Session 2
Paper (c)

TRUCK SIMULATION PACKAGES FOR PERSONAL COMPUTERS

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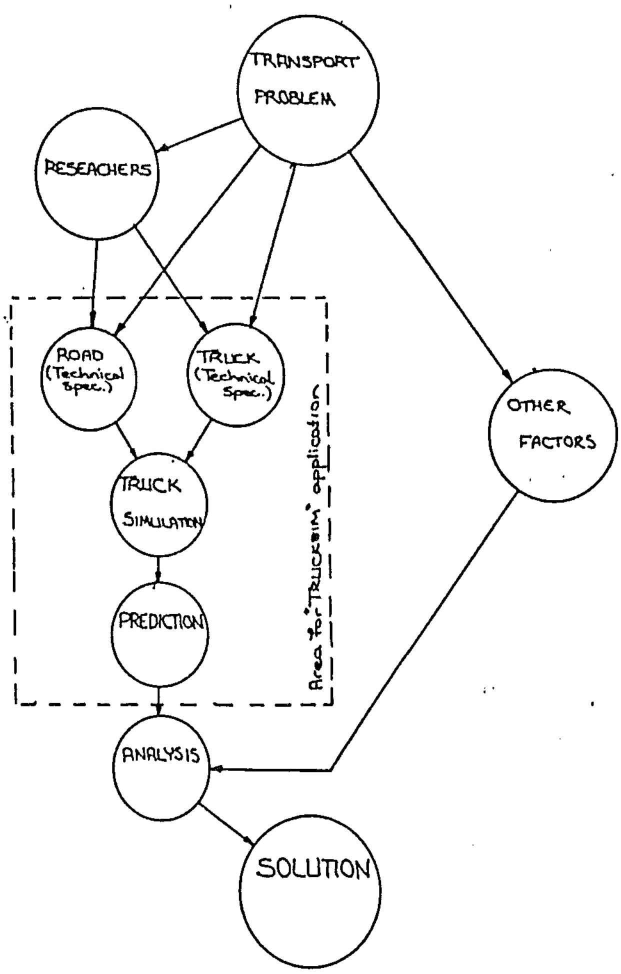
INTRODUCTION:

Log transportation costs are significant in virtually all harvesting operations. In some forests yet to be logged these costs will determine saleability of the crop. Road construction costs and longer haul distances will tend to tip the scales against profitable operation. There is a need then to determine ahead of time whether to proceed or not. Such planning requires many inputs to be accurate. This paper introduces two computer programmes suited to assist in obtaining performance data for economic analysis. They are not cure-alls but rather a step in the overall process. Figure 1 shows how such tools fit within a complete transport project.



TRANSPORT PROBLEM-SOLVING

Figure 1.

Computers have been utilised in both the models simply to allow the large number of calculations to be completed with a minimum of time. Because each evaluation takes such a small period of time it is possible to investigate a range of options thereby optimising the final choice. This has the potential for increasing economic returns. To improve the ease with which the industry can pick up these and similar tools L.I.R.A. has been pursuing software for Personal Computers (PC's). When available this makes it feasible to operate such planning aids on quite modest office budgets. There is however, a need for some caution in ensuring that operators are suitably trained both in computer operation and technical awareness of the problem at hand. Managers need to know the limitations of the predictions they are offered as computers calculate models not real life.

(A) TRUKGRAD:

INTRODUCTION:

TRUKGRAD as the name suggests is a programme which predicts the ability of a truck to climb a grade. It was developed as a means to assist with understanding how the road affects a trucks performance. As a result some directions have been determined in where to look for solutions to mobility problems and these will be discussed later.

MODEL DESCRIPTION:

Three typical New Zealand logging rigs have been modelled : Long Log Type , Bailley Bridge and Truck and Trailer. Road description inputs allow for :

------ Zero and adverse grade

------ Curves on constant radius

------ Super-elevation

The model assumes constant conditions to allow simple solution. Transitions between straight and curve , flat and super-elevation and changes in speed are not analysed by the programme. In most cases these will not reduce gradeability but if you need to start from zero speed an additional allowance will be needed .

In essence the programme is a GO/ NO GO test which is applied to the input data.
On one side the resistances to motion are calculated and summed. Grade resistance incorporates factors for curve and super-elevation. Other resistance include rolling and air.
On the other side the truck produces TRACTIVE FORCE (TF). For the truck to proceed TF must exceed the sum of the resistances. Figure 2 illustrates this balance.

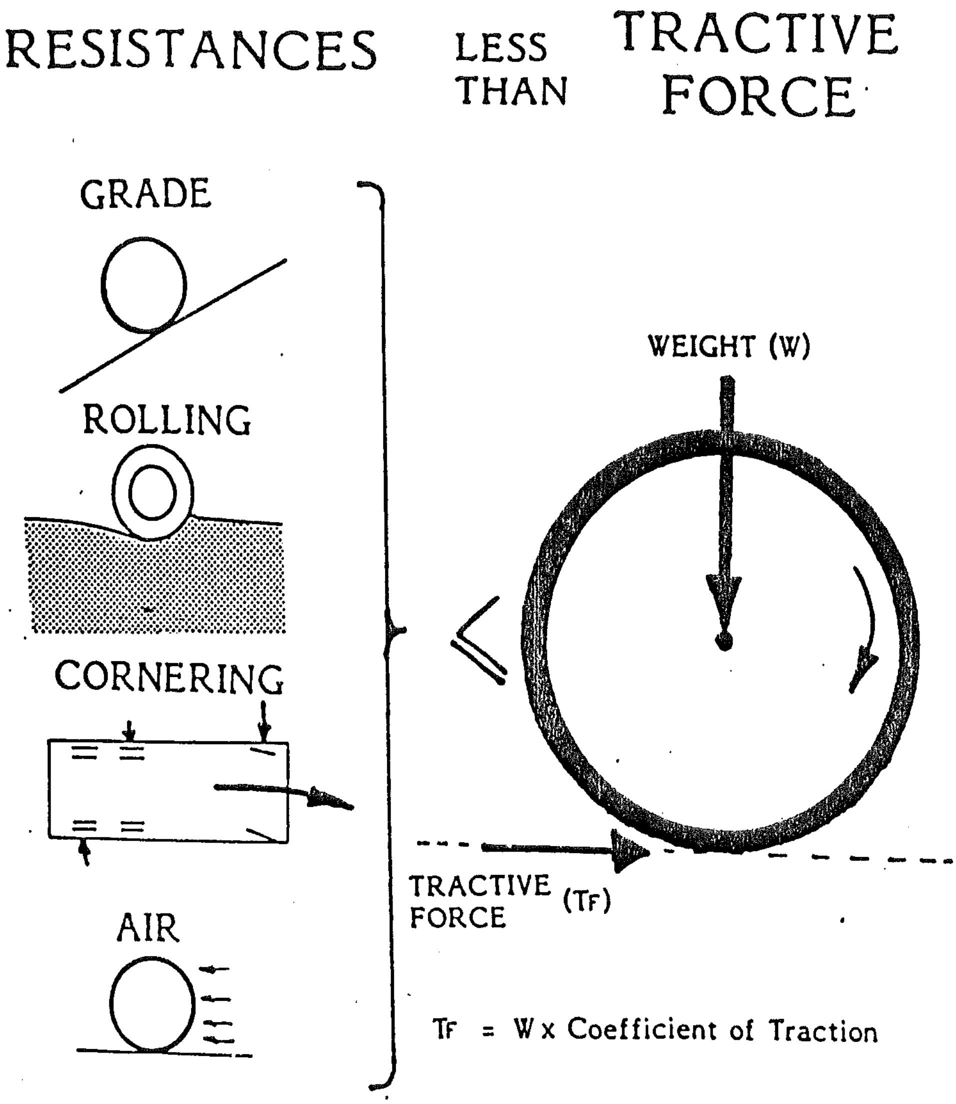


Figure 2

If the first set of input values do not give a small excess of Tractive Force, changes can be and further tests run until the truck can just proceed. In calculating the Tractive Force it has been assumed that the truck's differentials have not been locked. This means that any loading which causes a force across the truck will reduce traction. The two main causes of this are trailer inswing on corners and super-elevation. It is not unusual to see the drive wheels on the outside of a curve slipping for this reason.
(In some operations diff locks are applied under load on corners to achieve mobility. Further work is needed to model this situation.)

PREDICTIONS:

Instead of explaining the programme in detail I will now show some of the predictions it makes. These are helpful in determining whether to look at the truck or the road for a solution and some of the improvements that can be made to the road.

GRADE V's RIG TYPE: Figure 3

This graph tends to be contrary to the popular conception that certain rigs are less likely to get stuck. In poor conditions ,ie. low Coeficient of Traction (CoT), the difference between rig types is quite small . For a CoT of .2 (wet clay or mud) all three common rigs have a maximum gradeability in the range 5-7 % when loaded. If however the CoT is increased to 0.4 the poorest of these will increase to 12 % maximum grade. Such a change may be feasible especially when considered at the construction phase.

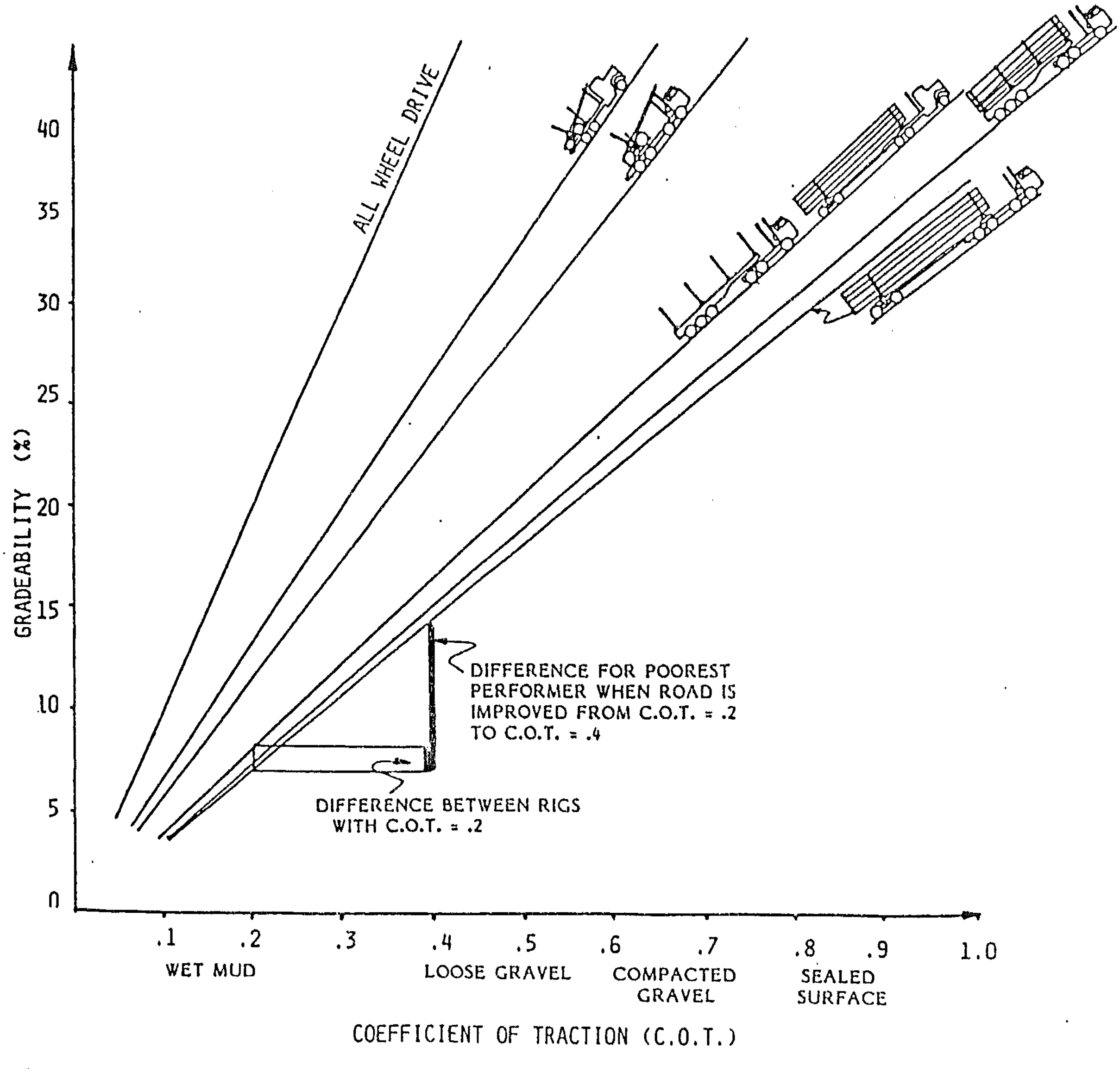
Features which will assist include:

----- Good drainage
----- Crushed gravel running surface (Possibly a thin layer)
----- Sufficient sub-base
----- No clay or soil infiltration

It should be noted that the comparison presented here assumes similar transmissions and suspensions. Further study is necessary to determine the significance of such factors.

SUPER-ELEVATION:Figure 4

At low speed and maximum grade super-elevation on corners becomes an obstacle for log trucks. Super-elevation is the cross slope on corners and is positive when water runs to the inside of the curve. Corners are normally banked to counter centrifugal force so the faster the vehicle the more slope can be provided. Logging roads are essentially for the transport of logs and as such should suit heavily laden trucks. Other vehicles can tolerate less than perfect solutions for their own operating conditions but trucks are quite sensitive. Actual operations have found that changing road levels by as little as 30 - 50 mm on the inside of a curve can make the difference between getting stuck or not.
Possibly one of the best ways of learning what trucks like best is to travel in the truck over a route of similar nature. This could apply to designers, builders and maintainers of roads.



(LIRA Preliminary Study of Straight Line Gradeability using rigs loaded for Class I road)

Figure 3

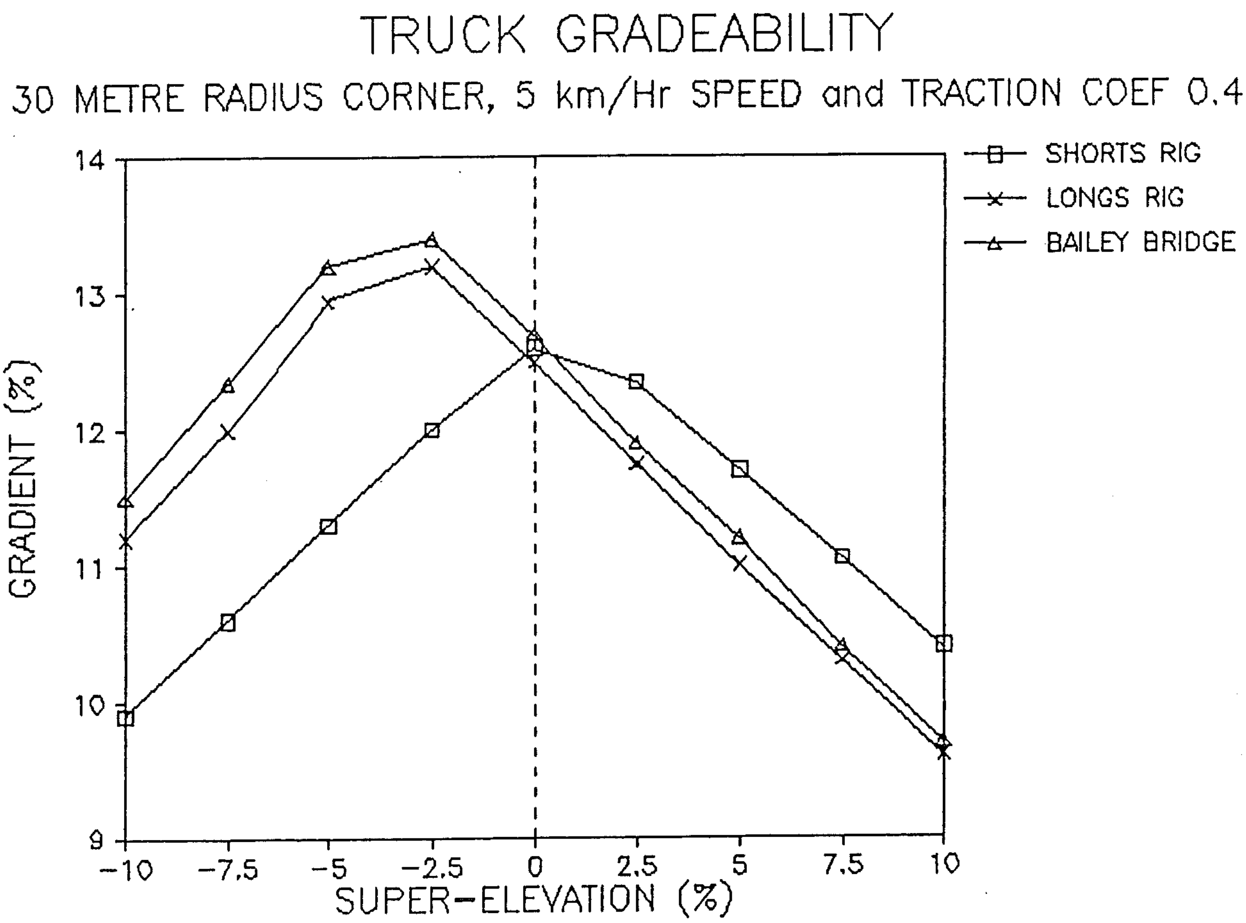

TRUCK GRADEABILITY
30 METRE RADIUS CORNER, 5 km/Hr SPEED and TRACTION COEF 0.4
SHORTS RIG
LONGS RIG
BAILEY BRIDGE
GRADIENT (%)
SUPER-ELEVATION (%)
14
13
12
11
10
9
-10
-7.5
-5
-2.5
0
2.5
5
7.5
10

Figure 4

CURVE RADIUS: Figure 5

Corner radii below 40 metres require centreline gradients to be reduced below that possible in a straight line if maximum gradeability is being sought. Inspection of existing roads has shown this to be done rarely. Mobility is maintained because the corner grade is negotiable but the straight line grades (which are the same) are less than could be achieved. This is not a problem unless grades are critical to achieve access.
A source of difficulty in this regard is the upgrading of silvicultural roads. Increasing corner widths often requires cutting towards the centre of the curve with consequent grade increases. Mobility on a steep corner may only be achievable by increasing the straight line grades either side and reducing the grade on the corner itself.
Truck drivers and other road users can help with getting the best out of the actual road by taking the longest possible route on each corner. All users need to cooperate in this measure as trucks need to follow the hard going and loose gravel sprayed on the best path by other vehicles cutting the corner will defeat the aims of the exercise.

PROGRAMME DESCRIPTION:

TRUKGRAD is based on a Personal Computer spread sheet programme. This provided an easy means of building a model without recourse to programming. Changes are possible at any stage and may be effected by any person who understands the model.
Users with basic knowledge of Supercalc3 spread sheet and access to truck data can run the model with ease. Figure 6 shows the screen display. After inputting data down to line 63 it is only a matter of "Recalculating" to get an answer at lines 113 - 116. Further recalculation is requested if the grade is too steep or the surplus of tractive effort is too high. Once the answer is acceptable the maximum design grade is displayed.

FUTURE DEVELOPMENTS:

This model is currently undergoing final mathmatical verification. Any changes are likely to be minor as field observations support the trends predicted. Field testing of absolute values will not be possible until a suitable means of measuring the Coeficient of Traction is found.
Once the model has been checked a detailed report on it and its predictions will be available. Copies of the software will also be available.

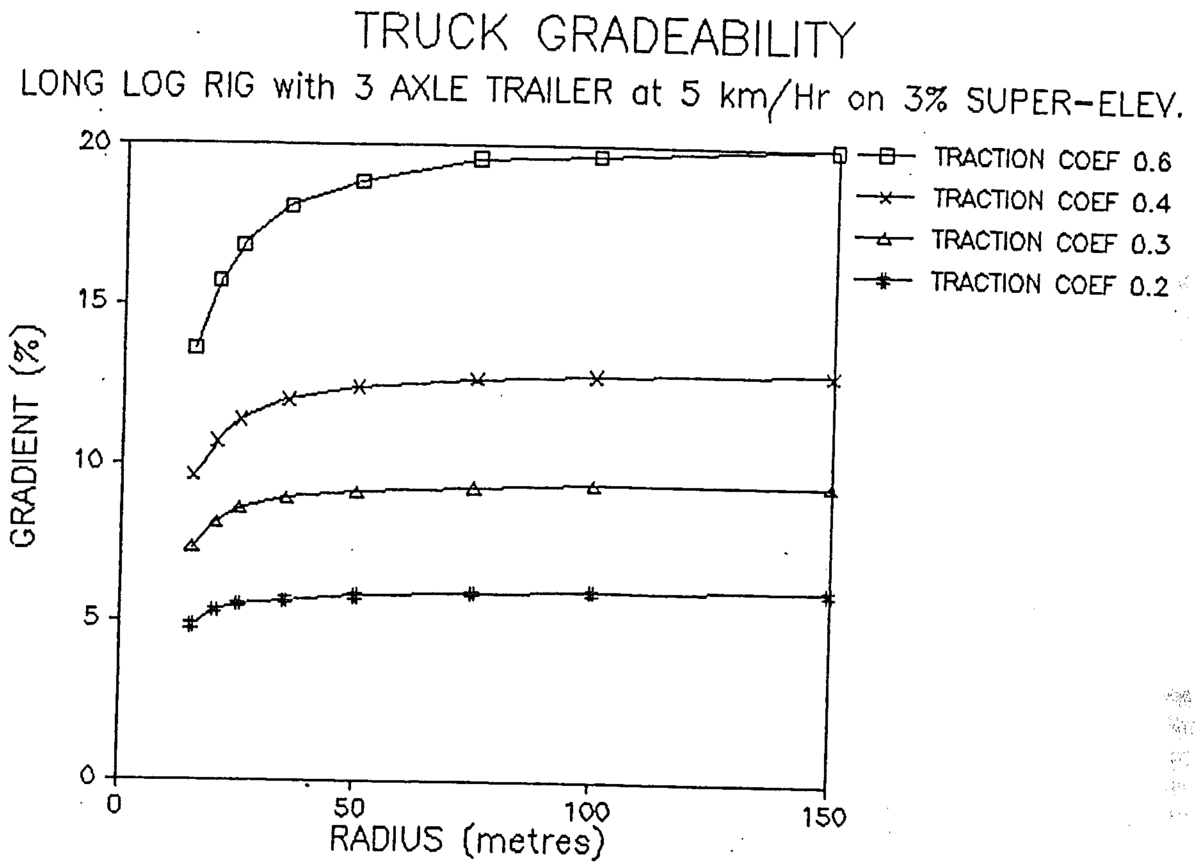

TRUCK GRADEABILITY
LONG LOG RIG with 3 AXLE TRAILER at 5 km/Hr on 3% SUPER-ELEV.
GRADIENT (%)
RADIUS (metres)
0
5
10
15
20
0
50
100
150
TRACTION COEF 0.6
TRACTION COEF 0.4
TRACTION COEF 0.3
TRACTION COEF 0.2

Figure 5

A || B || C || D || E	F	G	H || I || J

Row	Item	Symbol	Bailey Bridge	Long Log Trailer	Truck & Trailer
1					
2	********************				
3	TRUCK GRADEABILITY				
4	**************************************		************	***************	**************
5	INPUT DATA		BAILEY BRIDGE	LONG LOG TRAILER	TRUCK & TRAILER
6	**************************************		************	***************	**************
7					
8	**WEIGHTS**			WORK FULL COLUMN	
9	(Tonnes)			TO AVOID ERRORS	
10					
11	TRUCK TARE WEIGHT(Truck only OR Truck		10.50	10.50	10.50
12	& Piggyback Trailer)	(W)			
13	TRAILER BOGIE WEIGHT (REAR ON SHORTS)	(WT)	3.50	4.75	3.50
14	FRONT BOGIE OF SHORTS TRAILER	(WF)	NOT REQ'D	NOT REQ'D	1.50
15	PAYLOAD	(PL)	23.00	25.50	9.50
16	PAYLOAD (TRAILER FOR SHORTS ONLY)	(PL2)	NOT REQ'D	NOT REQ'D	16.00
17					
18	**DIMENSIONS**				
19	A.(Measured in metres from front axle)				
20					
21	TO CofG OF TRUCK	(X1)	2.50	2.50	2.50
22	TO TRUCK BOLSTER	(X2)	5.30	5.30	5.30
23	TO CENTRE OF TRUCK DRIVE TANDEM (Wheelbase)		5.60	5.60	5.60
24		(X3)			
25					
26	B.(Measured in metres from Trailer R/A)				
27					
28	TO PAYLOAD CENTRE OF GRAVITY	(X4)	2.75	3.60	1.50
29	TO TRUCK BOLSTER	(X5)	6.80	9.00	NOT REQ'D
30					
31	C.(Other dimensions in metres)				
32					
33	TRUCK C.of G HEIGHT(From Ground)	(Y1)	1.00	1.00	1.00
34	TRAILER CofG HEIGHT(From Ground)	(YT)	1.00	1.00	1.00
35	PAYLOAD C.of G. HEIGHT(From Ground)	(Y4)	2.75	2.75	2.75
36	TOP OF TRUCK BOLSTER(From Ground)	(Y2)	1.50	1.50	NOT REQ'D
37	DRIVE TANDEM SPACING	(L1)	1.30	1.30	1.30
38	TRACK OF DRIVE AXLE	(TR)	2.00	2.00	2.00
39	STING	(X6)	NOT REQ'D	2.50	2.50
40	TRAILER DRAW/BAR LENGTH	(X7)	NOT REQ'D	NOT REQ'D	2.00
41	TRAILER DRAW/BAR HEIGHT	(Y3)	NOT REQ'D	NOT REQ'D	.70
42	TRAILER W/BASE	(X5)	NOT REQ'D	NOT REQ'D	5.50
43				GO TO AA45	
44	**RESISTANCE COEFICIENTS**				
45	TRACTION	(Mu)	.40	.40	.40
46	ROLLING 1	(CR1)	7.25	7.25	7.25
47	ROLLING 2	(CR2)	.02	.02	.02
48	AIR	(K)	.06	.06	.06
49	CORNERING	(CC)	200.00	200.00	200.00
50					
51	**MISC. INFO.**				
52					
53	SPEED (k.p.h.)	(S)	5.00	5.00	5.00
54	No of Tyres (Truck only)	(n)	12	6	6
55	No of tyres (Shorts trailer only)		NOT REQ'D	6	6
56	FRONTAL AREA (Metres Sq.)	(A)	10.00	10.00	10.00
57	VELOCITY (m/sec)	(V)	1.39	1.39	1.39
58					
59	**ROAD DATA**				
60					
61	GRADIENT(%)	(G)	13.40	12.80	12.50
62	SUPER-ELEVATION(%)	(E)	3.00	3.00	3.00
63	CURVE RADIUS (Centreline, Metres)	(R)	1000.00	100.00	100.00
64					
108					
109					
110	RIMPULL (kN)	(TF)	52.62	55.43	54.62
111			.34	.17	.27
112			1.00	1.00	1.00
113			GRADE-OK	GRADE-OK	GRADE-OK
114	SURPLUS RIMPULL (OK IF LESS THAN 2)		.34	.17	.27
115	(TEST)		1.00	1.00	1.00
116	MAX. DESIGN GRADE (%)		13.40	12.80	12.50
117	********************		**********	**********	**********
118					

Figure 6

(B) TRUCKSIM

INTRODUCTION:

TRUCKSIM is a trip simulator for log trucks which predicts travel time , fuel consumption , engine utilisation and the number of gear changes. It has two main potential uses: optimisation of truck specifications for a given road and planning a road to suit a truck (fleet).
Other truck simulation programmes have been available , the most well known being Cummin's VMS service. The main problems with these have been the delay in getting answers because processing was done off shore or a lack of technical support. It was with this background that Bob McCormack of C.S.I.R.O. Forest Research Division, Canberra, started developing TRUCKSIM while working at F.R.I. Rotorua in 1984-5 . In March of this year the programme was released for industry evaluation in a workshop at F.R.I.
L.I.R.A. are currently pursuing a project to assess the accuracy of TRUCKSIM's predictions. This work will include measurement of real life performance . On completion of this study it is hoped to use the model for research of the influences between truck and road. Should refinements be necessary our views will be sent to Bob McCormach for consideration. Any interested person or company can gain access to TRUCKSIM.
At this time TRUCKSIM is available on the F.R.I. VAX computer. Longer term it is hoped that a PC version can be written to improve access. For storage and speed an IBM AT sized machine will be the minimum possible . These should also be fitted with a mathmatical co processor chip to speed number crunching.

MODEL DESCRIPTION:

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

At regular time intervals along the specified route the trucks progress , performance and dynamics are calculated, ie.

- ----- Distance down the road
- ----- Grade of the road estimated to be covered in the next tie 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 an up change will be made.
----- 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.
----- 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 7 shows how the program is structured and the sequence of operation. There are three main ingredients to the model: Truck , Driver and Road .
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 range of trucks to be simulated. Once they are set up future simulations can use them with considerable time saving.
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 as a long section and a set of speed limits. These files are further processed by other programs to a format suited to the simulation program.

With the three main ingredients stored within the computer it is then possible to use " RUN PREP " to combine one of each and initiate a simulation run. In addition an entry speed and gear are specified.

MODEL LIMITATIONS:

Like most other models TRUCKSIM is based on assumptions and simplifications which influence the accuracy of the result. Given sufficient time and money these could most probably be reduced to insignificant levels. This would however increase costs of the software and input data collection, probably to an unacceptable level. As the model stands it has the following limitations.

USER INPUT:

Considerable user data is needed to run a simulation. The accuracy of this must affect the final predictions.

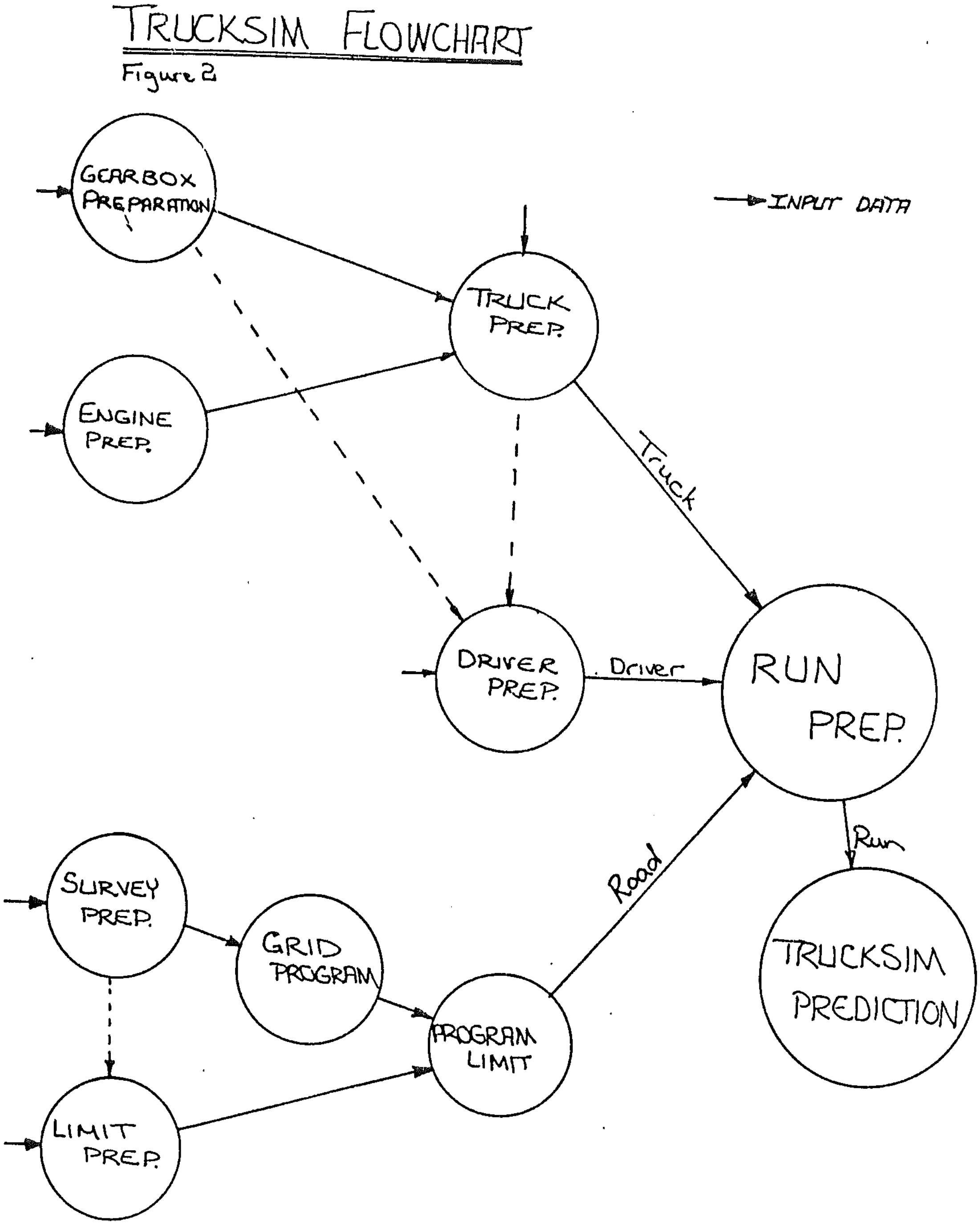

TRUCKSIM FLOWCHART
Figure 2
INPUT DATA
GEARBOX PREPARATION
TRUCK PREP.
ENGINE PREP.
Truck
DRIVER PREP.
Driver
RUN PREP.
Run
Road
SURVEY PREP.
GRID PROGRAM
PROGRAM LIMIT
LIMIT PREP.
TRUCKSIM PREDICTION

Figure 7

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 judgement 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.

EFFICIENCIES:

There are a number of power losses from the engine to the rear wheel hubs . These have to be assesed 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 as the errors often apply to both options.

APPLICATIONS:

Trucksim has yet to be applied to a commercial operation in New Zealand. This should be feasible in the near future as research determines its reliability.
Other simulation models have been used, in particular Cummins VMS has been employed by two companies to guide decisions in truck specification.
Such models readily assist with making decisions between engines, gearboxes , axle ratios etc.

Road design analysis applications are largely untested at this stage. Possible uses include:

----- Effects of grade change
----- Effects of lowering a road crest
----- Effects of changing the running surface

Research work in this area may produce guidelines for road designers although it is likely that some case studies would still be necessary .

```
*****************************************************************************
*
*  CSIRO - FRI      LOGGING TRUCK PERFORMANCE PROJECT                        *
*  -------------------------------------------------                          *
*  @@@@@ @@@@  @   @  @@@@ @   @       @@@  @@@ @   @                          *
*    @   @   @ @   @ @     @  @       @      @  @@ @@           Page  3     *
*    @   @@@@  @   @ @     @@@   @@@  @@@    @  @ @ @                       *
*    @   @  @  @   @ @     @  @          @   @  @   @           4-MAR-87    *
*    @   @   @  @@@   @@@@ @   @      @@@  @@@ @   @           21:14:54    *
*                                                                            *
*-PROG-: TRUCK-SIM Ver 2.1    :-RUN-ON-:  4-MAR-87 21:10:00   :- AT -: CSIRO DFR *
*-USER-: rwg                  :-RUN----: whaka33              :DRIVER: Standard  *
*-TRUCK: White Road B Tr    2 :-ENGINE-: CUM NTC300    Eng 10 :-GVW--: 40000. kg *
*-TRANS: Fuller RT 12515      :-DIFF---: EatonDS400 3.700     :-TYRE-: 11X22.5 R *
*                                                                            *
*****************************************************************************

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

        Total Distance                      :      4843.00  metres
        Total time                          :         7.65  mins
        Total number of gear changes        :           23
        Average Speed                       :        37.98  km/hr
        Total fuel used                     :         4.87  litres
```

Figure 8

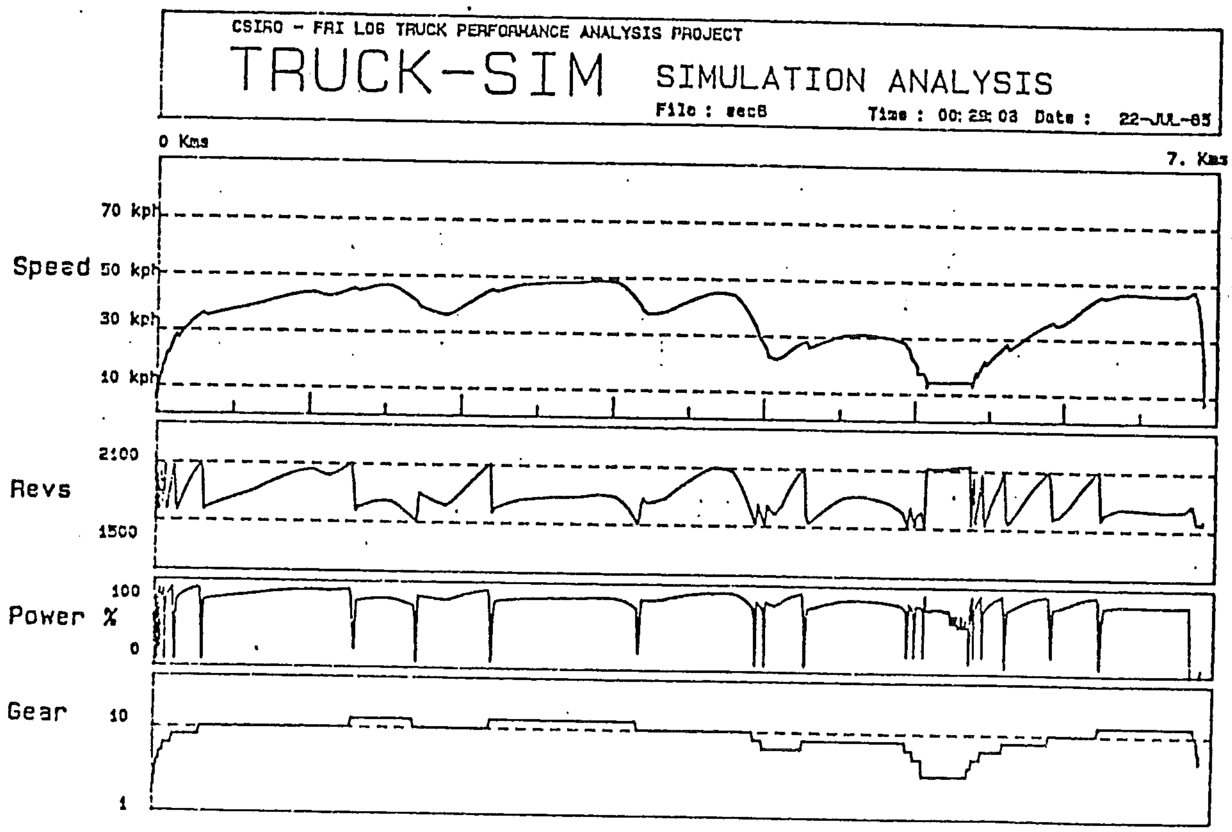


Figure 9

PROGRAM OUTPUTS:

TRUCKSIM produces a number of graphical outputs for general appraisal as well as numerical data for further analysis. Figures 8 and 9 show some of these.

CONCLUSION:

Computerised truck performance models offer a quick means of evaluating both truck and road options. In some cases researchers will be able to provide useful guidelines for operations staff but there will still be specific cases to be evaluated. Availability of these models on Personal Computer will allow such cases to be run in the local office.

ACKNOWLEDGEMENTS

L.I.R.A. acknowledges that TRUCKSIM is the creation of Bob McCormack of C.S.I.R.O. , Division of Forestry , Canberra , Australia , and that part of this development was achieved while he was at NZ FRI.