and construction of good forest roads can therefore be regarded as an excellent investment (Sunberg, 1976). A road should never be planned without considering future roads of the road network as well (Sedlak, 1978). This is a basic rule in forest road planning, but is often not followed, due to short-sighted planning procedures. There is no other field in forestry, where planning mistakes are as irreversible and costly as in forest road construction (Pestal, 1977). Before any road is planned, a general planning for the whole area is necessary, especially for main and secondary roads. During the planning of the whole area, two questions have to be answered for each proposed road. First, how is the road going to be integrated in the overall network, and second, how does the location of the proposed road affect the future expansion of the network.

At this time a decision must be made which function class has to be assigned to each road segment. This decision should be based on the expected traffic intensity, especially of logging trucks, for the completed network. The maximum and minimum intensity levels for each function class are based on the minimisation of the combined trucking, road construction and road maintenance costs. A higher class road means a higher construction cost, but above a certain traffic intensity level this will be compensated for by lower maintenance and trucking costs. The traffic intensity can be estimated by the part of the expected yearly harvest which will pass over that particular road segment (Haussman and Pruett, 1978). In some cases, the amount of non-truck traffic, such as tourist cars, has to be taken into account during the selection of the proper road classes.

As soon as an overall plan has been developed, the planning and exact location of the individual roads can start (Morofsky, 1977). The specifications used for the individual roads should reflect the function of the road in the completed network. In most cases it will be less expensive to over-design the road for the present situation, than having to upgrade it later on when the network expands. The upgrading often means almost complete reconstruction, because of differences in structural specifications, such as maximum slope, width, minimum sight distance, and maximum curvature, for the different road classes.

Except from the planning of roads for the opening up of newly established or planned forests, additional roads may be required because of salvage operations (Corcoran and Nieuwenhuis, 1985), changes in harvesting and/or transportation systems, upgrading of existing network segments, environmental policies, fire control, and recreation.

Research and Developments

During the last decade, the use of computerised geographic information systems (GIS) for forest management has increased rapidly (Tomlin, 1983; Reinders and Wijngaard, 1984). The capability of these systems to facilitate the accessibility of diverse data allows for the inclusion of all essential information in management planning procedures. The use of these systems to assist in the management and development of forest road networks is being studied widely. This includes network inventory systems (Nieuwenhuis, 1983); maintenance and upgrading procedures; road network analysis techniques such as travel time estimation, shortest route determination and capacity calculations (Pulkki, 1984); and new road location and design procedures (Nieuwenhuis, 1986; Sakai, 1984). The ability of GIS users to combine data sets, such as cover type, timber volumes, soil types, elevation, topographical features, and other management information, results in the enhancement of the decision-making processes.

In the area of road construction, the use of geotextiles is growing rapidly (O'Neill, 1982). The use of these materials can reduce the amount of excavation necessary, because it adds strength to the road base. In addition, road construction costs can be reduced because inclusion of geotextiles in road design will allow for the location of roads through areas which previously had to be avoided. The use of geotextiles in forest road construction, both for permanent and temporary roads, is being investigated (Jarrett, 1984; Douglas, 1985).

In areas where transport speeds are low, such as in mountainous terrain, transport cost may be reduced by the introduction of the central tyre inflation concept. A truck-mounted compressor would provide operator type-inflation control. Inflation pressure would be reduced on lower-speed aggregate roads, which can result in a substantial reduction of surfacing requirements, operator fatigue, and truck maintenance (Della-Morretta, 1984). The inflation pressure is increased when road conditions permit. The success of the central tyre inflation concept for log transport could start a major trend in the design and management of forest roads (Sessions et al., 1986).

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