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Session: Wed. 21, 8:30 - 10:30 am
Paper : 3

TITLE : TRUCK TRIP SIMULATION

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INTRODUCTION

This paper discusses the availability and application of computer programs which predict heavy truck trip performance. Typically these models produce estimates of; trip time, fuel consumption, engine utilisation, the number of gear changes and other factors. Before going on to more detail, I will introduce the organisation I work for and explain how we are involved in the heavy transport industry.

LIRA is an industry based research association involved only in tree harvesting. Tree harvesting means all operations from felling to unloading the log truck at the mill yard. A staff of 14 is employed, including the Director, eight researchers and 5 support staff. LIRA is funded by the Logging industry and the Government. The current ratio is approx. 60/40. To show the importance of transport related costs to logging; log transport can typically be 25% of the harvesting cost and forest roading some 7%. In more difficult terrain, the in-forest roading costs can increase significantly and there is an economic limit to the sensible transport distance between forest and mill. New Zealand has a large area of first rotation plantation forest, on steep and difficult country in more remote locations. For these reasons LIRA has an ongoing programme in transportation research.

Currently we are drawing to the close of a major roading project which has involved two researchers full time for three years. Part of this work has been a study of truck/road interaction with the aim to lowering total transport costs by the use of more suitable construction and maintenance practices on in-forest roads.

One of the methods being used in the study of road influences on truck performance is mathematical modelling. These models allow us to test the significance of many performance relationships without the expense of field testing. They are not a substitute, however, for real life data which must be used to substantiate any findings. So far, LIRA has concentrated on grade prediction and trip parameter estimation.

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THE PRINCIPLES OF TRUCK/ROAD INTERACTION

How well a particular truck performs over a certain stretch of road depends on the resistances the road presents to the truck (1).

Resistances can be either :

DIRECT, i.e. physical forces to be overcome such as :

- tyre rolling resistance
- grade resistance
- cornering resistances

or influences on traction :

- tractor lean because of road super-elevation (cross fall) (causing weight transfer from the high side drive wheels across to the lower side)
- different super-elevations at the truck and trailer (causing weight transfer across the drive axles through stiffness of the load)
- loose surfaces

INDIRECT, i.e. factors which impede the truck, usually because of the driver's perception :

- lane and shoulder widths
- sight distance
- roughness
- special speed restrictions

These direct interactions have been reasonably well understood for many years. Formulae and tables can be found in many references such as S.A.E. J688 Truck Ability Prediction 1958 (2) and McNally Trucks and Trailers and their Application to Logging Operations 1975 (3). More recently D. Ljubic of FERIC (4) has been testing and revising many of the resistance relationships.

It is possible to take these equations and determine the force required at the truck wheels to proceed down the road. From there the truck's ability to produce traction can be calculated using conventional mechanics of machines theory. With the supply and demand calculated it is possible to determine the net force available to accelerate the rig (refer Fig. 1). This procedure is the heart of any truck trip prediction model.

It should be noted that many of the equations used have limitations. For example: traction uses a coefficient to relate weight on the wheel to force along the road - this factor must be assessed from tables; rolling resistance has been described by a number of equations (2)(3)(4) - in all cases factors must be assessed from tables to suit the situation being modelled.

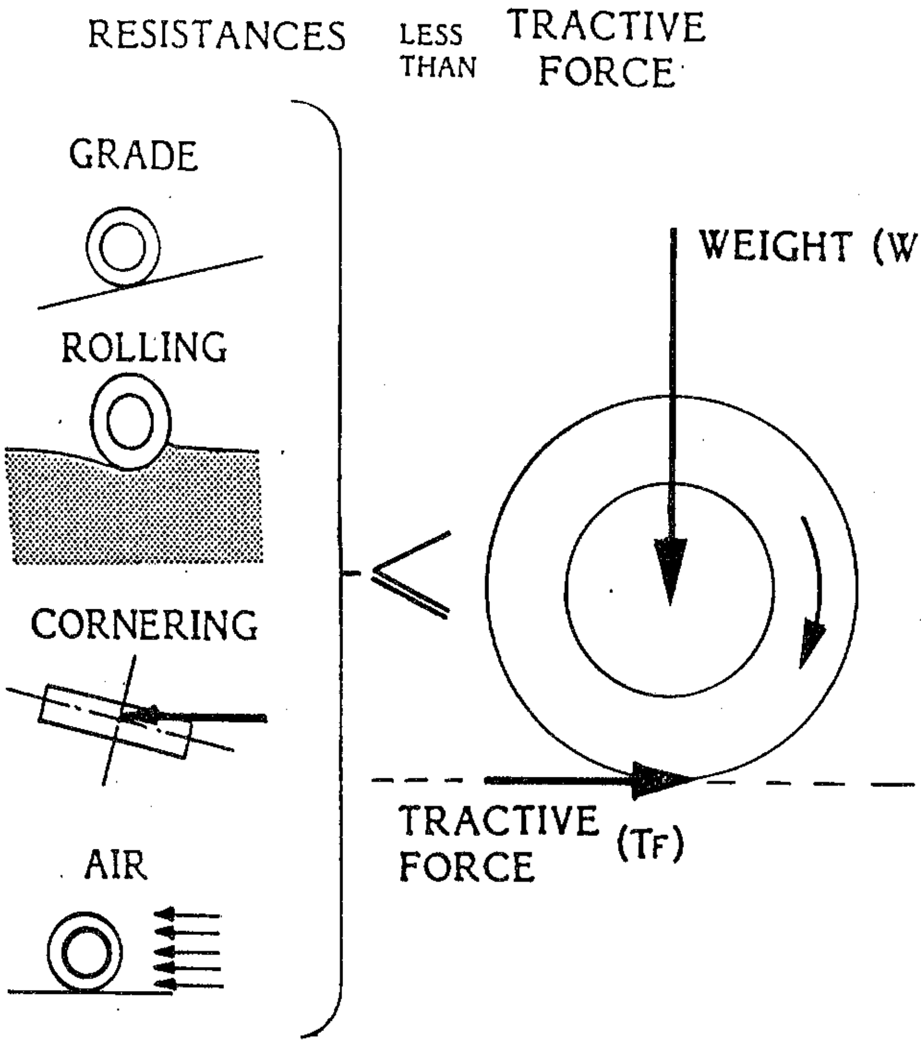

Figure 1 : DIRECT RESISTANCES VERSUS TRACTIVE FORCE

AVAILABILITY OF TRUCK TRIP PREDICTION MODELS :

A number of organisations have produced trip simulation models including I.C.E.S. - ROADS (5), and HEVSIM (6). LIRA assessed these for suitability to its research needs on the basis of :

- Interactive use (i.e. load and run the program in Rotorua)
- Technical support for both the model and computer facilities
- Unrestricted product application.

The commercial programs located, all had some difficulty in terms of our needs. This is not to say that they don't give useful answers. CUMMINS' VMS service has been used by at least two New Zealand companies to guide truck specifications. Apart from difficulties with VMS being an off-shore service, it is limited in its ability to model changes of road standard within one journey. Log trucks negotiate a wide range of road surface types between the landing and the mill.

The program we have chosen to evaluate in detail is TRUCKSIM (7), a jointly funded develompent between CSIRO in Australia and FRI* in Rotorua (N.Z.). Its author is Bob McCormack of CSIRO**, although FRI staff have assisted with some aspects of programming. TRUCKSIM is available already on a limited basis on FRI's VAX mainframe computer. This access is available on the understanding that the program is still under development. LIRA may be able to assist in running some evaluations as part of its own research programme.

Ultimately, it is hoped that a personal computer version will be available. Much of the work has been completed for this although the time of release and the degree of user friendliness achieved will depend on demand. It should be noted, however, that truck simulation programs are quite large and an "AT" sized PC is necessary. The good news is that these machines are still reducing in price.

* CSIRO : Commonwealth Scientific & Industrial Research Organisation, Division of Forest Research, Canberra, Australia

** FRI : Forest Research Institute, Harvest Planning Group, Rotorua, N.Z.

APPLICATIONS FOR TRIP SIMULATION MODELS :

If you have a need to estimate truck performance for a particular journey these models can help. Three main ingredients make up the model.

- TRUCK
- DRIVER
- ROAD

We can set any two of these constant and then vary the third systematically until an optimum result is found for it. Depending on your point of view, different problems can be solved:

The truck operator can take a route of interest to him, choose a typical driver and then proceed to try the various truck component options available to him. In this way the truck for a specific run can be optimised before purchase. Alternatively he may be interested in choosing the best rig out of those available to do a particular job.

LIRA's interest so far has been towards the effects the road has on the truck. For most transport this is an unrealistic approach but forestry is somewhat different in that it owns a large distance of road which it built to its own standards. The length of privately owned forest road is expected to double from the current length of about 13,000 km as the new forest areas are harvested through the 1990's and beyond.

The following examples are of hypothetical situations, but they serve to show how a trip simulator can be applied :

STUDY 1

This study is taken from work done by Bob McCormack (7). It compares the performance of a 6 x 4 logging truck and 2 axle jinker with various driveline component changes. The simulations are done over a 25 km section of highway between Scottsdale and Launceston in Tasmania, Australia.

Comparison 1 : The effect of a 300 kW (400 hp) engine instead of the original 224 kW (300 hp) version. For this given situation the changes are :

FUEL - Consumption increases by 7% (7.3 litres/ 100 km)

TRIP TIME - Reduces by 15% (5 min. in 37)

ENGINE LOADING - The average power used as a percentage of rated power reduced from 74% to 68%

Comparison 2 : Change the existing 9 speed transmission for one with 12 speeds. The 300 kW engine is still installed.

FUEL - Consumption reduces by 7.5% (8.3 litres/ 100 km)

TRIP TIME - Effectively unchanged

GEAR CHANGES - Three additional gear changes were needed for the journey (54 to 57)

The changes predicted here are significant in terms of operating costs. They should be taken as being specific to the conditions given but are also an indicator of what is possible. Obviously there are many other comparisons which can be made as well. In all cases it is important to remember that the results come from a model, not real life, and are subject to its accuracy.

STUDY 2

This example considers the effect of road design on a 50 tonne (gross weight) off-highway logging truck. The truck is fitted with a 239 kW (320 hp) engine, a 15 speed transmission and it pulls a two-axle jinker. The road has to give access over a 20 metre high ridge. Four options are evaluated ranging up through increasing amounts of earthworks. Options 1-3 use a design grade of 7.5% while the fourth one has a reduced grade through greater earthworks. The simulation was run over a 1 km section of road. Table 1 shows the results (8).

TABLE 1 : EVALUATION OF CUTTING DEPTH

Profile No.	Cutting Depth (m)	Maximum Grade (%)	Earthworks Vols. (cubic metres) Cut/Fill	Speed (km/hr)	Fuel (litre/ 100 km)
1	1.0	7.5	400/3500	30.5	173
2	4.0	7.5	3700/3500	31.0	160
3	6.1	7.5	8000/7000	31.3	151
4	8.2	4.5	16000/14000	37.5	142

These figures provide useful input data for cost/benefit analysis. The savings in going to options 3 or 4 appear small compared to the amount of earthworks involved. Their significance, however, can not be assessed until the traffic volume is known.

STUDY 3

In this study the access to a log landing is investigated. Two possible solutions are :

Alignment 1 uses a 10% maximum grade to gain the 100 metres of height to the landing. It takes 3.5 kilometres of road to achieve this.

Alignment 2 takes a steeper line on a grade of 20% and arrives at the landing in 2.5 kilometres.

The rig is a standard New Zealand type six axle long log unit powered by a 235 kW engine. Its gross weight is 41 tonnes.

Performance is simulated from a point 500 metres before the climb starts, goes to the top where a loading delay is built in and then returns to the starting point. See Table 2 for the results. The road profiles are shown in Figure 5.

As an additional study a higher geared differential was also tried.

TABLE 2 : EVALUATION OF ROAD GRADE

Simulation No.	1	2	3
Alignment No.	1	1	2
Diff Ratio	3.89	4.37	4.37
Distance (km)	3.5	3.5	2.5
FUEL (litre)	4.65	4.48	4.48
SPEED (km/hr)	19.0	18.8	11.4
TIME (minutes)	11.0	11.1	13.3
GEAR CHANGES	33	33	33

As with study two, these results can be valuable inputs to an economic analysis of which road to build.

MODEL DESCRIPTION :

A full description of TRUCKSIM is not feasible within the scope of this paper. Reduced to its essentials, it works as follows :

At regular time intervals (0.1 to 1.0 seconds) along the specified route the truck's progress, performance and dynamics are calculated, i.e.

- distance down the road
- grade of the road estimated to be covered in the next time interval
- resistance to motion (grade, rolling and air)
- tractive force at the wheels
- maximum acceleration possible given the tractive force and the total resistances

Given these parameters the model then checks what user specified speed limit applies to the section of road in question. It then assumes the truck will proceed as quickly as possible and calculates a new terminal speed for the time interval.

In addition to this the model also has to incorporate gear change logic. This is based on engine speed at the end of the time interval. Currently gear changing happens as follows :

- At a specified engine speed the transmission changes up.
- At a specified engine speed a down change will be made.
- Shifts of more than one gear are made if necessary to meet the new grade in the right engine speed range.
- The model also has a grade warning system to allow the best lugging gear to be selected for the section in question.
- When cruising the highest possible gear is chosen for fuel economy.

The values computed for each interval are saved for later analysis and graphical output.

PROGRAM STRUCTURE AND INPUTS :

Figure 2 shows how the program is structured and the sequence of operation. There are three main ingredients to the model : Truck, Driver and Road.

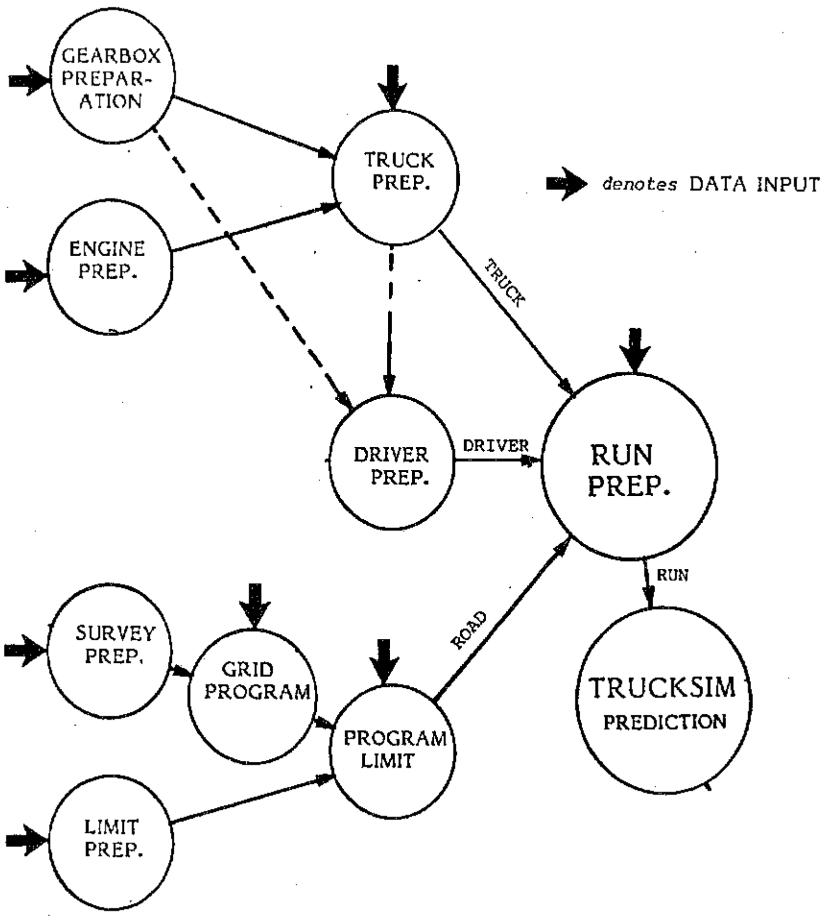

Figure 2 : TRUCKSIM FLOWCHART

The truck specification is made up of previously entered files for an engine and a gearbox plus user entered details for the specific truck, such as axle ratio. A library of Engine, Gearbox and Truck files can be created to cover the normal range of trucks to be simulated. Once they are set up, future simulations can use them with considerable time saving in data input.

Driver specification combines gearbox and truck data to set gear shift speeds. Shift times are also specified.

Road descriptions are made up of two parts: A survey of the road profile and a set of speed limits. These files are further processed by other programs to a suitable format for the simulation program.

With the three main ingredients stored within the computer it is then possible to combine one of each and initiate a simulation run. In addition a start speed and a starting gear are specified.

Most of the inputs can be gathered reasonably easily from manufacturers data and handbooks, e.g. (3). Road survey data, however, is more time consuming. It can be taken from plans (e.g. for future roads), from compatible computer files where available or from surveys of existing roads. The latter can be achieved relatively quickly by calibrated car odometer and very accurate barometer to an acceptable accuracy. Only the vertical profile is needed. While surveying, it is also possible to assess speed restrictions for corners, etc.

PROGRAM OUTPUTS :

TRUCKSIM produces a number of graphical outputs for general appraisal as well as numerical data for further analysis.

Figures 3-6 show some of these.

```
*****************************************************************************
*                                                                           *
*  CSIRO - FRI     LOGGING TRUCK PERFORMANCE PROJECT                        *
*  -----------------------------------------------                          *
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*                                                                           *
*-PROG-: TRUCK-SIM Ver 2.1   :-RUN-ON-: 1-OCT-87 14:01:59  :- AT -: CSIRO DFR *
*-USER-: RWG LIRA            :-RUN----: 20% FOREST         :DRIVER: SCANIA STD*
*-TRUCK: SCANIA T112  Tr   2 :-ENGINE-: SCANIA DSC   Eng 1 :-GVW--: 41000. kg *
*-TRANS: SCANIA GR/GRE871    :-DIFF---: SCANIA 437 4.375   :-TYRE-: 1100 X 22.*
*                                                                           *
*****************************************************************************

                          Journey Summary
                          ===============

        Total Distance                   :   2524.90  metres
        Total time                       :     13.33  mins
        Total number of gear changes     :        31
        Average Speed                    :     11.36  km/hr
        Total fuel used                  :      4.48  litres
```

Figure 3 : TRUCKSIM SUMMARY REPORT

CORNERS :

The model assumes the road to be straight with a vertical profile only. Horizontal curves have to be dealt with by artificial speed limits which requires good judgment on the part of the user. Tables of curve speeds could be compiled to help but this would require care because of the number of variables.

ENGINE POWER AND SPECIFIC FUEL CONSUMPTION :

It is difficult to find data on fuel consumption at part throttle. For this reason, the model uses the manufacturers full power fuel consumption curve and proportions use according to the percentage of full power needed at the time. Should more detailed information become readily available, it is possible for the model to be revised.

Engine power is another difficult figure to find accurately. Often new engines are higher than spec and then allowances have to be made as they wear.

MECHANICAL EFFICIENCIES :

There are a number of power losses from the engine to the rear wheel hubs. These have to be assessed according to best knowledge at the time of use. Currently, the model assumes fixed percentage losses.

The sum of these approximations is certain to produce a degree of error for any particular trip. Much better accuracy is normally achieved when doing comparative studies between various options as the errors often apply to all options.

TRUCKSIM VALIDATION :

In addition to work being carried out by Bob McCormack, LIRA is working through an evaluation of the model. This has involved simulation runs over simple road profiles such as adverse and favourable grades with stops at various points. These test runs have aimed to; check gear change logic, speed and grade limits and braking logic.

A comparison of field measurements with TRUCKSIM results is being undertaken. This has been delayed somewhat through equipment problems. It is now expected to measure real life fuel consumptions in November '87.

CONCLUSION :

Computerised truck performance models offer a quick means of evaluating both truck and road options on paper. Assumptions made in the models affect the answers but these errors are to a large extent avoided by comparing options rather than making absolute predictions. The possible savings in fuel consumption alone for our largest highway rigs is in the order of $400 p.a.

for every 1% improvement in average fuel consumption rate. Case studies show that improvements of 5% or more are feasible.

Indirectly prediction results can be used as inputs to cost models. This allows solution of questions such as, "should I buy a higher horsepower rig to save time?".

TRUCKSIM is available for use now on FRI mainframe computer. Your interest would add impetus to completing the PC version. Inquiries can be made through the author.

ACKNOWLEDGEMENTS

LIRA acknowledges that TRUCKSIM is the creation of Bob McCormack of CSIRO, Division of Forestry, Canberra, Australia, and that part of this development was achieved while he was at Forest Research Institute (N.Z.).

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