Evaluating Forest Road Construction Techniques: A Case Study of the Right-of-Way Logging and Construction Activities*

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Abstract
The forest road construction process is comprised of many phases including trailing/falling, skidding, processing, loading and hauling, and road and landing construction. Currently, there is little information available on the productivity and costs of alternatives for these phases. FERIC has initiated a series of case studies to document and evaluate the construction techniques, and investigate interactions between road construction and right-of-way logging activities. Field work for the first study was completed in southeastern British Columbia in January 2006 and data analysis is in progress. This paper introduces the study series and provides a brief description of the study methods being used. An overview of the construction technique used in the first case study is presented.

1. INTRODUCTION

In British Columbia’s Interior region, the conventional road building process is comprised of several phases including pilot trail construction, right-of-way felling, right-of-way skidding, log processing, log loading and hauling, and road and landing construction. There are many variations of the road building process but typically the roads are built in stages, with the equipment used for each phase continually switching positions along the right-of-way. Conflicts between road construction and right-of-way logging activities cause inefficiencies and poor equipment utilization.

As a result, many forest companies in the Interior would like to investigate alternative construction strategies. Currently, there is minimal information available on the productivity and costs of alternatives, so FERIC initiated a series of case studies to evaluate construction techniques. The studies will provide needed data on road building operations to help managers make decisions about where and when to apply alternative techniques, and to improve their assessments of operating costs.

Field work for the first study was completed in southeastern British Columbia in January 2006 and data analysis is in progress. This paper introduces the study series and provides a brief description of the study methods being used. An overview of the construction technique used in the first case study is presented.

2. OBJECTIVES

The objectives of the studies are to:

- Document selected road building techniques.
- Evaluate equipment utilization levels, productivities and costs by phase.
- Determine how the road building phases interact, identify inefficiencies between the right-of-way logging and subgrade construction activities, and recommend improvements.

3. STUDY METHODS

A case study approach is being used to evaluate road construction productivity and costs for selected construction techniques. FERIC is conducting two types of production studies, known as shift-level and detailed-timing studies. The two methods are complementary and are carried out concurrently. The combined approach provides the data needed to determine equipment productivities and costs, to analyze the interaction between construction phases, and to characterize the construction technique.

3.1 Shift-level study methods

All machines used for right-of-way logging and road construction will be equipped with MultiDAT electronic dataloggers. MultiDAT units will be connected to a machine's power supply to continuously monitor machine function. They will have four channels for electronic inputs, a channel to record machine vibration, and Global Positioning System tracking capability. The MultiDATs will be installed in the machine cabs accessible to the operators. For these studies, the dataloggers will be programmed to accept operator inputs identifying machine activity and sources of delays. The MultiDAT units will accumulate shift-level information about productive time, and mechanical and non-mechanical delays for each piece of equipment. The MultiDat units will have GPS capabilities and, thus, will be set to collect positional information for each machine at specified time intervals. The machine type and job function dictate the collection interval. More mobile machines (e.g. skidders) will have a more frequent point collection rate than more stationary equipment (e.g. excavator). The data collected from the machines will illustrate the position of a piece of equipment in time throughout the project study area. By having this positional, productivity and cost information, the cost of any selected area (zone) within the study site can be investigated.

The information from the dataloggers will be supplemented with daily shift reports. Two machine operators, one from the right-of-way logging crew and one from the construction crew, will complete the forms. The shift reports are used to gather additional information about equipment function and the road building process that would not be recorded by the MultiDATs alone. For example, descriptions of equipment downtime or unforeseen conditions encountered during construction will be noted on the forms.

FERIC researchers will visit the site regularly to download data from the MultiDATs, collect shift reports, observe the construction process, and discuss the operation with the crews. Digital photographs and video will also be taken during these site visits to further document the road building system.

3.2 Detailed-timing study methods
For some machines, productive time will be made up of several activities. For example, an excavator may push-fall right-of-way timber, construct a pilot trail, rearrange and present felled timber for skidding, and construct the final road prism. Major divisions in productive time will be captured in the shift-level data. However, to distinguish between the finer points of some phases, such as whether an excavator is push-falling timber or presenting it for skidding, detailed-timing methods must be used.

For each machine, the specific time elements that make up productive time will be identified in the field by the lead FERIC researcher. Detailed-timing of productive activity will be carried out by researchers who will use a stopwatch or a handheld computer programmed for equipment monitoring. Descriptive statistics for the elements of productive time will be developed and summarized in the final project report.

3.3 Equipment time distribution, productivity and costs

Total scheduled time, known as scheduled machine hours (SMH), will be summarized for each piece of equipment used in the project. Scheduled machine hours are the sum of productive machine hours (PMH), non-mechanical delays (NMD), and mechanical delays (MD).

Road construction production will be measured as lineal metres of completed road. For the right-of-way logging phases, the volume (m³) of timber processed will also be measured. Phase productivities will be calculated by dividing the measures of production by the time spent on right-of-way logging and subgrade construction.

Hourly equipment rates, comprised of ownership and operating costs, will be developed by FERIC for each machine. The rates will be generic rates applicable to the makes of machines used in the study as well as to other makes of the same type and weight class. Shift-level time and production information will be applied to the hourly equipment rates to determine the unit costs for the project. Unit costs, in terms of $/lineal-metre of road, will be presented for all phases of the project. Unit costs, in terms of $/m³ of right-of-way timber, will also be presented for the right-of-way logging phases.

4. THE “RAVENSHEAD” CASE STUDY

The first in the series of road construction studies was the Ravenshead project, located approximately 50 km east of Radium Hot Springs, B.C. The roads for the Ravenshead project were constructed in 30 working days falling within the period from November 18, 2005 to January 11, 2006. During this period, six machines were equipped with MultiDAT data recorders. The crew also recorded its activities on daily shift reports.

4.1 Site description

Located in the Interior of British Columbia, the study site is within the Kootenay Range of the Rocky Mountains on the eastern slopes of the Kootenay River Valley (Figure 1). The site is on public land outside Kootenay National Park. The logging and construction activities of this project were completed by one multi-phase contractor working for a major forest company.
The roads associated with this study consisted of 4.6 km of new construction, and developed 98 ha of harvestable timber (see Figure 2). The cutting units were comprised of lodgepole pine (Pinus Contorta Dougl.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and white spruce (Picea glauca (Moench) Voss) with an average age of 80 years. The stands were in the early stages of mountain pine beetle (Dendroctonus ponderosae Hopkins) infestation. Terrain conditions were flat to undulating with slopes ranging from 0 to 60 percent. The soils were silty clays overtopping limestone bedrock. Several small sections of highly fractured limestone rock were scattered throughout the project site, but rock was usually avoided and ripped only when necessary.
4.2 Road construction technique description

The right-of-way logging and road construction activities were closely coordinated on the Ravenshead project to produce a finished road in a systematic manner. A description of the main phases and the corresponding crew tasks follows. The overall process is illustrated in Figure 3.

4.2.1 Logging activities

**Trailing/falling phase.** A Caterpillar 320C LU excavator initiated pilot trail construction. The machine push-felled the trees in its path and concurrently constructed a narrow, 3-m-wide, stump-free skid trail within the lower half of the clearing width. This machine worked closely with a hand faller, and in some cases the operator had dual responsibilities as operator and faller. The faller’s job was to manually fell the upper half or remaining portion of the clearing width and landing areas.

**Skidding phase.** The skidding phase was completed using one, and sometimes two, Caterpillar 518 cable skidders. Tree-length stems were skidded along the newly constructed trail to the nearest finished landing. The stems were subsequently processed on the landing.

**Processing phase.** The processing phase was completed manually with a Caterpillar 315 excavator used to handle the stems and pile debris generated during this phase. The operator manually bucked and delimbed stems, and carried out any other activity necessary to convert the stems to their required specifications.
**Loading and hauling phase.** The logs were loaded using a Western Star self-loading tridem drive with tridem pole-trailer logging truck. This phase was carried out concurrently with road construction activities.

4.2.2 Construction activities

**Road and landing construction phases.** The construction activity is characterized by two phases—road and landing construction. These phases were completed with a John Deere 3554 excavator in conjunction with a Caterpillar D7R XR bulldozer.

In both the road and landing construction phases, the excavator pioneered ahead near the road centerline, but above the previously constructed pilot trail. Stumps and debris were placed on the outer edge of the subgrade fill. While moving forward, the excavator placed a windrow of material for the bulldozer to spread along the road centerline. The bulldozer shaped the material and established the finished grade level.

Table 1 lists the type of equipment used on the project by phase.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Equipment used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trailing/falling</td>
<td>Caterpillar 320C LU (22 000 kg) excavator</td>
</tr>
<tr>
<td>Skidding</td>
<td>Caterpillar 518 cable skidders</td>
</tr>
<tr>
<td>Processing</td>
<td>Caterpillar 315 (16 000 kg) excavator</td>
</tr>
<tr>
<td>Loading and hauling</td>
<td>Western Star self-loading tridem drive with tridem pole trailer</td>
</tr>
<tr>
<td>Road and landing</td>
<td>John Deere 3554 (39 000 kg) excavator</td>
</tr>
<tr>
<td>construction</td>
<td>Caterpillar D7R XR (26 000 kg) bulldozer</td>
</tr>
</tbody>
</table>
4.3 Crew complement

The crew complement for the Ravenshead project consisted of five operators and each had a principal job function. Most of the operators were skilled in more than one job function and could carry out other tasks as needed. The versatility of the operators allowed for much needed flexibility in planning and scheduling the operation.

Leadership and decision-making responsibilities were shared by the road builder and the trailer/faller. One person, known as a utility operator, would switch to any job function as needed. The utility operator was a key individual for this operation because this person could support a particular phase when required and maintain overall road building production. Table 2 shows the principal job functions for each operator and their primary equipment responsibilities.
Table 2. Crew functions and equipment responsibilities

<table>
<thead>
<tr>
<th>Operator</th>
<th>Principal job functions</th>
<th>Equipment responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road builder</td>
<td>Road and landing construction</td>
<td>Excavator (39 000 kg) Bulldozer (26 000 kg)</td>
</tr>
<tr>
<td>Trailer/faller</td>
<td>Clear and construct pilot trail, manually fall road clearing width and landing openings</td>
<td>Excavator (22 000 kg)</td>
</tr>
<tr>
<td>Skidding operator</td>
<td>Remove wood from clearing width and landings to an established landing for processing</td>
<td>Skidder(s)</td>
</tr>
<tr>
<td>Processing operator/bucker</td>
<td>Handle and process stems; skid to finished landing.</td>
<td>Excavator (16 000 kg)</td>
</tr>
<tr>
<td>Utility operator</td>
<td>Complete all of the above job functions as required to maintain consistent operations</td>
<td>Operated all of the above equipment</td>
</tr>
</tbody>
</table>

5. FUTURE WORK

The Ravenshead project is the first in a series of case studies investigating different road building techniques and the interaction between the right-of-way logging and road construction activities. Data analysis will be completed in the fall of 2006. A second study, also in southeastern British Columbia, will begin in the summer of 2006.

A longer-term objective of the work is to investigate relationships between equipment productivities and variables such as ground slope and timber type. The results from this project will be combined with future studies to develop a tool for predicting construction productivities and costs based on site variables. This tool will improve road construction planning and contract management.