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LOG TRUCK PERFORMANCE ON CURVES AND FAVOURABLE GRADES

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INTRODUCTION

The 1983 LIRA seminar on "Research and Development in Tree Harvesting and Transportation" identified the need for a greater understanding of road/truck interactions, particularly in areas with a marginal road infrastructure.

The high cost of road construction forces consideration of the tradeoffs between construction costs and hauling costs. In addition, analysis of road transportation networks requires that we be able to estimate the variable costs of hauling for different road conditions. In order to adequately do these analyses, we often rely on predictive models which estimate the effects of various design alternatives on vehicle travel speeds.

In the U.S.D.A. Forest Service, most estimates of the effects of road design on travel times are based on the original approach developed by Byrne, Nelson, and Googins (1960) commonly referred to as "BNG". BNG has also been adapted and used in New Zealand (Cornelius, 1979).

Few published time studies of log truck travel times have been done in recent years. The classic study of BNG is probably the most well known and widely used. During the subsequent thirty years, advances in truck technology, including the introduction of the Jacobs engine brake, changed the braking ability of log trucks on favourable grades. Previously, cumbersome water cooling devices were necessary to control brake temperatures while descending the steep mountainous terrain frequently encountered in logging operations in the Western United States.

In addition to better braking methods, improvements in engines, transmissions, steering and the introduction of citizens band (CB) radio have contributed to safer, more efficient log transportation today. Some of these technological changes can be expected to affect the accuracy of travel speed estimates based on pre-1960 truck technology. This Technical Release presents the results of a recent study at Oregon State University (Jackson, 1986). Some later work which evaluates the assumptions contained in BNG and another model, the Vehicle Operating Cost Model (VOCM), (Sullivan, 1977) which uses somewhat different assumptions, is also presented. The objective of the study was to gather and analyse log truck travel speed data on selected favourable grades and curves and compare the observed speeds to BNG and VOCM estimated speeds. Comparisons were made for individual curves and grades and for a portion of road to determine how well overall trip speeds are predicted when the effects of curvature, grade, and speed transitions are included.

The study was limited to favourable (downhill loaded) grades, since a major portion of the loaded haul cycle from forest to the mill is usually on favourable grades.

DATA COLLECTION

Data was collected at three different locations in western Oregon. Travel times were recorded for a variety of log truck makes, models, and ages. Drivers sampled included Company drivers, who are paid an hourly rate, and independent contractors, who are paid by the volume of logs hauled. A total of twenty-one different drivers and trucks is represented in the data. Log trucks in this study were 18 wheelers, having engines producing 260 to 340 kW, and weighing approximately 36 tonnes when fully loaded. Drivers interviewed ranged from ten to thirty years' experience. Data collected was; grade, curve radius, superelevation, road width (ditch to ditch), sight distance, ditch depth, time of day, and maximum engine braking horsepower. Regression models were developed using the time study data collected.

RESULTS

The primary factors found to influence vehicle speeds on single-lane roads were; grade and alignment.

Speeds on Grades

Downhill (loaded) truck speeds were shown by the time study data to be independent of grade up to -11% (Figure 1). On favourable grades steeper than -11%, grade strongly influences truck speeds. The most probable explanation is that alignment sets the speeds on these roads when grade is less than -11%. This is typical of many forest logging roads where alignment would be classified as poor.

The speed relationship developed by BNG is for roads free of the effects of alignment. In mountainous terrain, few logging roads will be completely free of the effects of alignment. Due to the poor alignment of the roads used in the study, no conclusions could be drawn concerning the ability of BNG or VOCM to predict speed when grades were less than -11%. It appears that both the BNG and VOCM methods predict speeds reasonably well for favourable grades between -11% and -16%. For steeper grades, the observed speeds were considerably slower than would be predicted by both methods. Uphill unloaded travel times were affected by grade in a manner similar to the loaded trucks. Uphill times would be expected to be limited by grade on these roads. The horsepower-to-weight ratios for unloaded piggyback trucks were sufficient to permit travel uphill at nearly 60 km/hr, if grade was the only limiting factor. No explanation could be found for the similarity in speeds between the unloaded and loaded trucks.

Speed on Curves

Figure 2 shows the relationship between curve radius and truck speeds observed in this study. The relationship between curve radius and speed indicates that truck speeds were less sensitive to increasing curve radius than predicted by either BNG or VOCM. The slope of the regression equation produced is somewhat flat above 45 metres radius. This implies that truck speeds for the road studied are not affected by changes in curve radius as much as might be predicted by BNG or VOCM.

The assumption that sight distances control vehicle speeds was not valid for the roads used in this study. A major contributing

Figure 1 - Speeds on Favourable Grades

(BNG, VOM, and Regression)

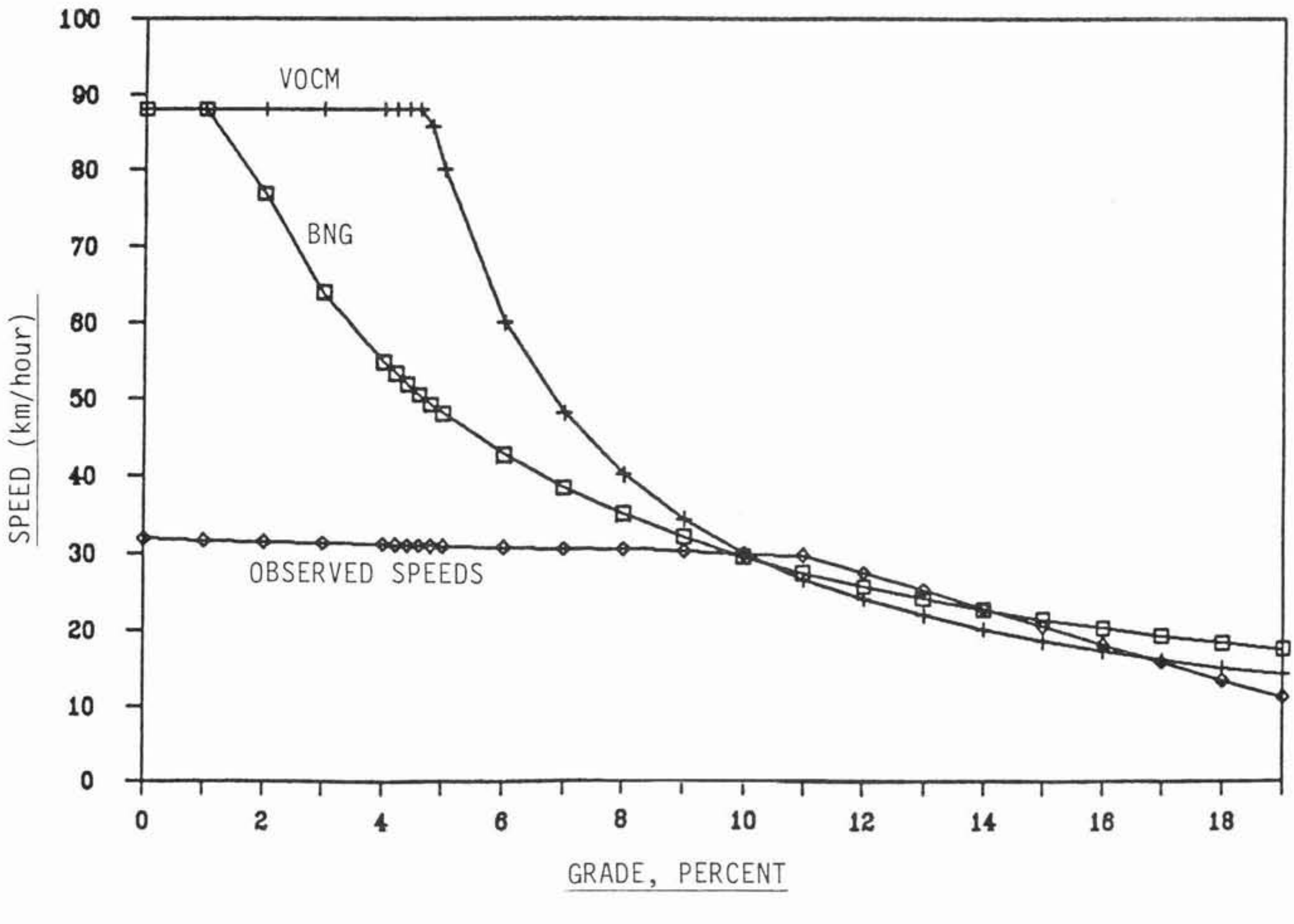
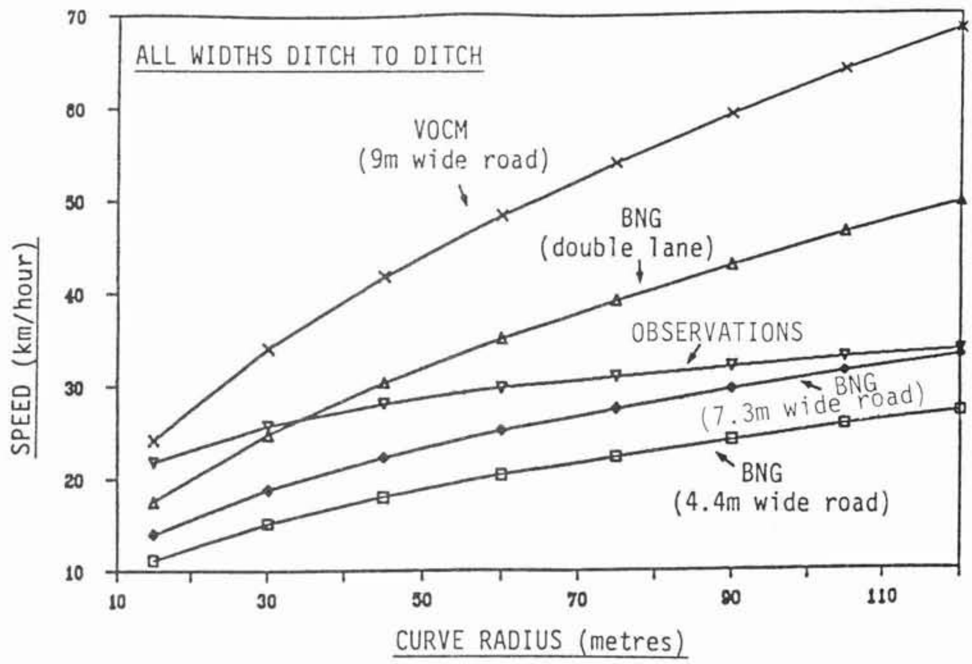


Figure 2 - Curve Speed Comparisons (BNG, VOCM, Regression Equation)



factor may be the extensive use of CB radios by the truck drivers. These radios, in effect, extended the "sight distance" in the curves by allowing the trucks to "see" ahead. The number of trucks per hour using this road (7 log trucks per hour) also proved helpful, since they were able to provide more frequent information on the various road segments. This CB contact alerted the drivers to non-logging traffic on the road. The small amount of non-logging truck traffic (approximately 5 vehicles/day) also reduced the probability of meeting other vehicles.

Under these circumstances, it might be expected that drivers would drive more nearly at speeds that followed an available friction relationship. However, the VOCM method, which uses this assumption, also did not predict speeds accurately. This may be due, in part, to the frequency of curves on the entire road. The effect of road sections ahead or behind a given segment could be expected to influence speeds. A driver might not accelerate to a speed permitted by a 90 metre curve, when a 45 metre curve is just ahead. However, when the data was re-analysed, speeds were found to be relatively unaffected by road conditions immediately ahead or behind the road segments. The comparisons of observed data to the other models are therefore valid.

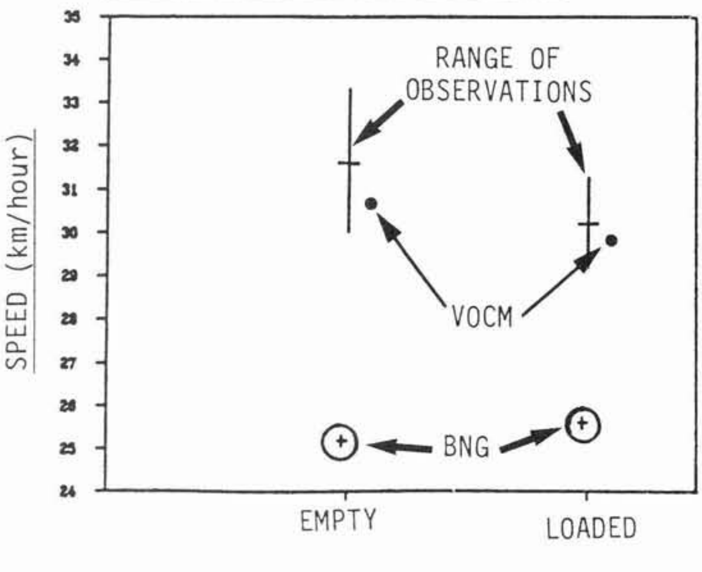
OVERALL COMPARISON

An overall comparison of predicted speeds against observed speeds using BNG and VOCM was carried out on a 12.3 kilmetre section of road. Curve radii on this section of road ranged from 20 metres to 300 metres and favourable grades ranged from -2% to -14%. Figure 3 shows the results of this comparison.

Empty trucks were observed to travel an average of 4.4% faster than loaded trucks. However, the variation was large enough that no statistically significant difference between loaded and unloaded truck speeds could be determined. Speeds of the empty trucks were 20.2% faster than predicted by BNG, while the loaded speeds were 13.1% faster than predicted. Round-trip speeds averaged 16.7% faster than predicted using the BNG method.

VOCM appeared to predict observed speeds fairly well. When the mean superelevation sampled and the mean engine braking horsepower of the trucks in the study was used, the predicted speeds fell within the 95% confidence interval of the observed data. This suggests the VOCM may be a good predictor of log truck speeds on roads similar to those in this study.

Figure 3 - Observed Speeds vs Predicted Speeds (95% Confidence Interval Shown)



IMPLICATIONS FOR ROAD DESIGN AND CONSTRUCTION

The implications of this study may have important consequences for road design and construction. If previous assumptions concerning the effects of various road geometry factors upon speed are not valid, these faulty assumptions may be leading to designs that are more expensive than needed. The marginal benefits of increased hauling speeds gained from alignment improvements may not be realised to the extent predicted if the models overestimate these gains. The rate of change of speeds with curve radius are more rapid than the observed data shows. If the observed relationships are accurate, the reduced travel time predicted for improved alignments may not be as great as expected.

Construction costs may be greatly increased by increasing the radius of curve in a given situation. When comparing speeds predicted by BNG to observed speeds, it can be seen that observed speeds on a 30 metre curve radius were equal to speeds predicted using BNG for a 75 metre radius curve and by VOCM for a 30 metre radius curve. Nelson (1955) calculated costs for excavation and hauling for a variety of curve radii in a representative situation. For example, for a 30 metre curve radius, the excavation quantity required on a 28% sideslope was 1375 cubic metres. For a 75 metre radius curve, the excavation quantity was 6500 cubic metres (almost 5 times more). Assuming a cost of US$1.50 per cubic metre for excavation, this would result in a cost difference of US$10,050.00 for this one curve.

The predicted reduction in travel time by going from a 30 metre curve to a 75 metre curve radius would be greater using BNG than using the observed data. If the full reduction in travel time assumed did not occur (as may be the case based on this study) the extra excavation would not have provided the same benefits as anticipated.

The estimate of the differences between speeds on curves is felt to be conservative, since the calculations for speeds using BNG or VOCM are based on a constant velocity on curves and grades, and do not include the acceleration or deceleration present in this study. If these factors were included, both BNG and VOCM would predict even slower times, which would make the differences even greater than observed.

CONCLUSIONS

The method used by BNG and VOCM appears to predict log truck speeds reasonably well for favourable grades free of alignment between -11% and 16%. The study could not conclude anything for grades less than -11%. Extrapolating the data above -16% could produce errors. On curves, the assumption that sight distance controls speeds did not seem valid. Neither BNG or VOCM predicted speeds on curves well. However, when an overall comparison was made, VOCM predicted log truck speeds well, while BNG underestimated speeds by 15% to 20%. The other variables of; superelevation, ditch width, ditch depth, time of day, sight distance, and engine braking horsepower were not significant in affecting speeds in this study.

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