Session 5
Paper (d)

DRIVER'S INFLUENCE ON POWER REQUIREMENTS IN LOGGING TRUCKS

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INTRODUCTION

In the past, when diesel fuel cost $.30 per gallon, we looked for drivers who could make their required number of trips per day, keep their load on, not wreck the truck, run icy hills without spinning-out or jack-knifing, and gear-down on the down-grade to compensate for questionable braking power. The super-star drivers prided themselves that they could shift a 5 & 4 without using the clutch during the entire trip.

In recent years, diesel fuel costs $.50 per litre, and hauling cost represents 25% to 60% of the total wood cost. This focuses the managers' attention on all aspects of transportation. The study of the human element, and driver training can no longer be avoided, for safety and to lower cost per tonne-kilometre.

The modern driver must know the design and technical function of the vehicle inside out, and understand its, responses. He must be engine-speed conscious, defensive, safe in traffic, easy on material, energy saving and environment conscious. The subject of people-training must receive attention before the desired high transport efficiency can actually be achieved.

Background of Driver-Training

The following is a light look at the formal induction which many present-day drivers received when they started out their driving careers.

In 1960, the 10-wheeler, 5 & 3, 180 HP gas "six-banger" grossed 25.5 tonnes. The trick was to keep it between the ditches, and get over that icy hill, where you had to move both shifters at the same time, without ending up in no gear at all, and going back down sideways.

In 1965, the 18-wheeler, 5 & 4, 409 gas V8 grossed around 33 metric tons. Since it was not governed, the driver training instructions were, "don't rev. it over 3500 rpm empty, and when you are loaded, go as fast as you can".

In 1970, graduating to a diesel, the instructions were, "keep'er on the governor, and downshift when she drops 300 revs". A lot of 13 speed transmissions were sold, and it was a mortal sin to "lug your engine".

There are a lot of drivers today for whom this basic training remains indellibly etched in their memory.

The Gear Shift and the Accelerator Pedal

The relationship between the motor, the direct-drive transmission, and the road speed can be introduced in simple terms.

There are various ways to use the shifter stick and the accelerator pedal. Take, for example, a 5-speed, 1.6 litre gas 4-wheeler. This engine "feels" like it wants to run at 3,200 rpm. The engine power is adequate, and it does sound like the revs. are too high (see Figure 1). At 4000 rpm (see Figure 2), the motor screams a bit, but it provides good power for aggressive driving. Probably the worst thing that can happen to one of these small engines is to be driven by someone accustomed only to north american cars (see Figure 3). The temptation is to shift up too soon.

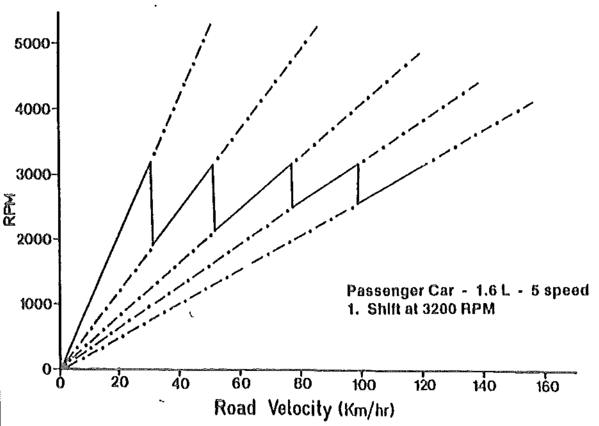

Figure 1. Passenger car. Shift at 3200 rpm.

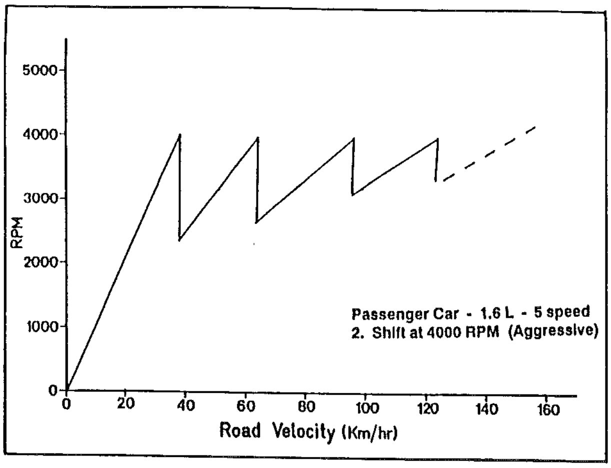

Figure 2. Shift at 4000 rpm.

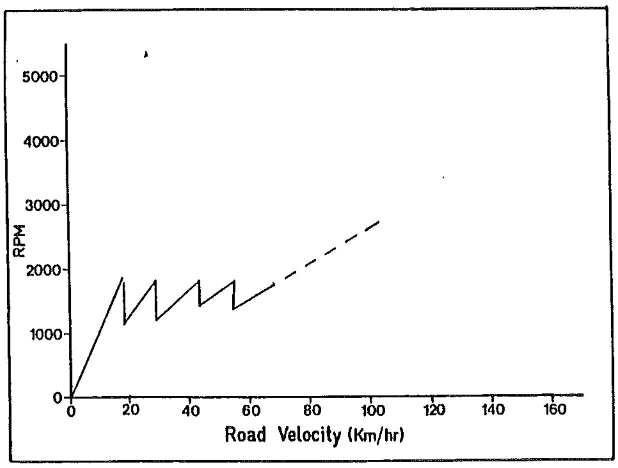

Figure 3. Shift at 1800 rpm.

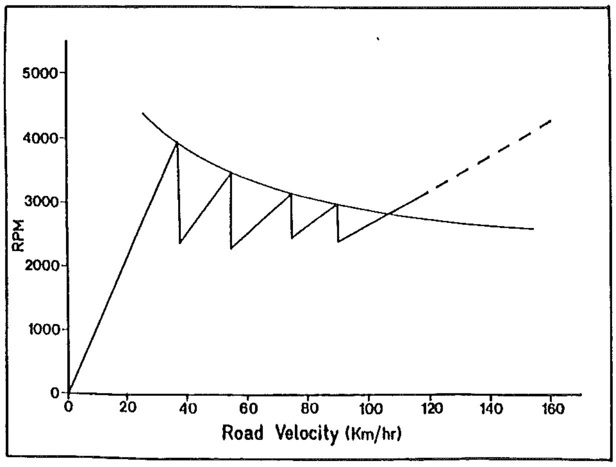

Figure 4. Decreasing speed progressive shifting.

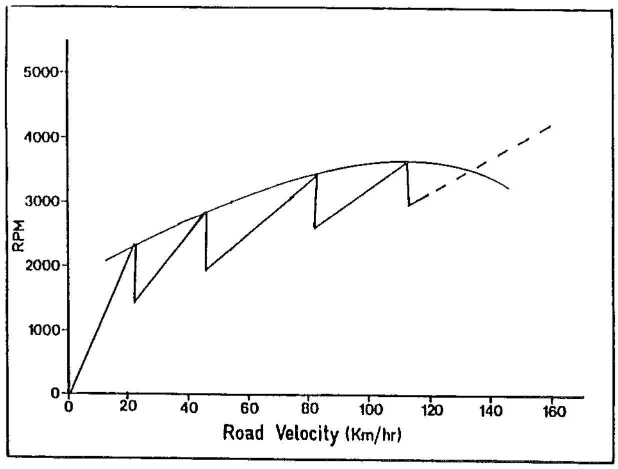

Figure 5. Rising speed progressive shifting.

If a driver wanted high acceleration in lower gears the pattern shown in figure 4 might be employed.

There is probably a "correct" rpm, depending on the grade and the road surface (this car notices slight grades and head winds the same way a loaded truck does).

If an "engine performance map" were available it might prove out that shifting up early, and down late in the lower gears, and running up to revs. which instinctively seem too high in the higher gears, is the best manner to use the accelerator and gear shift on this vehicle (see Figure 5).

The situation for a truck driver is not that much different, except that there are commonly 12 usable gears. The same logic has to be applied, quickly, sometimes in emergency, life-threatening situations.

FERIC Involvement

FERIC's research programme in Secondary Transportation has been clearly outlined in a previous paper. This may be described briefly as a strategy to define the factors which influence transportation cost and productivity. After having defined these factors, isolated and quantified them by somewhat primitive means using a truck, on the road as a test bench, the measurement techniques became progressively more sophisticated. The truck continues today to be the test bench, or "dynomometer", or mobile laboratory.

In early 1987, FERIC acquired a new tractor with specifications typical of logging tractors in eastern Canada. This unit is equipped with the instrumentation which has evolved during the past five years at FERIC.

A major part of the following presentation has been freely plaigerized from a paper recently presented to the Woodlands Section, Canadian Pulp and Paper Association annual meeting. The author of that paper, Mr. Daniel Ljubic, is the source of professional expertise, and has influenced the direction of much of the on-road transportation research at FERIC's eastern division during the past 6 years.

The examples presented on the following pages are little more than case studies, or spot "previews" of a more comprehensive Technical Report to follow. This paper is meant to give an idea of the potential of the "mobile laboratory", and of the direction which future studies might take.

The Truck

The tractor used in the driver tests discussed in this paper was a Ford 9000 equipped with a 350 Cummins diesel engine, a Fuller RT14615 transmission, a 3.72:1 rear end ratio, and tubeless 11R22.5 tires. All driver tests were done pulling a tri-axle high bed log trailer having a GCW of 46,000 kg.

The Instrumentation

Earlier experience with the modular recording instrument installed in the cab of the truck had its disadvantages for the field researcher. A sleeper cab was acquired to house the instrumentation and provide some room for an operator to do efficient work. There were often 36 information captors being recorded simultaneously at a rate of ten times per second. The goal of the drivers' technique experiment was to classify all drivers according to: fuel consumption, road speed, torque (power) used, accelerator pedal depression, quality and number of shiftings, steering wheel manipulation, acceleration (deceleration) on the road, quality and number of engine revolutions, etc. The system allows segregating and analysing any of the various measurements for short time periods.

Simultaneously, the results of the drivers' actions and of the road influences on engine intake air boost pressure and temperature, exhaust temperature and many other prarameters have also been recorded directly while on the move.

The FERIC Researchers

One researcher and one technician were on the job full time, as well as a full time professional driver. An instrumentation technician was available on short notice for field repairs as required.

The Drivers

A special experimental design was set up to test 29 different professional log truck drivers with the same truck, the same load, and over the same selected route. Each driver had the opportunity to familiarize himself with the vehicle prior to the test.

Once drivers were classified, a choice had to be made of the most characteristic cases (extremes) and their style analysed on several portions of the testing road in order to explain the differences between them.

From these comparisons, an "ideal" driving style should be drawn and recommendations extracted for drivers' future training. Also some drivers education aids (instruments) should be proposed.

The Route

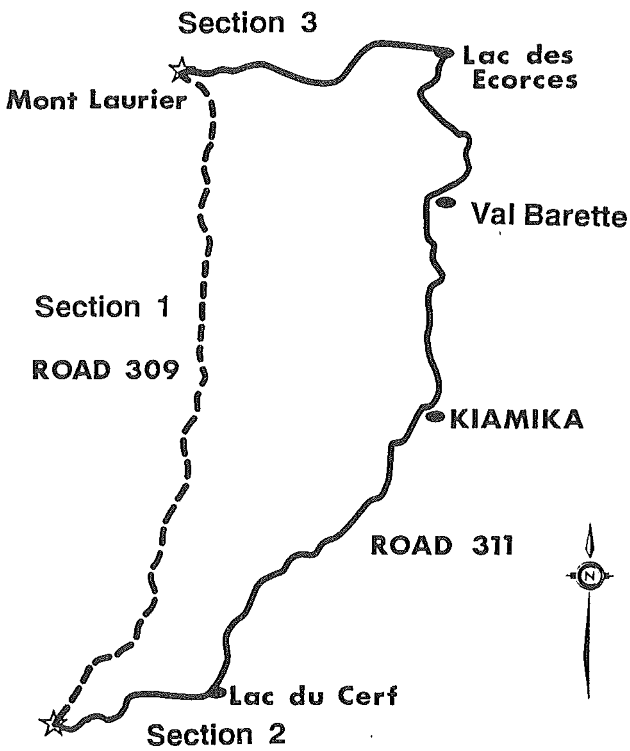

Figure 6. Driver testing circuit.

The circuit chosen was 86 km long, with varying surfaces, grades and curves, typical of local hauling conditions.

Three specific portions of the route were selected for detailed study, section 1 having a length of 3.0 km, section 2 and section 3, each being 2.0 km long. Each section included steep grades and curves, since these are the areas where the differences between and amongst the different drivers may best be isolated and measured for analysis.

Method of Comparison

The comparison of heavy duty truck drivers' techniques is not easy. In order to classify or study drivers' actions on the road some criteria must be chosen. FERIC is using here some of the comparisons which seemed to be most adequate for the purpose of this investigation.

All drivers had to accomplish the same work. As the GCW of the unit was 46 tonnes and the distance 86 km, the work to be done may be expressed as follows:

Work accomplished = 46 x 86 = **3956 tonne-kilometres**

Consequently, to move the unit on the circuit all drivers accomplished exactly the same task. For doing so they had exactly the same machine and it is their technique or style of driving which made the difference in performance, machine wear and tear and energy consumption.

While moving on the road the drivers used the potential energy of the fuel transformed by the engine into rotating torque at the output side. This torque in turn produces an engine accomplished work for a given amount of time expressed in kWh. If now the amount of fuel used in kg is divided by the amount of work they required from the engine in kWh the specific fuel consumption is obtained:

$$\frac{\text{fuel comsumption (kg/h)}}{\text{output engine power (kW)}} = \text{kg/kW.h}$$

To produce this engine work at a certain expense in fuel, a driver controls the per cent depression of the accelerator pedal using one of the pre-selected transmission gears, resulting in a certain engine speed expressed in revolutions per minute. This interplay between road demand, pedal depression and transmission gear shifting is one of the fundamental ways of comparing the quality of engine usage on the road.

A schematic example of this interrelationship is shown on Figure 7 where several isopedal depression curves are given (40, 50, 60, 70, 80, 90 and 99% of the total pedal depression).

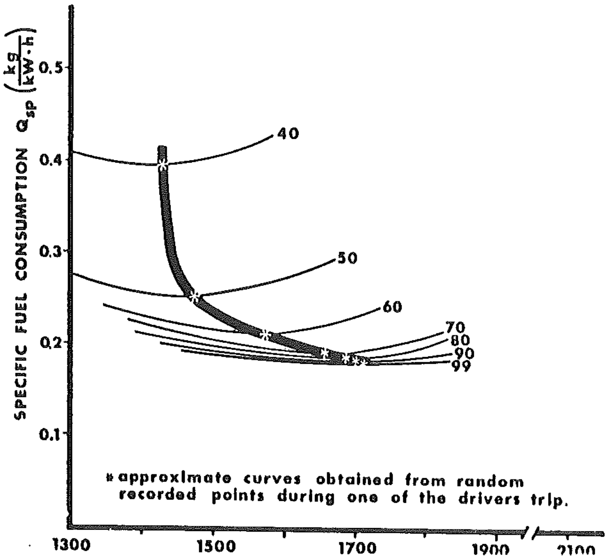

Figure 7. Illustration of the inter-relationship between specific fuel consumption, accelerator pedal depression and engine revolutions per minute.

It can be seen that for every pedal depression there is a relationship between the specific fuel consumption (or quality of engine usage) and the engine speed. In other words we are able to link together all the drivers' actions on the road (excluding brakings and steering). **A very important note is that for a given engine, each pedal depression has its minimum specific fuel consumption at a certain engine speed. These minimums can be linked together representing an ideal usage of the engine speed and power (in a given situation on the road) resulting in an ideal specific fuel consumption.** Consequently every driver should learn how to work in the vicinity of these minimums by judiciously choosing the transmission gear for a given pedal depression in function of the road performance demand.

Figure 8 gives a set of isopedal curves obtained by using a sample of five drivers' trips. It also contains average specific fuel consumptions (represented by isolated points) for 29 drivers for the whole trip.

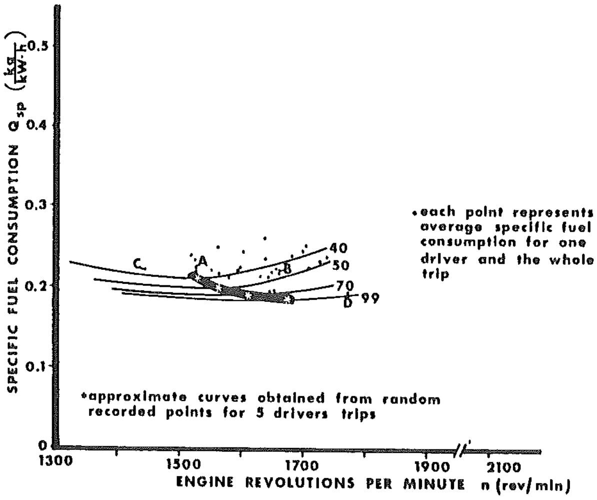

Figure 8. Illustration of the interrelationship between specific fuel consumption, accelerator pedal depression and engine revolutions per minute.

Let us examine some of them.

For example, Driver C accomplished his work with an average pedal depression of 38% of the total at an average engine speed of 1440 revolutions per minute and an average specific fuel consumption of 0.222 kg/kWh. This resulted (see Fig. 9) in an average road speed of 17.70 m/s or 63.72 km/h and an average road fuel consumption of 0.48 L/km. Driver D accomplished the same work with an average pedal depression of 98% (being almost constantly on the floor) at an average engine speed of 1770 r/min and at an average specific fuel consumption of 0.192 kg/kWh. This resulted (see Fig. 9) in an average road speed of 16.2 m/s or 58.32 km/h and an average road fuel consumption of 0.61 L/km.

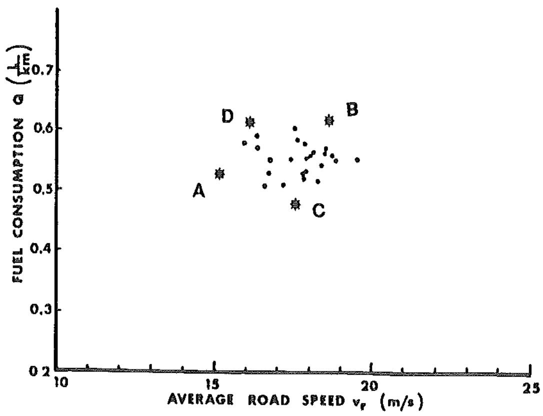

Figure 9. Average fuel consumption in L/km in function of the road speed in m/s for 29 drivers tested.

In other words, Driver D was further from the minimum specific fuel consumption than driver C (as it can be seen on Figure 8).

He was using considerably higher power (much higher pedal depression), considerably higher average engine speed (25% more cumulated revolutions for the trip), 21% more fuel and was slower on the road (12 minutes or 9% for the trip).

Looking at Figures 8 and 9, generally speaking, all of the 29 drivers represented except Driver C were using too high engine speed, and are therefore far off the minimum specific fuel consumptions for the pedal depressions used. **Almost all of them should be retrained in pedal depression/transmission gear usage.**

This is a dramatic demonstration of how much the driving technique (excluding steering and brakings) influences performance and fuel consumption.

Recall the theoretical shift patterns shown earlier of the 5 speed, passenger car. Recall the shift patterns prepared by your local truck dealer. Now observe the actual dynamic recordings produced from our mobile laboratory.

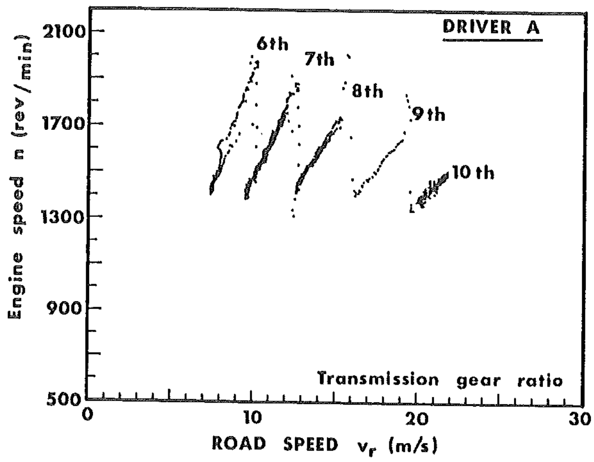

Figure 10a. Shift pattern for driver A on road section 1.

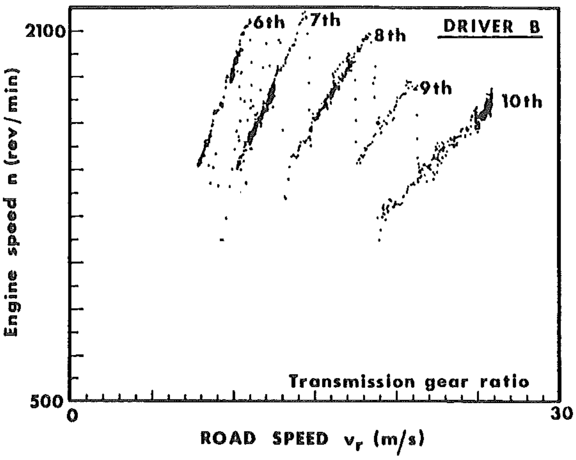

Figure 10b. Shift pattern for driver B on road section 1.

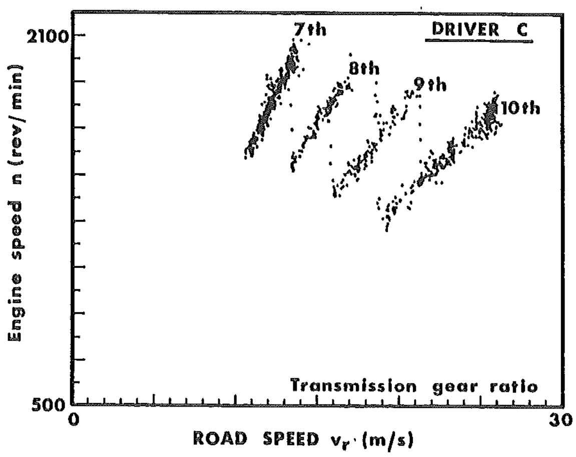

Figure 10c. Shift pattern for driver C on road section 1.

Comparison of Specially Chosen Road Stretches

To examine the differences between extreme techniques (A, B and C on Figures 8 and 9) three road sections have been chosen as previously mentioned.

Let us first examine what happened on road section 1, a 2.0 km section on the 86 km route.

The difference in cummulated fuel consumption between driver B and driver C, on this 2.0 km is of approx. 8.5% more for driver B.

This can be explained by the exaggerated pedal depression in the case of driver B and better gear shifting for driver C.

On road section 1, driver C was the fastest of the three, even though his cumulated fuel consumption is the lowest.

Let us now examine what happened on road section 2, a 2.0 km stretch, situated on the same 86 km route.

Comparing the fuel consumption in mL/m, once again, driver C was the best in cumulated fuel consumption (19% less than driver B and 4% less than driver A).

This again is influenced in part by exaggerated accelerator pedal depression in the case of driver B.

Another reason for the highest road speed and at the same time lowest fuel consumption of driver C is his shift pattern. He knew how to use higher transmission gears and to shift less than driver B on that combination of turnings and steep grades (see Figures 11a, 11b and 11c). This is the second reason why he had lowest fuel consumption and the highest road speed. In other words he used the inertia, or swing of the unit, very efficiently. He could "read the road".

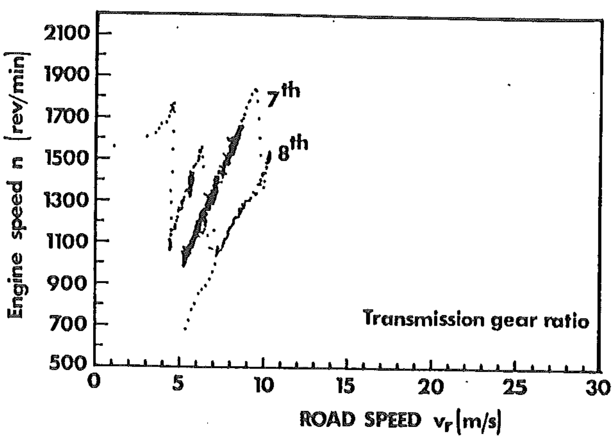

Figure 11a. Shift pattern for driver A on road section 2.

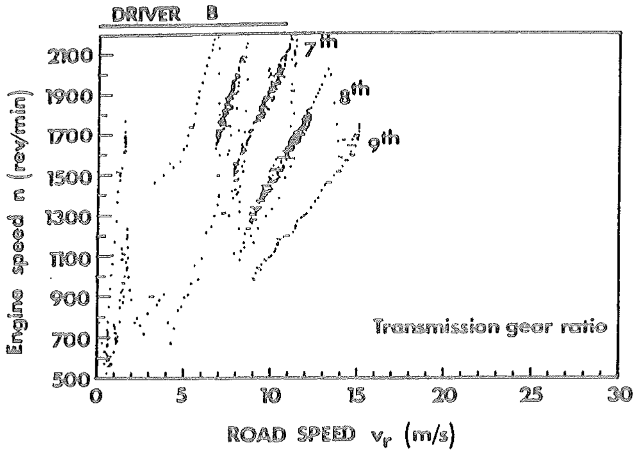

Figure 11b. Shift pattern for driver B on road section 2.

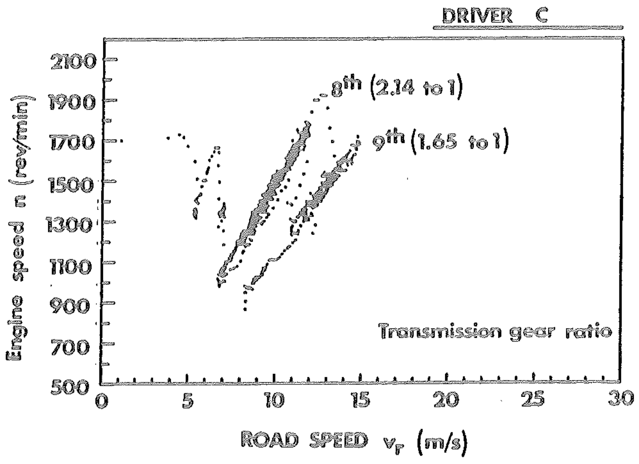

Figure 11c. Shift pattern for driver C on road section 2.

Another interesting comparison is the power used on this stretch. Driver A used 108 kW average power, driver B 280 kW and driver C 145 kW. The first comment here is that driver B, using 2.6 times more power than driver A and for an average difference in road speed of 1.43 m/s or 5.15 km/h in his favor, was wearing down the whole driveline considerably more. Also driver C could have been higher in engine speeds by letting the engine revolutions drop a little less, in other words, shifting just a little bit more.

Finally let us compare our three drivers on road section 3, another selected 2.0 km stretch. At the beginning of this stretch, there is a sharp curve and in the middle an 800 m long very steep grade (approx. 12%).

Figure 12 shows continuous fuel consumption for the whole stretch as well as cumulated values.

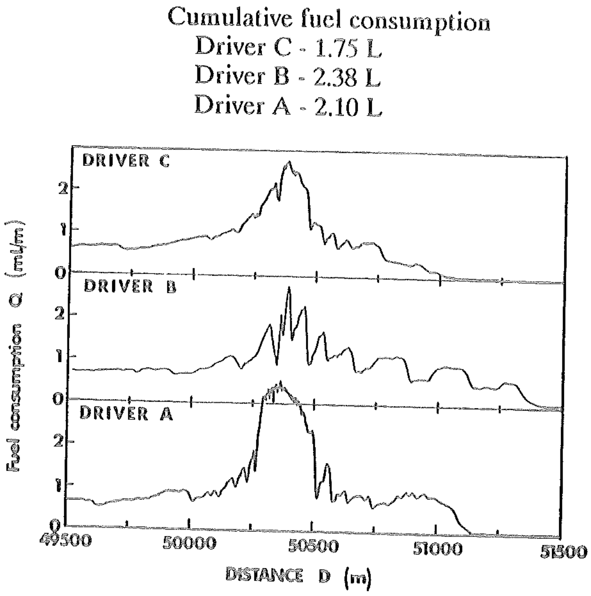

Figure 12. Fuel consumption comparison for drivers A, B and C on road section 3.

Again, driver C was the best. The difference between driver B and driver C in fuel consumption is 26%, and between driver C and A 17%. Driver C's road speed on the grade was barely below that of driver B and higher than that of driver A (see Fig. 13).

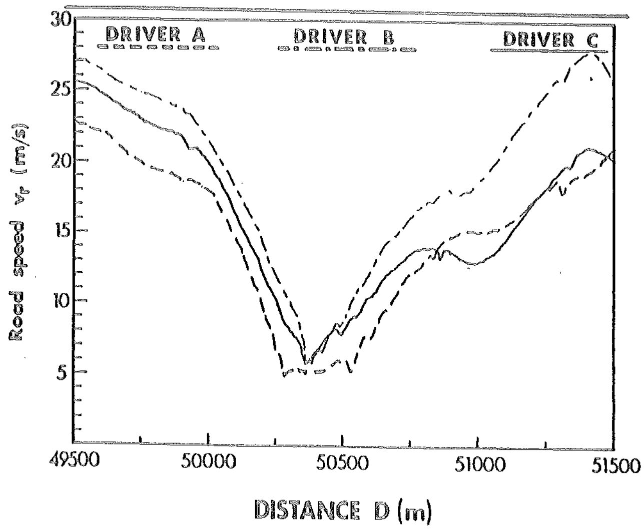

Figure 13. Road speed comparison for drivers A, B and C on road section 3.

On the descent, driver B's road speed was the highest because he kept the pedal on the floor.

Figures 14a, 14b and 14c are interesting for shift pattern examination. Driver B was very often close to 2100 rev/min while driver A never used more than 1900 rev/min. Driver C barely approached 2100 rev/min and in the 5th gear only.

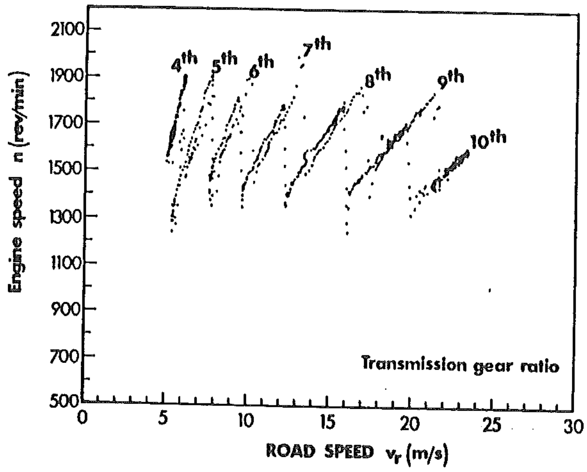

Figure 14a. Shift pattern for driver A on road section 3.

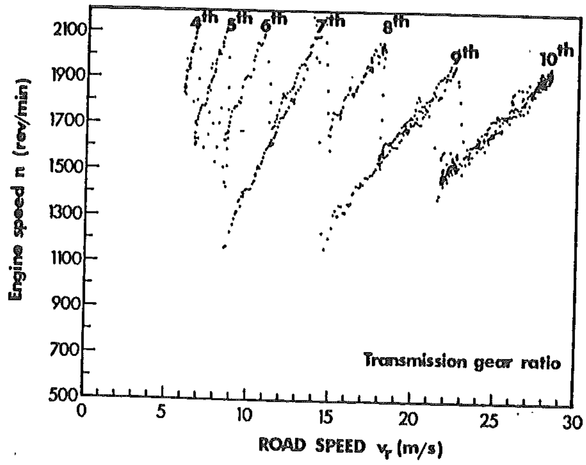

Figure 14b. Shift pattern for Driver B on road section 3.

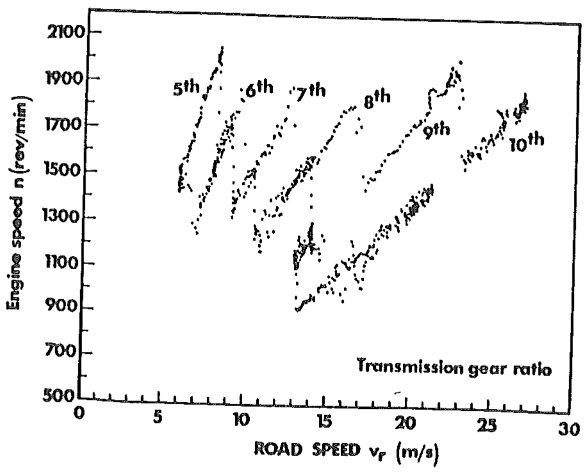

Figure 14c. Shift pattern for driver C on road section 3.

Once again, driver C used the inertia of the unit the best way, releasing the pedal when necessary (see around the road speed of 14 m/s on the Figures 14a, 14b and 14c). Driver A being the slowest of the three had the most regular and efficient gear shift pattern. A combination of drivers A and C's styles would be again an improvement.

Figures 15a, 15b and 15c show what a difference there is between the three drivers concerning the accelerator pedal depression.

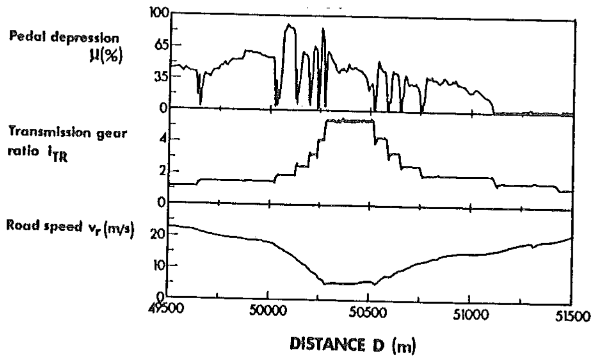

Figure 15a. Driving style on road section 3, driver A.

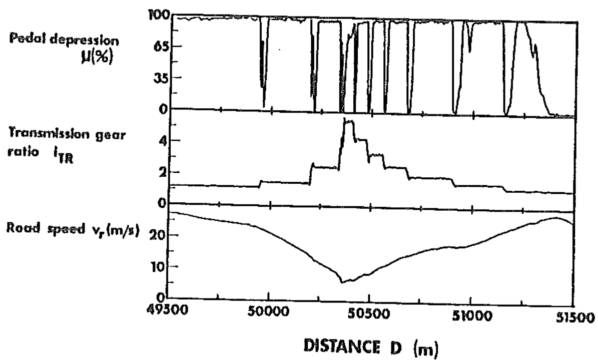

Figure 15b. Driving style on road section 3, driver B.

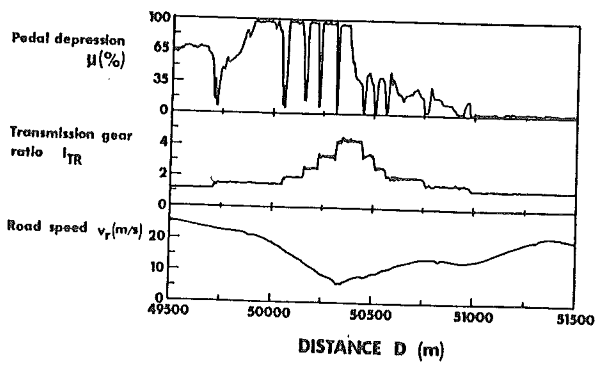

Figure 15c. Driving style on road section 3, driver C.

The maximum power used on the positive grade of this stretch is 122 kW for driver A, 152 kW for driver B, and 121 kW for driver C. Once again drivers A and C are not as tough on the machine as driver B.

These examples show clearly that the driver's technique can make a big difference in performance, wear and tear, safety and energy consumption of any transportation undertaking. This is the single most important factor contributing to the success of any transportation enterprise.

GENERAL DISCUSSION

To complete these partial findings, let us examine, for drivers A, B and C, some of the recorded averages for the whole trip given in the following table:

	A	B	C
Power	134KW (181hp)	199KW (267hp)	143KW (192hp)
Torque	1320N·m	1566N·m	1201N·m
Road Speed	(56km/h) 15,55m/s	(70km/h) 19,31m/s	(65km/h) 18,04m/s
Engine Speed	1537 rev/min	1698 rev/min	1497 rev/min
Cumulated Revolutions of the Engine	143,195	127,819	119,270
Cumulated Fuel Consumption	44,7L	52,5L	41,3L

From this table the following comments can be made:

- Driver A used the lowest average power, the lowest average road speed (the longest time), the average engine speed and the highest cumulated revolutions of the engine with an average fuel consumption slightly below the majority of drivers tested.

- Driver B used considerably higher power (torque) than the other two, had the highest road and engine speeds and the highest fuel consumption of all drivers tested.

- Driver C used average power, lowest torque, average road speed, lowest engine speed, lowest cumulated revolutions and lowest fuel consumption of all drivers tested.

It is interesting to note that driver B consumed, for the same one-way trip, on paved road, 11.2 L more fuel than driver C to perform the same transportation work of 3956 t∘km.

As for future possibilities let us go back to Figure 8 and 9. What we have on them is what has been really recorded with several drivers on the same road and with the same unit. From the material gathered we are going to study an ideal driving style and propose it to the transportation industry. For example why not find out an ideal driving technique which would give us the fictive point F on Figure 16, giving a fuel consumption of 0.48 L/km and a road speed of say 19.56 m/s with, at the same time, a specific fuel consumption situated on the minimum for a given (minimized) pedal depression.

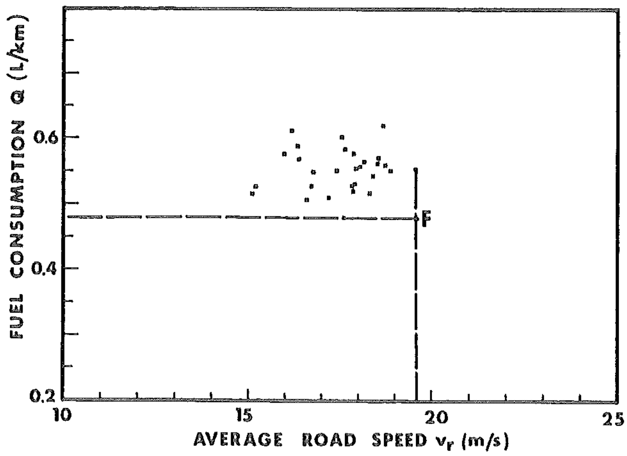

Figure 16. Average fuel consumption of a fictive ideal driver F in L/km as a function of the average road speed in m/s.

This idealized driving technique could then be developed for several small portions of the road and given to drivers to try to follow in order to approach the ideal.

On the other hand this could serve as a basis for future drivers training.

As for a practical and immediate guide for drivers, we could use, from Figure 8, the minimum points of specific fuel consumption for each pedal depression and design a simple and inexpensive instrument which will indicate at any point on the road the accelerator pedal depression and, underneath, the ideal engine speed (for that particular engine). This would guide drivers to follow ideal gear shifting practices.

CONCLUSION

With the recorded material FERIC intends to optimize the driving technique, for the unit and road used, based on best theoretical principles and propose it to the Forest Industry as the basis for future drivers training. Of course, there is also the question of different road conditions and optimized truck-trailer specifications for them. In other words, drivers' techniques can be influenced by the quality of roads and adaptability of machines. These questions are part and parcel of FERIC's long range road transportation research programme and are outside the scope of this paper.

In a few months FERIC will publish a report on the optimization of drivers' styles, including braking and front wheel steering styles.