COMPARISON OF DIESEL AND PETROL CAR FUEL CONSUMPTION WITH A STUDY OF FACTORS AFFECTING VEHICLE FUEL ECONOMY

by

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ABSTRACT

Over recent years, diesel engines have become an acceptable power unit for the private car, offering low fuel consumption, longer engine life and reduced maintenance costs. This thesis describes a programme of tests conducted at the Department of Transport Technology, Loughborough University of Technology, on behalf of the Transport Assessment Division, T.R.R.L., and compares the fuel consumption of three Vauxhall Cavalier cars, viz., a 1600LD diesel car and the 1300GL and 1600GL petrol versions. Using a number of statistical techniques, the work further investigates the effect a group of factors had on the fuel economy of the diesel test vehicle.

The fuel consumption of the diesel vehicle was compared to the 1300cc. petrol car which had a similar performance, and the two petrol cars were compared to show the effect different engine capacity had on fuel consumption. Seven test drivers, categorised by age and sex, participated in the tests which were conducted on a test route in the county of Leicestershire, encompassing all types of driving environments.

Results showed that the diesel vehicle used between 4% and 22% less fuel than its 1300cc. petrol counterpart, depending on traffic conditions. Similarly, the 1300cc. petrol vehicle had a fuel consumption between 12% and 9% more efficient than its 1600cc. version. A 9% reduction in the mean fuel consumption of all three vehicles was achieved by an "expert" driver in urban conditions, with a corresponding decrease of 6%, 9%, 14%, 21% and 36% in average speed, vehicle acceleration, vehicle deceleration, and "toe-down" throttle position and acceleration, respectively.

A comparison of total running costs concluded that an average motorist would have to annually drive over 40,000Km. to achieve a monetary saving with the diesel vehicle over its 1300cc. petrol-engined equivalent, due mainly to the additional capital investment of the diesel vehicle. This "break-even" distance was reduced by 30% for annual travel over purely urban road types. An analysis of comparative annual operating costs of the diesel and its petrol equivalent, for the range of driver "types" used in the tests, further showed that the more fuel efficient drivers had to complete a higher annual mileage to achieve the same savings in the diesel to those obtained by the more "aggressive", less

fuel efficient, drivers. On a national level, the study concluded that the introduction of equivalent diesel cars could optimally produce an annual 9.6% reduction in petroleum consumption in the traffic sector of the economy, giving a 4.6% saving in total United Kingdom petroleum consumption.

In addition to fuel consumption, the vehicle parameters of average speed, acceleration, deceleration, throttle control, and fuel and engine oil temperatures, plus a measure of the ambient conditions of temperature, pressure and relative humidity, were recorded over three main route sections representing urban, suburban and motorway traffic conditions. The statistical method of Factor Analysis was used to determine the underlying relationships between each variable and fuel consumption. In congested urban traffic, vehicle speed, ambient temperature and the measure of average throttle position showed significant effects on fuel consumption. On suburban road types average vehicle speed, acceleration, frequency of gear changing, and the average "toe-down" velocity and acceleration of the throttle pedal were all highly correlated with the variation of fuel consumption. Under the "free-flowing" environment of the motorway route section, fuel consumption was primarily influenced by the variables of average vehicle speed, engine speed, and throttle position. Of the three "ambient" factors the variation of ambient pressure had the greatest effect on motorway fuel consumption. Additionally, the factors of relative air humidity and ambient temperature both showed significant effects, with warmer and more humid weather improving fuel economy on all road types.

Regression models were constructed to predict vehicle fuel consumption over each type of traffic environment. For purely urban, suburban, motorway travel, and an overall journey based on a 50/40/10% split of urban, suburban and motorway road types, 93.8%, 92.4%, 88.2% and 95% of fuel consumption variance was explained by the respective regression models. In the model predicting the overall "50/40/10%" fuel consumption, the terms accounting for average tractive effort, heat energy of the fuel (diesel or petrol), and drivetrain ratio (engine speed/vehicle speed) were most significant. Regression variables based on the standard engine power correction factors for ambient temperature and humidity also showed a degree of statistical significance in all four models. The term accounting for ambient pressure correction of engine power (independent of the effect pressure variation has on vehicle drag) was not significant.

Under urban driving conditions, the method of Analysis of Covariance showed variations in traffic flow to correlate closely with variations of average vehicle speed, vehicle acceleration, throttle position, throttle velocity and acceleration, and the resulting fuel consumption; with a decrease in traffic density increasing the magnitude of each of the aforementioned parameters, except fuel consumption which was reduced.

Additional studies used the test data to investigate a method of performing a continuous energy balance calculation during vehicle motion, and the use of acceleration/deceleration histograms to categorise driver "types" with respect to fuel economy.

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NOTATION

Symbol	Description	Units
A	Projected frontal area	m^2.
"	Linear regression constant	lit/100Km.
A_d	Static rolling resistance coefficient	lit/100hrs.
B	Linear regression constant	-
B_d	Dynamic rolling resistance coefficient	s/m.
C	Regression model constant	-
C_1	Rolling resistance coefficient	-
C_2	Aerodynamic drag coefficient	-
C_3	Mass correction factor for rotating inertias	-
$C_{4,5}$	Regression model constants	-
C_p	Ambient pressure correction factor	-
C_t	Ambient temperature correction factor	-
C_h	Air humidity correction factor	-
C.I.	Compression ignition engine	-
D	Road-load drag expression	-
E	Engine displacement	Litres.
$E_{0,1,2}$	Energy at locations "0", "1" and "2"	Joules.
E_f	Fuel energy	Joules.
E'	Average fuel consumption gain	100Km/litre.
F	Average fuel consumption	lit/100Km.
F_d	Drag force opposing vehicle motion	N.
F_i	Factor (column) number	-
ΔF_d	Differential fuel consumption diesel/petrol	-
ΔF_p	Differential fuel consumption petrol/petrol	-
H	Relative air humidity	%.
N	Average engine speed	r.p.m.
"	Number of samples for probability curves	-
P	Ambient pressure	mBars.
P_e	Engine brake horsepower	B.h.p.
Q	Heat combustion of fuel	KJoules/lit.
R	Universal gas constant	287 J/Kg.°K.
R^2	Determination coefficient (goodness of fit)	%.
S.I.	Spark ignition engine	-
T	Ambient temperature	°K.
U	Unique error factor	-

Symbol	Description	Units
V	Average vehicle speed	Km/Hr.
V_i	Subject variable for Factor Analysis	–
W	Total vehicle weight	N.
X^i	%-v-m-t values for histograms	%.
$\overline{X}$, $\overline{Y}$	Limit values on X and Y axes of histogram	m/s^2, %.
a, d	Factor Analysis regression weights	–
c	Resolution of accn./decn. histograms	–
f	Fuel flow rate	Litres/hr.
g	Acceleration due to gravity	m/s^2
log, ln	Logarithm to base "10" and "e"	–
m	Vehicle mass	Kg.
η_e	Engine brake thermal efficiency	%.
η_t	Transmission mechanical efficiency	%.
θ	Road gradient	°.
ρ	Air density	Kg/m^3
γ, ∂, ψ, τ	Power indexes for regression models	–
α, β, η, ω	" " " " " " " "	–
$\int$, Σ	Integration and summation notation	–
FUEL	Average sectional fuel consumption	Lit/100Km.
SPEED	Average sectional vehicle speed	Km/hr.
VACC	Average sectional vehicle acceleration	m/s^2
VDEC	Average sectional vehicle deceleration	m/s^2
TPOS	Average sectional throttle position	"degrees".
TVEL	Average sectional throttle velocity	"degrees/s".
TACC	Average sectional throttle acceleration	"degrees/s^2".
GEAR	Average gear change frequency	No./Km.
REVS	Average sectional engine speed	r.p.m.
FLOW	Average sectional fuel flow rate	Litres/hr.
TFUEL	Average sectional fuel temperature	°K.
TOIL	Average sectional oil temperature	°K.
TRAF	Average sectional vehicle flow rate	p.c.u./hr.
TAMB	Average sectional ambient temperature	°K.
PRESS	Average sectional ambient pressure	mBars.
HUMID	Average sectional relative air humidity	%.
W.G.F.T.	Working Group on Fuel Consumption Targets	–
T.R.R.L.	Transport and Road Research Laboratory	–
S.M.M.T.	Society of Motor Manufacturers and Traders	–

CHAPTER 1

INTRODUCTION

1.1. General background.

In the last decade there has been a growing concern to improve our nations use of its energy resources, especially in the road transport sector of the economy where difficulties exist to find alternative fuels. Though transportation is not the prime user of national energy, as other sectors of the economy find substitute fuels, the proportion of natural oil consumed by road transport is expected to rise steadily over future years. This effect is illustrated by Figure No.1, showing that in 1980 road transport as a whole accounted for 43·5% of petroleum energy consumption. By 1984 this figure had increased to 51·7%, with the trend for the next five years appearing unlikely to change [1]*.

The automotive industry and motoring community are totally dependent on the finite supplies of crude oil from which both petrol and diesel (derv) fuels are refined, and this dependency will not alter until other propulsive methods and/or sources of energy are established. Before such technological advances are at hand the avoidance of oil shortages, resulting in quite extensive economic, social and industrial damage, can only be accomplished by efficient and frugal use of existing supplies. In the late 1970's the importance of petroleum conservation was endorsed when the Government initiated discussions with the motor industry, aimed at aiding the United Kingdom's energy policy by improving the fuel consumption of cars by design changes. As a result of the talks, the "Working Group on Fuel Consumption Targets" (W.G.F.T.) was founded to set feasible targets and methods for the improvement of new car fuel consumption. For the period October 1978 to October 1985, a 10% reduction in the "National Average Fuel Consumption" (based on the Department of Energy's official list of new car E.C.E.15/03 consumption figures) was issued by the W.G.F.T. and the Society of Motor Manufacturers and Traders (S.M.M.T.) [2].

In 1984, Rice and Parkin [3] showed that the target set by the W.G.F.T. and S.M.M.T. had been accomplished two years earlier than planned. Their measure of the overall new car fuel consumption, incorporating fuel consumption figures from the three standard E.C.E.15/03

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* Numbers in square parentheses designate references in Section 11.

tests, implied that a 13·2% improvement in "new model year car fuel consumption" had been achieved by October, 1983. Though changes in engine sizes and car sales aided the reduction of the overall fuel consumption figure, it was observed that a 12·2% improvement was achieved purely by fuel efficient gains in car design.

Looking more closely at the transportation sector, in 1984 private passenger cars accounted for 80% of the national highway traffic [1] during a year when a record 26·98 million tonnes of petroleum were consumed by road transport. During 1974 to 1984 both the ownership of private cars and the annual mileage driven in such vehicles increased by 20% and 35% respectively [1]. This ever increasing demand for private transportation and the resulting growth in the consumption of petroleum fuels illustrate the need for the private car to be the subject of continued development and transformation, so that future targets of fuel consumption reduction can be met to assist the national conservation of petroleum.

1.2. The diesel alternative.

Of the more recent developments in passenger car design the introduction of the small, lightweight diesel engine for use in private cars has been regarded as a promising solution to the continued desire to reduce vehicle fuel consumption, offering a generally accepted fuel saving of 25% over its petrol-engined counterpart [4].

It is readily accepted that diesel engines provide a more efficient use of fuel than their spark-ignition counterparts, with a longer service life, low maintenance requirements and more favourable lead-free emissions. In past years, the use of diesel engines has been limited to applications where the running costs, primarily fuel and maintenance, form a large proportion of an operator's total costs; viz., heavy goods vehicles, taxi fleets and as industrial power plants. During this time, with diesel fuel prices closely following those of petrol, the question of their real fuel economy benefit, especially in the small private car sector, was not realised by consumers with relatively low annual mileages. The diesel unit was always considered an unsuitable power source for small private cars, due largely to its often misleading portrayal as a smoky and noisy engine of relatively poor performance. Though this view held some truth a decade ago, advances in automotive technology have destroyed these myths.

In the late 1970's a renewed interest in the diesel unit was led by Volkswagen in Germany, who manufactured a diesel engined option to its popular VW Golf model [5]. Fitted with a 1500cc. diesel engine based on the cylinder block of the petrol unit of similar capacity, the vehicle offered a comparable performance to its 1100cc. petrol powered counterpart, yet retained its inherent fuel economy advantage. A previous T.R.R.L. report by Weeks [6], compared the fuel economy of the two VW Golf models. An overall fuel saving of 28% with the diesel vehicle was noted over its petrol equivalent, with a 40% reduction in fuel consumption achieved in purely heavy urban traffic.

Since the introduction of the VW Golf diesel model, manufacture and sales of small private diesel cars has increased rapidly. By 1984 automobile manufacturers offered a total of 75 diesel variants to their popular petrol-engined models, accounting for 2·6% of the United Kingdom market, compared to 0·38% in 1980 [7]. With each vehicle new developments attempted to alleviate the problems of smoke, noise and low horsepower-to-weight ratio, and promote the favourable characteristics of excellent fuel consumption, long service life and better exhaust emissions.

As diesel vehicles take a larger proportion of the automobile sales in the United Kingdom, their operation and subsequent "on-road" fuel economy is worthy of investigation to ascertain the effect they will have on the national consumption of petroleum fuels.

1.3. Factors affecting car fuel economy.

The real "on-road" fuel consumption of a car is dependent on a number of factors, namely the type of vehicle, the performance or "behaviour" of the driver, the design of the road network and the immediate traffic flow [8].

1.3.1. Vehicle design.

The effect "vehicle type" has on fuel consumption results directly from the "state-of-the-art" in the automotive industry at the time of production. It is this "state-of-the-art" or level of technological ability in the industry, in terms of car design and manufacturing techniques, which has the predominant effect on the datum level of private car fuel consumption. Due to the complexity of the end product, which is basically an assembly of independent sub-systems, improvements to car fuel efficiency can be achieved by contributions from a number of sources. These are best categorised by:

Reduction in vehicle mass - By using new light-weight materials and advanced methods of vehicle production, vehicle mass can be reduced to improve fuel economy. Fuel consumption of cars is known to relate directly to the power-to-weight ratio [12], with a higher ratio value inferring a better fuel economy.

The W.G.F.T. report [2] noted that a 10% reduction in vehicle mass can achieve a 4-6% saving in the fuel consumed by a car under pure acceleration conditions, with a 1% reduction for a vehicle subjected to constant speed travel. For the seven year period of the W.G.F.T. and S.M.M.T. proposals, a 3% reduction in vehicle mass was considered a viable target.

Limitations do exist for mass reduction in vehicle design by way of structural safety standards and the practical restriction of producing light-weight vehicles for load-carrying applications.

Power unit design - The two main sources of power for vehicle propulsion are the spark ignition (S.I.) engine and the compression ignition (C.I.) engine, or diesel as it is more commonly known. Though other types of engines do exist in small quantities, i.e., electric motors, gas turbines and steam (Stirling and Rankine) engines, it is the S.I. and C.I. units that are favourable for automotive purposes because of their simplicity, adaptability and relatively low cost.

At present S.I. engines are the most common power unit for the passenger car, and as a result a large proportion of automotive research is directed at improving the fuel and thermal efficiency of the engine. Particular interest is aimed at increasing the poor "part-load" thermal efficiency of the engine which is its main disadvantage when compared to the diesel unit. Methods such as the "stratified charge engine" which operates on a mixture gradient in a single or split cylinder, and the high-compression "lean-burn" engine with its high-turbulence combustion chambers and accurately retarded spark timing, are at the forefront of engine development.

In addition, attention has been focused on the techniques of "dual fuelling" (where hyrogen gas is introduced to the air/fuel mixture, enabling the more efficient full-throttle setting to be employed over the complete load-range) and "cylinder disablement" which involves the ability to cut out individual cylinders on a "cycle-to-cycle" basis, to control engine power output and improve the thermal efficiency by reducing heat loss to the coolant system.

An alternative solution to improve the fuel efficiency of motor transport is through "dieselisation", i.e., by increasing the use of the C.I. engine which has an inherently higher thermal efficiency than its petrol-fuelled counterpart. The introduction of the VW Golf diesel car and its effectiveness in improving the average fuel consumption of small private cars has already been noted.

Transmission design - Little scope exists for improvements in the mechanical efficiency of car transmission systems, currently estimated at approximately 97% or more [13]. However, fuel saving possibilities do exist by achieving a better "match" between the transmission system and the engine "speed"torque" characteristics, thus improving their joint ability to meet the requirements of efficient road travel. Of recent years the introduction of a fifth forward gear to small car transmission systems has had greatest effect on gains in car fuel economy.

Reduction in vehicle drag - This predominantly exists in two forms, viz., aerodynamic drag and rolling resistance. Though advances in aerodynamic design are continually being met by improving the shape of the vehicle front-end, the flow separation characteristics at the rear-end, underbody drag and the drag caused by proturberances, the future affect on fuel economy of this field of research is somewhat limited due to the practical requirements of passenger and luggage accomodation.

Reductions in rolling resistance through improvements in tyre and brake design can contribute significantly to a better fuel consumption. A major reduction in the energy dissipated at the wheels was achieved when radial-ply tyres were introduced to replace cross-ply tyres which had poor "rolling" characteristics. In the near future advances in tyre profile and reductions in brake-drag losses may only contribute towards marginal improvements in car fuel economy.

Other measures that are being researched to advance vehicle fuel efficiency are the reduction of power output to auxiliary drives (e.g., thermostatically controlled cooling fans), improvements in automotive fuels for "cleaner" more efficient combustion, and better "cold-start" characteristics of both S.I. and C.I. engines.

1.3.2. Driver performance.

The performance of the driver and the effect of his or her behaviour on car fuel consumption has been the subject of a number of studies [10][11][12][13], which have investigated the driver's influence in both "off" and "on-road" environments. Without specific instructions, drivers have shown a variation of 20% in returned fuel consumption over a predetermined test route in an "off-road" environment, with little or no variation in journey time [13]. By instructing a driver to operate a vehicle "cautiously" or "aggressively", deviations of ±12% in fuel consumption have been measured over a route consisting of rural and urban driving environments [15].

Under purely urban conditions, where the effect of driver behaviour on fuel consumption is at its greatest, Evans [11] showed that an unaided driver with no particular expertise at fuel saving, could vary his/her driving technique to achieve up to a 15% variation in fuel consumption, with a corresponding 15% variation in average journey time. Evans further noted that an "expert" driver could save fuel without increasing journey time by skillfully adjusting the speed of the vehicle to avoid unnecessary stopages.

To be able to investigate and advise on the essentials of a fuel-efficient driving style it is necessary to reduce the operation of a vehicle into physically measurable quantities such as a driver's choice of average vehicle speed, acceleration and deceleration levels, and the characteristics of the throttle motion. Although fuel saving tips offered to the motoring community serve a purpose, i.e.;

"Avoid jackrabbit starts. Imagine an egg between your foot..

...and the accelerator pedal. If you break the egg, you smash your chances for best fuel economy" (from [14])

it is often the case that there is a lack of technical information to back up the advise. Evans and Takasaki [14], studied one aspect of fuel-efficient driving, namely economical acceleration of a car from rest and from a constant speed. They concluded that from rest an average acceleration of $0{\cdot}8m/s^2$ should be used up to a speed of approximately 48Km/hr. Over this speed an acceleration of $0{\cdot}7m/s^2$ or less was advised. All drivers used for the study exhibited levels of acceleration higher than those suggested.

By describing the individual effects a number of chosen parameters have on fuel economy, similar to the work of Evans and Takasaki [14], a clearer picture of fuel-efficient driving can be drawn to aid future savings in national and personal fuel consumption.

1.3.3. Road network design.

The road layout and traffic flow characteristics have a combined effect on vehicle fuel consumption. Previous studies [15] [16] have showed that additional fuel is used by road transport as a result of obstructions preventing constant speed driving; viz., traffic lights, road junctions, parked and moving vehicles. It is generally accepted that the fuel consumption of vehicles on roads in built-up areas, where traffic flow is of the "stop-start" mode, is higher than the fuel consumption over roads in rural areas where the traffic environment is more free-flowing and obstruction to traffic movement less frequent. As traffic flows approach the ideal constant speed mode with little or no obstructions to vehicle motion, i.e., motorways, the speed of travel becomes the most significant factor in fuel economy [15].

It is not the intent of this thesis to investigate strategies for fuel-efficient road network design, however, an insight is given into the effect marginal variations of urban traffic density had on vehicle fuel consumption.

1.4. Aims of the work.

On-road fuel consumption tests have been conducted using three Vauxhall Cavalier cars, the 1600GL and 1300GL petrol vehicles, and the 1600LD diesel vehicle. The object of the work was to obtain a detailed comparison of the fuel consumptions of the three vehicles, in particular to compare the average fuel consumptions of the diesel car and the lower-powered petrol version, and of the two petrol vehicles.

The test route was a mixture of urban, suburban and motorway roads, enabling the effect of different traffic environments on fuel consumption to be accounted for in the comparisons. Using a selection of seven drivers, the work further investigated the effect of driver behaviour on the returned average fuel consumption of each car. Additionally, the data collected during the test programme were used to give an insight into the national fuel savings which could be created by the more widespread use of diesel powered private cars in the United Kingdom.

The previous section outlined the importance and complexity of the measurement of "on-road" vehicle fuel economy. To study the effect a number of factors have on fuel consumption, it is convenient to try to separate the contributions made by each. Though this can be achieved to some degree using the unrealistic "controllable" test environment of a modern chassis dynamometer, for tests conducted in the normal driving environment, where in essence the real problem exists, other methods of data reduction have to be adopted. In this report, the data analysis were based on a number of statistical techniques, which used the average values of a number of measured test variables, describing the vehicle motion, and the traffic and environmental conditions, over the three main types of road used, viz., urban, suburban and motorway.

Using the data collected for the fuel consumption comparison of petrol and diesel cars, the aim was to achieve statistical measures of the interrelations existing within a group of factors, and the effect each had on vehicle fuel consumption.

In addition, the study constructs a number of regression models for predicting the fuel consumption of the test vehicles. Expressing fuel consumption by analytical relationships is beneficial to both road and vehicle engineer because of the ability to eliminate, with a degree of statistical confidence, capricious events present in practical road trials due to driver behaviour, and marginal changes in vehicle performance and traffic conditions. Rather than base the expressions on purely experimental linear combinations of explanatory factors, that possess little or no theoretical reasoning for their form, the regression models developed in this report were structured from established fundamental laws of vehicle propulsion.

CHAPTER 2

THE EXPERIMENTAL DESIGN

2.1. Vehicle characteristics. [17]

The characteristics of the three vehicles used in the experimental programme are given in Table No.1. For the comparison of equivalent petrol and diesel powered vehicles, the 1300GL (petrol) and 1600LD (diesel) versions of the hatchback Vauxhall Cavalier (1982 model) cars were used; refer to Plate No.1. Although the diesel engine had a greater cubic capacity and compression ratio than the 1300cc. petrol unit, its maximum torque and power output, being developed at comparatively lower engine speeds, were notably less than those of the petrol engine. To account for the difference in engine speed characteristics, the diesel vehicle was fitted with higher transmission gearing. The performance of the 1300cc. petrol vehicle was marginally better than that of the diesel, which had a lower maximum speed and poorer acceleration capabilities. The diesel car was fitted with a larger battery and weighed approximately 80kg. more than its petrol counterpart. At slower vehicle speeds the diesel vehicle was marginally noisier than the petrol. This was more noticeable at idle.

To compare the fuel consumption of two petrol cars with different engine capacities, the 1600GL and 1300GL models were used. Compared to its 1300cc. version, the 1600cc. vehicle had a greater engine capacity with the same compression ratio, producing 20% more power at the same engine speed. The transmission gearing was the same as the diesel version, giving the 1600cc. vehicle a higher maximum speed and improved acceleration characteristics than its smaller version. The 1600cc. car had an unladen weight approximately 65kg. heavier and produced an engine noise level similar to the 1300cc. version. All vehicles used the same size and make of radial tyres.

Two Austin-Rover Montego vehicles were used for a set of subsidiary tests. The cars were identical 1600cc. "HL" petrol-engined models except for their different body colours (white and ivory) which were used to distinguish between the vehicles; refer to Plate No.2.

The five test vehicles had all received routine warranty services a number of weeks before the commencement of the test programmes. The cars were not serviced again until the testing had finished. The tyre pressures of the cars were checked before and after each completed test.

All vehicles carried a full tank of fuel at the start of each test.

2.2. Driver characteristics.

A description of the drivers, classified by sex, age and driving experience is shown in Table No.2. None of the drivers had previously participated in fuel consumption tests. For the main test programme, comparing the overall fuel consumption of the three vehicles, driver Nos.1 to 6 were used, consisting of four male and two female drivers. Within each sex category the drivers were chosen to provide a range of age groups.

Driver No.7 was selected to act as an "expert" driver. For the work studying the effect of driver behaviour on fuel consumption, the data recorded by this driver were used as "datum-line" measures. These were then compared to the corresponding mean values obtained by driver Nos.1 to 6, to highlight possible fuel savings that can be achieved by driving economically. During the running of the test programmes, none of the drivers (except No.7) were informed that the purpose of the tests was to measure the fuel consumption of the three vehicles.

2.3 Data collection.

2.3.1. Vehicle motion measurements.

Figure No.3 shows a schematic illustration of the instrumentation system fitted to each car to measure and record a range of vehicle-motion parameters, using an on-board "MICRODATA M1680" data logger (Plate Nos.9, 10 and 11). The logger was a self-contained unit, powered from a rechargeable power pack (Plate No.12). Prior to each test, the logger was manually input with the date, time of day, test identification number, and programmed to scan seven channels of data for each half-second interval of the test. The time elapsed was monitored by a quartz-electric clock contained within the data logger. With respect to Figure No.3, the seven parameters measured during each scan were:

Channel 1 - Distance travelled.

A slotted disc ("Optoswitch") was inserted in the speedometer cable of each vehicle to act as a pulse generator (Plate No.5). Conversion of the pulse frequency to a corresponding voltage measured the distance travelled over each ½-second interval. One pulse represented approximately 2.5cm. of vehicle travel.

Channel 2 - Throttle position.

A "Schaevitz R30" potentiometer was fitted to the carburettor linkage (petrol), or the fuel control rod (diesel). The analogue signal produced was converted to a digital representation of throttle position and recorded on each ½-second scan.

Channel 3 - Engine speed.

A "Siemens" magnetic resistor was fitted adjacent to the toothed ring of the engine flywheel. As each tooth passed the sensor a single pulse was produced. Over each ½-second interval, the data logger recorded the total number of pulses produced, giving a measure of engine rotation.

Channel 4 - Event marker.

This channel acted purely as a counter, which was set to a value of zero at the commencement of each test. A number of sites were chosen along the test route (described in Section 2.4) where, on passing, the test observer operated a simple hand-held switch that produced a single electronic pulse. By adding each pulse, the value of this channel was used to extract data of different route sections from the complete data set contained on each tape cartridge.

Channel 5 - Fuel used.

A single "Transflo" fuel flowmeter using four rotary pistons, was fitted to each vehicle (Plate Nos.7 and 8). To account for "spill-back" and fuel aeration with a single flowmeter, the fuel supply circuit of the diesel vehicle had to be redesigned. A more detailed description of both the diesel and petrol modified fuelling systems is given in Appendix 1 (Figure Nos.4 and 5). For each cm^3 of fuel passing through a "Transflo" meter, a single electronic pulse was output. The number of pulses during each ½-second was recorded.

Channel 6 - Fuel temperature.

To measure the fuel temperature a "Bush Beach" platinum resistance thermometer was installed in the fuel supply line adjacent to the fuel flowmeter. The analogue output from the thermometer was converted to a digital signal and recorded as a numerical value proportional to temperature. A continuous measure of the fuel temperature at the entry of the flowmeter was required to enable the fuel volume measurements to be corrected to a standard temperature of 15·6 degrees Celsius (conversion factor given by Figure No.2). Correction was required because fuel volume measurements ignore changes in the fuel density, and hence specific energy content of fuel, caused by variations in the ambient conditions.

Channel 7 - Oil temperature.

A transducer identical to that used for fuel temperature was fitted into the engine sump of each vehicle. A digitally converted analogue signal representing oil temperature was similarly recorded at each half-second scan of the data logger.

During the course of a test drive, the information measured for each half-second scan was recorded on a ¼ - inch magnetic tape cartridge, which could be removed from the logger once the test had finished. For a normal test duration of approximately three and a half hours, nearly 1,000,000 data characters were stored.

2.3.2. Ambient conditions.

Immediately before and after each test, measurements of ambient temperature, pressure and relative air humidity (using a whirling hygrometer) were taken and noted on the test data sheet (Appendix F(i)). Because the test route was to be divided into a number of main route sections, intermediate measures of the three ambient parameters were required. These were estimated by constructing a linear relationship of each variable against the time period of a test. As the elapsed test time at the midway position of each route section was known, corresponding values of average temperature, pressure and relative humidity could be obtained for each section.

Average wind speed and direction were also recorded for the period of each test. All ambient parameters were measured at the weather station situated on the campus of Loughborough University.

2.3.3. Traffic flow measurement.

To investigate the effects of traffic congestion on vehicle fuel consumption and driver behaviour, the Traffic Control Division of Leicester City Council was approached for measurements of the traffic flow experienced during the urban route section (refer to Section 2.4) of each test conducted in the main test programme.

Using electronic road sensors, the Division was able to give measures of hourly traffic flow at a number of road locations. To give an indication of the traffic density on the urban section of each test, data collected at the location shown on Figure No.9 were used. The sensor measured the flow of southbound traffic joining the "Holiday Inn" roundabout; a junction traversed several times during the urban route section (Section 2.4).

Data collected for the time periods 09.00-10.00a.m. and 10.00-11.00a.m. were used to correspond with the first and second laps of the urban circuit, respectively.

2.3.4. Test procedure.

Before the commencement of each test the operation and calibration of the seven logger channels were checked to ensure no faults existed in the instrumentation system. To check for correct distance measurement, the vehicle was driven over a 50m. section of smooth road with the output of channel 1 being compared to a known value of 2220 (44·5 pulses/metre).

The accuracy of the "Transflo" fuel flowmeter could not be checked before each test, however, manufacturer's text and a calibration analysis conducted at T.R.R.L. informed of a nominal error of less than 0·5% under normal operating conditions.

With the data logger initiated and programmed to scan the transducer outputs as listed in Section 2.3.1., the vehicle was ready for the commencement of a test. A test observer accompanied the driver during the full duration of each test, giving directions around the test route and operating the "event marker" switch when appropriate. A data sheet was completed for each test by the observer (Appendix F(i)) giving details of en route weather conditions, use of any auxiliary vehicle equipment, road surface and traffic conditions, and the locations of any obstructions to vehicle travel, i.e., road works. The presence of the test observer was considered a purely "passive" one, with him having no influence on a driver's behaviour.

On the completion of each test, the logger calibrations were re-checked and the tape cartridge removed from the logger for subsequent data analysis.

2.4. Design and selection of a test route.*

The main objectives of the road tests were to:

i) compare the average fuel consumption of the three test vehicles,
ii) compare the performance of each driver, and
iii) numerically describe how each vehicle was driven, over various traffic environments.

To achieve the above, a test route in the county of Leicestershire was chosen to include all types of driving conditions [18]. Each road used for the test route was classified by type and speed limit, and designated to a particular route section; categorised as either "urban", "suburban" or "motorway" traffic environments.

Apart from designing the route to account for different traffic conditions, the length and mix of each main section had to resemble actual car journeys. Since a prime interest of this study was the effect the relative fuel savings between each vehicle would have on a national level, the route design was based on the national travel statistics of Great Britain for 1984, issued by the Department of the Environment [1]. The figures shown in Table No.3 give an overall national proportion of approximately 50/40/10%, for the total annual travel on the road classes of urban/suburban/motorway, respectively. The length and mix of road

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* For a more detailed account of the test route, the reader should refer to a report by the Author, issued at the Department of Transport Technology, L.U.T. [18]. In addition to text and mapwork the route is described by a section of photographs depicting all the main junctions, as shown by Figure Nos.9a and 9b.

types used for the test route were based on this statistic [18].

Figure Nos.6 and 7 show the location and layout of the route in detail, which started and finished in Loughborough, following a clockwise direction via Quorn, Birstall, Leicester city centre, junctions 21 and 22 of the M1 motorway, Coalville and Shepshed. To separate the test route into different sections, nineteen locations were chosen and named as "event markers". The position of each event marker is shown on Figure No.8, in addition the distance between each pair of event markers (and main route sections) is given on Table No.4. For the purposes of the fuel consumption comparison study, the test route was divided into the following four main sections:

<u>Suburban 1</u> - Event marker Nos.1 to 4.

This section covered the route from the start of a test at Loughborough, to the commencement of the urban road network at Birstall.

<u>Suburban 2</u> - Event marker Nos.16 to 19.

This route section travelled from the exit at junction 22 of the M1 motorway, via Coalville and Shepshed to the finish of the test route at Loughborough.

<u>Urban 1 & 2</u> - Event marker Nos.5 to 6, and 9 to 10.

The urban section of the test route consisted of two laps of a cyclic road circuit in Leicester city centre. Each lap was 9·2Km. in length and called an "Urban Cycle" (refer to Figure No.9). The first Urban Cycle (event Nos.5 to 6) followed the completion of the Suburban 1 route section.

After the first Urban Cycle the route detoured to the Leicester motorway services for an intermission in the test for the driver's benefit. The stop was for approximately 30 minutes, with entrance and exit to the service area denoted by event marker Nos.7 and 8. After the break, the test route was rejoined taking the vehicle to the commencement of the second Urban Cycle (event marker Nos.9 to 10).

<u>Motorway</u> - Event marker Nos.11 to 16.

The standard motorway route section was planned between junctions 21 and 22 of the M1 motorway; travelling northwards.

For a number of subsidiary tests an additional section of the motorway was driven. In these instances the motorway section ran from junctions 21 to 24 and returned southbound from junction 24 to exit as normal from junction 22. The additional event marker Nos.14 and 15 were used in these tests (refer to Figure No.8).

Event marker Nos.12 and 13 were used to section a horizontal 200m. stretch of the motorway. Data from this section was used to study a method of performing a continuous energy-balance.

2.5. Test programmes.

Each test in all of the following test programmes commenced at the location of event marker No.1 in Loughborough, at 8.30a.m. on a weekday; unless otherwise stated. As a result of the start time, the route sections of Suburban 1 and the first Urban Cycle contained part of the morning rush-hour traffic to Leicester.

Apart from the "Hot start" tests detailed in Section 2.5.2., all test vehicles started the tests with cold engines. The 1600cc. petrol vehicle was fitted with an automatic fuel enrichment device, whilst the 1300cc. petrol version had a manual choke controlled by the driver. The test observer ensured that the manual choke was operated correctly and not left "active" after event marker No.2. The diesel vehicle was fitted with a "glow-plug" device used only to assist engine starting.

As previously noted, the test observer accompanied each driver throughout the full duration of a test, he was present only to direct and observe, and not to influence a driver's behaviour. The participants were left to drive as they would in their own vehicles.

2.5.1. Main "Spring" test programme.*

For this series of tests the three Vauxhall Cavalier cars

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* The "Spring" label was used to differentiate this programme of tests from a similar set run in the warmer summer months (programme No.(iii)).

and all seven drivers were used. During the period March to May, 1985, each vehicle completed two test drives around the Leicestershire route with each driver (Nos.1 to 6); i.e., a total of 36 tests. Three additional tests were conducted with the "expert" driver (No.7) who completed a single test in each Vauxhall car.

The order of each vehicle/driver test was controlled to randomise the use of each vehicle and driver, and to minimise bias in the results due to changes in the weather and daily traffic flows. None of the 39 tests were subjected to extreme weather conditions, i.e., heavy rainfall, gales or snow. Test sequence given in Table No.6.

2.5.2. Subsidiary test programmes.

Five additional test programmes were completed during the spring and summer of 1985 to account for a number of factors expected to affect the fuel consumption of each test vehicle. These were:

i) Additional motorway tests.

Although each main section (urban, suburban or motorway) formed part of an extensive test route, the distance travelled over the motorway section was only 12·03Km. long and may have been insufficient for the test vehicles to reach their "running equilibrium" for this type of traffic environment. Statistics from 1984 [1] informed that an average motorway journey in Great Britain was approximately 42Km. Thus, in accordance with this statistic a longer motorway section of 45·04Km. was devised (described in Section 2.4).

Three tests were completed by driver No.1, one in each vehicle, using the normal test route with the additional motorway section. Using the corresponding "normal" tests, i.e., same vehicle/driver, a comparison was made to investigate any affects the extra motorway distance may have had on vehicle fuel consumption, on and immediately after the motorway section. Refer to Appendix 2.1 for discussion of results, and Table No.7 for test sequence.

ii) "Late start" tests.

To investigate the effect that the time of day had on vehicle fuel consumption, especially in the urban traffic environment, three additional tests were completed by driver No.1, one in each Vauxhall

Cavalier. The tests were identical to those of the main test programme except the starting time of 10.30a.m. (i.e., 2 hours late).

The delayed start avoided the morning rush-hour traffic normally encountered on the first suburban and urban sections, but introduced the secondary lunch-time traffic peak to the second Urban Cycle. A discussion of the comparison (in terms of fuel consumption) between these tests and the corresponding "normal" tests is given in Appendix 2.2.

iii) "Hot start" tests.

All tests conducted during the other programmes commenced with the vehicle engine cold. To give an indication of the fuel savings created by starting a journey with a car engine at normal running temperature, three tests were completed by driver No.3; one in each Vauxhall Cavalier, with a hot engine at the start of each test.

A comparison of fuel consumptions obtained from the early route sections of these tests to the corresponding measurements from the "normal" tests, is given in Appendix 2.3.

iv) Vauxhall Cavalier "Summer" test programme.

To provide a wider range of ambient conditions for statistical investigations into the effect of ambient temperature, pressure and air humidity on car fuel consumption, a secondary programme of tests was conducted during a spell of hot and dry weather in September, 1985. Both the diesel and 1600cc. petrol vehicle were driven four times by driver No.3 around the standard test route. The 1300cc. petrol vehicle was not available for this programme of tests.

Thus, for the same driver, data from six "identical" tests, conducted in a range of environmental conditions, was collected from each vehicle. A discussion of the data obtained from this programme of tests is given in Appendix 2.4.

v) Austin-Rover Montego test programme.

To compare the fuel consumptions of two identical Austin-Rover Montego vehicles (1600HL petrol-engined models), a test programme consisting of five test drives was conducted. Two tests in each vehicle were driven by driver No.6 and an additional test in the "ivory" coloured vehicle was completed by the "expert" driver. A discussion of the results from this test programme is contained in Appendix 2.5.

2.6. Data analysis.

For each test drive completed over the Leicestershire route, the following sources of "raw" data were available.

i) a magnetic tape cartridge contained data readings representing the distance travelled, throttle position, engine revolutions, event marker number, fuel used, and fuel and oil temperatures, for each half-second interval of the test period. A header code stored on the tape before the data matrix designated the vehicle type and test number.

ii) a test data sheet (Appendix F(i)) was completed by the test observer en route, describing traffic conditions, road works and road surface conditions (due to weather) throughout the test drive. The sheet also contained recordings of the ambient conditions (temperature, pressure, relative air humidity, and wind speed and direction) taken immediately before and after the road test.

To analyse the "raw" data stored on each tape cartridge, the contents were transferred, via a "COLUMBIA 300C" cartridge recorder, to a directory file of a main-frame computer system (refer to Figure No.3a). Remaining in the format produced by the on-board data logger (refer to Appendix D(ii)), each file was input to a Fortran 77 software package specifically written for the research, which both analysed and checked the recorded data. The software, named "ROADTEST.FORTRAN", was an interactive package enabling a number of data analysis options to be performed via a V.D.U. terminal. A flow-diagram and listing of ROADTEST.FORTRAN is given in Appendixes A(i) and B(i), respectively.

For each route section of interest (determined by two event marker numbers, i.e., Nos.1 and 4 for the first suburban section), the computer software would output two files: one file containing seven columns of checked "raw" data (Appendix D(iii)) and the second containing information of the vehicle parameters analysed over the particular route section (see Appendix D(iv)). An example of the terminal prompts and replies when using the software is given in Appendix D(i). The prompts shown produced the two output files used as examples.

To complete the data aquisition procedure, a computer data file was constructed containing the details of every test in a matrix format. The file was named "ROADTEST.DATA" and is listed in Appendix C(i). In the matrix, each test was summarised by 10 rows (or route sections) of data, with each row containing 21 values identifying the test number, the vehicle, the driver, and the average measurements of vehicle motion and ambient conditions recorded for the particular route section.

For the rows describing the urban route sections, values of traffic flow were also given. A value of "zero" traffic flow was entered for all other route sections.

For a more detailed account of the contents of ROADTEST.DATA refer to the header-block text contained in the computer listing given in Appendix C(i).

CHAPTER 3

EXPERIMENTAL RESULTS

3.1. Vehicle fuel consumptions.

The initial comparisons of vehicle fuel consumption were carried out on the results collected during the main "Spring" test programme, with each vehicle completing 12 tests, two by each driver (Nos.1 to 6). Figure Nos.10 and 11 present the average fuel consumption and vehicle speeds measured over the following four main route sections:

3.1.1. Urban route section.

The urban route section used the data recorded from the two Urban Cycles completed in each test, i.e., mean values taken from a total of 24 Urban Cycles in each vehicle (Table No.8). Under these driving conditions, the diesel car used 22% less fuel than the 1300cc. petrol vehicle, and the 1300cc. petrol car used 9% less fuel than the 1600cc. petrol version.

Compared to the Government fuel consumption figures published by the motoring press (refer to Table No.1), all three vehicles returned a higher consumption figure (i.e., less miles per gallon) than might have been expected. The 1600cc. petrol, 1300cc. petrol and diesel vehicle urban fuel consumptions were respectively, 13%, 3% and 10% greater than the official figures.

Previous studies [6][15] showed that the average speed of a vehicle, in real traffic conditions, had a significant effect on the fuel consumption (a regression analysis of the relationship between average vehicle speed and fuel consumption is given in Section 3.4). Thus, to ascertain a true comparison of the three test vehicles, a collation of their corresponding average speeds was also required. Figure No.11 shows that under the urban traffic environment, the three vehicles had very similar overall average speeds, with a mean and "standard error" of 22·43Km/hr. and 0·43Km/hr., respectively. Hence, for this route section the fuel consumption measures shown on Figure No.10 give a true comparison between the urban fuel economy of each vehicle.

3.1.2. Suburban route section.

The suburban figures of fuel consumption and vehicle speed were averaged from two independent suburban sections completed during each test drive (Table No.9). As with the urban section, the average speeds of each car were virtually the same, with an overall mean of 46·68Km/hr. and "standard error" of only 0·30Km/hr. The fuel consumptions recorded under these driving conditions can thus be compared directly. The fuel saving of the diesel vehicle over its petrol counterpart was 17% (5% less than the saving achieved in the urban environment). A similar reduction in fuel economy advantage was observed for the lower-powered petrol car which was 7% more efficient than the 1600cc. model.

3.1.3. Motorway route section.

Over the motorway route section, the fuel consumptions of the vehicles were influenced less by the immediate traffic environment, and were more a result of the drivers' choice of cruising speed (Figure No.11 and Table No.10). The greater variability in average speed, compared to other sections, is shown by the higher "standard error" values for each car. It is interesting to note that the overall average speeds for the three vehicles seemed to relate closely to their respective performance figures (Table No.1), i.e., with the higher performance car returning the faster journey speed.

The diesel vehicle returned a fuel consumption 4% better than its equivalent 1300cc. petrol version which had an average speed 3% greater. The 1600cc. petrol vehicle used 12% more fuel than the lower-powered petrol car, which had an overall average speed 3% slower.

3.1.4. Overall route section.

As an overall comparison of the fuel consumptions of each vehicle, a 50/40/10% split of the data from the urban/suburban/motorway road types was conducted to relate to the annual mileage statistics of Great Britain for 1984 (Table No.3).

Over this "analytical" route section, the diesel was the most fuel-efficient vehicle with a mean fuel consumption 18·4% and 25·6% better than the 1300cc. and 1600cc. petrol cars, respectively. The 1300cc. petrol car obtained an overall fuel saving of 9%, compared to the 1600cc. version (refer to Table No.11).

The overall fuel consumption advantage of the diesel test vehicle was not as high as the 28% figure obtained in a previous study [6] using equivalent diesel and petrol cars. This shortfall could be explained by the variation of a number of factors during each set of tests i.e., traffic conditions, driver types and average weather conditions. It may further be a result of the vehicle types used for each comparison, with the diesel car in Weeks [6] being a more economical petrol-equivalent than the diesel vehicle used for this study. Alternatively, the 1300cc. petrol car tested in this report could be more economical (relative to its diesel version) than the petrol vehicle used by Weeks [6].

Whereas the diesel and petrol cars used by Weeks [6] had similar performances, the diesel car used in this study, compared to its petrol equivalent, was marginally underpowered. Thus, to accurately correlate the findings of this report to those of Weeks, a diesel car with a larger engine capacity (in the region of 1·8-2·0 litres), improved performance, and hence poorer fuel consumption than that used, should be envisaged. This would effectively reduce the comparitive fuel savings of the diesel vehicle over its petrol-engined equivalent concluded in this report, and thus increase the differential between the findings of Weeks [6] and this study.

Even under urban traffic conditions, the diesel fuel saving was less than the commonly accepted figure of 25% [4].

3.2. Driver performance.

The following section compares the performance of each driver (Nos. 1 to 6) during the main "Spring" test programme. All results presented are overall averages taken from the six tests completed by each driver, i.e., two in each vehicle. Refer to Table Nos.12 and 15.

3.2.1. Average fuel consumption and vehicle speed.

Figure Nos.12 and 13 show the average fuel consumption and average vehicle speed attained by the drivers over the four main route sections.

Under urban driving conditions, the average fuel consumption varied by ±7% from the mean value of 9·689 lit/100Km., yet the corresponding average speeds were very similar (except driver No.4 who consistently returned a higher average speed under all traffic environments). The effect of a drivers' behaviour on fuel consumption was illustrated by the results of driver No.5. She was the most fuel-efficient driver in the urban section with a fuel consumption 10% lower than the mean, yet her corresponding average speed was only 0·5% slower than the mean, for all drivers. Over the suburban and motorway sections, the rank order (with respect to fuel economy) of the drivers changed. Under these traffic environments, the average speed had a significant influence on fuel consumption, illustrated by the similarity between the two histograms. On the motorway section driver No.4 showed that with an average vehicle speed 23% greater than the mean of the other drivers, his returned fuel consumption was respectively, 40% higher than the mean of 8.692 lit/100Km.

For the overall (50/40/10% split) route section, the driver rank order, in decreasing fuel efficiency, was Nos.5, 3, 1, 2, 6 and 4. Although the position of driver No.4 was largely dictated by his higher than average vehicle speeds over all route sections, the relative performance of the drivers, especially in the urban driving conditions, was not directly related to their respective average speeds. Such a result was shown by driver No.5, who attained the lowest fuel consumption but did not have the lowest average speed in the urban environment.

To study more closely the drivers' performances and how their actions influenced the fuel consumption, four additional parameters describing average vehicle acceleration and deceleration, and the average position and "toe-down" acceleration of the throttle linkage (control rack linkage for the diesel vehicle), were analysed.

3.2.2. Average vehicle acceleration and deceleration.

Figure Nos.14 and 15 show the average vehicle accelerations and decelerations for each driver over the same four route sections. Both of these parameters are known to affect fuel consumption, especially in the urban environment where the vehicle often has to stop and accelerate from rest. Unnecessary deceleration of a vehicle with the application of brakes can increase fuel consumption because the motion energy of the vehicle is transformed primarily into heat energy, which in turn is released to the surroundings and cannot be reclaimed. With acceleration, however, the additional fuel energy used is not wasted but primarily transformed into kinetic energy of the vehicle. Although necessary, acceleration of a vehicle does increase the instantaneous fuel consumption at any particular speed. Studies on fuel-efficient strategies of vehicle acceleration, have shown that a doubling and halving of the acceleration and deceleration rates, can change the fuel consumption by 7% and -7%, respectively [19]. The study by Evans and Takasaki [14], noted in Section 1.3.2, has previously shown the effect acceleration levels can have on vehicle fuel economy. Laurell [25] concluded with his study of driver effects on fuel consumption that a "light foot" on the throttle pedal with minimum variation in vehicle speed will lead to a good fuel economy. Laurell also noted that low g-force decelerations conserved fuel, with least fuel being used when vehicle decelerated to desired speed in neutral. Though coasting in neutral is fuel-efficient it is not considered a safe practice in real traffic conditions.

In the urban environment driver No.4 returned average values of acceleration and deceleration 21·8% and 14·7% higher than the mean for all drivers, respectively. A 4% and 15·6% higher average fuel consumption and speed resulted. Driver No.5 however, obtained average acceleration and deceleration levels 13·8% and 2·5% lower than the mean, respectively. Although her corresponding fuel consumption was 11·4% lower than the mean of the other drivers, her average vehicle speed was similar.

Over the suburban route section, the relationship between these factors and fuel consumption was not so clear. Driver No.4 was again the most "aggressive" driver, with acceleration and deceleration levels 7% and 15% higher than the mean respectively; resulting in a fuel economy 14% poorer.

The motorway histograms of average acceleration and deceleration were very similar in profile to each other, and to the fuel consumption figures, implying that a direct relationship may exist between the three parameters, i.e., a decrease in average acceleration and/or deceleration leads to a proportional lowering of the fuel consumption. The overall levels of acceleration and deceleration were much lower (in magnitude) in this section because of the more "free-flowing" driving environment. The reader should note that the motorway route section did not include the initial acceleration and final deceleration of the vehicle on the slip-roads for "entry" and "exit" to the motorway.

3.2.3. Average throttle position and acceleration.

The effect a driver has on vehicle fuel economy has been the subject of a number of previous studies [11][15][20] which used measurements of average speed, acceleration and deceleration, etc., to describe vehicle motion in traffic. All of these parameters result primarily from the driver's operation of the throttle pedal of a car. To this effect, the average throttle motions of position and "toe-down" acceleration were measured for each driver over the four main route sections (refer to Figure Nos.16 and 17).

The throttle position in each vehicle was measured on a comparative scale of "degrees", representing the extent of throttle valve opening (petrol) or fuel rack setting (diesel). An increase in "degrees" implied an increase in power demand from the engine, with a degree value of zero inferring a "foot-off" position.

The conversion required to obtain "degree" values from the integer data output on channel 2 of the data logger tape, was performed by the computer software package "ROADTEST.FORTRAN".

The profile of the average throttle position histogram bears a close similarity to both the fuel consumption and vehicle speed histograms (Figure Nos.12 and 13, respectively), especially under the "free-flowing" environments of the suburban and motorway traffic conditions.

In urban conditions, driver No.4 recorded an average throttle position 25% greater than the mean, showing his inherent desire to attain a comparatively high average speed, resulting in a poor fuel economy. The corresponding acceleration of the throttle linkage by this driver measured 40% higher than the mean for all drivers, which could be considered a further implication of his "aggressiveness", or desire to obtain a relatively high vehicle speed. Driver No.5 achieved good fuel economy in urban traffic with an average throttle position and acceleration, 12% and 33% lower than the six-driver mean, respectively.

For the suburban route section, a direct comparison between average throttle position and fuel consumption existed (Figure Nos. 12 and 16). The average throttle accelerations under this driving environment showed two distinct groups of drivers; Nos.1, 4 and 6, and Nos.2, 3 and 5. Driver Nos.1, 4 and 6, who incidentally were the youngest participants of their respective sexes, drove the vehicles with a mean throttle acceleration 80% higher than the mean of the remaining drivers. Their average fuel consumptions, vehicle speeds and accelerations were similarly related to the mean values of driver Nos.2, 3 and 5.

Similar to the results observed for the parameters of average vehicle acceleration and deceleration, the measures of throttle position and acceleration obtained in the motorway section corresponded very closely (i.e., by driver rank order and profile of histogram) to the driver variations in average fuel consumption and vehicle speed.

It is of interest to note that the correlation between driver age and/or sex and high levels of throttle motion, or "aggressiveness" (resulting in poor fuel economy), observed in this study, was not noted by Claffey [21]; who, from a series of similar tests conducted on a 5·6Km. urban test route, concluded that the measures of fuel economy recorded, did not relate to a driver's age or sex. With reference to the urban section of this study (Figure No.12), the relationship between high fuel consumption and age (or sex) was certainly not as significant as that noted over the more "free-flowing" traffic conditions of the motorway and suburban sections. For the motorway and suburban route sections, the histograms on Figure Nos.12 to 16 show that the three youngest drivers recorded the three highest values for all six vehicle-motion parameters studied.

For all vehicle-motion parameters, the histogram results for the 50/40/10% route section were found to be of similar magnitude and profile to the suburban measures.

The reader should note, that for a more detailed account of the comparative behaviour of each driver, in each vehicle (i.e., parameter values averaged from two and not six tests), reference to Table Nos.17 to 28 should be made.

Though analysed separately, the vehicle-motion parameters discussed in the preceding sections are known to influence vehicle fuel economy both individually and interactively. To determine the significance* of the effect each parameter had on vehicle fuel consumption, the statistical techniques of "Factor Analysis", "Analysis of Covariance" and "Regression Analysis" were used on the test data contained in "ROADTEST.DATA". These statistical analyses are described in Chapter Nos.5 and 6.

3.3. Expert driver fuel consumption comparison.

With reference to Table No.16, under urban driving conditions the expert driver (No.7) returned an overall fuel consumption (averaged for all three vehicles) 9% less than the mean value for driver Nos.1 to 6, with an average speed 6% slower; a result similar to the findings of [10][11][12] and [13], previously referenced in Section 1.3.2. The parameters of average vehicle acceleration, deceleration, throttle position and acceleration, were correspondingly 9%, 14%, 21% and 36% less than the mean values of the other drivers.

Over the suburban route section a 10% fuel saving was achieved by the "expert", compared to driver Nos.1 to 6, with only a 1% decrease in average speed. The parameters of average vehicle acceleration, deceleration, throttle position and "toe-down" acceleration were respectively 14%, 11%, 14% and 38% less than the mean values of the other drivers.

On the motorway route section, the expert driver returned a fuel consumption 24% less than the mean of driver Nos.1 to 6, however, his average speed was 22% lower. Similar to the urban and suburban sections, the expert driver obtained comparative reductions of 28%, 24%, 37% and 56% in the mean values of vehicle acceleration, deceleration and throttle position and acceleration, respectively.

Comparing the vehicle performances, the expert driver achieved an overall (50/40/10% route split) fuel saving of 16% in the diesel vehicle, over its 1300cc. petrol counterpart. Further, the 1300cc. petrol car

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* Throughout this thesis the term "significance" is used in the statistical sense.

attained an overall fuel consumption 5% lower than its 1600cc. version.

To compare the behaviour of the expert driver with that of driver Nos.1 to 6, in each vehicle, the reader is referred to Table Nos.19 to 32, which give the vehicle-motion parameters of the expert driver for each vehicle and route section.

3.4. Regression of fuel consumption with average speed.

3.4.1. Regression for all route sections.

To study more closely the effect of average vehicle speed on the resulting average fuel consumption in the various traffic environments, the scatterplot shown by Figure No.18 was produced. The data plotted represents the corresponding average fuel consumption and vehicle speeds recorded for the four main route sections of each test conducted in the main "Spring" test programme. The spread of the data was due to three main reasons:

i) sectional fuel consumption variations due to the three different test vehicles,
ii) sectional average speed variations due to the six different test drivers, and,
iii) variation on the fuel consumption and average speed relationship due to the different traffic and weather conditions experienced throughout the test programme.

To extract the vehicle effect, Figure Nos.19, 20 and 21 were produced. On each plot a curve was employed to describe the distribution of the data. The curves for each vehicle were of similar shape and obtained by a detailed regression analysis, of the form "$fuel = a + b/s + c.s + d.s^2$", which was carried out on each data set [22].

The details of two regression equations used to fit the data are given in Table No.44. Regression equation No.1 was based on an original study of route section average fuel consumption of private cars by Everall [15]. On average, for the three vehicles, a total explained variance (quality of curve fit) of 78% was achieved by this equation, which only contained a reciprocal and squared term in average speed which increased the average explained variance to 82·5%. The improved fit of this equation to this type of data was previously noted by Weeks [6].

With respect to Table No.44, fuel consumption was measures in litres/100Km. and vehicle speed in Km/hr. The "standard error" and "F-values"* beneath each coefficient (in parentheses), denote the statistical significance or "confidence" in each of the coefficients calculated. Values are given for both regression models. All "F-values" were significant to the 1% confidence level, except the "reciprocal of speed" terms for the 1300cc. petrol and diesel vehicle in Regression No.2: these were, however, significantly different from zero.

Figure No.22 compares the speed regression curves for each vehicle. The diagram shows that for each vehicle the minimum fuel consumption was obtained when the average sectional speed was between 60 and 80 Km/hr. Though no data points existed in this speed range, confidence in the shape of the regression curves was gained from the studies by Weeks [6] and Everall [15] which illustrated similar results. Weeks noted a minimum sectional fuel consumption between a sectional average speed range of 60 to 90Km/hr. Everall observed a sectional average speed range of 50 to 70Km/hr. for optimum fuel economy.

The effect of measuring sectional average speed from an "on-road" environment compared to an "off-road" (constant speed) environment was shown by the results concluded by Laurell [25]. He noted a minimum fuel consumption speed range of 40 to 50Km/hr., for a vehicle in top gear. This implied that in real traffic conditions a vehicle must attain an average speed approximately 50% higher than its "off-road" constant speed, for minimum fuel consumption.

With respect to Figure No.22, as the average speed increased from the urban traffic environment (between 18 and 25Km/hr.) to the suburban driving conditions (up to 60Km/hr.), the fuel economy of each vehicle improved. Over the same speed range the fuel advantage

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* Refer to Section 5.2.2 for an explanation of the statistical terms "F-value" and "confidence level".

of the diesel over its petrol counterpart gradually decreased as the speed increased.

The fuel saving of the 1300cc. petrol vehicle over its 1600cc. petrol car remained virtually constant in the speed range of 20 to 40Km/hr. As the average speed increased beyond approximately 40Km/hr., the fuel advantage of the 1300cc. petrol vehicle became greater, reaching a maximum at about an average vehicle speed of 90Km/hr.

On route sections where the average vehicle speed was greater than 80Km/hr., typical of motorway driving, the regression curves of all vehicles on Figure No.22 resembled the typical constant speed relationships of fuel consumption with average speed. Over this speed range the diesel vehicle was shown to have no distinct fuel advantage over its petrol counterpart. In addition, the fuel economy advantage of the 1300cc. petrol over its 1600cc. version decreased as the cruising speed increased. With all vehicles, an increase in motorway speed produced a proportional increase in fuel consumption.

3.4.2. Linear regression of urban and suburban section data.

For a closer examination of the speed-fuel relationship, Figure Nos.23 and 24 show the two distinct portions (above and below the speed range for minimum fuel consumption) of the regression curves. Over the speed range given by Figure No.23 (20 to 60Km/hr.) the main feature was the scatter of data. This was, in part, explained by the variability of the road conditions experienced in the urban and suburban sections of each test drive, i.e., traffic signals, roundabouts, parked vehicles, day of week and time of day fluctuations in traffic congestion, and variations in the weather. The use of six test drivers also contributed to the scatter, with each obtaining a different fuel consumption for similar average speeds, and vice versa.

To describe the properties of each vehicle over this lower speed range, a relationship developed by Chang et al [23] was used. Namely;

$$F = {}^{1}/_{E'} = A + {}^{B}/_{V}$$

where:

F is the average fuel consumption (litres/100Km.),

E' is the average fuel consumption gain (100Km./litre),

V is the average speed (Km/hr.),

and A & B are constants with units of litres/100Km. and litres/100hrs., respectively.

The authors of [23] noted that the constant "A" and "B" terms were proportional to vehicle mass and idle fuel flowrate, respectively.

The equation coefficients for each vehicle, with a measure of statistical confidence, are given in Table No.45. Compared to the regression expression used for Figure Nos.19 to 22, the linear relationships achieved an average (all vehicles) *explained variance* of 83·24% (0·8% higher).

The constant "A" terms for the two petrol cars (4·552 and 4·147 for the 1600cc. and 1300cc., respectively) were found to correspond closely with their comparative masses (Table No.1), i.e., in a ratio of ∿1·08:1. Additionally, as noted by Chang [23], the "B" coefficients for each vehicle seemed to be indicative of the respective idling fuel efficiencies (i.e., the diesel lowest and the 1600cc. petrol vehicle highest). A report by Pearce et al [24] showed that in the fully warmed up condition a diesel engine idling will use, comparatively, 15% less fuel than a petrol engine.

By taking a difference between two of the linear expressions, the speed dependence of the relative fuel economy between each pair of vehicles was obtained. For example, comparing the diesel and 1300cc. petrol vehicle:

$$\Delta F_d = \underbrace{(4{\cdot}15 + 131{\cdot}44/_V)}_{\textit{1300 petrol}} - \underbrace{(3{\cdot}99 + 85{\cdot}84/_V)}_{\textit{1600 diesel}} \simeq \underbrace{\underline{0{\cdot}16 + 45{\cdot}6/_V}}_{\textit{"saving"}}$$

where, ΔF_d is the positive fuel saving (litres/100Km.) achieved by the diesel vehicle. This expression only remains true for average speeds less than 60Km/hr.

A similar relationship for the fuel consumption advantage of the 1300cc. petrol car over its 1600cc. counterpart was:

$$\Delta F_p = \underset{\text{1600 petrol}}{(4{\cdot}55 + 139{\cdot}07/_V)} - \underset{\text{1300 petrol}}{(4{\cdot}15 + 131{\cdot}44/_V)} = \underset{\text{"saving"}}{\underline{0{\cdot}40 + 7{\cdot}63/_V}}$$

where, ΔF_p is the fuel consumption saving of the 1300cc. car in litres/100Km.

For each expression the constant "A" term indicated the datum (i.e., independent of speed) fuel saving between vehicles. It is of interest to note that by omitting the speed term, the constant value related directly to the idling advantage of a particular vehicle, e.g., the 0·16 value for the diesel saving corresponded very closely with the 15% figure noted by Pearce et al [24].

The "B" coefficients indicated both the magnitude and rate of decrease in comparative fuel savings as a function of vehicle speed; i.e., 45·6 and 7·63 litres/100hrs. for the "diesel/petrol" and "petrol/petrol" comparisons respectively; suggesting that variations in average speed (below 60Km/hr.) had a greater influence on the fuel advantage of the diesel vehicle over the 1300cc. petrol, than the fuel consumption difference between the two petrol cars. This observation was also illustrated by Figure No.22, obtained from the regression analyses of Section 3.4.1.

3.4.3. Linear regression of motorway section data.

Figure No.24 shows the fuel consumption data for average speeds greater than 80Km/hr. (i.e., motorway section results). The scatter of data points was less prominent due to the lessening effect of traffic congestion on vehicle motion and the omission of road obstructions (e.g., junctions, traffic lights, etc.). As with the urban and suburban data, the characteristics of each vehicle were described by linear expressions; given in Table No.45. The average explained variance was 76·58% compared to the 82·5% explained by the regression curves of Figure No.22.

The respective fuel savings between each pair of vehicles were:

$$\Delta F_d = \underset{\text{1300 petrol}}{(20{\cdot}13 - 1290{\cdot}09/_V)} - \underset{\text{1600 diesel}}{(117{\cdot}78 - 1033{\cdot}83/_V)} = \underset{\text{"saving"}}{\underline{2{\cdot}35 - 256{\cdot}26/_V}}$$

and,

$$\Delta F_p = (25{\cdot}65 - 1814{\cdot}60/_V) - (20{\cdot}13 - 1290{\cdot}09/_V) = \underline{5{\cdot}52 - 524{\cdot}51}/_V$$

1600 petrol 1300 petrol "saving"

where, ΔF_d and ΔF_p are in units of litres/100Km.

Similar to the speed range of the urban and suburban data (below 60Km/hr.), the coefficients of "A" and "B" for all vehicles related closely to the comparative vehicle masses and idling fuel flowrates.

First, with respect to the above expressions, it can be seen that for the greater average speeds of the motorway section, the "datum-line" difference in fuel consumption for the "petrol/petrol" comparison (neglect of vehicle speed variations), was more significant than the "diesel/petrol" comparison; shown by the respective "A" coefficients of 5·52 and 2·35. Further, variations in average speed had a greater effect on the "petrol/petrol" fuel consumption differential "ΔF_p" than on the "diesel/petrol" fuel comparison "ΔF_d", shown by the respective "B" coefficients of -524·51 and -256·26. For both comparisons the negative "B" values implied that an increase in average speed decreased the differential fuel savings between pairs of vehicles; an observation previously noted from Figure No.22.

CHAPTER 4

ENERGY SAVINGS

4.1. Fuel consumption: units of measure.

During the course of this thesis the fuel consumption of each vehicle was measured by volume of fuel per unit distance (litres/100Km.). For the motorist this choice of unit is ideal, both as a comparative measure of vehicle fuel economy, and as a direct measure of the differential fuel running costs between vehicle types, when based on an individuals annual mileage. On a national level however, interest in fuel conservation lies with possible savings in primary energy, not comparative savings between refined fuels.

Both petrol and diesel fuels are refined from natural crude oil and although their respective production costs can fluctuate, due to variations in the quality of the oil used and the grade of petrol fuel produced, on average three times more primary energy is consumed to produce petrol (by volume) than diesel fuel [6]. Further, the density and energy content of diesel fuel are approximately 12% and 9% greater than petroleum, respectively.

Accounting for the higher "energy density" of diesel fuel and its relatively low production costs when compared to petrol, the factor calculated to convert the vehicle fuel consumption figures (litres/100Km.) into units denoting primary energy savings was near to unity [26][27]. Hence, the fuel consumption figures presented throughout this section are applicable to both individual "petroleum" and national "primary" energy savings.

4.2. Vehicle fuel comparison for the motorist.

To compare the total running costs of the three test vehicles and the savings made by a driver between two particular cars, a number of factors have to be accounted for;

Annual mileage	- comparative fuel savings between vehicles will be greater for higher annual mileages,
Road class mix	- fuel consumption characteristics of each vehicle depend on the traffic environment, hence, the chosen proportion of various road classes used for the analysis will affect the comparative annual fuel savings,

Driver "type" - driver behaviour not only affects the total fuel consumption of a vehicle, but can also affect the comparative fuel consumption characteristics between vehicles,

Vehicle maintenance - variations in repair and servicing costs for each vehicle affect differential running costs,

Standing charges - insurance, depreciation, car licence, and interest lost on capital investment all contribute to standing charges, which both add to total annual running costs, and "weight" the fuel savings achieved between vehicle types,

Running costs - fuel and oil consumption, tyre wear, repairs and servicing all contribute to total vehicle cost. These quantities are usually denoted as costs per unit distance.

It should be noted that the monetary figures presented in this section, particularly those representing the annual total costs for each driver, are used only to provide a comparative measure to indicate cost variations between vehicle types, by themselves they have no great intrinsic value.

4.2.1. Comparison of vehicle operation costs for each driver.

As a guide to the typical annual fuel savings between the three test vehicles, all seven test drivers were used to represent different driver types. Table No.46 shows the differential fuel savings of the diesel vehicle over the 1300cc. petrol, and the 1300cc. petrol over the 1600cc. petrol (in parentheses) for each route section. Note the steady reduction in the diesel fuel consumption advantage for all drivers, as the traffic environment changes from the urban, to suburban, to motorway route sections; i.e., with increasing average speed.

Assuming that each driver completes a similar annual road class mix to the national figures (50/40/10% - urban/suburban/ motorway) and using estimates of their annual mileages (Table No.2), obtained from driver questionnaires completed during the test programme (Appendix F(ii)), the annual fuel savings (by volume) achieved by individual drivers, for both vehicle comparisons, were calculated. Monetary fuel savings between the diesel and 1300cc. petrol vehicles were calculated for each driver using their overall fuel consumption in each vehicle, the estimate of their annual mileage and the average prices of petrol and derv for 1984 [1]. Note the influence of a high annual mileage on the differential fuel savings for both pairs of vehicles (driver No.4 with a high mileage obtained high fuel savings, and driver No.6 with a low mileage achieved comparatively low fuel savings).

Table No.47 gives estimated standing and running charges for each of the test vehicles [28], based on 1984 prices. Insurance costs were based on average premium figures for Class 1 policies in Area B (rural and semi-rural counties) with no loadings or discounts [29]. The 1300cc. petrol and diesel vehicles were insurance Group 3 and the 1600cc. petrol was either Group 3 or 4. Depreciation costs were based on the new purchase price of each vehicle in 1984 and the money lost if sold a year later. Prices of new 1983 model Cavaliers and their used prices in 1985 [30], indicated that over a two year period 37·5% of their original cost was lost. Half this figure was used to estimate the depreciation of each car during 1984. Vehicle parking, and garaging was based on the £3.00 per week estimate used by the Automobile Association [28].

For total standing charges (per annum), the 1600cc. petrol and diesel vehicles were 15.4% and 18.4% more expensive than the 1300cc. vehicle, respectively. With regard to the running costs, fuel used was calculated from the overall (50/40/10% road class mix) fuel consumption figures of each vehicle, annual travel of 15,000Km. and 1984 fuel prices [1]; the lubricating oil figures accounted for the annual consumption and replacement, averaged for a vehicles' life; tyre cost was based on an estimated life of 50,000Km. with annual travel of 15,000Km.; and the annual servicing and repair costs were based on the manufacturers' recommendations of estimated maintenance required over a 150,000Km. vehicle life. Per kilometre, the diesel vehicle was found to have a running cost 7.9% less than that of its equivalent 1300cc. petrol version. An 11·7% difference occurred between the two petrol cars, in favour of the 1300cc. model.

Based on the average fuel consumptions (for all drivers) and a standard annual travel of 15,000Km. the total costs, "standing" and "running", were calculated "per kilometre" for each vehicle. Using this measure the 1600cc. petrol and diesel cars were found to be 13·9% and 7·8% more expensive to run that the 1300cc. petrol car, respectively.

To account for different driver types and their respective variations in annual mileage and fuel economy in each vehicle, Table No.48 and Figure No.26 were constructed. The difference in standing charges for each vehicle comparison were used for all drivers. The comparative running cost savings (not including the fuel costs) for individual drivers, were based on the estimated annual mileage of each driver and the "cost per kilometre" of each vehicle from Table No.47. The overall annual operating cost comparisons for each driver were obtained using the above figures from Table No.48 and the annual fuel cost savings from Table No.46.

With regard to the figures at the bottom of Table No.48, only one driver was shown to benefit from using the diesel vehicle (to the 1300cc. petrol), namely driver No.4. The estimated annual saving of £122.29 achieved, was due mainly to his significantly higher annual mileage and hence fuel saving, which outbalanced the additional £281.16 in standing charges.

Figure No.26 shows the differential "total" and "fuel" cost savings for the two comparisons plotted against annual driving distance. Straight lines were used to link the data points of all the drivers, denoted by their corresponding test number. The "break-even" mileage for the total operating costs of the diesel car, compared to its petrol-engined equivalent was approximately 27,500 miles (45,000Km.). With respect to the results of driver Nos.1 to 6, the relationships plotted on Figure No.26 implied that as annual mileage increased, the savings acquired from each comparison also increased. However, the results of the expert driver (No.7) produced a significant "flat" in the general linear trend of each comparison, implying that a more economical driver would require a greater annual mileage to achieve the same comparative savings as a less economical driver. This observation was investigated further in the following section.

Note that the two "fuel cost" relationships pass through the origin at zero annual mileage, and the "total cost" expressions intersect the monetary axis at the differential standing charges. For both comparisons the gradients of the "fuel costs" were steeper than those of "total cost" indicating the increasing significance of fuel cost savings with higher annual mileages.

Only driver No.4 achieved a cost saving with the diesel vehicle over the 1300cc. petrol car because of his estimated annual mileage. All drivers showed a lower overall cost with the 1300cc. petrol car compared to the 1600cc. model, with the magnitude of saving similarly influenced by annual mileage.

4.2.2. Cost comparisons for a range of driver "types" and annual travel.

Using a similar approach to the analysis used in Section 4.2.1, Figure Nos.27 to 34 were produced. Rather than compare annual vehicle operating costs for a finite set of drivers, each with a particular annual mileage, the three-dimensional surface plots presented in this section enable any permutation of driver "type" and annual mileage to be studied. Each plot has three scaled axes X, Y and Z, used to represent the following quantities:

X-axis - annual distance travelled from 0 to 50,000 kilometres
Y-axis - relative driver fuel economy driver (scaled 0 to 1)
Z-axis - annual comparative cost saving in pounds.

The measure of relative driver fuel economy was calculated in the following manner. First, for each pair of vehicles and route section, a measure of "overall average fuel consumption" for each test driver was found by taking a mean of the sectional fuel consumptions obtained by the individual driver in the four tests he/she completed with both vehicles. Then, for each vehicle comparison and route section, the driver with the lowest overall average fuel consumption was given a rating of "0" and the driver with the highest average fuel consumption was rated at "1". In the majority of analyses the former was driver No.7 and the latter, driver No.4. The remaining five drivers were then rated on a linear scale of 0 to 1 with respect to their own overall average fuel economy. Thus, for each plot shown in Figure Nos.27 to 34, an increment along the Y-axis represents a reduction in relative driver fuel economy, or alternatively, an increase in a representative measure of driver "aggressiveness".

The measure of annual cost saving given along the Z-axis of each plot represents either the comparative saving with the diesel car over the 1300cc. petrol version (Figure Nos.27 to 30), or the comparative saving with the 1300cc. petrol car over the 1600cc. petrol car (Figure Nos.31 to 34). Note that for all route sections and driver "types", at zero annual travel (x=0) the monetary savings represent the differential standing charges of -£281.16 and +£235.50 for the "diesel/petrol" and "petrol/petrol" comparisons, respectively.

The smooth surface plots for each comparison were obtained by calculating cost savings for each of the seven drivers at intervals of 1000Kms., giving a total of 350 data points. Using interpolation techniques, a "bicubic patch" was fitted at each data point giving a total of 50x50 segments to represent the surface. The interpolation routine used for the analyses effectively smoothed the data to give the visually flat figures shown on Figure Nos.27 to 34. This effect was especially significant with the relationship of driver "type" to annual cost savings (lines parallel to the Y-axis), which were initially only represented by seven datum points.

i) <u>Diesel/Petrol cost comparison.</u>

Figure No.27 shows the "diesel/petrol" comparison for annual travel on purely <u>urban</u> road types. With all driver "types", an increase in annual travel increased the comparative running cost savings made by the diesel vehicle, thus reducing the initial difference in vehicle standing charges. By 50,000Kms. all drivers were shown to obtain an annual saving in total operating costs. Further, the surface of the plot also implied that as the driver became less fuel-efficient (as Y-values increased), the comparative running cost advantage of the diesel car improved. Hence, whilst the most economical driver achieved a saving of £12.80 with the diesel car, over an annual distance of 50,000Kms., the respective saving by the most "aggressive", fuel-inefficient, driver was £175.15. A result similar to this was previously noted in Section 4.2.1 with the expert driver in Figure No.26. The lowest annual distance required to "break-even" with the diesel vehicle, under purely urban traffic conditions, was approximately 27,500Km.

Figure No.28 shows the same vehicle comparison over purely suburban road types. As with the above study for urban conditions, increases in either annual travel or driver "aggressiveness" improved the relative cost of the diesel vehicle. However, under the more "free-flowing" environment of suburban driving there was a significant decrease in the effect of annual travel on the running cost savings of the diesel vehicle. Again, this was probably due to the small differential in average fuel consumption between the diesel and 1300cc. petrol cars over this route section; previously shown by the regression equations in Section 3.4.1 and Figure No.22. Additionally, the effect of driver "type" on comparative operating costs was greater than that observed for urban driving. Because of the changes in the effect of driver "type" and annual travel on the cost comparison, only the most "aggressive" driver achieved a saving with the diesel vehicle (£2.82), after 50,000Km. of suburban driving. The remaining, more fuel efficient, drivers all obtained overall operating cost savings with the 1300cc. petrol car, with the most economic obtaining a saving of £221.66.

Figure No.29 shows the motorway section cost comparison. Although annual travel effected the comparative cost between the diesel and petrol cars, the direction of its "effect" appeared to be determined by driver type. Whereas the more "aggressive" driver benefited from greater annual travel in the diesel vehicle, the most economic driver did not. As shown previously by Figure No.22, the motorway section fuel consumption advantage of the diesel vehicle, compared to its petrol equivalent, was negligible, hence, over the range of annual travel given, no driver was able to achieve a comparative annual saving with the diesel vehicle. With an annual travel of 50,000Km. losses of £107.75 and £368.67 were obtained by the least and most fuel efficient drivers, respectively. Because of the constant speed traffic environment of the motorway section, the variation in driver "type" related primarily to each driver's choice of average speed, rather than to his/her ability to drive economically. The "fluctuation" in the surface was probably due to the approximate measure used to denote driver "aggressiveness" for the analyses, and the negligible difference in the average fuel consumption of the two vehicles.

Figure No.30 shows the surface plot of the "diesel/petrol" annual cost comparison for the overall route section representing a 50/40/10%

mix of urban/suburban/motorway travel. Similar to the urban and suburban plots (Figure Nos.27 and 28) the running cost advantage of the diesel was enhanced by increases in either annual travel or driver "aggressiveness". For an annual travel of 50,000Km. only the three highest ranked (least fuel-efficient) drivers, Nos.4, 1, and 2, obtained overall annual savings of £76.39, £54.12, and £0.72 respectively, with the diesel vehicle. At the same annual 50,000Km. distance the most fuel-efficient driver (No.7) acquired a loss of £83.47 with the diesel vehicle when compared to its petrol equivalent. By extrapolating the plot along the X-Z plane at y=0, this driver would "break-even" with the diesel at an annual travel of approximately 75,000Km. (45,000miles). The corresponding "break-even" distance for the most "aggressive" driver (No.4) was 40,000Km. (25,000miles).

The Transport Statistics of Great Britain [1] informed that the average annual distance travelled in 1984 by private car owners was 14,000Km. Over this distance the overall (50/40/10%) "diesel/petrol" cost differential for the range of driver types was between -£181.05 and -£226.15, with an average of -£207.30. Thus, assuming that the range of drivers was representative of the national proportion of driver "types", on average a motorist using the diesel vehicle instead of its 1300cc. petrol version would save approximately £73.86 per annum on running costs, but, because of the additional £281.16 annual standing charge, would have an overall operating cost £207.30 higher.

ii) Petrol/Petrol cost comparison.

The surface plots shown by Figure Nos.31 to 34 give the annual cost comparison for the 1600cc. and 1300cc. petrol cars, when the annual travel is completed on road classes defined by the four main route sections. Similar to the results of the "diesel/petrol" comparison, in all route sections, an increase in annual travel and/or driver "aggressiveness" improved the cost differential of the more fuel-efficient 1300cc. vehicle.

Referring to Figure No.22 (Section 3.4.1), which shows the "speed-fuel" regression curves for each vehicle, the maximum differential in the average fuel consumptions of the two petrol cars occured on the motorway section where average speeds were in excess of 80Km/hr. As a result, the maximum cost savings with the 1300cc. vehicle, for all driver types, were obtained when the annual travel was defined as purely motorway driving (Figure No.33). For an annual distance of 50,000Km. the "motorway" savings ranged from £513.85 to £959.94, for the most efficient, to the most "aggressive" driver, respectively.

Under purely urban driving conditions, where the fuel consumption characteristics of the two petrol vehicles are known to be almost identical (Figure No.22), a "fluctuation" in the surface plot shown by Figure No.31 was present. A result similar to this occurred with the "diesel/petrol" comparison on purely motorway road types. The occurance of these "fluctuations" in the surface plots was probably due to the computer graphics software being too sensitive to small variations in the test data.

Though not visible from Figure No.33, the driver who achieved the highest comparative saving on the motorway section (£959.94 at 50,000Km.), with the lower-powered vehicle, was driver No.6 who was rated as the second most "aggressive" driver with a Y-value of 0·883. Similar results were found with the surface plots representing annual travel of purely suburban and the overall 50/40/10% road class mix (Figure Nos.32 and 34). In both analyses the driver with the highest comparative saving was the second most "aggressive" driver, who incidently was driver No.6 in both cases, with effective savings of £667.26 and £826.72 for the suburban and 50/40/10% road types respectively, when using the 1300cc. petrol car.

4.3. Overview of diesel running costs.

At the time of writing, the fuel cost saving achieved with the diesel car was greatly outweighed by the comparatively high standing charge of the diesel vehicle over its 1300cc. petrol version, due mainly to the additional capital investment. To alleviate this problem, a number of European countries, in recent years, have offered a reduced road tax for diesel cars, thus decreasing the purchase price differential [31].

Excise duty on diesel is marginally lower than that on petrol: during the 1980's the prices charged at the pumps have been within a few pence. Reintroduction of a marked price differential here would significantly reduce the "break-even" mileage of the diesel car.

In conclusion, it was found that only high annual travel (above 40,000Km.) would produce an annual cost benefit in the diesel vehicle over its petrol counterpart. Within a more congested traffic environment of urban driving, the "break-even" point was reduced to approximately 27,500Km. per annum. Further, the "break-even" annual distance was influenced by a driver's relative fuel economy, with a more fuel-efficient driver requiring greater annual travel to achieve the same comparative cost savings in the diesel vehicle as that of a more "aggressive" driver. A similar observation was made with the fuel saving obtained by using the 1300cc. petrol car relative to its 1600cc. version.

4.4. National energy savings.

In this section an estimation of the national fuel saving is given with respect to the introduction of diesel private cars to the transport sector. In order to perform the necessary calculations a number of assumptions were taken:

i) the mean vehicle fuel consumptions, using all test drivers, was assumed representative of the national average in each vehicle, i.e., each test driver represented specific "driver types" (six in total) who exist nationally in the same identical proportions;

ii) each test driver (driver "type") completed the same national annual mileage over the same road class mix; and,

iii) the fuel advantage of the Vauxhall Cavalier 1600cc. diesel vehicle, over its 1300cc. petrol counterpart, was representative of the fuel savings achieved if each "on-road" petrol vehicle was substituted with its diesel equivalent (i.e., model and performance).

Though necessary for the analyses, the assumptions noted above are quite unrealistic. It is virtually an impossible task to categorise a complete range of driver "types"; the six drivers used for this study can only summount to a small representation of the total variation. It may also be the case that driver "types" (in relation to fuel economy) have no relation to the classification used in this report defining their age or sex. Particular traits of a drivers personality, driving knowledge (measurable from detailed questionnaires) or even physical agility may give better correlations with driver performance.

Further, the assumption that all petrol vehicles could be replaced by diesel equivalents has a number of limitations. Firstly, only a relatively small number of diesel variants are offered by manufacturers at present, secondly, the initial replacement costs for consumers would be high and thus reduce the sales of new diesel vehicles, and finally, the transport sector will always contain a very high proportion of second-hand petrol vehicles.

For the five-year period (1980-1984), Table No.49 shows the national road travel for the three distinct traffic environments of urban, suburban and motorway driving. Using the average (all drivers) fuel consumptions of each vehicle, over each road type, a national annual fuel consumption was calculated, representing the fuel used if the particular test vehicle typified the average private car. The national fuel savings (by litres of petroleum and "pump" costs) created by comparing two vehicles, if each type was used nationally, were calculated. For both the "diesel/petrol" and the "petrol"petrol" comparisons, the cost differentials steadily increased over the five-year period 1980-1984, this was due mainly to the subsequent rise in national annual mileage.

The national implication of substituting all private cars (and taxis) with their equivalent diesel vehicles is shown by Figure No.25. For the period 1980-1984, a mean annual fuel saving of 2·44 million tonnes would have been obtained, representing a 4·6% saving on total petroleum consumption in the United Kingdom, and a 9·6% saving on the petroleum consumption in the transport sector of the United Kingdom*.

Extrapolation of Figure No.25 would suggest that the future fuel savings created by the introduction of diesel cars are unlikely to change. The future monetary savings for the motoring community will depend significantly on the future price differentials of petrol and diesel fuels at the pumps.

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* No account was taken of the private diesel cars already in use on the national road network; approximately 1% - 2% (rising) for period shown.

CHAPTER 5

STATISTICAL ANALYSIS OF TEST RESULTS

5.1. Factor Analysis of effects on fuel consumption.

Factor Analysis is not a single statistical technique for data reduction. Its concept covers a variety of analytical procedures, which must be custom-suited to the study at hand. The statistical methods used for Factor Analysis are of a complex nature, and as a consequence, the brief explanatory notes given in this section may be misleading if taken verbatim. The reader is therefore advised to consult other standard texts, which treat the subject of this section in more detail [32][33].

Given an array of correlation coefficients* for a set of parameters, Factor Analysis will provide an indication of underlying relationships that may exist within the data set. The "raw" data may then be reduced or rearranged to a smaller set of factors (components) that exhibit the same interrelations between the data variables. For the purposes of this study, Factor Analysis was employed on two counts; firstly, to measure the association between various vehicle and environmental variables with vehicle fuel consumption, and secondly, to indicate the combination of the variables that best explains the measure of vehicle fuel consumption, for a particular vehicle and route section.

5.1.1. Statistical procedure.

Factor Analysis is a statistical technique used to investigate the relationship between "metric" (physically measured) quantities. The vehicle and driver codes adopted in this report (Table Nos.1 and 2) were not indicative of any fundamental relationship between the members of each variable, and as a result both "non-metric" variables were omitted from the Factor Analysis procedure. The effect of these parameters on fuel consumption variation was studied using an

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*Correlation coefficients (usually represented within a matrix) indicate the degree to which variation in one variable is related to variation in another. The value not only summarises the strength (with respect to unity) and direction (-ve or +ve "gradient") of association between a pair of variables, it also provides a measure of association between two pairs of variables.

alternative statistical technique called the "Analysis of Covariance"; described in Section 5.2.

The tests completed by driver No.3 in the diesel vehicle were chosen for the analysis; i.e., a total of six tests; two from the main test programme and four from the subsidiary test programme. Hence, the driver and vehicle variables were controlled. The choice of these tests also provided a significant variation in ambient conditions within the data set.

To account for any effects different traffic conditions may have had on the interrelations between variables, three independent Factor Analyses were completed for each type of road class, using data from the urban, suburban and motorway route sections.

In general the Factor Analysis procedure had three distinct steps:

i) <u>Formation of the Correlation Matrix.</u>

This is the foundation for the statistical procedure describing the principal relationship between each pair of test variables. A correlation matrix was produced for the data set of each route section studied (Table Nos.50, 52 and 54).

ii) <u>Formation of New Factors.</u>

Data reduction possibilities are resolved by the creation of new variables called "factors", deduced from "observed" sources of variation (i.e., via statistical algorithms) within the structure of the data. Note that if the factors are defined by mathematical transformations of the original data, similar to regression analysis, then the technique is known as "principal-component" analysis.

iii) <u>Rotation.</u>

Having established a set of factors, there are many equivalent ways to structure them statistically - their configuration is not unique. An option exists, therefore, to "tune" the factors to simpler, more meaningful patterns. This option is known as "rotation". The Factor Analyses conducted in this report used "Varimax" rotation, which endeavours to simplify the columns of a factor matrix. The contents of each column describe how the test variables associate with the structure of a particular factor.

Output from the analyses of steps (ii) and (iii) are given for each route section in the form of a factor matrix with an associated list of eigenvalues (Table Nos.51, 53 and 55). The eigenvalues are calculated from "summing the squares" of the entries in each column of the factor matrix. The values obtained give a relative measure of the total explained variance (of the data analysed) achieved by each factor. The implication of these values are described by example in the following section.

5.1.2. Results of Factor Analysis.

For each analysis fourteen parameters were used to "explain" the variation of the subjective variable fuel consumption. Namely: average vehicle speed, acceleration and deceleration; throttle position, "toe-down" velocity and acceleration; frequency of gear change; average engine speed, fuel flow, fuel and engine oil temperatures; and the ambient temperature, pressure and humidity. For explanation of the variable notation used refer to Notation, page No.1.

i) Urban fuel consumption.

Table Nos.50 and 51 list the Factor Analysis results for the test data collected with the 1600cc. diesel vehicle in urban driving conditions. Summarising by reference to the correlation matrix in Table No.50 (note the main diagonal entries of unity), the top entry of each column shows the association between each variable and the resulting fuel consumption. Average speed had a significant effect on fuel consumption with a value of approximately -0·75. Its association was negative, implying that as average speed increased the fuel consumption decreased. This result has previously been observed by regression analyses of fuel consumption and vehicle speed in congested traffic - Section 3.4. (Figure No.22) and by [6][15].

Variations in ambient temperature ("TAMB"), and the subsequent changes in fuel and oil temperatures ("TFUEL" and "TOIL") all showed similar associations with fuel consumption. Their respective coefficients of -0·48, -0·46 and -0·51 all inferred that warmer ambient conditions improve fuel consumption (more miles per gallon).

The correlation coefficient of average engine speed ("REVS") was also shown to be positively associated with fuel consumption with a value of 0·34. Thus a high average engine speed, implicit of late gear changing and comparitively high vehicle speeds, resulted in a poorer fuel economy.

Digressing briefly from the association of the variables with fuel consumption, it is of interest to note the interrelations existing between other variables in the matrix. An increase in average vehicle acceleration ("VACC") was associated with an increase in vehicle speed with a coefficient of 0·57. A higher level of acceleration was also correlated with an increase in average throttle opening ("TPOS") and a resulting increase in fuel flowrate ("FLOW"), with coefficients of 0·74 and 0·81 respectively.

Note that the frequency of gear changing ("GEAR") was virtually uncorrelated with average vehicle acceleration and deceleration levels and fuel consumption, with coefficients of -0·07, 0·09 and -0·09 respectively. Average vehicle deceleration showed a significant correlation with fuel flowrate, with a coefficient of -0·5. Although the association is of a negative sign, fuel consumption will increase with higher levels of deceleration (positive association) because the measures of deceleration were input as negative values (refer to Appendix C(i)). The parameters of average throttle position, velocity and acceleration were all highly correlated with each other, implying for example that if a driver recorded a relatively high throttle position (high engine power demand) his/her motion of the throttle pedal was also distinctly faster and more impulsive. Further, the three throttle parameters were all highly correlated with average engine speed, vehicle speed, vehicle acceleration and deceleration, and fuel flowrate, with the respective coefficients all inferring "positive" associations.

With reference to Table No.51, a total of fifteen factors (equal to the number of variables, including fuel consumption) were formulated from the data. A measure of the statistical significance of each factor was given by their respective explained variances ("PCT OF VAR"). The first five factors in total explained 92·7% variance of the data set, thus the remaining insignificant factors (Nos.6 to 15) could be omitted from the analysis as their information was, in a sense, redundant. A common guide used to determine whether a factor contributes significantly to explaining the total variation of the data set, is to observe its associated eigenvalue. If the value is less than unity, the factor can be regarded as insignificant. Note that Σ eigenvalues = number of factors, and for each factor, explained variance (%) = eigenvalue/number of factors.

With respect to the factor matrix at the base of Table No.51, the loadings given in each row represent the regression coefficients associated with each factor to describe a given variable. Hence, in essence, the five columns present the structure of five factors (or hypothetical constructs), as yet unnamed and unquantifiable in terms of dimensions, and the numbers in each row represent regression weights. Thus the basic factor postulate is:

$$V_i = a_{i1}F_1 + a_{i2}F_2 + a_{i3}F_3 + a_{i4}F_4 + a_{i5}F_5 + d_iU_i$$

where, V = subject variable,
F = factor (index denotes column number),
a,d = regression weights,
i = row number,
and, U = unique (error) factor.

Hence, the expression for fuel consumption was given by:

$$\text{FUEL} = 0{\cdot}09513F_1 - 0{\cdot}77023F_2 - 0{\cdot}34439F_3 + 0{\cdot}25671F_4 - 0{\cdot}44785F_5 + d_1U_1$$

In the given regression for fuel consumption, the second factor was the most important term, accounting for 59% of the total variance in fuel consumption ($0{\cdot}77023^2$). The complete regression explained 98·7% variance of the fuel consumption data (from Σa_i^2). Note that the regression coefficient of Factor 2 had a negative coefficient, implying that as the value of the factor increased, fuel economy improved. Having established the importance of Factor 2, the final stage of the analysis was to investigate how this factor was structured. This was achieved by looking at the contents of the second column in the factor matrix. The values given down the column denoted the relative measures of the contributions that each test parameter gave to Factor 2, to explain the variation of urban fuel consumption. High positive weightings with average speed (0·79), throttle position (0.63), and ambient, fuel and oil temperatures (0·7, 0·69 and 0·64, respectively) were given.

Hence, in conclusion, the variation of fuel consumption under urban conditions can optimally be explained by a regression expression containing the aforementioned variables of average speed, throttle position and average fuel, oil and ambient temperatures. Note that an additional 20% explained variance ($0{\cdot}44785^2$) was accounted for by Factor 5, the structure of which was prominently contributed by average vehicle deceleration. This parameter is known to have a significant effect on fuel consumption because the vehicle's kinetic energy (originating from the fuel) is dissipated as heat energy from the brakes.

ii) Suburban fuel consumption.

Table Nos.52 and 53 show the results from the Factor Analysis using the test data from the suburban route sections. The correlation matrix (Table No.52) shows a number of changes to the coefficients describing the interrelations between the set of variables. The effect of speed on fuel consumption was similar to that noted in the urban traffic, though the magnitude of the association was lower with a value of -0·45. This reduction in the effect of vehicle speed on fuel consumption is shown by Figure No.22, where the gradients of the regression curves decrease as the speed increases through the suburban speed range of approximately 40 to 60Km/hr. The correlation coefficients of average vehicle acceleration, throttle pedal "toe-down" velocity and acceleration (0·967, 0·987 and 0·988, respectively), implied a high dependence of suburban fuel consumption on these parameters of vehicle motion, with an increase in either parameter contributing to a poorer fuel economy.

The eigenvalues and measures of "% explained variance" contained in Table No.53 show that the first five factors accounted for the total variation of suburban section data. With respect to the factor matrix, the factor regression for fuel consumption was:

$$\text{FUEL} = 0{\cdot}99500F_1 - 0{\cdot}00490F_2 + 0{\cdot}08459F_3 + 0{\cdot}00466F_4 + 0{\cdot}05275F_5 + d_1U_1$$

with 99% ($0{\cdot}995^2$) of the fuel consumption variance explained by Factor 1. Because of its dominance within the factor regression, the structure of Factor 1 served as an accurate indicator of the test variables that contributed significantly to variations in fuel consumption.

Average vehicle acceleration, and the throttle pedal velocity and acceleration terms, all weighted highly (0·97, 0·993 and 0·989, respectively) in the first column describing the make-up of Factor 1, implying that an increase in either of these parameters would have resulted in a greater fuel consumption.

High negative factor coefficients for the ambient, fuel and oil temperatures, further indicated the significant effect of ambient temperature on fuel consumption, with a warmer environment increasing vehicle fuel economy. This high correlation is due to a number of effects on fuel economy, resulting from hotter ambient conditions. First, vehicle drag is reduced because of changes in the air density and tyre rolling resistance, and secondly fuel combustion is more efficient with a higher air inlet ("under-bonnet") temperature.

It is of interest to note that of the three ambient variables present in the analysis, humidity was also highly weighted in Factor 1, with a value of -0·874. The negative association of this term with Factor 1 (which in turn was positively related to fuel consumption) implied that an increase in relative humidity, i.e., towards more damper conditions, improved fuel economy. A closer examination of the ambient effects on fuel economy (using regression analysis) is detailed in Section 6.3 and Appendix 3.2.

iii) <u>Motorway fuel consumption.</u>

Table No.54 presents the correlation matrix for the Factor Analysis conducted on the motorway test data. With respect to the first row of the matrix, the coefficient for average vehicle speed was 0·471, with the "positive" direction of the association opposite to that noted for the lower journey speeds from the urban and suburban sections, i.e., as motorway speeds increased, the fuel consumption also increased; Figure No.22 illustrated this relationship for each test vehicle.

Due to the rarity of gear changes on the motorway section, the correlation of engine speed with fuel consumption was similar to that of vehicle speed with fuel consumption, i.e., 0·449 and 0·471, respectively. This result was additionally shown by the significant association between these two speed variables of 0·996.

The variable with the closest association with the variation of fuel consumption was throttle position ("TPOS"). Its value of 0·987 implied that the greater the average throttle opening (inferring higher engine demand and hence higher average vehicle speed and acceleration), the poorer the fuel economy.

The variable of fuel flowrate ("FLOW" - fuel used per unit time) was highly correlated (0·956) with fuel consumption (fuel used per unit distance) under the constant-speed environment of the motorway route section. The corresponding coefficients from the urban and suburban analyses (-0·06 and 0·227, respectively) implied that as the average vehicle speed increased, the association between these two measures of fuel usage became more significant.

Of the three variables describing the ambient conditions during the motorway tests, the parameter of air pressure ("PRESS") showed the highest correlation with fuel consumption with a coefficient of 0·583. Because of the greater average vehicle speeds on the motorway section, this result may be due to the increased effect of aerodynamic drag that opposes vehicle motion. Aerodynamic drag varies with air density, and at constant temperature air density is directly proportional to ambient pressure. Thus, a rise in air pressure should increase both vehicle drag and fuel consumption. This result was shown by the "positive" association between pressure and fuel consumption.

The Factor Analysis result given in Table No.55, showed that the total variance of the 15-variable date set was explained by the first five factors (i.e., (Σ eigenvalues)/No.factors $\approx$ 1·0). Using these factors to describe the variance of fuel consumption, the following regression was obtained.

$$\text{FUEL} = 0{\cdot}60131F_1 - 0{\cdot}66681F_2 + 0{\cdot}32529F_3 + 0{\cdot}29317F_4 + 0{\cdot}04518F_5 + d_1U_1$$

The expression shows that 80·6% ($0{\cdot}60131^2 + 0{\cdot}66681^2$) of the fuel consumption variance was explained by Factors 1 and 2. When two such factors have a similar significance in the expression, resulting from their similar regression coefficients, their structures should be orthogonal (independent), so that test variables highly weighted in one factor have low weightings in the other factor.

Factor 1 was highly correlated to the measures of vehicle speed, engine speed, and throttle position (0·969, 0·977 and 0·679, respectively) with an increase in either of these variables significantly raising the fuel consumption. Factor 1 was also highly correlated to the variations of ambient temperature and air humidity (0·917 and 0·889, respectively), both of which have been previously noted for their "positive" association with fuel consumption.

Factor 2 had a regression coefficient opposite in sign to Factor 1, implying that within the structure of this second factor, a negative variable weighting denoted a "positive" association of a particular variable to fuel consumption. The variable with the highest correlation to the structure of Factor 2 was ambient pressure, with a value of -0·888 denoting an overall "positive" association with fuel consumption; previously shown by the pressure coefficient in the correlation matrix (Table No.54). Because pressure was significant in a factor different to that containing the variables of ambient temperature and humidity, the analysis inferred that the variation of pressure with fuel consumption was independent to that of the other ambient variables. The structure of Factor 2 was also closely correlated to the variation of average vehicle acceleration and deceleration with regression weights of 0·868 and -0·858 respectively, implying that an increase in either parameter would have resulted in a higher fuel consumption (remember deceleration was recorded with negative values).

In conclusion, the intention of the Factor Analyses was to indicate the main influencing parameters on fuel consumption for the three main types of traffic environment. The results obtained gave comparative measures of the significance each test variable had on fuel economy, and the optimal way to combine their "effects" to best explain the variation of fuel consumption.

5.1.3. Factor Analysis with density.

To investigate the effects of ambient condition on fuel consumption, the Factor Analyses described in Section 5.1.2 contained the variables of air temperature, air pressure and humidity. The choice of parameters was to enable the most fundamental physical properties of the atmosphere, namely, temperature and pressure, to describe the environmental conditions - a method consistent with basic thermodynamic principles. A term related to both of these parameters is density, ρ, given by:

$$\rho = 100.P/_{(R.T)} \quad (Kg./_{m^3})$$

where, P = is ambient pressure (mBars.),

T = is ambient temperature (°K),

and, R = is the universal gas constant (287J./$_{Kg.°K}$).

In some respects density could be regarded a more suitable term to include in the original factor analyses, because of its direct relationship with the expressions of aerodynamic drag and engine power output; both of which affect vehicle fuel economy.

To study the association of density with fuel consumption three Factor Analyses were conducted, using the same test data to that used in Section 5.1.2 describing urban, suburban and motorway travel in the diesel vehicle. Though the parameter of density can be treated as an independent variable, it is a function of both temperature and pressure, and thus only two of these three ambient parameters need be included in a Factor Analysis.

The Table below gives the correlation coefficients for temperature, density, and pressure with fuel consumption, for each route section.

Variable	Correlation Coefficient		Factor Column Weighting	
URBAN:				
Temperature -	-0·478	(-0·478)	0·632	(0·699)
Pressure -	-	(0·132)	-	(-0·100)
Density -	0·412	-	-0·507	-
Factor No.2 (2)	-0·740	(-0·770)		
SUBURBAN:				
Temperature -	-0·906	(-0·906)	-0·945	(-0·936)
Pressure -	-	(0·416)	-	(0·356)
Density -	0·858	-	0·856	-
Factor No.1 (1)	0·993	(0·995)		
MOTORWAY:				
Temperature -	0·342	(0·342)	0·161	(0·310)
Pressure -	-	(0·583)	-	(-0·889)
Density -	0·128	-	-0·604	-
Factor No.2 (2)	-0·766	(-0·667)		

The same fourteen variables were used for each analysis, with the exception of ambient pressure* which was omitted and replaced by air density.

The coefficient of the most significant Factor with fuel consumption is given, together with the weightings of each "ambient" variable contained within the respective Factor. The corresponding values from the original analyses using pressure and not density (see Table Nos.51, 53 and 55) are shown in parentheses.

With reference to the figures given, a number of observations can be made. First, because density is a direct function of temperature and pressure, its association with fuel consumption was accordingly determined by the correlations of temperature and pressure with fuel consumption. Over the test data used, the variation of pressure was very small, hence the values of density were approximately inversely proportional to ambient temperature (from relationship given in section 5.1.3). This result was shown to be significant over the urban and suburban route sections, where density attained similar correlation coefficients and factor weightings to those of ambient temperature. Note that the values for density are opposite in sign to temperature due to the inverse relationship between these variables, and that over the urban and suburban route sections, the explained variance of fuel consumption, achieved by the same (most significant) factor, was marginally reduced, i.e., 0·593 to 0·547, and 0·990 to 0·986, respectively, when density replaced ambient pressure in the analyses.

Under motorway conditions, the original analysis showed pressure to be the most highly associated "ambient" variable with fuel consumption; a result that seemed to reflect the increased significance of pressure, and hence density variation on fuel economy, caused by the greater effect of aerodynamic drag due to higher vehicle speeds. As data for the motorway temperature had a noticeable variation over the tests used for the analysis, density was not proportionally

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*Pressure was chosen to be omitted because it had little variation within the test data used, and additionally, the original analyses showed ambient temperature to correlate higher with the variance of fuel consumption.

related to pressure, and thus the magnitude of the correlation coefficients and factor weightings for density showed little resemblance to those of pressure; unlike those for the term of ambient temperature under urban and suburban conditions.

The "direction" (or sign) of the density results, however, were similar to those obtained for pressure, and not temperature, due to the greater significance of the pressure variable over the motorway section shown by the original factor analysis. Using density instead of the pressure variable for the "motorway" analysis marginally increased the association of Factor No.2 with fuel consumption, implying that at greater average speeds, pressure can best explain fuel consumption variations when expressed as a function of density, and not as an independent variable.

5.2. Analysis of Covariance.

5.2.1. Introduction.

In Section 5.1 the effects of all physical and environmental factors on fuel consumption were investigated. However, the categorical (non-metric) variables of driver and vehicle were not included. To give an insight into the significance of both driver and vehicle type on fuel consumption, an "Analysis of Covariance" was conducted on the complete data set of the main test programme (i.e., all vehicles, drivers and route sections).

Analysis of Covariance is a statistical technique to determine the association between the variance of an independent variable and the variance of the dependent (or criterion) variable. Unlike Factor Analysis, the process can account for both measured variables (covariables) and non-measured variables (factors). It does not attempt to construct regression relationships, but gives an insight into the significance between the criterion variable (in this case fuel consumption) and its independent variables. As with the previous section, reference to associated statistical texts would assist the reader with a more detailed explanation of the technique used [34].

5.2.2. Statistical results.

Table Nos.56 and 57 show the results from four separate analyses carried out on the test data. The independent covariables used in each case were average vehicle acceleration, deceleration and the throttle parameters of position, "toe-down" velocity and acceleration. The independent factors were the type of vehicle and number of driver. With respect to Table No.56, the first analysis accounted for all route sections, so an additional factor "ROUTE", denoting the particular traffic environment for each measure of fuel consumption, was included in the analysis.

The figures of interest are the "F-values" which indicate the significance of the relationship between each variable and fuel consumption, and the "SIGNIF OF F" column which gives information on the percentage-level of each significance*.

All five covariables exhibited significant effects on fuel consumption, with F-values of 3·75 and above, giving confidence levels all below 1%. The measurable effect of these variables on fuel consumption was illustrated in the previous section.

Of the three factors, the variable denoting traffic environment ("ROUTE") had a greater effect than that describing type of vehicle (with respect to the three test vehicles only). Both had high F-values of 95·9 and 69·5, respectively. The driver effect on fuel consumption was also significant with an F-value of 12·7. All the factors had confidence levels less than 0·1%.

Note the F-values for the three interation effects between the factors of vehicle, driver and route section, which showed that the fuel consumption was significantly affected by each permutation; e.g., the significant "vehicle-route" interaction (F-value = 4·643) suggested that the effect the type of vehicle had on fuel consumption

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*As a guide, a level of confidence of 5% ("SIGNIF OF F" = 0·05) infers that there exists "..a 95% probability that.." the variation of a particular factor explains the variation of the criterion variable. A lower %-level implies a greater confidence in the association.

was influenced by the traffic environment. This result was previously illustrated by the regression curves of Figure No.22, which showed how the comparative fuel consumptions from the "diesel/petrol" and "petrol/petrol" studies changed over the 20 - 140Km/hr. range of average sectional speeds. The "vehicle-driver" interaction was most significant (F-value = 5·626) inferring that driver "type" influenced the "vehicle" effect on fuel consumption; a result highlighted previously in Section 4.2.2 and Figure Nos.48 to 53.

Under urban traffic environment the analysis confirmed the association of vehicle acceleration and deceleration characteristics with fuel consumption; with F-values of 12·7 and 13·7 respectively; both below the 0·1% level of statistical confidence. The variation of each of the average throttle motions was shown to have no statistical association with the variation of average fuel consumption in urban driving. The analysis showed further that both the vehicle and driver "types" had a significant effect on the fuel consumption in urban conditions, with the driver effect being the greater, i.e., the "aggressiveness" or variation of a test driver, had a greater effect on the variation of the fuel consumption than the choice of vehicle. The "vehicle-driver" interaction F-value of 4·44 (less than 0·1% confidence level) showed that the significance of a driver's effect on fuel consumption depended upon which car he/she was driving; or, vice versa, the significance of the effect vehicle "type" had on fuel consumption depended on the driver. A result previously noted by the analysis accounting for all route sections.

Under suburban conditions (Table No.57), the fuel consumption variation was highly correlated to the driver "type" and average vehicle deceleration, both with 0·1% confidence levels. The effect of vehicle "type" was also prominent, with a 0·9% level of statistical confidence. Both the average throttle position and "toe-down" velocity showed reasonable evidence that they influenced the fuel consumption variation, with 5% and 3% confidence levels, respectively.

Finally, the analysis of the motorway section data (Table No.57) illustrated the now established correlation between fuel consumption and average throttle position, showing an F-value of 49·5 with a confidence level less than 0·1%. Vehicle type was highly correlated with fuel consumption, with an F-value and confidence level of 24·01 and "less than 0·1%" respectively. However, the driver variation was not as significant, highlighting that in the motorway environment the driver behaviour effect on fuel consumption (other than the variation in choice of average vehicle speed, which was already accounted for by the "SPEED" variable), was negligible. An interaction effect did exist between the vehicle and driver factors (significant to a 1·2% confidence level), again probably resulting from the effect of a driver's choice of cruising speed, which is known to affect the comparitive fuel consumption characteristics of the test vehicles (illustrated by Figure No.22).

In conclusion, the Analysis of Covariance showed that both the variation of vehicle "type" and driver "type" (by age and sex), had significant effects on fuel consumption, though each effect and the overall variation in fuel consumption were greatly influenced by the traffic environment.

5.3. Effect of urban traffic flow on fuel consumption.

For each Urban Cycle completed in the main test programme, a measure of the respective traffic flow at the junction shown by Figure No.9 was recorded. As it is virtually an impossible task to define the immediate traffic congestion to a test vehicle throughout the duration of an "on-road" journey, an average measure of traffic density must be employed. The statistics of vehicular flow rate used for this study (p.c.u.* per hour), were taken as representative measures of the average urban traffic congestion for the hourly period encompassing each Urban Cycle: as described by Section 2.3.3.

To illustrate the effect of traffic flow on vehicle fuel consumption the statistical technique of "Factor Analysis" was used.

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* Passenger car units (p.c.u.'s) are measures normally adopted for traffic flow surveys. Each type of road vehicle is converted to a representative number of p.c.u.'s which denotes its effect on traffic flow and road space: i.e., in p.c.u.'s: cars = 1·0, H.G.V. = 2·0, L.G.V. = 1·0, motorcycles = 0·75 and buses = 3·0.

5.3.1. Factor Analysis of traffic flow data.

To omit the effect of vehicle "type" from the analysis, only the tests conducted in the 1600cc. diesel vehicle were used, giving a total of twenty-four Urban Cycles. Similar to the Factor Analyses of Section 5.1, fifteen variables describing "vehicle" and "environmental" parameters were used, in addition to the variable "TRAF" denoting hourly traffic count. The factor rotation was similarly based on the "Varimax" technique. Table Nos.60 and 61 present the results of the analysis.

The correlation coefficient matrix (Table No.60) showed that traffic flow rate had a significant and "positive" association to fuel consumption (0·638). Thus, the more congested the urban traffic, the poorer the vehicle fuel economy (greater the fuel consumption). This result was as expected, because an increase in traffic congestion is known to decrease average vehicle speed [35][36][37], and within the urban speed range of approximately 0 to 45Km/hr., any reduction in vehicle speed would result in a proportionally higher fuel consumption (from Figure No.22). The correlation coefficient for traffic flow with vehicle speed (-0·618) affirmed the relationship of these two parameters previously noted by Gyenes [16], who estimated that for a selection of United Kingdom conurbations, a 30% decrease in average vehicle speed existed between "peak" and "off-peak" periods of travel. Briefly, the matrix also showed that a more congested traffic flow significantly reduced average vehicle acceleration (-0·587), and the throttle pedal parameters of position (-0·495), "toe-down" throttle velocity (-0·398) and throttle acceleration (-0·235).

The average rate of gear changing also increased within heavier traffic (0·259), due probably to the more frequent use of the lower gears for "stop-start" driving in queues of traffic.

Finally, the matrix showed the variation of urban traffic congestion to be highly correlated with air humidity (0·579), suggesting perhaps that in damper weather (associated with rainfall), the use of private road transport increased.

Table No.61 presents the eigenvalues and factor matrix produced from the analysis. As with the previous studies in Section 5.1, the majority of the total variance (89%) was explained by the first five factors, with Factor 1 explaining 43·4% variance of the urban fuel consumption data. Associated to fuel consumption, with a regression coefficient of -0·249, Factor 1 contained a weighting of -0·543 with traffic flow. Note the overall positive correlation of traffic congestion with fuel consumption. Within Factor 1 the weighting of the traffic flow variable was not as significant as the effects of average vehicle speed, acceleration and deceleration, or the parameters describing throttle pedal motions; however its contribution was greater than those explaining the variation of ambient conditions and the related measures of fuel and engine oil temperature.

Unlike the other variables, the traffic flow parameter was not orthogonal, i.e., it had similar regression weightings in a number of factors. With Factors 2 and 3, which combined explained 79·3% ($-0{\cdot}361^2 + 0{\cdot}814^2$) of the variation in fuel consumption, the traffic flow variable had significant weightings of -0·531 and 0·455, respectively. As a result, the first three factors which together explained 74·9% of the total data variance, and 85·5% of the fuel consumption variance also explained 78·4% of the corresponding variance of the traffic congestion.

In conclusion, the variation of traffic flow, at the junction chosen to represent the urban cycle congestion, had a measureable effect on fuel consumption. The association of fuel consumption with the traffic flow was not as statistically significant as the independent variables of average vehicle speed, acceleration and deceleration and the throttle motions, however, the variations of all these independent factors was correlated highly to the measure of average traffic flow.

CHAPTER 6

PREDICTION OF ON-ROAD FUEL CONSUMPTION

6.1. Introduction.

Mathematical models constructed to predict vehicle fuel consumption can have a wide range of application to problems confronting both the automotive engineer and co-ordinators of traffic controls and road networks. A study by Langdon [35] has illustrated the use of regression analysis to predict and model the effect of a new road layout on fuel consumption.

In this section an evaluation is made of several regression models, which were constructed using the measurements of vehicle and environmental factors recorded during each test drive of the main test programme. Rather than model the fuel consumption by trying arbitrary explanatory expressions, the basic form of each regression model was based on established physical properties of vehicle propulsion (i.e., the "road-load" equation), and correction factors used by the automotive industry to standardise ambient conditions for laboratory engine power tests.

6.2. Regression model derivation.

Fuel is consumed by a vehicle in order to propel it against a number of resistive forces, namely aerodynamic drag, rolling resistance, inertial and gradient effects. The tractive effort (or driving force) required to overcome such resistive forces is commonly written [38]:

$$F = \underbrace{C_1.W}_{\text{rolling resistance}} + \underbrace{\tfrac{1}{2}.\rho.C_2.A.V^2}_{\text{aerodynamic drag}} + \underbrace{C_3.W/_g.(\delta v/_{\delta t})}_{\text{inertial acceleration}} + \underbrace{W.\sin\theta}_{\text{gradient effect}} \qquad .....\{i\}$$

where, C_1 = rolling resistance coefficient,
C_2 = air drag coefficient,
C_3 = mass correction for rotational inertial accelerations,
W = total vehicle weight,
A = projected frontal area of vehicle,
ρ = air density,
g = acceleration due to gravity,
and, V = vehicle velocity.

To transform this general expression into a predictive model for fuel consumption, a number of analytical steps were taken based on fundamental relationships and standard correction factors [39][40]. A complete derivation based on a similar study by Bascunana [41] is given in Appendix 3.1, together with symbol notation. The basic regression model obtained to predict average sectional fuel consumption (FC) was:

$$FC = C.W^{1-\gamma}(E^{\partial}/_{Q}\psi)(\bar{N}/_{\bar{V}})^{\tau}(0\cdot012 + 0\cdot0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_{W} + 0\cdot107\{\delta\bar{V}/_{\delta t}\})^{\alpha}.C_p^{\beta}.C_t^{\eta}.C_h^{\omega} \quad \text{.....\{ii\}}$$

The model given above was a general expression to which the data collected in <u>all three</u> Vauxhall Cavalier test vehicles was fitted. To utilise a common form of regression analysis [22], the expression {ii} was transformed into a linear equation by taking logarithms. Hence:

$$\log_{10}(FC) = \log_{10}C + (1-\gamma)\log_{10}W - \psi\log_{10}Q + \partial\log_{10}E + \tau\log_{10}(\bar{N}/_{\bar{V}}) + \alpha\log_{10}D + \beta\log_{10}C_p + \eta\log_{10}C_t + \omega\log_{10}C_h \quad \text{.....\{iii\}}$$

where, $D = (0\cdot012 + 0\cdot0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_{W} + 0\cdot107\{\delta\bar{V}/_{\delta t}\})$.

To simplify {iii} for the regression process, the following substitutions were made:

$Y = \log_{10}(FC)$	$f = \alpha$	$X_3 = \log_{10}W$
$a = \log_{10}C$	$g = \beta$	$X_4 = \log_{10}E$
$b = -\psi$	$h = \eta$	$X_5 = \log_{10}D$
$c = \tau$	$j = \omega$	$X_6 = \log_{10}C_p$
$d = (1-\gamma)$	$X_1 = \log_{10}Q$	$X_7 = \log_{10}C_t$
$e = \partial$	$X_2 = \log_{10}(\bar{N}/_{\bar{V}})$	$X_8 = \log_{10}C_h$

Hence, equation iii became the linear expression:

$$Y = a + b.X_1 + c.X_2 + d.X_3 + e.X_4 + f.X_5 + g.X_6 + h.X_7 + j.X_8 + \xi \quad \text{.....\{iv\}}$$

where ξ is an error term used to account for unexplained variance within the regression analysis. Note that to include the error term in the original expression, equation {ii} must be multiplied by ε, where $\xi = \log_{10}\varepsilon$.

6.3. Regression results.

Table Nos.58 and 59 show the results obtained when the regression equation was fitted to each set of test data (for all vehicles) from the four main route sections, i.e., motorway and urban (Table No.58), and, suburban and the "overall" 50/40/10% mix (Table No.59). To act as an example, the regression model for the 50/40/10% route section will be evaluated. With respect to the aforementioned substitutions in equation {iv}, and the regression coefficients given in Table No.59, the index values calculated were:

$$C = 2492710, \quad \psi = 1{\cdot}386534, \quad \tau = -0{\cdot}5011631, \quad 1-\gamma = 0{\cdot}313999,$$

$$\alpha = 0{\cdot}7007434 \quad \beta = 0{\cdot}085599, \quad \eta = 0{\cdot}8858873, \quad \omega = -0{\cdot}20698.$$

Note that the regression analysis found the engine capacity parameter "E" to have no significant variation with fuel consumption within the structure of the regression expression, and hence $\partial = 0$.

Thus, the fuel consumption prediction model applying to the data collected with all vehicles over the 50/40/10% route section, was:

$$FC = 2492710.W^{0{\cdot}314}/_{Q^{1{\cdot}387}}(\bar{V}/_{\bar{N}})^{0{\cdot}501}(0{\cdot}012 + 0{\cdot}0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_{W} + 0{\cdot}107\{\delta\bar{V}/_{\delta t}\})^{0{\cdot}7} \rightarrow$$

$$\rightarrow (\bar{P}/_{1000})^{0{\cdot}086}.(300/_{\bar{T}})^{0{\cdot}886}.(\bar{H}/_{60})^{0{\cdot}207} \qquad .....\{v\}$$

All parameters were measured in S.I. units; refer to Notation on pp.1.

With respect to Table No.59, this model was shown to account for 95% of the total variance ("R SQUARE %" column) of the fuel consumption data. The statistical significance of the regression model was further shown by the F-value of 76·17 at a confidence level significant to 0·1%.

As with the example studied, the regression analyses for each route section were completed in eight distinct stages, where, during each stage (or "step"), a new parameter was added to the expression in its approriate form. By using this "step" approach, the contribution of each term towards the prediction of fuel consumption could be obtained. The magnitude of each contribution was shown by the values in the "R SQ. CHANGE" column, which inform of the additional explained variance (%) achieved by each new step. An additional measure of the significance of each parameter in the model was the associated F-value; those shown in parentheses were not within the 5% level of confidence.

For the 50/40/10% route section, 81·12% of the total 95·01% explained variance was accountable to just two terms; namely the heat combustion (fuel energy) term "Q" indicating the variation in fuel consumption data created by the use of both diesel and petrol fuelled vehicles, and, secondly the "road-load" equation "D" which was expected to have a significant effect on fuel consumption because of the fundamental physical properties of vehicle propulsion associated with this term.

With respect to the three correction factors included in the model to explain the variation in fuel consumption due to changes in ambient conditions, both temperature and humidity showed small but significant effects with F-values of 3·549 and 9·291, and explained variances of 1% and 1·65% respectively: both terms were within a 5% level of confidence. The term for ambient pressure correction had a negligible effect within the expression; a result that was true for all route section models. It should be noted that the pressure-correction term "C_p" only expressed the pressure variation effect on engine performance and not the pressure related effect on aerodynamic drag, this was accounted for in the "road-load" variable.

The structure of the regression equation {v} shows the basic relationship between each parameter and the measure of "overall" vehicle fuel consumption, from which a number of observations can be made. First, a heavier vehicle (with all other parameters held constant) will return a poorer fuel economy by an amount proportional to the cube-root of vehicle weight. If an engine uses a fuel with a higher energy content, i.e., by employing the more fuel efficient diesel-cycle, the fuel consumption will reduce by an amount proportional to the increase in fuel energy. The overall drivetrain ratio (vehicle speed/engine speed "$\bar{V}/_{\bar{N}}$") is noted to increase proportionally with fuel consumption. This result was previously observed by Murrel [9] who, using linear regression analysis, showed that "$N/_V$" was a significant determinant of vehicle fuel consumption (m.p.g.). Note that in this report the drivetrain ratio was reciprocated because of the metric units of fuel consumption. Murrel also concluded that the product of engine capacity ("Cubic.Inch.Displacement.") with the drivetrain ratio improved the fit of the multiple regression. It is of interest to note that in this study the term for engine displacement, when treated separately, was found to be statistically insignificant.

The suburban fuel consumption prediction model was:

$$FC = 1469260.W^{0\cdot177}/_{Q^{1\cdot236}}(\bar{V}/_{\bar{N}})^{0\cdot500}(0\cdot012 + 0\cdot0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_W + 0\cdot107\{\delta\bar{V}/_{\delta t}\})^{0\cdot647} \rightarrow$$

$$\rightarrow (\bar{P}/_{1000})^{-0\cdot003}.(300/_{\bar{T}})^{1\cdot239}.(\bar{H}/_{60})^{0\cdot216} \quad .....\{vi\}$$

The figures on Table No.59 show similar findings to those of the 50/40/10% route section, with the "fuel-energy" and "road-load" variables explaining the majority of fuel consumption variation (63·57% and 15·88% explained variances, respectively). The terms for ambient pressure and vehicle weight showed little significance in the regression model, with 0·0% and 0·05% explained variances respectively.

Table No.58 gives details of the urban regression model for fuel consumption prediction, given by:

$$FC = 28681400.W^{0\cdot432}/_{Q^{1\cdot800}}(\bar{V}/_{\bar{N}})^{0\cdot696}(0\cdot012 + 0\cdot0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_W + 0\cdot107\{\delta\bar{V}/_{\delta t}\})^{0\cdot502} \rightarrow$$

$$\rightarrow (\bar{P}/_{1000})^{-0\cdot192}.(300/_{\bar{T}})^{0\cdot933}.(\bar{H}/_{60})^{0\cdot202} \quad .....\{vii\}$$

Under this driving environment, the analysis showed fuel consumption to be highly dependent upon the "fuel-energy" and "drivetrain-ratio" terms: the significance of the latter "$\bar{V}/_{\bar{N}}$" term under congested traffic conditions, could be explained by the influence that a number of urban "driving factors" can have on its value. The gear selection characteristics of each test driver, the overall vehicle transmission gearing, and further, the effect of traffic flow on the choice and duration of travel in particular gears and time spent idling, would all contribute to the variation of this term with fuel consumption.

Though less significant than the "road-load" term, note the explained variance of 1·47% and corresponding F-value of 15·308 (confidence level of 0·1%) attributed to the humidity "C_h" term, which was the most prominent ambient correction factor in urban traffic conditions.

On the motorway section (Table No.58) the regression model was:

$$FC = 13\cdot8166.W^{0\cdot240}/_{Q^{0\cdot192}}(\bar{V}/_{\bar{N}})^{-2\cdot851}(0\cdot012 + 0\cdot0107.\bar{P}/_{\bar{T}}.\bar{V}^2/_W + 0\cdot107\{\delta\bar{V}/_{\delta t}\})^{1\cdot039} \rightarrow$$

$$\rightarrow (\bar{P}/_{1000})^{0\cdot273}.(300/_{\bar{T}})^{2\cdot600}.(\bar{H}/_{60})^{0\cdot060} \quad .....\{viii\}$$

The expression was dominated by the "road-load" equation, which accounted for 68% of the explained variance, with an associated F-value of 111·88. The influence of this term on vehicle fuel consumption can be best explained by the increase in the marginal engine power demand, required to overcome the greater rolling and aerodynamic resistances (proportional to the square of vehicle speed) resulting from variations in average vehicle speed. The only other statistically significant term in the motorway regression model was the correction term for ambient temperature, with an explained variance and F-value of 2·66% and 6·658 respectively.

The results from Table Nos.58 and 59 show that the regression models satisfactorily explained the variance of fuel consumption of the population (all vehicles and drivers) represented by the data set. Although high values of the "determination coefficient" (R^2) were achieved for all route sections, in each case the regression could have been confidently based on only two or three highly significant parameters, with the choice dependent upon traffic environment.

With respect to the three ambient correction factors, for the low to average speed range (below 60Km/hr.) humidity and temperature were the most significant correction terms; the former having an index (power) value of approximately 0·20 (a result consistent for all driving environments). High-speed fuel consumption was shown to be affected the most by the temperature correction term. Note that for the overall 50/40/10% route section, the index for temperature correction in the regression model (for all vehicles) was 0·866. This correlated closely with the standard convention of an index of 0·55 (petrol) and 1·2 (diesel) for engine power correction [40]. The pressure correction factor (for effect on engine performance only) was observed as having no significance under all traffic conditions; noting that the pressure effect on air density, and hence aerodynamic drag, was already accounted for by the "road-load" term in the expression.

A subsidiary investigation into the regression modelling of ambient correction factors is given in Appendix 3.2. The work described gives a further insight into how the three fundamental parameters of ambient temperature, pressure and humidity affected the "on-road" fuel consumption of the diesel vehicle. Based on the findings, the section concludes with possible improvements that could be made to the commonly accepted and established standard correction factors for ambient conditions, used by the automotive industry for laboratory engine testing [39][40].

CHAPTER 7

DRIVER ACCELERATION/DECELERATION HISTOGRAMS

7.1. Introduction.

This Chapter details an analytical technique that was investigated during the course of the research, to categorise numerically the variation of driver "types" experienced in the test programmes; i.e., a method able to give a consistent and relative measure of driver "aggressiveness". The term "aggressiveness" being used to describe a drivers' desire to operate a vehicle with actions that primarily result in a poor fuel economy, and relatively high levels of vehicle speed, acceleration and deceleration.

In Section 3.2 the relationship between average fuel consumption and the parameters of average vehicle speed, acceleration, deceleration, throttle position and average "toe-down" throttle acceleration, was discussed for each main route section, using the results obtained from driver Nos.1 to 6 in the main test programme (Figure Nos.12 to 17). Of the five parameters used, the measures of average sectional acceleration and deceleration exhibited a close relationship (shown by their similar histogram profiles) to the corresponding values of the subjective variable fuel consumption.

The measures of acceleration and deceleration used for the analysis of Section 3.2 were overall average values for each driver and route section. To look more closely at the relationship between fuel consumption and the levels of acceleration and deceleration, an alternative approach was required. Rather than represent vehicle acceleration and deceleration (or any other parameter describing vehicle operation) by a single average value, a spectrum of values was used to produce a distribution. By adopting the x-axis to denote the acceleration and deceleration level, which was subsequently divided into a number of minor equal "g-level" bandwidths, the y-axis was then used to represent the frequency or "%-time" the motion of the vehicle fell into each acceleration/deceleration category. Examples of such a diagram are given by Figure Nos.43 and 44, which describe the acceleration and deceleration distributions obtained by driver No.1 in the 1600cc petrol vehicle, over the Urban route section. Note that the chosen range of acceleration and deceleration levels had a maximum and minimum of $\pm\frac{1}{2}$g. and that Figure Nos.43 and 44 had x-axes divided by g-level resolutions of 0·05g and 0·025g respectively.

For the purposes of this Chapter, the acceleration and deceleration distributions studied are based on test data from the urban route section, where driver behaviour was considered to have a greater influence on fuel consumption.

7.2. Characteristics of distributions.

With respect to Figure No.43, which was based on the data produced by the "low-resolution" analysis described by Appendix D(iv), the main observation was the symmetry of the distribution, inferring that the brake and throttle controls were operated in a manner that resulted in the vehicle motion having similar acceleration and deceleration properties. The profiles of both the acceleration and deceleration distributions showed peak values of "%-vehicle-motion-time" (i.e., the proportion of time, by %, that the acceleration/deceleration of the vehicle fell into each g-level category) at very low g-levels, implying that for the majority of travel time the vehicle was subjected to a motion approaching* constant speed travel, or at rest.

The minimum %-vehicle-motion-time values recorded for acceleration and deceleration levels were between 0·25g to 0·30g and -0·25g to -0·30g respectively, indicating that the maximum rates of acceleration and deceleration for driver No.1 in the urban environment were both approximately 0·25g to 0·30g. This result was consistent with the findings of Easingwood-Wilson et al [44], who illustrated a similar acceleration/ deceleration histogram for vehicle performance tests conducted in Central Glasgow.

To investigate further the information contained in the acceleration/ deceleration distributions, the 0·05g resolution of Figure No.43 was doubled to 0·025g. Using the same "raw" test data, the software "Roadtest. Fortran" was employed to produce the high-resolution analysis output shown in Table No.5 and illustrated by Figure No.44. Though the same "bell" shaped profile remained, both the acceleration and deceleration "halves" of Figure No.44 showed an additional secondary peak between the g-levels

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* The histogram software contained in the package "Roadtest.Fortran" was written to account only for the values of acceleration and deceleration that were non-zero. Vehicle-motion-time recorded with the vehicle at rest or at a constant speed (very infrequent) was ignored.

of 0·125g to 0·15g and -0·125g to -0·15g, respectively.

The double-peaked acceleration distribution maybe due to the following two distinct forms of acceleration;

i) low gear acceleration from rest, contributing mainly to the to the secondary, high g-level (0·125g to 0·15g) peak, and,

ii) high gear acceleration whilst the vehicle is in motion, contributing to the low g-level accelerations accounted for in the larger peak.

A double-peaked acceleration distribution similar to Figure No.44 was illustrated in a study by Wasielewski et al (from reference [43]), which also showed that under normal urban driving conditions a large low g-level peak existed together with a secondary peak centred at an acceleration level of approximately, 1·3 m/s^2 ($\sim$ 0·133g).

The above hypothesis explaining why two peaks exist in the urban acceleration distribution requires further investigation to be proven.

The double-peaked profile of the deceleration distribution in Figure No.44 was more pronounced - a result also shown by Wasielewski [43]. An explanation of this profile could be that two distinct forms of vehicle deceleration exist;

i) <u>inertial braking</u>, i.e., allowing the vehicle to decelerate due to the resistive forces of aerodynamic drag, rolling resistance and the inertial forces of the engine and transmission system with the throttle closed and clutch engaged, or,

ii) <u>driver braking</u>, i.e., driver application of the vehicle braking system in addition to the inertial braking described by (i).

The first low g-level deceleration peak would be due to the inertial deceleration described by (i), and the secondary high g-level deceleration peak would result from additional "driver" braking as described by (ii) above. To check this theory a simple test could be performed with an additional logger channel recording the voltage supply to the vehicle brake lights. By comparing channel recordings simultaneously, "brake" and "no brake" decelerations could be distinguished.

To study further the profiles of the acceleration and deceleration distributions shown by Figure Nos.43 and 44, the same data was used to construct the smooth curve plots of Figure No.45; obtained by joining the mid-points of each "bar" in the histograms.

To enable the high and low-resolution sets of acceleration and deceleration distributions to be correlated on the same diagram, the y-axis of Figure No.45 was "normalised", by dividing the %-vehicle-motion-time data by the resolution (i.e., 0·05 or 0·025).

To distinguish further the profiles of each curve, the same distributions were produced on "log/log" axes (refer to Figure No.46).

The most prominent feature of both Figure Nos.45 and 46 was the additional tertiary peak introduced to the "normalised" 0·025g acceleration distribution, centred at a high g-level of approximately 0·2g. One final salient observation from Figure No.46 was the symmetry of the "normalised" acceleration and deceleration curves for each resolution.

In addition to the drivers operation of the vehicle, the general profiles of the acceleration/deceleration distributions may be indicative of the type of traffic environment the vehicle was exposed to, i.e., a discrimination between "stop-start" or "constant speed" travel may be possible by noting the position, number and size of peaks in each distribution. An insight into this ability is given in the following section.

7.3. Driver "aggressiveness".

The basic hypothesis is as follows:

An "aggressive" driver will obtain an acceleration/deceleration distribution with a greater spread and a low g-level peak of smaller magnitude than that of a normal driver, due to higher acceleration rates and harsher braking. Alternatively, a cautious driver will obtain a distribution with a narrower spread and relatively high centre peak, resulting from gentle acceleration and less reliance on the vehicle braking system.

With respect to the aforementioned hypothesis, the Wasielewski report [43] illustrated three acceleration/deceleration distributions, representing "aggressive", "normal" and "conservative" driving behaviour. The three diagrams (representations of which are given overleaf) showed that the magnitude of the low g-level peak and "spread" of the distribution increased and decreased respectively, as the driver behaviour varied from "aggressive" to "conservative". In all instances, the double-peaked profile of both sides of each distribution was evident.

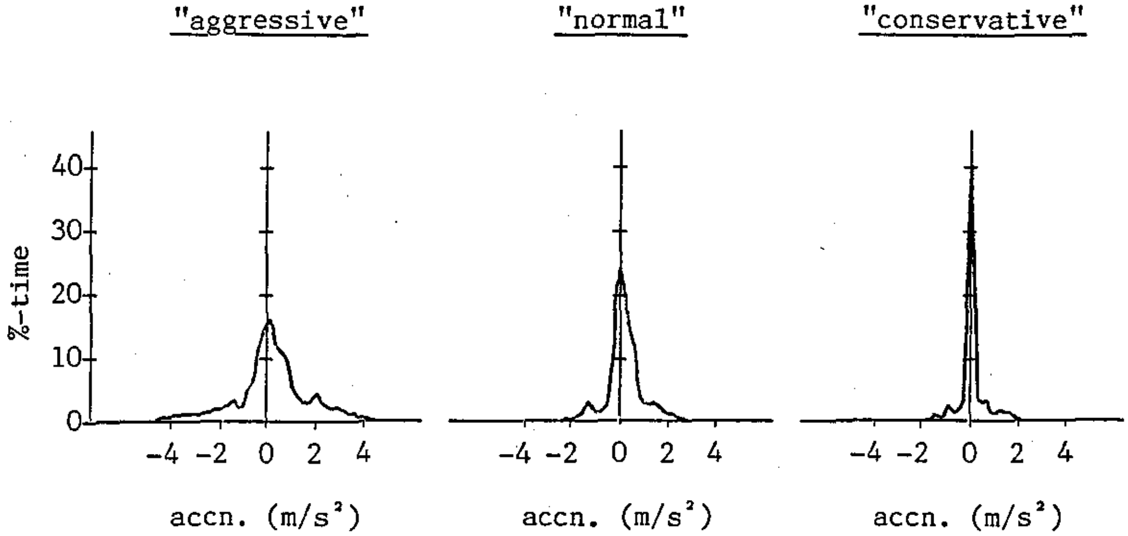


Figure Nos.37 to 42 detail the Urban route section acceleration/deceleration histograms (at a 0·025g resolution) for each driver (Nos.1 to 6) in each test vehicle. At first glance the six distributions showed little variation in shape and profile, however by observing overlapped transparent copies of the figures, the order of "aggressiveness" was attained. With reference to the distributions for the 1600cc diesel vehicle, the driver orders from most "aggressive" to most "conservative" were:

for acceleration - Nos.4, 1, 2, 6, 3 and 5

for deceleration - Nos.4, 2, 1, 6, 5 and 3

The orders of "aggressiveness" given above differ depending on whether acceleration or deceleration was used as the subjective parameter. This finding would imply that when assessing driver "aggressiveness", the acceleration and deceleration distributions should be treated as two independent methods, to determine either a drivers' "aggressiveness" in terms of braking or in terms of accelerating a vehicle. A method to amalgamate the two distributions to give an overall indication of driver "aggressiveness" may be possible. Though the driver orders given cannot be directly compared to the corresponding orders shown by Figure Nos.12 to 17 of Section 3.2, which were averaged for all vehicles, a general resemblance was noted.

Figure Nos.37 to 42 further showed that the type of vehicle consistently affected the profile of the urban acceleration/deceleration distributions for each individual driver.

In comparing the diesel and 1300cc petrol vehicles, all drivers were noted to be comparatively more "aggressive" in acceleration and more "cautious" in deceleration with the diesel vehicle; an interesting observation, considering that the diesel car was marginally under powered with respect to its petrol counterpart. Additionally, a comparison of the two petrol vehicle distributions showed that each driver operated the higher powered 1600cc vehicle more "aggressively" under both acceleration and deceleration.

To give a brief insight into the relationship between acceleration and deceleration distributions and the corresponding measures of fuel consumption, the three-dimensional plots given by Figure Nos.48 to 53 were produced. Each diagram shows a surface plot constructed from six acceleration/deceleration distributions for each route section. The three axes used were as follows:

x-axis represents the measure of relative driver fuel economy using a value between 0 (most fuel efficient) and 1 (least fuel efficient).

y-axis represents the g-level of acceleration or deceleration (i.e., similar to the x-axis in the acceleration/deceleration distribution diagrams).

z-axis represents the %-vehicle-motion-time for each g-level (i.e., similar to the y-axis in the acceleration/deceleration distribution diagrams).

Under all traffic environments, the magnitude of the low g-level peak of all distributions decreased as the driver fuel economy became less efficient, i.e., towards x = 1. Simultaneously, the spread of this peak was greater as fuel efficiency reduced, i.e., a more "aggressive" driver returned a relatively poorer fuel consumption. Though similar findings existed for the motorway section (Figure Nos.52 and 53), the differences in distribution profiles were only marginal due to the nature of the "constant speed" traffic environment. By comparing the plots for each route section, it was observed that the magnitude of the low g-level peaks of both the acceleration and deceleration distributions increased as the traffic environment changed from the urban "stop-start" mode ($\sim$ 45% vehicle-motion-time) to motorway "constant speed" travel ($\sim$ 95% vehicle-motion-time).

In addition it was noted that the secondary peaks for both acceleration and deceleration were more pronounced on the motorway distributions. Though visually obvious from Figure Nos.52 and 53, the greater magnitude of these secondary peaks on the motorway was hidden to a certain extent by the relatively larger scale of the z-axis when compared to the corresponding suburban and urban surface plots.

Because of the practical difficulties and the inconsistent nature of visually comparing acceleration and deceleration distributions, an alternative analytical technique was investigated.

7.4. Analytical representation of distributions.

To act as an example, the data used to construct Figure Nos.43 and 44, namely driver No.1 in the 1600cc petrol vehicle under the urban environment, will be used throughout this section.

Figure Nos.43 and 44 presented histogram acceleration/deceleration distributions, with resolutions of 0·05g and 0·025, respectively. To enable a measure of distribution "spread", the first stage was to fit consistently and accurately analytical curves to the histogram data. Because of the general shape exhibited by Figure No.45 and the need for a convenient method of curve fitting, the exponential function ...

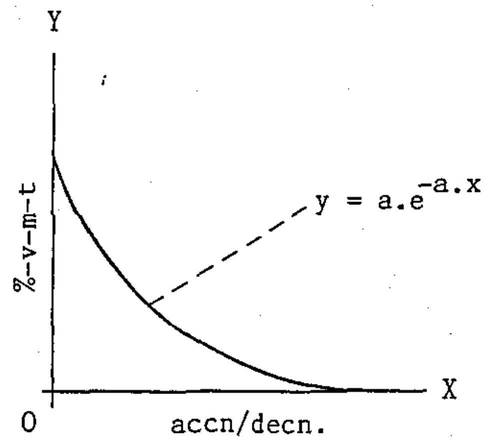
$$y = a.e^{-a.x} \qquad \text{... was chosen.}$$

This yields the following results to describe the "spread" of the distribution fitted:

namely;

Mean $\overline{X} = {}^{1}/_{a}$

Variance Var(X) $= {}^{1}/_{a^2}$



Having established this curve function as the most convenient form, to provide both a good "fit" and produce simple instantaneous measures of distribution "spread" from the "a" coefficient, a problem existed. The curve-fitting software used for this study was not able to produce an exponential curve with the limitation that the coefficient and power index should be equal. Exponential curve fitting of this type is usually produced using the function "$y = c.e^{-a.x}$" (where $a \neq c$). This not only provides a greater flexibility for curve fitting, but additionally yields the same simple calculations of ${}^{1}/_{a}$ and ${}^{1}/_{a^2}$ to describe the "spread" of the data (refer to Appendix 4.1). Unfortunately this type of function could not be used because of the nature of the data illustrated by the acceleration/deceleration distributions.

The distributions represent "probability curves" based on a %-time measure of all acceleration and deceleration g-levels experienced, and hence the "area" under each distribution (acceleration or deceleration) must equal unity:

$$\text{i.e.,} \quad \int_0^\infty c.e^{-a.x}\,dx = 1$$

which is only true if a=c. Thus the more limited function of $y=a.e^{-a.x}$ must be used to fit curves that are consistent with the histogram data.

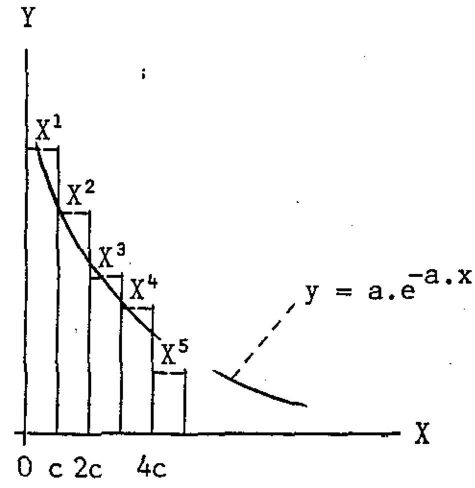
An additional constraint on the use of the function $y=a.e^{-a.x}$ was that the data points used to produce the distributions had to be "normalised", as those used to produce Figure No.45. The necessity to divide the %-vehicle-motion-time data by the x-axis resolution was similarly due to the curve representing a probability function. With reference to the figure and notation overleaf, the requirement for "normalising" the data is proven as follows;

the area under the curve must equal unity, i.e., $\int_0^\infty a.e^{-a.x}\,dx = 1$

X^i = %-vehicle-motion-time

c = resolution (0·05/0·025g)

N = No. of samples (100)



Alternatively, the sum of all the "bar" areas must also equal unity; hence,

$$\sum_{i=1}^{n} \{c.\frac{X^i}{N}\} = 1 = c.\sum_{i=1}^{n} \{X^i/N\} \qquad \ldots.(1)$$

However, from the total No. of samples,

$$\sum_{i=1}^{n} \{X^i\} = N \rightarrow \sum_{i=1}^{n} \{X^i/N\} = 1 \qquad \ldots.(2)$$

therefore, from the result given in (2), the values of "X^i" in (1) must be divided by the resolution "c" (i.e., normalised) for the relationship in (1) to remain true.

Due to the inability to perform "$y=a.e^{-a.x}$" curve fits to the data of Figure Nos.37 to 42, the "spread" of each drivers' acceleration and deceleration distributions could not be compared. To give an insight into the feasibility of this technique, Figure No.47 shows curves fitted to the two sets of distribution data from Figure Nos.43 and 44, using the exponential function "$y=c.e^{-a.x}$". All curves were fitted to a minimum R^2 value ("goodness of fit") of 0·78. Note the similar values of the index "a" for corresponding acceleration and deceleration distributions. By comparing the two sets of distributions, the error from using data that was not "normalised" was shown by the two different magnitudes obtained for index "a", implying two independent measures of "spread" or driver "aggressiveness".

CHAPTER 8

DISCUSSION

8.1. Overview.

The results and conclusions contained within this report relate to tests carried out on three Vauxhall Cavalier cars, over a purposely designed test route in Leicestershire. The route and its individual sections were regarded as typifying the driving conditions experienced nationally on each type of road class. The test vehicles, especially the diesel, were considered representative of their type on the automotive market for their year of production (1982).

However, since the commencement of this study new petrol and diesel vehicles have entered the market with noticeable reductions in fuel consumption which may affect both the national and individual comparative costs concluded in this report. Though somewhat restricted by emission regulations, the advent of the "lean-burn" petrol engine and "direct-injection" diesel engine will contribute significantly to fuel economy advances over the next few years; advances, which must be noted when assessing the comparative energy savings created by petrol or diesel car usage in future years.

One intention of this report, was to put into perspective the various effects on fuel consumption accountable to a number of independent factors, describing the operation and motion of a vehicle, and the environmental conditions of weather and traffic flow. The group of factors used for the analyses was by no means complete. The effects of road gradient, driver type (categorised by traits in personality, social status or accident history, etc.), use of auxiliary equipment, the state of engine tuning, effect of automatic or manual transmission, road surface quality, poor wheel alignment, brake drag and vehicle maintenance, all contribute to variation in fuel consumption; however, for the purpose of this study, these effects were either controlled by the experimental design, disregarded or assumed to be negligible.

8.2. Fuel-efficient driving.

Vehicle fuel consumption is dependent on a number of influencing factors, which can be summarised under three main headings. These are;

i) Vehicle effects.

The basic design of a vehicle, and the capacity and type of engine used will set the "datum-line" fuel consumption. Variations in the fuel consumption may result from the use of different grades of petroleum or diesel fuel.

ii) Environmental effects.

Changes in ambient conditions and the immediate traffic environment cause variations in vehicle fuel consumption. Both of these factors vary continuously throughout the course of a car journey.

iii) Driver effects.

Driver type, classified by either the physical measures of a vehicle's operation, driving experience or knowledge, or a "measure" of the driver's personality, is known to affect vehicle fuel consumption. A driver's behaviour can also be influenced by a constraint on journey time, which introduces a "time-saving" factor that may outweigh the perceived additional costs resulting from a comparatively higher fuel consumption, due to increased levels of acceleration, deceleration and vehicle speed.

Assuming the factors of (i) and (ii) above to be fixed, and with no constraint on journey time, the fuel consumption of a car may be significantly reduced by following certain guidelines.

Under urban and suburban driving conditions, where the average vehicle speed was between approximately 20 to 60Km/hr., the test results showed that fuel consumption decreased as average speed increased. Though this result remained true for speeds up to approximately 60Km/hr., in urban traffic environments average vehicle speed is somewhat restrained by the maximum speed limits of 30 or 40Km/hr. Although a vehicle is continually accelerated and decelerated in the "stop-start" conditions of urban driving, a high average speed should not be a result of high levels of acceleration or deceleration (above $0{\cdot}8 m/s^2$)[14]. Ideally, a vehicle should be smoothly accelerated, changing through to the highest gear selection as soon as possible to minimise average engine speed [25] (subject to practical limitations), and kept in continual motion with the anticipation of traffic controls, entrance to roundabouts and the possible effects of other road obstructions and users. The underlying effect of this strategy is to minimise the use of brakes.

Additionally, fuel consumption can be reduced by increaseing the average speed of the traffic flow in congested areas, this can be achieved by improvements in the road network, vehicle restrictions, and car-pooling to reduce road-space demand.

On suburban and motorway roads similar driving techniques to those outlined for the urban environment can be recommended, though under these "free-flowing" traffic environments, average vehicle speed is the prime factor. For best fuel economy an average speed of approximately 70Km/hr. should be attained using smooth acceleration from rest, and with minimal fluctuations in cruising speed due to road obstructions or overtaking.

8.3. Future improvements in fuel economy.

Having established the most important factors that influence vehicle fuel economy from the statistical analyses of Chapters 5 and 6, the next concern is the optimisation of these variables in practice, to achieve future fuel savings within the automotive transport sector of the economy. In the short-term, future improvements could include a substantial reduction in average vehicle weight, a parameter shown to affect the variation in fuel consumption, even between three very similar test cars. Replacement of steel body components with aluminium or composite materials would not only achieve a significant reduction in total vehicle weight, but would enable the re-design of load-carrying components to aid further vehicle weight reduction.

Although the regression analyses of Section 6.3 did not show the 300cc. difference in petrol engine displacement to affect fuel consumption significantly, it did establish that the drivetrain ratio "$N/_V$" had a great influence on fuel consumption, with its numerical relationship dependent on the traffic environment. Future concepts in transmission design could attempt to optimise this variable under different traffic conditions by the better matching and control of engine characteristics and drivetrain gearing.

The benefit of diesel powered-vehicles was denoted in the regression analyses by the influence of the "heat of combustion" term on fuel consumption. The comparitive fuel economy advantage of diesel vehicles over their petrol equivalents was additionally shown by the regression analyses of Chapter 3 and the operating cost comparison of Chapter 4. Although the diesel vehicle was shown to be between 22% and 4% more fuel efficient than its petrol counterpart, depending on traffic conditions, reductions in the differential standing charges, increases in the differential fuel prices and better "power-to-weight" ratios are required to make present day diesel cars a more viable proposition for the average motorist in Britain.

Apart from future improvements in vehicle design, an alternative long-term solution to improve overall fuel economy would be the reduction, restriction and optimisation of traffic flows, especially in the "stop-start" environment of urban driving. The control of traffic for better fuel economy must be aimed at increasing average vehicle speed (within the 0 to 65Km/hr. speed range), and reducing the frequency of brake applications and vehicle accelerations.

8.4. Recommendations for future work.

The continuous undertaking of research studies, to attempt to explain in greater depth the various influencing factors that effect car fuel economy, or to appraise new technological developments aimed at minimising vehicle fuel consumption, is of great importance. The automotive industry is heavily dependent upon the supply of natural crude oil, and with sources being of a finite nature, future conservation and frugal usage are primary concerns, even during times when a "glut" of oil exists in the world economy.

Advances towards lighter vehicles and more efficient power units are continually taken by the industry; however, two other main areas of improvement do exist, and both could play a significant role in future improvements of fuel economy. First, the influencing factors of vehicle acceleration, deceleration, gear change frequency and throttle motions have shown that the operation of a car (i.e., driver behaviour) can significantly affect fuel consumption.

Numerous studies have outlined methods of fuel-efficient driving, and the benefits of various driver-aids aimed to improve fuel economy [42] [43]; however, the effectiveness of all the strategies presented required the conscious interaction of the driver. Instead of relying on changing a driver's behaviour and knowledge, to reduce vehicle fuel consumption (which in most cases only works on a short-term basis), a future study could investigate methods of redesigning the vehicle control mechanisms to improve any driver's fuel economy without awareness to the driver, impaired vehicle performance, or danger to other road users. A simple example being electronic control of a "drive-by-wire"* throttle pedal linkage.

The second area of study could be an investigation into possible ways of reclaiming the wasted fuel energy expelled as heat, via engine coolant, vehicle braking and the exhaust gases. In the "stop-start" mode of urban driving the significant effect on fuel economy of frequent braking and accelerations would be greatly reduced by the application of inertial regenerative braking systems similar to those already used by larger road vehicles. Although partially achieved by engine turbocharging, other methods of re-cycling exhaust gas energy could be investigated. To prevent heat losses and enable higher, more efficient combustion temperatures, the development within the industry of adiabatic engine components is a concept of great interest, with the saving of heat energy directly increasing the running efficiency and hence fuel economy of reciprocating engines.

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* By replacing the mechanical linkage between the throttle pedal and carburettor (fuel control rack for diesel) with an arrangement consisting of electronic servo actuators, the driver's operation of the engine fuelling can be optimised by the use of on-board electronic control software.

CHAPTER 9

CONCLUSIONS

9.1. Conclusions.

During the Spring and Summer of 1985, a programme of road tests was conducted over a Leicestershire test route, using three Vauxhall Cavalier cars and seven test drivers. Two cars were 1300cc. and 1600cc. petrol vehicles and the third was a 1600cc. diesel vehicle having similar performance to the small petrol vehicle. Comparisons of the fuel consumptions of each vehicle, and of the performance of each test driver were carried out over different driving environments.
The main results were as follows:

1. In urban, suburban and motorway driving conditions, the diesel vehicle used 22%, 17% and 4% less fuel than its petrol counterpart, respectively. Similarly, the 1300cc. petrol car obtained 9%, 7% and 12% better fuel economy than its 1600cc. petrol version. Using a 50/40/10% route mix of urban/suburban/motorway road classes, the same comparisons showed an 18% fuel advantage for the diesel and a 9% fuel advantage for the smaller petrol car.
2. Average vehicle speed was shown to have a significant effect on the fuel consumption of each car. A regression analysis was constructed similar in format to that used by Weeks [6]. All vehicles showed a minimum fuel consumption at approximately 65Km/hr. Below this speed, the diesel fuel advantage decreased with increasing speed. Above 65Km/hr. the diesel car fuel economy was similar to the 1300cc. petrol vehicle, with the latter vehicle obtaining its optimal fuel saving over the 1600cc. petrol car at approximately 85Km/hr.
3. Driver "performance" was studied by comparing the results of six test drivers differing by sex and age, to those of an "expert" (trained) driver. In urban conditions where the driver effect on fuel consumption was greatest, the "expert" returned a fuel consumption 9% less than the mean of the other six drivers, with a corresponding average speed 6% slower. Corresponding measures of average vehicle acceleration, deceleration, throttle "toe-down" position and acceleration were also reduced by 9%, 14%, 21% and 36%. Over the more "free-flowing" suburban traffic environment the expert driver attained a 10% fuel saving over the other drivers, with a 1% decrease in average speed.
4. For the individual motorist, it was found that only high annual travel of approximately 40,000Km. or more, over a mixture of road types,

would produce a total annual cost saving with the diesel vehicle over its petrol counterpart. With annual travel confined to purely urban traffic conditions, an annual distance of approximately 27,500Km. or greater would produce the same comparitive saving. For an annual travel of 14,000Km. (based on the national average distance [1]), over a mixture of road types, the average motorist would pay, approximately, an additional £207.30 per annum in total operating costs if he/she used the diesel vehicle instead of its 1300cc. petrol equivalent.

5. The "type" of driver was also shown to effect the differential annual costs of the diesel vehicle over its petrol-engined counterpart, with a more "aggressive", less fuel-efficient, driver requiring lower annual travel for the "break-even" point in total operating costs. A similar effect of driver "type" was apparent with the petrol car comparison.

6. Hypothesising that all petrol vehicles on the United Kingdom road network were replaced by their equivalent diesel versions, an average national fuel saving of approximately 2.44 million tonnes per annum would have been achieved during the period 1980 to 1984; representing a 4·6% saving in total national petroleum consumption, and a 9% saving of fuel consumption in the transport sector of the United Kingdom.

Statistical association and regression analyses were used to investigate the effects that a finite number of factors, describing the physical motion of the vehicle, urban traffic flow and ambient conditions, had on car fuel consumption. The main results from these studies were:

7. Under urban driving conditions the parameter of average speed had the greatest effect on fuel consumption, with an increase in speed improving fuel economy (for speeds below 65Km/hr.). A decrease in average engine speed reduced urban fuel consumption, whilst the frequency of gear changing had a negligible effect. The levels of average vehicle acceleration and deceleration levels were highly correlated to fuel flow rate (fuel used per unit distance). The variation of ambient temperature and the resulting variation of fuel and oil temperatures were significantly associated with fuel consumption, with warmer conditions improving fuel economy. A greater average throttle opening (fuel control rack setting on diesel) was shown to increase fuel consumption significantly. Depression or "toe-down" velocity and acceleration of the

throttle pedal were virtually uncorrelated to fuel consumption. The variation of fuel consumption due to different driver "types" was greater than that due to different vehicle types (with respect to the three test vehicles used).

8. Under suburban conditions an increase in vehicle speed resulted in a better fuel economy, though the significance of this parameter in explaining the variance of fuel consumption was not as great as that noted within the data from urban traffic conditions. Average vehicle acceleration, gear-change frequency and the parameters describing throttle motion all correlated highly with fuel consumption, with an increase in magnitude of either variable resulting in a greater fuel consumption. High correlations to fuel consumption also existed for the parameters of ambient temperature and relative air humidity, implying that an increase in either variable (i.e., towards hotter, more humid conditions) would improve fuel economy.

9. Under the motorway driving environment a high correlation between fuel consumption and average speed was observed. In contrast to the relationship observed for slower journey speeds (below approximately 65Km/hr.), with the faster average speeds of the motorway section an increased vehicle speed increased fuel consumption. The variance of the parameter describing average throttle position had the most significant influence on motorway fuel consumption, with a greater throttle opening, indicative of higher engine power demand, vehicle speed, engine speed, and acceleration levels, resulting in a poorer fuel economy. Ambient pressure had a greater affect on fuel consumption than the variations of ambient temperature and air humidity in this traffic environment.

10. Under the "free-flowing" conditions of motorway driving, the choice of vehicle type (1600cc., 1300cc. petrol or 1600cc. diesel) had a greater influence on fuel consumption than the choice of driver. However, as the traffic environment became more congested, from suburban to urban road types, the driver steadily had a significantly greater effect on fuel economy than the type of vehicle used. The variation of traffic environment (route section) had a greater affect on fuel consumption than the different cars or drivers used for the programme of tests. Measurable interactions also existed between the variables of vehicle, driver and route section when used to explain the variation of fuel consumption.

11. Regression models based on the fundamental "road-load" equation and ambient correction factors for engine power tests, were constructed to

explain and predict the fuel consumption of the three test vehicles over each type of driving environment. For an overall journey based on a 50/40/10% split of urban/suburban/motorway road classes, 95% of the variance of fuel consumption was explained by the respective regression model. The terms expressing vehicle "road-load" and heat energy of the fuel (i.e., diesel or petrol) accounted for 81% of this figure.

12. The drivetrain ratio "$N/_V$" was a significant factor in the regression models for each route section. Below the average speed for minimum fuel consumption (i.e., for urban and suburban data < 65Km/hr.) an increase in this variable improved fuel economy. For average speeds above the 0 to 65Km/hr. range, this variable was found to be inversely proportional to fuel economy, with a rise in its magnitude increasing fuel consumption.

13. In the regression analyses for each type of road class, the parameter denoting the variation in engine displacement (300cc capacity differential for the test vehicles used) was found to be statistically redundant, and was omitted from the expressions.

14. The regression term accounting for the variation in air humidity had a significant effect on the variation of fuel consumption in the urban section of the test route. This effect diminished as traffic congestion decreased.

15. The term accounting for the effect of ambient pressure variations on fuel consumption (other than aerodynamic effects) was not significant in any of the regression analyses.

16. The correction factor explaining the effect of ambient temperature on fuel consumption was significant in all regression models.

17. The parameter denoting traffic flowrate was shown to have a significant influence on urban fuel economy. Not only did heavier traffic result in a poorer fuel economy, it consequently reduced the measures of average speed, average vehicle acceleration and the degree of average throttle opening, "toe-down" throttle velocity and acceleration.

18. A relationship was shown to exist between the profiles of driver acceleration/deceleration histograms and the variation of driver "type" or "aggressiveness", i.e., corresponding to average measures of vehicle speed, fuel consumption and throttle motions.

19. An exponential curve-fitting technique to provide a measure of driver "aggressiveness" was outlined.

CHAPTER 10

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CHAPTER 11

APPENDIXES

APPENDIX 1

FUEL MEASUREMENT

1.1. Fuel measurement.

The "Transflo" fuel flowmeters used for the work were of the "positive-displacement" variety, using an arrangement of four rotary pistons to give an electrical pulse output for each cm^3 of fuel passed (see Plate Nos.7 and 8). Calibration checks on the fuel flowmeters, conducted at T.R.R.L., showed their nominal accuracy to be within ±0·5% for the fuel flow rates expected under normal driving conditions. Although the volumetric measurements recorded were corrected for changes in fuel temperature (Figure No.2), the accuracy of the meters was specified not to alter within the temperature range of 0 to 40 degrees Celsius.

1.2. Petrol fuel measurement.

With reference to Figure No.4 the fuel flowmeters were fitted immediately "down-line" from the fuel tank of each vehicle, together with a filter to protect the mechanism of the unit. A de-aerator was also fitted in the fuel line before the fuel meter to prevent air vapour from being included in the volume measurements.

Using the recordings of fuel temperature taken throughout each test drive, the volumes measured by the meter were corrected to a standard volume at 15·6 degrees Celsius, in most cases the change in volume was less than 1%.

In each petrol vehicle the mechanical fuel pump was disconnected and replaced by an electronic pump. Located in the rear boot compartment, the replacement pumps were installed in the fuel system immediately "down-line" from the fuel tank before the fuel flowmeter. (Plate No.7).

1.3. Diesel fuel measurement.

The usual procedure when measuring diesel fuel in automotive applications is to use two flow meters, one to measure fuel flow to the injectors and the second to measure the "spill-back" or returned fuel from the injectors. The difference between measures gives the actual fuel used. By arranging the fuelling system so that only one flowmeter can be used, the considerable loss of accuracy, created by subtracting readings from two flowmeters (especially with a large amount of "spill-back"), can be avoided. Problems can also arise using the dual flowmeter design because the "spill-back" fuel usually has a higher density (approximately 5% to 15%) and temperature, than the supply fuel. Normally corrections would be made for these effects when the volume measurements of each flowmeter are compared.

To overcome the aforementioned difficulties, the Vauxhall Cavalier diesel model was fitted with the fuel supply system shown by Figure No.5. A single "Transflo" fuel flowmeter was used which measured the flow of fuel into a small reservoir in the engine compartment. The reservoir was also supplied by the "spill-back" fuel from the injectors (see Plate No.6). With a constant level of fuel always maintained in the reservoir, the flowmeter only accounted for the actual fuel burnt by the engine.

A de-aerator was fitted in the supply line before the flowmeter to ensure that no air vapour corrupted the fuel volume measurements. In the "spill-back" line, a water separation unit expelled any air vapour introduced by the injector and pump mechanisms.

Similar to the petrol measurements, the recorded volumes of fuel were corrected to a standard of 15·6 degrees Celsius (Figure No.2).

APPENDIX 2

RESULTS FROM SUBSIDIARY TEST PROGRAMMES

2.1. Additional motorway section effect.

Table No.33 summarises the average fuel consumption and vehicle speed recorded by driver No.1 in each vehicle, for the four main route sections of the three additional tests. The corresponding results from the "normal" tests conducted with driver No.1 in the main test programme, are shown in parentheses.

The "Urban 2 to Motorway" section was used to compare the vehicle performances immediately before the motorway section. In all vehicles a poorer fuel consumption was obtained during the additional subsidiary test programme, with a mean for all vehicles 5% higher than the corresponding mean fuel consumption from the "normal" tests. For the two petrol vehicles, the difference in fuel economy over this section was partly explained by the corresponding difference in average speeds observed between each test programme. With the diesel vehicle, a better fuel economy was achieved in the "normal" tests, with a comparatively higher average speed. This anomally may have resulted from differences in traffic conditions or the significant variation in ambient conditions (shown in Table No.33) between the diesel tests, with the additional (less fuel-efficient) test drive conducted in heavier traffic under cooler, more humid weather.

On the motorway section (accounting for variations in average speed) the journey length had no significant effect on the fuel consumption obtained in each vehicle.

The route section of prime interest was the "Suburban 2" journey, immediately following the motorway section. Similar to the motorway data, the results suggested no apparent effect of the additional motorway section on the subsequent vehicle fuel consumption. The overall (mean for all vehicles) fuel consumption figure was 2% lower after the additional motorway section, however, the overall average speed was comparatively 4% slower.

2.2. Effect of late test start on fuel consumption.

Table No.34 summarises the result for the "normal" (in parentheses) and "late" tests completed by driver No.1; one "late" test in each vehicle.

On the motorway and suburban route sections, the "time of day" effect on fuel consumption due to daily changes in traffic flow, was not expected to be significant because of the normal "free-flowing" characteristics of the traffic environment. The results showed that the normal motorway tests conducted between 10.30 and 10.45a.m. were on average 3% faster and 10% less fuel-efficient than the "late" test runs with the motorway section completed during the lunchtime period of 12.30 to 12.45p.m. The speed dependence of fuel consumption was similarly shown by the suburban results, where a comparative 8% reduction in vehicle speed for the "normal" tests, conducted during the morning rush-hour traffic, produced a fuel consumption 8% greater than that obtained in the "late" tests. Note that the speed effect was reversed under suburban conditions (i.e., lower speed implied a higher fuel consumption), a result illustrated by Figure No.22 (Section 3.4.2).

The Urban Cycles completed in the "late" test programme avoided the normal inclusion of the Leicester morning rush-hour traffic. As a result, the average speed for all vehicles during the "late" tests was 6% higher, with a respective 12% improvement in fuel economy. These figures were significantly higher than comparative findings concluded by a report in 1976 [16], which measured a 3·4% (off-peak to peak) fuel saving for a typical built-up area in the United Kingdom. Accounting for the variations in traffic congestion over the complete test route, the "overall" 50/40/10% fuel saving achieved for all vehicles during the "late" tests was 9%, with a 7% increase in average vehicle speed.

2.3. "Hot start" fuel consumption effect.

Table No.35 presents the fuel consumption and average speed for each vehicle over the first mile of the test route, and the first suburban and urban sections, for tests started with an engine at normal running temperature (the standard "cold start" results from the mean test programme are shown in parentheses).

For an almost identical average speed, the 1600cc. petrol vehicle was 16% more fuel-efficient over the first mile, when starting with a "hot" engine. This vehicle was fitted with an automatically adjusted fuel enrichment device, thermostatically controlled by the water jacket temperature. The 1300cc. petrol car possessed a manual choke operated by the driver. This was usually only employed up to the completion of the "first-mile" section. A "hot start" in this vehicle resulted in a

23% reduction in fuel consumption over the same "first mile" section. The diesel car employed electrical "glow plugs" to heat the combustion chambers to aid cold starting. These heating elements were not used to assist engine running: the heat produced by fuel compression is sufficient for this. Over the first mile a "hot start" with the diesel car produced a 10% reduction in fuel consumption.

Over the "Suburban 1" and "Urban 1" route sections, the overall fuel consumption advantage of the 1600cc. petrol vehicle, after a "hot start", were 1·1% and 5·6%, respectively. Similarly for the 1300cc. petrol car, the fuel economy over the same route sections was improved by 5·4% and 7·7%, respectively, after a "hot start".

The tests were not exhaustive enough to account for all aspects of "cold" and "hot start" tests, and especially to extract the effect of vehicle speed from the comparative fuel consumptions obtained over each route section. This was illustrated by the diesel/Suburban 1 results, where a speed variation of 9·8Km/hr. existed which camouflaged the "hot start" effect on fuel economy because of the influence of speed variation on fuel consumption.

In conclusion, the results indicated that for the petrol cars, after a "hot start", the 1600cc. vehicle (fitted with an automatic choke) obtained a higher comparative ("hot" to "cold") fuel saving than that obtained in the 1300cc. vehicle (fitted with an manually operated choke). The diesel vehicle produced the smallest differential between "hot" and "cold start" fuel consumptions, implying that when starting a journey from "cold", and not "hot", a diesel vehicle uses proportionally less fuel than its petrol counterparts. Similar findings have been observed for constant speed vehicle tests [24].

The "hot start" fuel savings of each car were greatest over the "first mile" route section due to the operation of the choke and low running temperature of the vehicles under "cold start" conditions.

2.4. Summer test programme results.

The main purpose of the "summer" test programme was to provide additional data for the statistical analysis of Section 5.1 and Appendix 3.2, investigating the effect of ambient temperature, pressure and humidity variation on vehicle fuel consumption. However, with reference to Table Nos.36 to 39, the basic findings will be discused.

On average, the summer tests were conducted in marginally hotter and more humid conditions with a 3% increase in absolute temperature and a 4% decrease in % relative humidity. Over the urban route section the petrol and diesel vehicles were 9% and 8% more fuel efficient in the warmer climate, respectively. Over the suburban and motorway route sections, the petrol car exhibited "summer" fuel savings of 3% and 9%, whilst the corresponding "summer" fuel economy of the diesel vheicle was improved by 12% and 8%, respectively for the same route sections.

Summarising, the results showed that in warmer ambient conditions both the petrol and diesel vehicle fuel consumptions decreased. A result that was true for all traffic environments. This effect can be explained by a number of contributing factors. First, in warmer conditions an internal combustion engine will operate at a higher, more "thermal-efficient" temperature, and secondly (though subject to the corresponding variation of ambient pressure), a higher ambient temperature will lower the air density, which in turn will both reduce the aerodynamic drag acting on the vehicle and affect the engine power output ("charge-weight" law).

Additionally under poor weather conditions, increased rolling resistance due to wet roads and the use of auxiliary equipment items (window wipers and demistors), all aid a poor fuel economy, though these conditions were not experienced in either test programme.

2.5. Austin-Rover Montego fuel comparison.

Figure Nos.35 and 36 show the average fuel consumption and vehicle speed for each test vehicle over the four main route sections. The 1600cc. "Ivory" and "White" vehicle results were averaged from two tests completed in each vehicle by driver No.6. The "expert" figures were recorded on a single test by the expert driver in the "Ivory" vehicle.

Comparing the two supposedly identical vehicles over the urban section, the "White" vehicle achieved a fuel consumption 9% less than the "Ivory", with a marginally lower average speed. Over the suburban and motorway routes, the comparatively better fuel economy of the "White" car decreased, and the comparison became more dependent upon the vehicles' respective average speeds.

Using the 50/40/10% route mix, as an overall comparison of the fuel economy of each vehicle, the "White" Montego returned a fuel consumption

6% better than its "Ivory" version, with an average speed that was 4% greater.

During each test the vehicles had the same payload (driver, instructor, instrumentation system and fuel) and were driven under similar traffic and weather conditions. The inherent differences in fuel economy must therefore be due to variations within the vehicles themselves; i.e., different torque curve characteristics, engine tuning, carburettor settings, or transmission lubrication.

In terms of fuel economy, the performance of the expert driver was similar to that obtained in the main "Vauxhall Cavalier" test programme. In urban driving conditions, he achieved a comparitive fuel saving of 10% in the "Ivory" vehicle, over the average fuel consumption from the two tests completed by driver No.6 in the same vehicle. The corresponding average vehicle speed of the "expert" was 6% less than the mean of driver No.6. With respect to the urban results, the fuel-efficient behaviour of the expert driver made the less economic "Ivory" vehicle perform similar to the more economic "White" vehicle when driven by driver No.6.

Over the suburban and motorway sections the expert driver was respectively 21% and 35% more fuel efficient, in the "Ivory" vehicle than driver No.6; however, under these more "free-flowing" traffic conditions, the gains in fuel economy appeared to result from respective speed reductions of 13% and 24%, rather than fuel-efficient skills of anticipation, smooth braking and acceleration required in heavily congested traffic.

APPENDIX 3

REGRESSION DERIVATION FOR PREDICTION MODELS OF "ON-ROAD" FUEL CONSUMPTION AND AMBIENT EFFECTS

3.1. Derivation of regression models to predict vehicle fuel consumption.

The basic function for vehicle tractive effort "F" is:

$$F = C_1.W + \tfrac{1}{2}.\rho.C_2.A.V^2 + C_3.W/_g.\delta V/_{\delta t} + W.\sin\theta \qquad .....\{i\}$$

Now, instantaneous engine power can be represented by:

$$P_e = f.Q.\eta_e \qquad .....\{ii\}$$

where, P_e = engine brake horsepower,
f = fuel flow rate,
Q = heat of combustion of fuel per unit volume,
and, η_e = engine brake thermal efficiency.

Further, the vehicle tractive power given by $P_e.\eta_t$, where η_t is the transmission efficiency, is equivalent to equation {i} multiplied by vehicle speed; hence:

$$f.Q.\eta_e.\eta_t = (C_1.W + \tfrac{1}{2}.\rho.C_2.A.V^2 + C_3.W/_g.\delta V/_{\delta t} + W.\sin\theta).V \qquad .....\{iii\}$$

Fuel consumption measured by volume per unit distance (litres/100Km.) is given by $f/_V$, therefore equation {iii} can be written:

$$f/_V = FC = (C_1.W + \tfrac{1}{2}.\rho.C_2.A.V^2 + C_3.W/_g.\delta V/_{\delta t} + W.\sin\theta)/_{(Q.\eta_e.\eta_t)} \qquad .....\{iv\}$$

To simplify this general expression for fuel consumption, a number of first order approximations can be utilised.

First, the transmission efficiency, η_t, has been shown to relate closely to vehicle speed and engine speed [41], such that:

$$\eta_t = C_4.(V/_N)^{\tau} \qquad .....\{v\}$$

Further, the engine brake thermal efficiency, η_e, has been shown to relate closely to vehicle weight and engine displacement [41], such that:

$$\eta_e = C_5.W^{\gamma}/_E\partial \qquad .....\{vi\}$$

where, C_4, C_5, τ, γ and ∂ are constants,

N is engine speed,

and, E is engine displacement.

Substituting {v} and {vi} into {iv}, letting $C = 1/_{(C_4C_5)}$, and extracting the term for vehicle weight "W" from the "road-load" equation, fuel consumption "FC" becomes:

$$FC = C.E^{\partial}/_{Q}.W^{1-\gamma}(N/_{V})^{\tau}(C_1 + \tfrac{1}{2}.\rho.C_2.A/_{W}.V^2 + C_3/_{g}.\delta V/_{\delta t} + \sin\theta) \quad .\{vii\}$$

Now, for the three Vauxhall Cavalier vehicles used for the road tests, the following values in S.I. units can be used for the constant terms:

$C_1 = 0{\cdot}012$, $C_2 = 0{\cdot}4$, $C_3 = 1{\cdot}05$, $A = 2{\cdot}0m^2$ and $g = 9{\cdot}806m/s^2$

Further, the air density term, ρ, can be replaced with:

$$\rho = 100.P/_{(R.T)} \quad .....\{viii\}$$

where, P is the ambient pressure (mBars.),

T is the ambient temperature (°K),

and, R is the Universal Gas Constant ($287J/_{Kg.°K}$).

Substituting {viii} and the given constant values into {vii}, and converting all terms in "road-load" parentheses to S.I. units, the following expression is obtained:

$$FC = C.E^{\partial}/_{Q}.W^{1-\gamma}(N/_{V})^{\tau}(0{\cdot}012 + 0{\cdot}0107.P/_{T}.V^2/_{W} + 0{\cdot}107.\delta V/_{\delta t}) \quad ...\{ix\}$$

Finally, to account for the effects of ambient condition on engine power development (effect upon aerodynamic drag is accounted for by the density term), three non-dimensional "environmental" terms, related to the standard correction factors used by the automotive industry for "test-bed" power correction [39][40], were employed; namely:

$$C_t = 300/_{T(°K)}, \quad C_p = P(mBars)/_{1000}, \quad C_h = 60/_{H(\%)},$$

where, H = relative air humidity.

Although technically the parameters of $\bar{N}$, V and $\delta\bar{V}/_{\delta t}$ represent continually varying quantities, for the purpose of the regression analyses, constant average values recorded over individual route sections were used for these variables. To denote the the use of average "sectional" data for terms that are fundamentally variables, a "bar" (i.e., "$\bar{\ }$") was employed.

The term "$\delta\bar{V}/_{\delta t}$" was calculated from a "root-mean-square" of the average vehicle acceleration and deceleration data ("VACC" and "VDEC", respectively: refer to Appendix C(i)).

The completed expression for fuel consumption prediction over each route section was thus:

$$FC = C.W^{1-\gamma}(E^{\partial}/_{Q}\psi)(\bar{N}/_{\bar{V}})^{\tau}(0{\cdot}012 + 0{\cdot}0107.\bar{P}/_{\bar{T}}.\bar{V}^{2}/_{W} + 0{\cdot}107.\{\delta\bar{V}/_{\delta t}\})^{\alpha}.C_t^{\beta}.C_p^{\eta}.C_h^{\omega}$$

where, $\bar{P}$ is the average sectional pressure, ...{x}

and, $\bar{T}$ is the average sectional temperature.

The powers of ψ, α, β, η and ω were applied to conform to the necessary format for logarithmic transformation of the model into a linear expression.

The units of each parameter entered into the regression from "ROADTEST.DATA" were as follows:

fuel consumption (FC)	-	Litres/100Km.
vehicle weight (W)**	-	Newtons.
heat combustion (Q)*	-	KJoules/litre.
engine displacement (E)**	-	Litres.
average engine speed ($\bar{N}$)	-	Revs./second.
average vehicle speed ($\bar{V}$)	-	Metres/second.
ambient temperature ($\bar{T}$)	-	°K.
ambient pressure ($\bar{P}$)	-	mBars.
r.m.s. of "VACC" & "VDEC" ($\delta\bar{V}/_{\delta t}$)	-	Metres/second^2.

* Heat combustion ("Q") values used for the regression analyses were; 31383·4KJoules/litre and 36716·4KJoules/litre, for petrol and diesel.

** Values for vehicle weight ("W") and engine displacement ("E") taken from Table No.1.

For the purposes of this study, the error term "ξ" contained in the linear equation {iv} of Section 6.2 was assumed to be "heteroskedastic" [41], i.e., it had constant variance within the test data.

3.2. Derivation of ambient effects on fuel consumption.

The statistical analyses of Chapter Nos.5 and 6 showed that the ambient parameters of temperature, pressure and relative air humidity all had a significant effect on "real" on-road fuel consumption of private cars. Further, the magnitude of each "effect" was shown to be influenced by the type of traffic environment; viz., urban, suburban, motorway or an overall 50/40/10% mix of road types.

With respect to the fuel consumption prediction models of Section 6.3, it was observed (for the urban, suburban and "50/40/10%" road types) that the term explaining the effect of air humidity on fuel consumption was statistically more significant than those denoting the effects of ambient temperature and pressure. This somewhat unexpected result of a "humidity" effect on fuel consumption appeared to contradict the standard "test-bed" correction factors used in the automotive industry (excluding the I.S.O. codes of practice), which only make a sketchy, if not non-existent reference to its effect on engine performance and/or the method for its correction.

The experimental data used for the analyses of Chapter Nos.5 and 6 were collected from on-road tests, and were hence subject to capricious events and effects that exist in real traffic conditions - unlike the controlled environment of engine test-bed data collection. Respectively, the conclusions of this section relate primarily to data correction for "real" on-road car fuel consumption. Using the same on-road data a number of prediction models were set-up to find the most significant format of the three ambient terms to best explain fuel consumption variation.

3.2.1. Standard correction factors - codes of practice.

The following section outlines the correction fectors and reference conditions used in the automotive industry for atmospheric standardisation of test-bed engine performance data.

E.C.E. 15/04 regulations. (Annex Nos.4 and 9)

Atmospheric conditions for vehicle road tests - based on air density, ρ, which should not deviate by $\pm 7{\cdot}5\%$ from reference value. To use reference ambient conditions of:

Pressure (P_s) = 1000 mBars.

Temperature (T_s) = 293·2 °K.

i.e., $$\rho_{test} = \rho_{standard} \times {}^{P_t}/_{P_s} \times {}^{T_s}/_{T_t}$$

No reference is made to a standard humidity condition or correction.

S.A.E. Engine power test code - spark ignition and diesel.

(S.A.E. J 1349 - June 1985)

Standard inlet air conditions of P_s = 1000 mBars.

T_s = 298 °K.

Though reference is made to a pressure of 1000 mBars., the included correction factors use a dry pressure of 990 mBars. to exclude a constant proportion of water vapour from the standard air conditions.

Note that correction factors are for engine brake power data and not fuel consumption data. Assuming an overall mechanical efficiency of 85%, the following factors are presented for full-throttle (-control rack) setting:

i) Spark-ignition engines.

$$\text{Atmospheric factor} = \frac{\text{corrected brake power}}{\text{observed brake power}} = [1{\cdot}18({}^{99}/_{P_t})({}^{T_t}/_{298})^{0\cdot5} - 0{\cdot}18]$$

with the limitation that $0{\cdot}93 \leq \text{factor} \leq 1{\cdot}07$.

ii) Diesel engines.

$$\text{Ambient factor} = \frac{\text{corrected brake power}}{\text{observed brake power}} = (f_a)^{f'}$$ where,

for the naturally aspirated and mechanically supercharged engines;

Atmospheric factor, $f_a = ({}^{99}/_{P_t})({}^{T_t}/_{298})^{0\cdot7}$ and,

Engine factor, $f' = 0{\cdot}3$ (based on an average engine speed and fuel flow of 2000 r.p.m. and 3 lit./hr. respectively.)

hence, ambient correction factor for diesel engine used in this report is given by:

$$\left(\frac{99}{P_t}\right)\left(\frac{T_t}{298}\right)^{0.21}$$

with the limitation that $0{\cdot}90 \leq$ correction factor $\leq 1{\cdot}10$.

The S.A.E. procedure for measuring basic highway vehicle engine fuel consumption - S.A.E. J 1312 September, 1980 - similarly accounted for humidity by deducting from the standard barometric pressure a vapour pressure of 0·38" Hg. (1·3 KPa.).

<u>I.S.O. standard atmospheric correction regulations.</u>[39][40]

Reference conditions: Temperature (T_s) - 298 °K.
Pressure (P_s) - 990 mBars.

(i.e., similar to the S.A.E. practice to deduct 1 KPa. for the vapour pressure in the "standard" air conditions.)

For naturally aspirated and pressure charged S.I. engines;

$$\text{ambient power correction factor} = \left(\frac{99}{P_t}\right)^{1.2}.\left(\frac{T_t}{298}\right)^{0.6}$$

again, this formulae is only applicable if $0{\cdot}93 \leq$ factor $\leq 1{\cdot}07$.

The correction factor for naturally aspirated and mechanically pressure charged diesel engines is identical to that presented in the S.A.E. regulations.

In addition to the correction factors for net power conversion, I.S.O. present regulations for fuel consumption standardisation [40]. Under these regulations the standard atmospheric conditions are:

Total barometric pressure (P_s)	-	1000 mBars.
Air temperature (T_s)	-	300 °K.
Relative air humidity (H_s)	-	60%.

(the standard humidity H_s = 60% corresponds to a water vapour pressure of 2·133 KPa. at a temperature of 300 °K).

The fuel consumption adjustment factor is given by β, where;

$$\beta = {}^{b_x}/_{b_r} = {}^{k}/_{\alpha} \quad ; \qquad \text{where,}$$

b_x, b_r are the specific fuel consumptions under "test" and "reference" conditions, respectively;

k is the ratio of indicated power and equal to:

$$\frac{(P_x - a.\phi_x.P_{sx})^m.(T_r)^n.(T_{cr})^q}{(P_r - a.\phi_r.P_{sr})^m (T_x)^n (T_{cx})^q} \qquad \text{and,}$$

α is the power adjustment factor and equal to:

$$k - 0{\cdot}7(1 - k).({}^{1}/_{\eta_m} - 1) \qquad \text{where,}$$

η_m is the mechanical efficiency (i.e., approximately 80%),

T_{r}, T_{x} are the "test" and "reference" absolute air temperatures, respectively, and,

$T_{cr,cx}$ are the "test" and "reference" absolute charge air coolant temperatures, respectively.

Rather than use the above formulae to find the value of β, I.S.O. present a series of reference tables which can be used instead. Unlike other correction standards, I.S.O. present a method that accounts for variation in air humidity between the "test" and "reference" conditions by deducting the respective saturation vapour pressures. The notation used in the evaluation of "k" is:

ϕ_x, ϕ_r are the "test" and "reference" relative air humidities,

P_r, P_x are the "test" and "reference" total barometric pressures,

$P_{sx,sr}$ are the "test" and "reference" saturation vapour pressures respectively, and,

factor "a" and exponents "m", "n" and "q" have pre-determined values given in the I.S.O. text. For the vehicles used in this study their values would be as follows:

petrol engines – 1, 1, 0·5 and 0, respectively;
diesel engine – 0, 1, 1 and 0, respectively, or
1, 1, 0·75 and 0, respectively, for diesel engine power limited by air excess or thermal reasons.

3.2.2. Prediction models for analysis of ambient effect.

To study the significance of the ambient effects of pressure, temperature and humidity on the variance of fuel consumption, two comparative regression models were used. Each model was "fitted" to the fuel consumption data from each main route section, viz., urban, suburban, motorway and 50/40/10% mix; based on the six tests conducted in the diesel vehicle by driver No.3 from both the "Spring" and "Summer" test programmes.

By using the aforementioned tests, it was assumed that the driver "effect" on fuel consumption variation was eliminated from the regression analyses. Further, as each model was fitted to the diesel vehicle data for a particular route section, the "vehicle" and "route section" effects on fuel consumption were additionally extracted from the regression analyses.

For each logarithmic regression analysis (similar to those of Section 6.3), the model is given together with the F-value and R^2 (explained variance) of each ambient term. Terms that were found to be statistically not-significant are denoted by "NS". The total explained variance of each model is also given to show the quality-of-fit to the fuel consumption data. The two models analysed were:

Model (1): $\text{FUEL} = C.(\frac{T}{298})^{\alpha}.(\frac{P}{1000})^{\beta}.(\frac{H}{60})^{\gamma}$ where,

P is the ambient pressure (mBars.),
T is the ambient temperature (°K),
H is the relative air humidity (%),
α, β, γ are power indexes,
C is a constant and,
FUEL is fuel consumption (litres/100Km.).

Model (2): $\text{FUEL} = C.(\frac{T}{298})^{\delta}.(\frac{P}{1000 - 10.P_V})^{\nu}$ where, as above and,

δ is the power for temperature correction,
ν is the power for pressure correction, and
P_V is the partial pressure of the water vapour (KPa.).
This model combines the pressure and humidity terms using the relationship between their saturation and

partial pressures, respectively.

i.e.,

Relative humidity "ϕ" is defined as "the ratio of the mole fraction of the vapour in the mixture to the mole fraction of vapour in a saturated mixture at the same temperature and total pressure". Since the vapour is considered an ideal gas, the ratio reduces to the ratio of the partial pressures of the vapour as it exists in the mixture "Pv", to the saturation pressure of the vapour at the same temperature, "Pg".

i.e., relative humidity, $\phi = \frac{Pv}{Pg} . 100 \ \%$

$$\text{or,} \quad Pv = \phi . \frac{Pg}{100} \ \text{KPa.}$$

Though the usual procedure is to obtain the value of "Pg" for the corresponding temperature from standard tables, for the purposes of the computer software regression analyses, the relationship between "Pg" and gas temperature "T" had to be defined by an analytical expression. By applying a regression analysis to the tabulated data, a polynomial expression of the form;

$$Pg = 0 \cdot 6182123 + 0 \cdot 0387692(T) + 0 \cdot 00207982(T^2) + 0 \cdot 0000007353934(T^4)$$

was fitted, with an $R^2 = 0 \cdot 99$ (i.e., 99% quality of fit). This relationship is shown graphically by Figure No.54.

<u>Model</u> (1) results:

URBAN FUEL $= 6 \cdot 159 \left(\frac{T}{298}\right)^{-2 \cdot 09} \left(\frac{P}{1000}\right)^{0 \cdot 358} \left(\frac{H}{60}\right)^{0 \cdot 789}$

		T	P	H
			(NS)	
F-value	-	4·889	0·092	2·310
R^2(%)	-	23·0	0·0	17·2
total R^2(%)	-		<u>40·3</u>	

SUBURBAN FUEL $= 5 \cdot 038 \left(\frac{T}{298}\right)^{-1 \cdot 67} \left(\frac{P}{1000}\right)^{0 \cdot 335} \left(\frac{H}{60}\right)^{-0 \cdot 132}$

		T	P	H
			(NS)	(NS)
F-value	-	1·327	0·115	0·094
R^2(%)	-	82·3	1·9	0·7
total R^2(%)	-		<u>84·9</u>	

MOTORWAY FUEL $= 9{\cdot}473(\frac{T}{298})^{5{\cdot}175}(\frac{P}{1000})^{3{\cdot}878}(\frac{H}{60})^{-0{\cdot}482}$ (NS)

F-value	-	1·768	3·954	0·624
R^2(%)	-	12·04	51·0	8·79
total R^2(%)	-		<u>71·82</u>	

50/40/10% FUEL $= 7{\cdot}352(\frac{T}{298})^{0{\cdot}079}(\frac{P}{1000})^{0{\cdot}216}(\frac{H}{60})^{-0{\cdot}395}$
(NS) (NS) (NS)

F-value	-	0·002	0·026	0·469
R^2(%)	-	41·33	4·65	10·27
total R^2(%)	-		<u>56·24</u>	

<u>Model</u> (2) results:

URBAN FUEL $= 6{\cdot}982(\frac{T}{298})^{-1{\cdot}41}(\frac{P}{1000-10.Pv})^{0{\cdot}132}$
(NS)

F-value	-	2·714	0·011
R^2(%)	-	23·0	0·1
total R^2(%)	-	<u>23·1</u>	

SUBURBAN FUEL $= 4{\cdot}713(\frac{T}{298})^{-2{\cdot}17}(\frac{P}{1000-10.Pv})^{0{\cdot}489}$
(NS)

F-value	-	16·01	0·424
R^2(%)	-	82·28	2·2
total R^2(%)	-	<u>84·4</u>	

MOTORWAY FUEL $= 7{\cdot}167(\frac{T}{298})^{1{\cdot}425}(\frac{P}{1000-10.Pv})^{3{\cdot}651}$
(NS)

F-value	-	0·870	4·269
R^2(%)	-	12·04	51·7
total R^2(%)	-	<u>63·7</u>	

50/40/10% FUEL $= 6{\cdot}137(\frac{T}{298})^{-1{\cdot}24}(\frac{P}{1000-10.Pv})^{0{\cdot}611}$
(NS)

F-value	-	2·367	0·303
R^2(%)	-	41·3	5·4
total R^2(%)	-	<u>46·7</u>	

3.2.3. Conclusions from analyses.

Due to the nature of the data used for the analyses of ambient effects on "real" fuel consumption, the magnitudes of the powers of each term in the regression expressions had no great intrinsic value. The prime interest of this study was the statistical significance (explained variance and F-value) associated with each correction term, representing the "effect" of each ambient condition on the fuel economy of the diesel vehicle. In addition, the "fit" of the regression models to the overall variation of fuel consumption, for each route section, was used to indicate the total combined effect of the environmental conditions on fuel economy.

Two models were analysed. The first used three independent terms relating to the correction of temperature, pressure and humidity effects on fuel consumption. Of the three terms the "effect" of the humidity parameter was of great interest because of its high statistical significance previously noted in the analyses of Chapters 5 and 6. To further the study of the humidity term, the second model used a combined "pressure-humidity" variable based on a relationship associating air humidity to the partial pressures of air and water vapour; a technique similar to that adopted by the I.S.O. standard correction procedures [40].

For each route section, viz., urban, suburban, motorway and a 50/40/10% mix, the total explained variance (R^2) of the respective regression analysis was higher when humidity was treated as a separate variable (model 1), than when combined with ambient pressure (model 2). Note that the explained variance of the temperature terms, for all route sections, were identical for both regression models, inferring that the pressure and humidity "effects", whether singular or combined, were analysed independent of temperature.

Using the urban data the regression of model 1 showed ambient temperature to have the most significant effect on fuel consumption (23·0%), with the humidity term accounting for a further 17·2% variance. Pressure correction was not significant. The corresponding regression of model 2 lost the 17·2% explained variance associated with the independent humidity "effect" because of its amalgamation with the statistically insignificant pressure term. Thus the total explained variance was similarly reduced. The signs of the index values of both regression models implied that urban fuel consumption decreased with a rise in ambient temperature and/or a reduction in ambient air humidity (i.e., towards drier conditions).

On the suburban route section, the regression of model 1 resulted in temperature providing the only significant correction for fuel consumption variation; explaining 82·3% of the total 84·9%. Both pressure and humidity were found to be statistically redundant. With model 2 the regression results were unchanged.

Over the motorway route section the regression of model 1 showed only the humidity term to be statistically insignificant. Pressure was most significant explaining 51·0% of the total 71·82% variance. By combining the pressure and humidity "effects" the regression of model 2 achieved a total explained variance of only 63·7%. For both models a rise in ambient pressure resulted in an increased motorway fuel consumption.

On using the 50/40/10% route section data, the correction terms of both models were all found to be statistically insignificant, with the exception of the temperature correction of model 2 which had an explained variance of 41·3% and an F-value of 2·367.

Two final observations from the study were that;

i) the constant terms for each regression model gave relative measures denoting the average fuel consumption of each route section; i.e., motorway highest, then urban and finally the lowest value for suburban road types, and,

ii) the total explained variances of each model inferred that the magnitude of the combined "effect" of all three ambient conditions on fuel consumption was dependent on the type of driving environment; i.e., ambient "effect" was highest on the suburban fuel consumption and lowest on the motorway fuel consumption.

With reference to the temperature correction term, the greatest "effect" on fuel consumption was noted on the suburban route section, and the lowest on the motorway section. A similar result was obtained by Eccleston and Hurn [45], who studied the effect of a 20 to 100°F temperature variation on "city" and "highway" fuel economy.

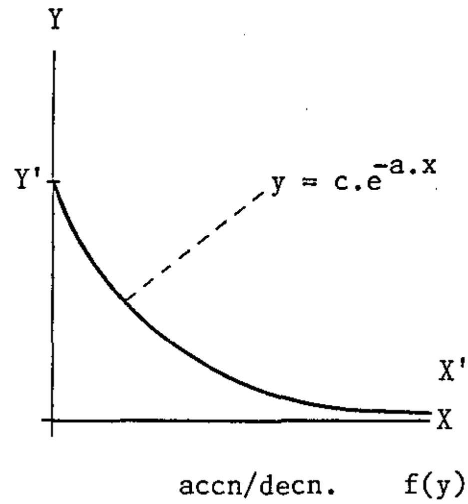
APPENDIX 4

DERIVATION OF DISTRIBUTION "SPREAD" VARIABLES, DRIVE-CYCLE APPLICATION OF TEST DATA AND $\frac{1}{2}$-SECOND ENERGY-BALANCE ANALYSIS

4.1. Derivation of distribution "spread" variables.

The following analysis proves that the mean ($\overline{X}$) and variance (Var.X) of the function "$y = c.e^{-a.x}$" are $^1/_a$ and $^1/_{a^2}$ respectively; i.e., that the measures of distribution "spread" are independent of the coefficient "c".

With respect to the adjacent figure;



$$y = c.e^{-a.x}$$

$$\therefore \quad {}^y/_c = e^{-a.x}$$

Now, by taking the natural logarithms of both sides:

$$\ln({}^y/_c) = -a.x$$

and hence, $x = -{}^1/_a.\ln({}^y/_c)$.

As the curve lies within definite limits along the Y-axis, the integration used to determine the mean and variance of x-values (i.e., acceleration or deceleration) is written with respect to "dy".

Mean $\overline{X}$: $$\overline{X} = \int_0^{Y'} f(y)/_{Y'}\,dy \quad = \quad {}^1/_{Y'}\int_0^{Y'} -{}^1/_a.\ln({}^y/_c)\,dy$$

$$\therefore \quad \overline{X} = -{}^1/_{(a.Y')}.\left[\ln({}^y/_c).y - \int_0^{Y'} {}^y/_y\,dy\right]_0^{Y'}$$

$$\therefore \quad \overline{X} = -{}^1/_{(a.Y')}.[\ln({}^{Y'}/_c).Y' - Y' - 0 + 0]$$

$$\therefore \quad \overline{X} = -{}^1/_a.\ln({}^{Y'}/_c) + {}^1/_a$$

Now, from above; $\ln({}^y/_c) = -a.x$ $\qquad \ln({}^{Y'}/_c) = -a.X' = 0$

$\therefore$ Mean $\overline{X} = {}^1/_a$. (i.e., the mean $\overline{X}$ is independent of "c")

Variance $\overline{X}$: Variance $\sigma^2 = {}^1/_N\sum(x - \overline{X})^2$

$$\therefore \quad \text{Variance } \overline{X} = {}^1/_{Y'}\sum[f(y) - \overline{Y}]^2$$

Now, $\text{Var.X} = \frac{1}{Y'} \int_0^{Y'} [-\frac{1}{a}.\ln(\frac{y}{c}) - \frac{1}{a}]^2 \, dy$

$$= \frac{1}{Y'} \int_0^{Y'} [\frac{1}{a^2}.\ln(\frac{y}{c})^2 + \frac{2}{a^2}.\ln(\frac{y}{c}) + 1] \, dy$$

$$= \frac{1}{Y'.a^2}.\int_0^{Y'} [\ln(\frac{y}{c})^2 + 2\ln(\frac{y}{c}) + 1] \, dy$$

$$= \frac{1}{Y'.a^2}.[\tfrac{1}{3}.\ln(\frac{y}{c})^3.(\ln(\frac{y}{c}).y - y) + 2.(\ln(\frac{y}{c}).y - y) + y]_0^{Y'}$$

$$\therefore \quad \text{Var.X} = \frac{1}{Y'.a^2}.[\tfrac{1}{3}.\ln(\frac{y}{c})^4.y - \tfrac{1}{3}.\ln(\frac{y}{c})^3.y + 2.\ln(\frac{y}{c}).y - y]_0^{Y'}$$

Again as $\ln(\frac{Y'}{c}) = 0$,

$$\text{Var.X} = \frac{1}{Y'.a^2}.[-y]_0^{Y'} \quad = \quad -\frac{1}{Y'.a^2}.Y'$$

Hence, $\underline{\text{Var.X}} = -\frac{1}{a^2}$

Thus, the value of the variance of the distribution "spread" is $\frac{1}{a^2}$, i.e., its value is independent of the function coefficient "c".

As described by Section 7.4, the exponential curve "$y = c.e^{-a.x}$" may be used to fit the profile of acceleration/deceleration histograms, though statistically a "perfect" fit to the data could never be achieved because it does not comply with the requirements of a probability function; i.e., area under curve equal to unity.

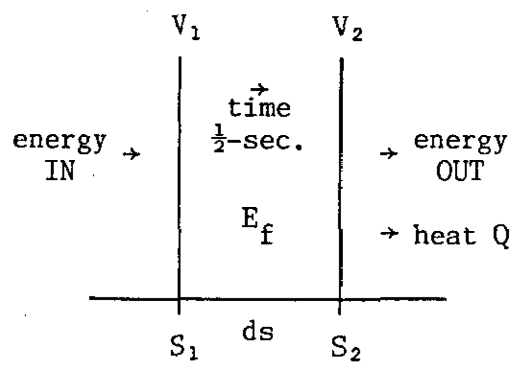
4.2. Instantaneous energy balance derivation.

The vehicle instrumentation system and on-board data logger used for this research had the ability to measure a range of vehicle-motion parameters for each half-second interval of a test.

By using the data collected for a particular half-second interval and constants describing vehicle characteristics (e.g., mass, frontal area, drag coefficients, etc.), a possibility to perform an energy-balance existed. This could also be repeated for each proceding half-second interval to produce a continuous energy-balance calculation throughout the duration of a test.

Though time and resources were not available to investigate the full potential of this technique, an outline of a suitable approach to this analysis is given as follows:

Consider a time interval of half a second in duration, as illustrated in the adjacent diagram, with the vehicle travelling a small distance "ds".



Neglecting any change in vehicle mass (i.e., including fuel used during interval);

$$\text{Energy IN} = KE_1 + PE_1 + IE_1$$

where, KE_1 is the kinetic energy of the vehicle at "1",
PE_1 is the potential energy of the vehicle at "1",
and IE_1 is the inertial energy of the vehicle at "1".

Hence, $$\text{Energy IN} = E_1 = \tfrac{1}{2}.m.V + m.g.h + IE_1$$

further, $$\text{Energy OUT} = KE_2 + PE_2 + IE_2$$
where, KE_2, PE_2, and IE_2 are as above for the vehicle at "2".

Thus, $$\text{Energy OUT} = E_2 = \tfrac{1}{2}.m(V + dV) + m.g(h + dh) + IE_2.$$

Now, energy given out to the atmosphere during the interval "ds" is given by;

$$E_0 = F_d . ds + Q$$

where "Q" is the heat energy dissipated during vehicle braking, and "F_d" is the drag force opposing vehicle motion and is equal to:

$$F_d = [m.g(A_d + B_d V) + \tfrac{1}{2}.\rho.C_d.A.V^2].$$

Now, if the interval "ds" is small, the drag force "F_d" can be assumed constant, such that:

$$E_0 = \overline{F}_d . \int_1^2 V.dt + Q. \quad \text{(bar "}\overline{\ }\text{" denotes mean value)}$$

or,

$$E_0 = [m.g(A_d + B_d\overline{V}) + \tfrac{1}{2}.\rho.C_d.A.\overline{V}^2].ds + Q.$$

Energy from fuel over interval "ds" is given by:

$$E_f = \text{(fuel used).(calorific value)}.\eta_e.\eta_t$$

where, η_e is the brake thermal efficiency of the engine,
and η_t is the transmission efficiency of the vehicle.

Using the energy variables noted above, the concluding energy balance over interval "ds" is given by;

Energy INTO interval "ds" = Energy OUT OF interval "ds"

or,

$$E_1 + E_f = E_2 + E_0$$

hence,

$$E_f = E_2 - E_1 + E_0.$$

During the reduction of this analysis a number of assumptions were made. First, the vehicle speed and hence drag force "F_d" were taken as constants throughout the distance interval of "ds" and secondly, variations in vehicle mass, road surface (i.e. affecting the drag coefficients A_d and B_d) and environmental conditions (i.e., wind speed) were not accounted for.

A number of practical problems exist in order to calculate the energy balance. The main problem to overcome is the delay in the measure of fuel flow (or fuel used): i.e., because of fuel supply to a float chamber (petrol) or "spill-back" from injectors (diesel), the fuel measured during a particular half-second interval would probably relate to the previous "interval", or say, some half-second interval momentarily before the instant of the logger scan. A further problem associated with the energy balance is the ability to measure the road gradient, or the small variation in road height "dh" that exists between the interval boundaries of "1" and "2". A final parameter that would be difficult to assess for each interval is "Q", which represents the heat energy dissipated to the surroundings due to brake application or binding.

If the aforementioned problems were overcome by improved data logging facilities, the energy-balance technique could be used on a wide range of applications. The algorithm could calculate a continuous measure of the engine and transmission efficiencies during vehicle operation in various traffic conditions, or, if these quantities were assumed to be constant (i.e., efficiencies of 0·3 and 0·97 respectively) the amount of heat energy dissipation could be obtained. A final application for this technique would be the accurate reduction of the vehicle drag coefficients A_d, B_d and C_d - a problem that is best solved at present using the somewhat unrealistic environment of a chassis dynamometer.

4.3. Drive-cycle application for experimental test data.

Chassis dynamometers provide the automotive engineer with a consistent and controllable method of testing road vehicles. Of their many applications, dynamometers are primarily used to obtain comparable measures of vehicle fuel consumption, exhaust emissions and power/torque performance characteristics. Further, vehicle tests can be conducted to simulate different driving conditions by either programming the dynamometer computer software with a "speed vs. time" relationship, or, by having a test driver follow a visual "speed vs. time" profile on a display adjacent to the vehicle. The most commonly used drive-cycle is the E.C.E. 15/03 urban cycle, adopted by the automotive industry as a standard "laboratory" test to give a comparable measure of vehicle fuel consumption and to act as part of the regulations governing vehicle exhaust emissions.

During the course of this research a chassis dynamometer was installed in the Department of Transport Technology, Loughborough University. Of the many projects being conducted on the dynamometer, one main piece of work was investigating an improved vehicle "coast-down" technique to obtain accurate drag coefficients and hence improve the dynamometers' simulation of a vehicles' "on-road" motion characteristics. In association with this work, an undergraduate project was aimed at programming a satellite micro-computer to provide a visual drive-cycle aid. As a source of "speed-time" data for the visual aid, it was decided that the experimental data collected from the tests in this research could be used to programme a number of drive-cycles into the dynamometer software, thus enabling the chassis dynamometer to simulate particular sections of the Leicestershire test route [18]; e.g., an urban, suburban or motorway driving environment. As an "acid" test, to ascertain the ability of the dynamometer to simulate real "on-road" vehicle motion and drag forces, it was proposed that one of the test vehicles (fully instrumented) could be tested on the dynamometer using a drive-cycle that it had previously completed during a road test. Comparison of the fuel consumption measured on the dynamometer to that actually recorded "on-road" would then prove an interesting study to check the realism of the dynamometer.

To obtain the necessary data for the drive-cycle application, a software program written in Fortran 77 was compiled; named "dyno.fortran", a listing of the software package is given in Appendix E(i).

"Dyno.fortran" was written as an interactive program and once initiated was prompted to accept as input the 8-column data files obtained from the output of "roadtest.data". A truncated example of such an input file is given in Appendix E(ii) - the data shown was obtained from the test previously analysed by Appendix D. The corresponding truncated output file from "dyno.fortran" is shown by Appendix E(iii). Similar to the input data the output file contained eight columns of data, detailing the distance driven, time elapsed, vehicle speed, engine speed, route section, fuel used, fuel temperature, oil temperature and notification of gear changes for each half-second interval of the route section, or drive-cycle, analysed.

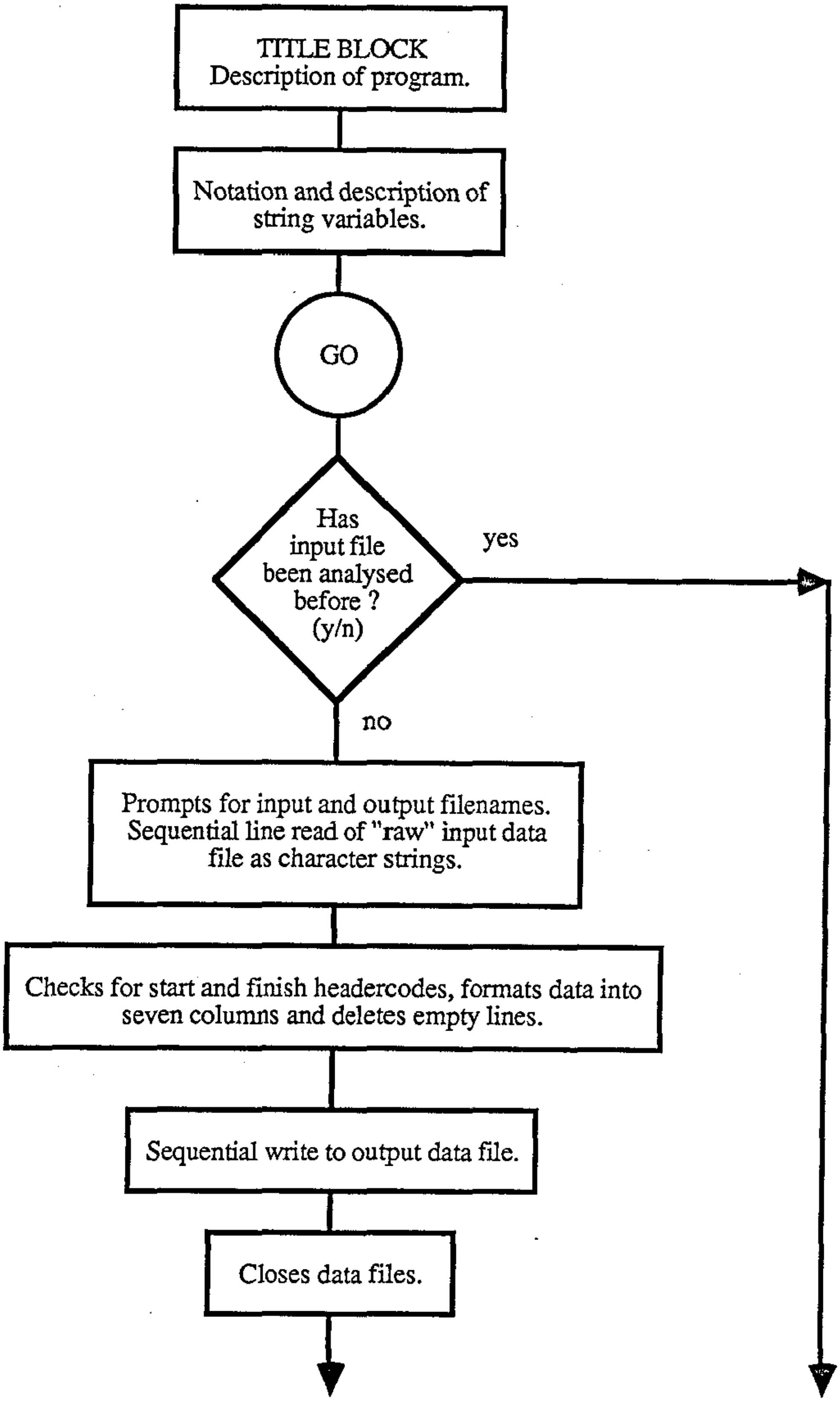
Similar to the energy-balance algorithm described in section 4.2 of this Appendix, the drive-cycle data files required the additional information of average road gradient for each half-second interval. During the course of this research the Assessment Division of the Transport and Road Research Laboratory, who commissioned the experimental work, informed they were engaged in an experimental project investigating a "trailer" mechanism, which could provide a continuous gradient measure of a test route for future work.

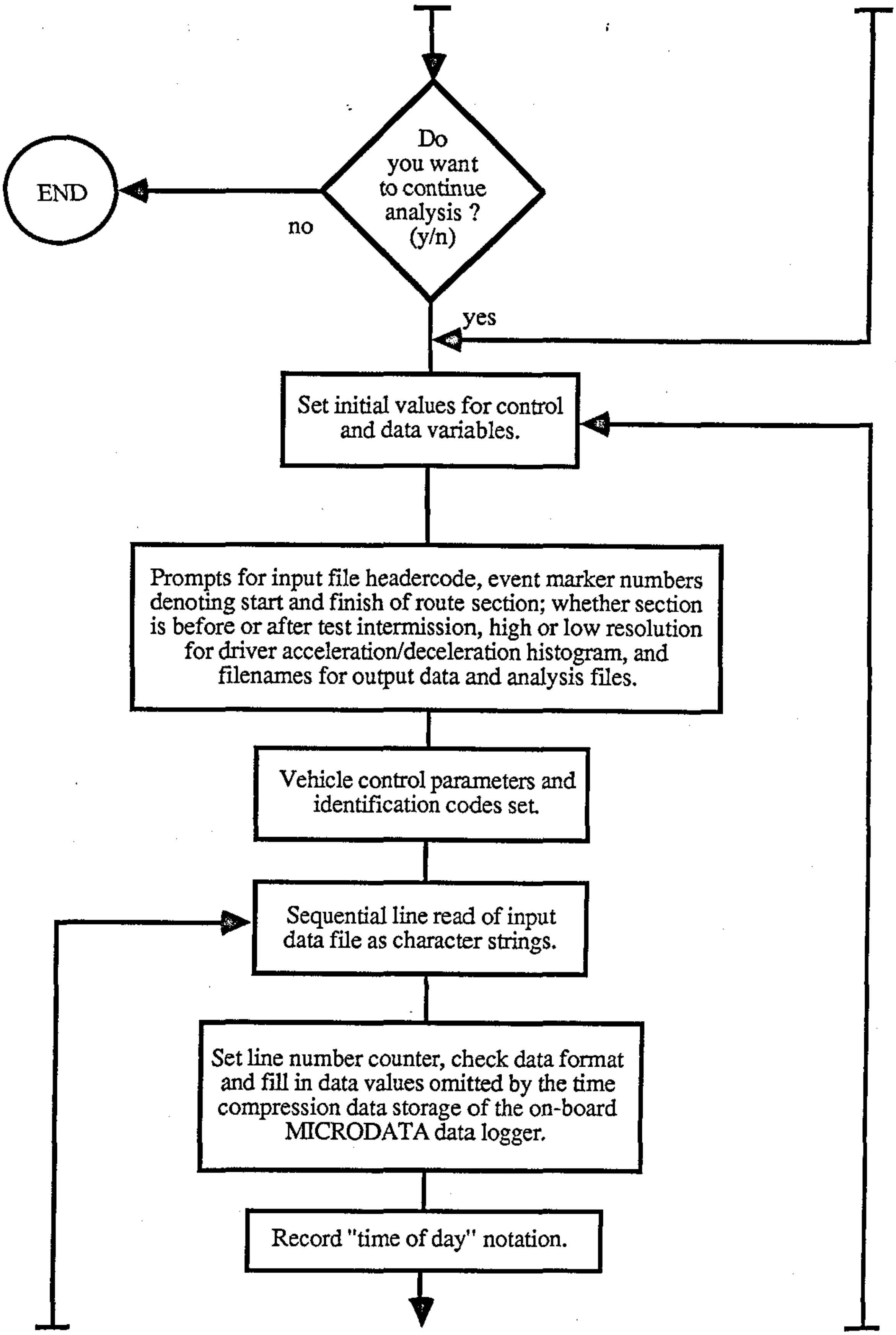
With a limitation on time and resources, and the omission of the "gradient" parameter, both the "energy-balance" and "drive-cycle" applications of the test data remained two avenues of research to be explored to their full potential.

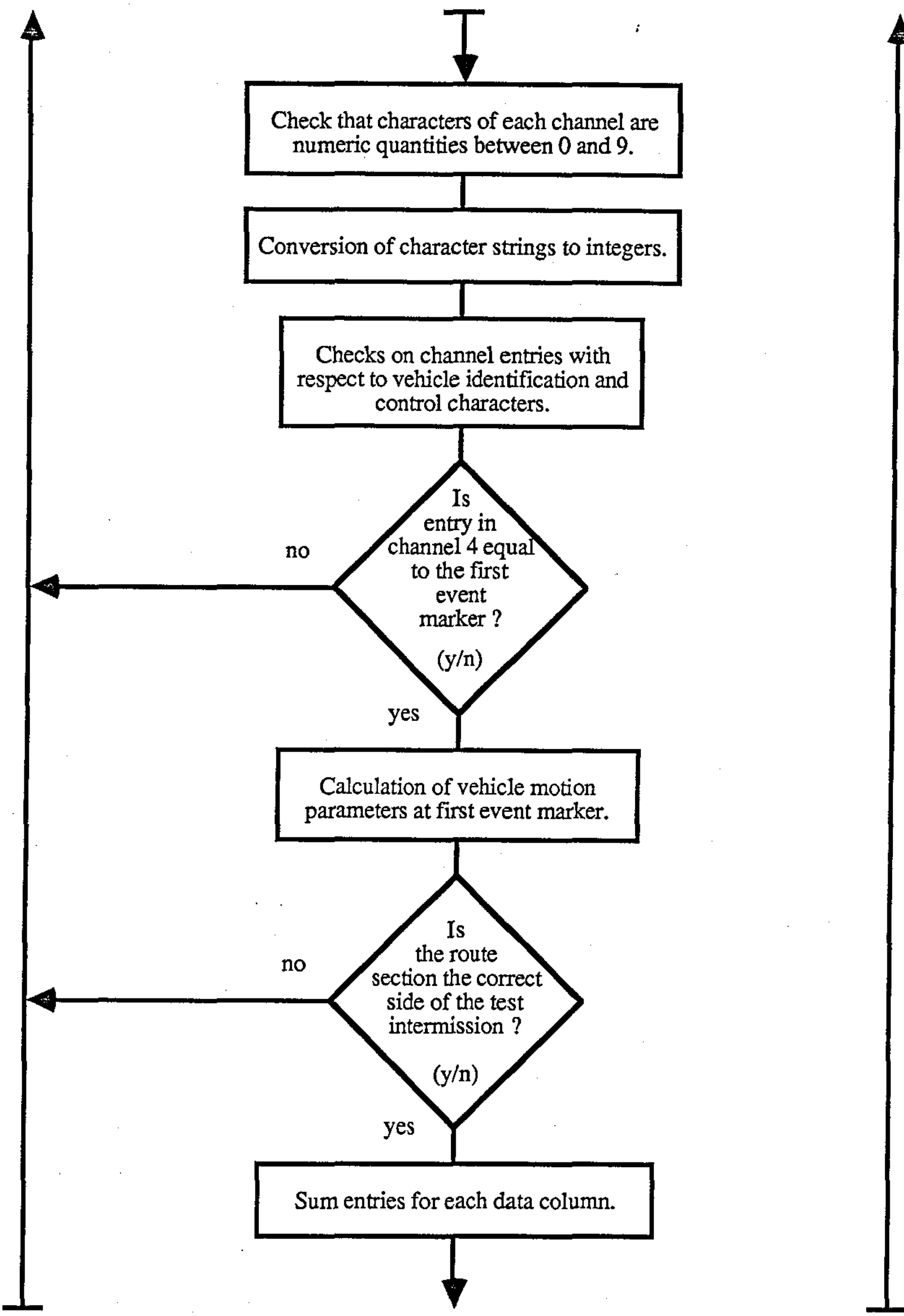
APPENDIX A

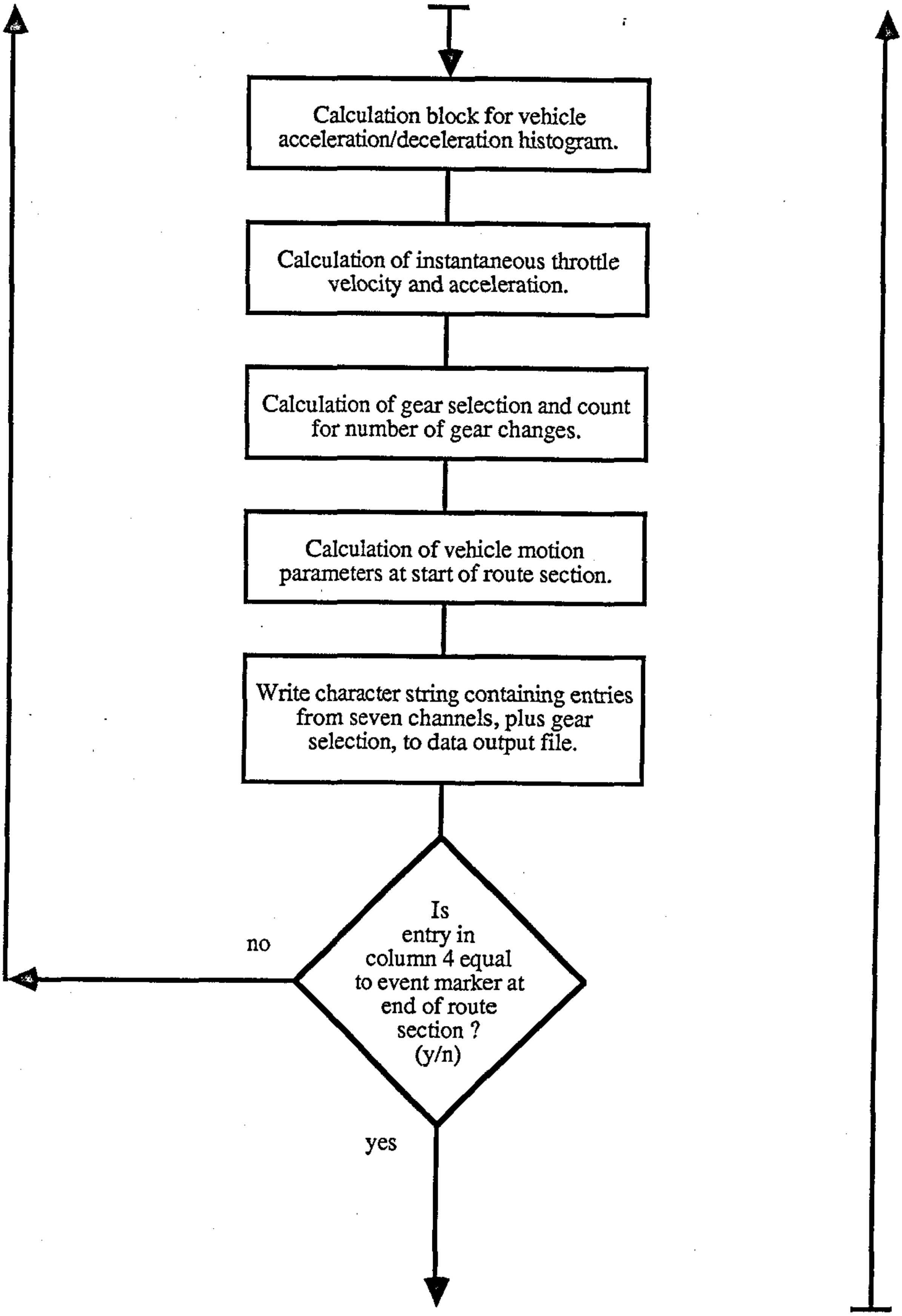
DESCRIPTION OF FORTRAN PROGRAM ROADTEST.FORTRAN

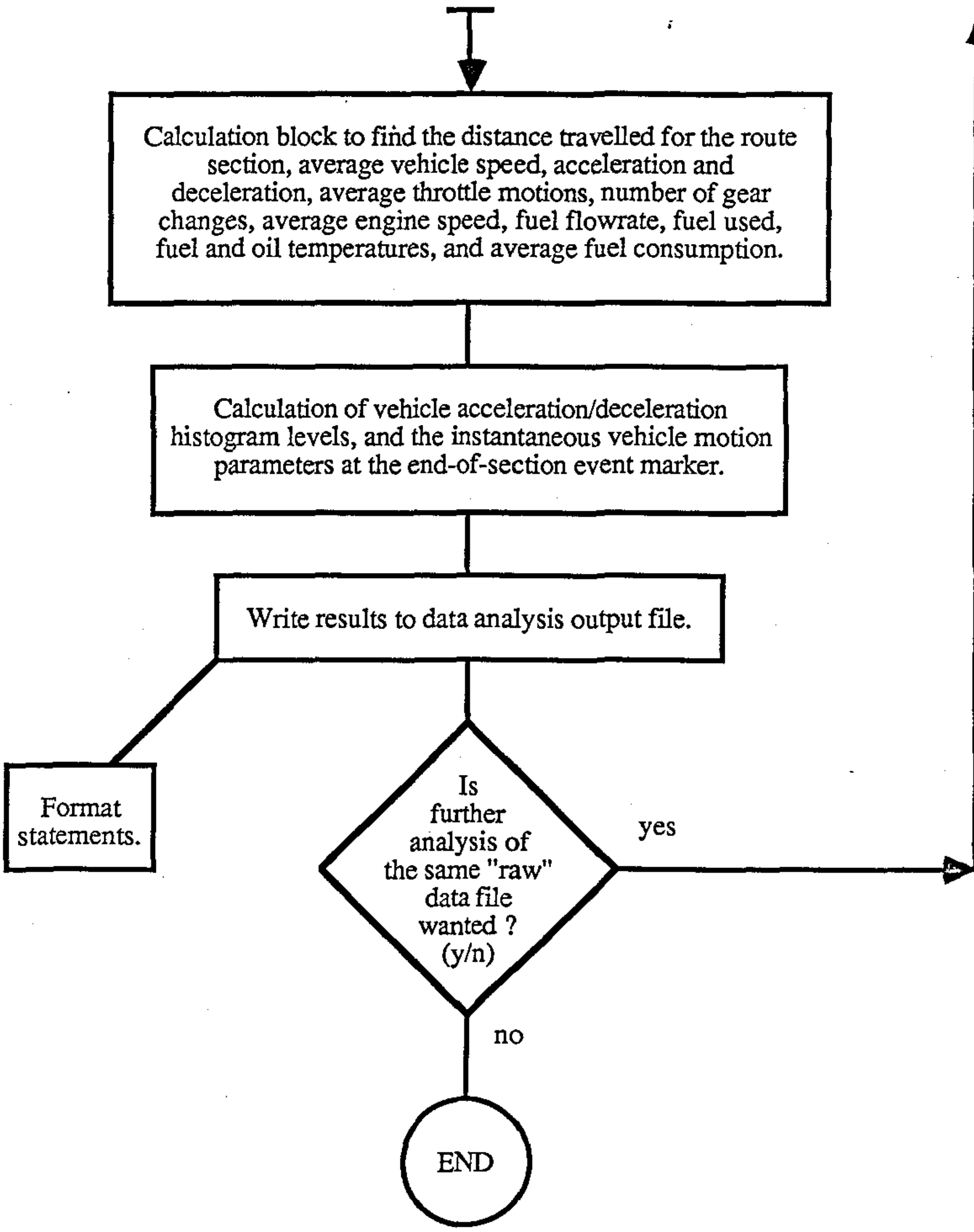
"ROADTEST.FORTRAN"




Do you want to continue analysis ? (y/n)
END
no
yes
Set initial values for control and data variables.
Prompts for input file headercode, event marker numbers denoting start and finish of route section; whether section is before or after test intermission, high or low resolution for driver acceleration/deceleration histogram, and filenames for output data and analysis files.
Vehicle control parameters and identification codes set.
Sequential line read of input data file as character strings.
Set line number counter, check data format and fill in data values omitted by the time compression data storage of the on-board MICRODATA data logger.
Record "time of day" notation.


Check that characters of each channel are numeric quantities between 0 and 9.
Conversion of character strings to integers.
Checks on channel entries with respect to vehicle identification and control characters.
Is entry in channel 4 equal to the first event marker ?
(y/n)
no
yes
Calculation of vehicle motion parameters at first event marker.
Is the route section the correct side of the test intermission ?
(y/n)
no
yes
Sum entries for each data column.


Calculation block for vehicle acceleration/deceleration histogram.
Calculation of instantaneous throttle velocity and acceleration.
Calculation of gear selection and count for number of gear changes.
Calculation of vehicle motion parameters at start of route section.
Write character string containing entries from seven channels, plus gear selection, to data output file.
Is entry in column 4 equal to event marker at end of route section ? (y/n)
no
yes


Calculation block to find the distance travelled for the route section, average vehicle speed, acceleration and deceleration, average throttle motions, number of gear changes, average engine speed, fuel flowrate, fuel used, fuel and oil temperatures, and average fuel consumption.
Calculation of vehicle acceleration/deceleration histogram levels, and the instantaneous vehicle motion parameters at the end-of-section event marker.
Write results to data analysis output file.
Format statements.
Is further analysis of the same "raw" data file wanted ? (y/n)
yes
no
END

APPENDIX B

LISTING OF FORTRAN PROGRAM ROADTEST.FORTRAN

```
c       ********************************************************
c       ****************LOUGHBOROUGH UNIVERSITY****************
c       ***********DEPARTMENT OF TRANSPORT TECHNOLOGY***********
c       ********************************************************
c       ********************************************************
c               VAUXHALL CAVALIER AND AUSTIN-ROVER MONTEGO
c               FUEL CONSUMPTION TESTS SPRING/SUMMER 1985.
c                  M.REDSELL - CONTRACT No.TRR/842/459
c       ********************************************************
c       ********************************************************
        program roadtest
c       ********************************************************
c       Roadtest analyses input files containing time compressed,
c       formatted data, recorded on 'Verbatim' magnetic tapes by
c       on-board MICRODATA M1680B PROLOG data loggers during
c       fuel consumption road tests, conducted at Loughborough.
c       The data is written to a personnel directory file via a
c       COLUMBIA DATA CARTRIDGE RECORDER 300C, reading raw data
c       from the 'Verbatim' cartridges. On execution of program
c       Roadtest the data is formatted into 7 columns each
c       containing character strings of length 5 ( i.e. "*NNNN" )
c       where 'N' is a digit. Each column is separated by a space
c       and the data begins and finishes with a headercode,
c       identifying vehicle, logger unit, program and test number.
c       The program checks for any inconsistencies in the data
c       format and content. Prompts are made for vehicle type,
c       filename, event numbers to commence and terminate
c       data analysis, notification of whether data is read before
c       or after road test intermission, and names of two output
c       files; one for the analysis of the data ( i.e., average
c       speed, fuel consumption, etc.) and the other for the 'raw'
c       data columns formatted and read by Roadtest.
c       The analysis of the data file and output of results are
c       tailored for each vehicle due to differences in vehicle
c       parameters and on-board instrumentation systems.
c       Roadtest calculates the acceleration and deceleration
c       spectrums of the vehicles' motion, with a choice of two
c       levels of resolution available ( package avalable for
c       Cavalier vehicles only ).
c       ********************************************************

c       ********************************************************
c       alphabetical variable index
c       ********************************************************
c       a - character string of data in column 1
c       b - character string of data in column 2
c       c - character string of data in column 3
c       d - character string of data in column 4
c       e - character string of data in column 5
c       f - character string of data in column 6
c       g - character string of data in column 7
c       h - count of number of instantaneous throttle accns.
c       i - count of number of data lines analysed
c       j - counter to check input data format of ten-line blocks
```

```
c       k - counter to check commencement of data analysis
c       l - count of number of instantaneous throttle velocities
c       m - count of number of data lines read
c       n - count of number of instantaneous vehicle accns.
c       o - numerical value of data in column 1
c       p - numerical value of data in column 2
c       q - numerical value of data in column 3
c       r - counter used to check for non-numerical data
c       s - number of seconds elapsed before time recording
c       t - character string of real time check in test data
c       u - numerical value of data in column 6
c       v - numerical value of data in column 7
c       w - numerical value of data in column 5
c       x - event No. to commence data analysis
c       y - event No. to terminate data analysis
c       z - count of number of instantaneous vehicle decns.
c       *****************************************************

c       *****************************************************
c       string variables - alphabetical
c       *****************************************************
c       a1,a2,..a20 - % of total counts in each accn. level of g.
c       accel - instantaneous vehicle acceleration - g.
c       accn - average acceleration of vehicle - m/s/s.
c       accn1 - summation of instantaneous vehicle accelerations
c       accn2 - instantaneous acceleration of throttle
c       an1,an2,..an20 - sum of vehicle accns. at ten g. levels
c       answers - name of file containing analysis of input data
c       asum - summation of counts in all acceleration levels of g.
c       axle - vehicle axle ratio
c       calib - calibration constant for data in column 1
c       celcius - variable for division of fuel temperature data
c       centi - variable for division of oil temperature data
c       change - sum of number of gear changes including neutral
c       check - counter to check existence of non-numerical data
c       chuck - summation of whole gear changes
c       clog - continually updated value of gear selection
c       code - (y/n) entry to indicate existence of headercode
c       cog - instantaneous value of gear selection
c       count - count to determine before/after break data
c       d1,d2,..d20 - % of total counts in each accn. level of g.
c       data - character string of data read from input file
c       deccel - instantaneous vehicle deceleration - g.
c       decn - average deceleration of vehicle - m/s/s.
c       decn1 - summation of instantaneous vehicle decelerations
c       denom - sum of 'foot-¦on¦ & off' throttle readings
c       derv - average fuel flowrate check - lit/hr.
c       derv1 - average fuel flowrate check - galls/hr.
c       diff1 - instantaneous vehicle acceleration
c       diff2 - instantaneous velocity of throttle
c       dist - distance travelled - Km.
c       dn1,dn2,..dn20 - sum of vehicle decns. at ten g. levels
c       dsum - summation of counts in all deceleration levels of g.
c       eng1 - sum of column 3 readings prior to analysis
c       eng2 - engine speed prior to analysis - r.p.m.
c       eng3 - engine speed at end of analysis - r.p.m.
c       f1,f2,..f10 - updated column 5 readings prior to analysis
c       faccn - average acceleration of throttle- deg/s/s.
c       fang - average angle of throttle - degrees
c       fcon - average fuel consumption - lit/100 Km.
```

```
c       fcount - number of 'flow' values summed in 'ftot'
c       filename - character string of input file headercode
c       filname - name of data input file
c       flow - fuel used in 5 secs. period - lit/hr.
c       flow1 - fuel flow prior to data analysis - lit/hr.
c       flow2 - fuel flow prior to data analysis - gals/hr.
c       flow3 - fuel flow at end of data analysis - gals/hr.
c       fpet - average fuel consumption - miles per gallon
c       ftot - sum of 'flow' values for each line of data
c       fuel - average fuel flowrate - litres per hour
c       fuel1 - average fuel flowrate - gallons per hour
c       gas - total fuel used - litres
c       gast - average fuel temperature - deg C
c       gear - instantaneous gearbox ratio
c       hist - (h/l) entry to indicate resolution of histogram
c       limit - integer value to check data in column 5
c       mark - (y/n) entry to indicate before/after break data
c       max0,1 - entries from column 1 prior to data analysis
c       max2 - 'foot-off' throttle reading
c       oilt - average oil temperature deg C
c       pedal - retained value of instantaneous throttle velocity
c       pedoff - retained value of 'foot-off' throttle reading
c       pedon - retained value of 'foot-on' throttle reading
c       petrol - total fuel used - gallons
c       quest - (y/n) entry to the request for further analysis
c       prom - entry to determine format of input data
c       prompt - entry to commence data analysis
c       results - name of file containing 8 column data matrix
c       revs - average engine speed - r.p.m.
c       saccn2 - sum of instantaneous throttle accelerations
c       sdiff2 - sum of instantaneous throttle velocities
c       select - gear selection at start of data analysis
c       speed1 - sum of two column 1 entries prior to analysis
c       speed2 - vehicle velocity prior to analysis - Km/hr.
c       speed3 - vehicle velocity at end of analysis - Km/hr.
c       speed4- vehicle velocity prior to analysis - m.p.h.
c       speed5 - vehicle velocity at end of analysis - m.p.h.
c       sum1,2,..7 - summations of columns 1,2,3,4,5,6,7
c       temp1 - sum of two entries from column 6 prior to analysis
c       temp2 - sum of two entries from column 7 prior to analysis
c       temp3 - fuel temp. prior to data analysis - deg. C
c       temp4 - oil temp. prior to data analysis - deg. C
c       temp5 - fuel temp. at end of data analysis - deg. C
c       temp6 - oil temp. at end of data analysis - deg. C
c       throt1 - sum of two entries from column 2
c       throt2 - throttle angle prior to data analysis - deg.
c       throt3 - throttle angle at end of data analysis - deg.
c       u1,u2 - entries from column 6 prior to analysis
c       v1,v2 - entries from column 7 prior to analysis
c       vehicle - character string of vehicle identification
c       vel - average velocity of vehicle - Km. per hour
c       w1,w2 - entries from column 3 prior to analysis
c       walk - distance travelled - miles
c       whip - average vehicle velocity - m.p.h.
c       x1,x2 - entries from column 1 prior to analysis
c       y1,y2 - entries from column 2 prior to analysis
c       ********************************************************

c       ********************************************************
c       subprogram for initial formatting of 'raw' data
```

```
c       ****************************************************
        character *1 prom,prompt
        write (*,*) 'has the input data been previously analysed? (y/n) '
        read (5,*) prom
        if (prom.eq.'y') goto 5
c       ****************************************************
c       variable index
c       ****************************************************
c       str - character string length variable
c       add - data line length variable
c       sub - line count variable for input file
c       raw - character string of a line of input data
c       test1 - name given to input data file
c       test2 - name given to output data file
c       test3 - header code for road test data in input file
c       ****************************************************

c       ****************************************************
c       character strings
c       ****************************************************
        character *11 test1
        character *11 test3
        character *15 test2
        character *60 raw
c       ****************************************************

c       ****************************************************
c       set input file line number
c       ****************************************************
        integer sub
        sub=1
c       ****************************************************

c       ****************************************************
c       prompts to terminal screen
c       ****************************************************
        write (*,*) 'enter name of input file'
        read (*,710) test1
        write (*,*) 'enter name of output file'
        read (*,710) test2
c       ****************************************************

c       ****************************************************
c       opening of input and output files
c       ****************************************************
        open (2,file=test1,form='formatted')
        open (3,file=test2,form='formatted')
c       ****************************************************

c       ****************************************************
c       header code read/write & data read
c       ****************************************************
        read (2,710) test3
        write (3,710) test3
  710   format (a)
  720   read (2,710,end=740) raw
c       ****************************************************

c       ****************************************************
c       line count update, correction of sign notation, check
```

```
c     on data spacing, and flag for end-of-data header code
c     ********************************************************
      sub=sub+1
      add=index(raw,'    ')-1
      if (raw(3:3).eq.' ') goto 720
      if (raw(1:1).ne.' ') goto 730
      if (raw(2:2).eq.'D'.or.raw(2:2).eq.'S') goto 725
      if (raw(2:2).eq.'L') then
      write (3,710) raw(1:add)
      goto 750
      endif
      if (raw(9:9).ne.' ') goto 730
      if (raw(17:17).ne.' ') goto 730
      raw(4:4)='+'
  725 raw(20:20)='+'
      raw(28:28)='+'
      raw(36:36)='+'
      write (3,710) raw(1:add)
      if (raw(2:2).eq.'L') goto 750
      goto 720
c     ********************************************************

c     ********************************************************
c     prompts to terminal screen due to data errors
c     ********************************************************
  730 print *,'a space is missing on line ',sub,' of ',test1
      goto 720
  740 print *,'no end-of-data header code in ',test1
c     ********************************************************

c     ********************************************************
c     closure 'raw' data input and output files
c     ********************************************************
  750 close (2)
      close (3)
c     ********************************************************

c     ********************************************************
c     end of subprogram for formatting MICRODATA road test tapes
c     ********************************************************
      print *,'if data errors are present in ',test1
      print *,'answer "n" to the following question and'
      print *,'use the edit facility to correct file contents.'
      write (*,*) 'do you wish to continue data analysis? (y/n)'
      read (5,*) prompt
      if (prompt.eq.'n') goto 610
c     ********************************************************

c     ********************************************************
c     set initial conditions
c     ********************************************************
      integer o,p,q,w,u,v
    5 sum1=0.0
      sum2=0.0
      sum3=0.0
      sum5=0.0
      sum6=0.0
      sum7=0.0
      max0=0.0
      max1=0.0
```

```
      accn1=0.0
      accn2=0.0
      decn1=0.0
      sdiff2=0.0
      diff1=0.0
      pedal=0.0
      saccn2=0.0
c     ****************************************************

c     ****************************************************
c     vehicle accn./deccn. g-level control variables
c     ****************************************************
      an1=0
      an2=0
      an3=0
      an4=0
      an5=0
      an6=0
      an7=0
      an8=0
      an9=0
      an10=0
      an11=0
      an12=0
      an13=0
      an14=0
      an15=0
      an16=0
      an17=0
      an18=0
      an19=0
      an20=0
      dn1=0
      dn2=0
      dn3=0
      dn4=0
      dn5=0
      dn6=0
      dn7=0
      dn8=0
      dn9=0
      dn10=0
      dn11=0
      dn12=0
      dn13=0
      dn14=0
      dn15=0
      dn16=0
      dn17=0
      dn18=0
      dn18=0
      dn19=0
      dn20=0
      ****************************************************

      ****************************************************
      fuel flow control variables
      ****************************************************
      f1=0.0
      f2=0.0
```

```
      f3=0.0
      f4=0.0
      f5=0.0
      f6=0.0
      f7=0.0
      f8=0.0
      f9=0.0
      f10=0.0
      fcount=0.0
      ftot=0.0
c     ***********************************************************

c     ***********************************************************
c     boundary control parameters
c     ***********************************************************
      x1=0.0
      w1=0.0
      u1=0.0
      v1=0.0
c     ***********************************************************

c     ***********************************************************
c     character strings
c     ***********************************************************
      character *1 mark,code,quest,hist
      character *2 x,y
      character *5 a,b,c,d,e,f,g,cog,clog,select
      character *11 filname,filename
      character *15 results,answers,t
      character *19 vehicle
      character *60 data
c     ***********************************************************

c     ***********************************************************
c     prompts to screen
c     ***********************************************************
      if (quest.eq.'y') goto 6
      write (*,*) 'enter name of raw-data file'
      read (5,10) filname
    6 write (*,*) 'enter two figure event No. to commence data transfer'
      read (5,*) x
      write (*,*) 'enter two figure event No. to end data transfer'
      read (5,*) y
      write (*,*) 'do the markers come before the break? (y/n) '
      read (5,*) mark
      if (quest.eq.'y') goto 8
      write (*,*) 'high or low histogram resolution? (h/l) '
      read (5,*) hist
      write (*,*) 'enter name of data output file'
      read (5,*) results
      write (*,*) 'enter name of data analysis file'
      read (5,*) answers
      write (*,*) 'does the data begin with a header code? (y/n) '
      read (5,*) code
c     ***********************************************************

c     ***********************************************************
c     control characters set
c     ***********************************************************
    8 j=0
```

```
      i=1
      m=0
      l=0
      h=0.0
      n=0
      z=0.0
      change=0.0
      count=0
      check=0
   10 format (a)
c     ***********************************************************
c     ***********************************************************
c     vehicle parameters set
c     ***********************************************************
      if (filname(2:4).ne.'117') goto 11
      vehicle='1600 Petrol   (RED)'
      max2=447
      pedon=-479
      axle=3.74
      calib=2220.6
      limit=3
      celcius=10
      centi=10
      goto 15
   11 if (filname(2:4).ne.'121') goto 12
      vehicle='1600 Diesel (GREEN)'
      max2=170
      pedon=-259
      axle=3.74
      calib=2220.6
      limit=3
      celcius=10
      centi=10
      goto 15
   12 if (filname(2:4).ne.'132') goto 13
      vehicle='1300 Petrol  (BLUE)'
      max2=525
      pedon=-532
      axle=4.18
      calib=2220.6
      limit=3
      celcius=10
      centi=10
      goto 15
   13 if (filname(2:4).ne.'014') goto 14
      vehicle='1600 Petrol (WHITE)'
      calib=94.78
      limit=8
      celcius=1
      centi=10
      goto 15
   14 if (filname(2:4).ne.'015') then
      print *,'vehicle type undetermined from headercode'
      goto 5
      endif
      vehicle='1600 Petrol (IVORY)'
      calib=94.306
      limit=8
      celcius=10
```

```
      centi=5
   15 pedoff=max2
      y1=pedoff
c     *******************************************************

c     *******************************************************
c     opening of files and data reading
c     *******************************************************
      open (2,file=filname,form='formatted')
      open (3,file=results,form='formatted')
      if (quest.eq.'y') goto 18
      open (4,file=answers,form='formatted')
c     *******************************************************

c     *******************************************************
c     initial reading of header data
c     *******************************************************
   18 if (code.ne.'y') goto 20
      read (2,10) filename
      m=m+1
   20 write (3,10) results
      write (3,30)
   30 format (2x,'dist',2x,'foot',2x,'revs',2x,'mark',2x,'fuel'
     *,2x,'tmpf',2x,'tmpo',2x,'gear')
      d='+0000'
      e='+0000'
      f='+0000'
      g='+0000'
      k=0
   40 read (2,10,end=320) data
      m=m+1
c     *******************************************************

c     *******************************************************
c     formating of data
c     *******************************************************
      if (data(3:3).eq.' ') goto 40
      if (data(2:2).eq.'L') then
      i=i-1
      goto 330
      endif
      if (data(2:2).eq.'S') goto 50
      if (data(2:2).ne.'D') goto 60
      if (k.eq.0.or.k.gt.120) goto 50
      t=data(2:16)
      s=i/2
   50 if (j.ne.10.and.i.gt.10) goto 310
      j=0
      goto 40
   60 j=j+1
c     *******************************************************

c     *******************************************************
c     data format check
c     *******************************************************
      if (data(1:1).ne.' ') goto 300
      if (data(9:9).ne.' ') goto 300
      if (data(17:17).ne.' ') goto 300
      if (data(25:25).ne.' ') goto 300
      if (data(33:33).ne.' ') goto 300
```

```
      if (data(41:41).ne.' ') goto 300
      if (data(49:49).ne.' ') goto 300
      if (data(12:12).ne.'*'.and.data(13:16).ne.'NNNN') goto 70
      data(12:16)=b
c     ******************************************************

c     ******************************************************
c     corrections for data time-compression
c     ******************************************************
   70 a=data(4:8)
      b=data(12:16)
      c=data(20:24)
      if (data(27:27).ne.'4') goto 80
      d=data(28:32)
      goto 110
   80 if (data(27:27).ne.'5') goto 90
      e=data(28:32)
      goto 110
   90 if (data(27:27).ne.'6') goto 100
      f=data(28:32)
      goto 110
  100 if (data(27:27).ne.'8') goto 110
      g=data(28:32)
  110 if (data(35:35).ne.'5') goto 120
      e=data(36:40)
      goto 140
  120 if (data(35:35).ne.'6') goto 130
      f=data(36:40)
      goto 140
  130 if (data(35:35).ne.'8') goto 140
      g=data(36:40)
  140 if (data(43:43).ne.'6') goto 150
      f=data(44:48)
      goto 160
  150 if (data(43:43).ne.'8') goto 160
      g=data(44:48)
  160 if (data(51:51).ne.'8') goto 161
      g=data(52:56)
  161 a(1:1)='+'
      c(1:1)='+'
      d(1:1)='+'
      e(1:1)='+'
c     ******************************************************

c     ******************************************************
c     data numerics' check
c     ******************************************************
      do 163 r=2,5
      if (a(r:r).ge.'0'.and.a(r:r).le.'9') goto 163
      check=check+1
  163 continue
      do 165 r=2,5
      if (b(r:r).ge.'0'.and.b(r:r).le.'9') goto 165
      check=check+1
  165 continue
      do 167 r=2,5
      if (c(r:r).ge.'0'.and.c(r:r).le.'9') goto 167
      check=check+1
  167 continue
      do 169 r=2,5
```

```
      if (e(r:r).ge.'0'.and.e(r:r).le.'9') goto 169
      check=check+1
  169 continue
      do 171 r=2,5
      if (f(r:r).ge.'0'.and.f(r:r).le.'9') goto 171
      check=check+1
  171 continue
      do 173 r=2,5
      if (g(r:r).ge.'0'.and.g(r:r).le.'9') goto 173
      check=check+1
  173 continue
      if (check.eq.0) goto 174
      print *,'non numeric on line ',m,' of ',filname
  174 check=0
c     ******************************************************

c     ******************************************************
c     conversion to numerics
c     ******************************************************
      read (a,290) o
      read (b,290) p
      read (c,290) q
      read (e,290) w
      read (f,290) u
      read (g,290) v
c     ******************************************************

c     ******************************************************
c     channel limit checks
c     ******************************************************
      if (o.lt.1000.and.o.ge.0) goto 175
      print *,'channel 10 = ',o,' on line ',m,' of ',filname
  175 if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 177
      if (p.le.(pedoff+50).and.p.ge.(pedon-50)) goto 176
      print *,'channel 11 = ',p,' on line ',m,' of ',filname
  176 if (q.lt.6000.and.q.ge.0) goto 177
      print *,'channel 12 = ',q,' on line ',m,' of ',filname
  177 if (w.le.limit.and.w.ge.0) goto 178
      print *,'channel 15 = ',w,' on line ',m,' of ',filname
  178 if (u.lt.400.and.u.ge.0) goto 170
      print *,'channel 16 = ',u,' on line ',m,' of ',filname
  170 if (v.lt.1300.and.v.ge.0) goto 172
      print *,'channel 18 = ',v,' on line ',m,' of ',filname
c     ******************************************************

c     ******************************************************
c     fuel flow variables update
c     ******************************************************
  172 f10=f9
      f9=f8
      f8=f7
      f7=f6
      f6=f5
      f5=f4
      f4=f3
      f3=f2
      f2=f1
      f1=w
c     ******************************************************
```

```
c      ********************************************************
c      vehicles' parameters up-date
c      ********************************************************
       x2=x1
       x1=o
       y2=y1
       y1=p
       w2=w1
       w1=q
       u2=u1
       u1=u
       v2=v1
       v1=v
c      ********************************************************

c      ********************************************************
c      pre-event distance record
c      ********************************************************
       if (k.ne.0) goto 179
       max1=max0
       max0=o
c      ********************************************************

c      ********************************************************
c      determination of before/after break scanning
c      ********************************************************
       if (x.gt.'07'.and.x.lt.'13') then
       count=1
       endif
  179  if (data(27:27).eq.'4') goto 180
       if (count.gt.0) goto 200
       goto 40
  180  if (data(31:32).eq.x) goto 190
       if (data(31:32).gt.x) goto 200
       goto 40
  190  count=count+1
  200  if (mark.eq.'y') goto 210
       if (count.gt.1) goto 210
       goto 40
  210  k=k+1
c      ********************************************************

c      ********************************************************
c      summation of data columns
c      ********************************************************
       sum1=sum1+o
       sum2=sum2+p
       sum3=sum3+q
       sum5=sum5+w
       sum6=sum6+u
       sum7=sum7+v
c      ********************************************************

c      ********************************************************
c      differentiating for vehicle accn./deccn.
c      ********************************************************
       diff1=(o-(max1))*4
       max1=o
       if (diff1.lt.0.0) goto 220
       accn1=accn1+diff1
```

```
      n=n+1
c     ************************************************************
c     ************************************************************
c     summation of columns for accn. histogram
c     ************************************************************
      accel=diff1*50/(calib*9.806)
      if (accel.eq.0.0) goto 230
      if (hist.eq.'l') goto 215
      if (accel.gt.0.0.and.accel.lt.0.025) then
      an1=an1+1
      goto 230
      endif
      if (accel.ge.0.025.and.accel.lt.0.05) then
      an2=an2+1
      goto 230
      endif
      if (accel.ge.0.05.and.accel.lt.0.075) then
      an3=an3+1
      goto 230
      endif
      if (accel.ge.0.075.and.accel.lt.0.1) then
      an4=an4+1
      goto 230
      endif
      if (accel.ge.0.1.and.accel.lt.0.125) then
      an5=an5+1
      goto 230
      endif
      if (accel.ge.0.125.and.accel.lt.0.15) then
      an6=an6+1
      goto 230
      endif
      if (accel.ge.0.15.and.accel.lt.0.175) then
      an7=an7+1
      goto 230
      endif
      if (accel.ge.0.175.and.accel.lt.0.2) then
      an8=an8+1
      goto 230
      endif
      if (accel.ge.0.2.and.accel.lt.0.225) then
      an9=an9+1
      goto 230
      endif
      if (accel.ge.0.225.and.accel.lt.0.25) then
      an10=an10+1
      goto 230
      endif
      if (accel.ge.0.25.and.accel.lt.0.275) then
      an11=an11+1
      goto 230
      endif
      if (accel.ge.0.275.and.accel.lt.0.3) then
      an12=an12+1
      goto 230
      endif
      if (accel.ge.0.3.and.accel.lt.0.325) then
      an13=an13+1
      goto 230
```

```
      endif
      if (accel.ge.0.325.and.accel.lt.0.35) then
      an14=an14+1
      goto 230
      endif
      if (accel.ge.0.35.and.accel.lt.0.375) then
      an15=an15+1
      goto 230
      endif
      if (accel.ge.0.375.and.accel.lt.0.4) then
      an16=an16+1
      goto 230
      endif
      if (accel.ge.0.4.and.accel.lt.0.425) then
      an17=an17+1
      goto 230
      endif
      if (accel.ge.0.425.and.accel.lt.0.45) then
      an18=an18+1
      goto 230
      endif
      if (accel.ge.0.45.and.accel.lt.0.475) then
      an19=an19+1
      goto 230
      endif
      if (accel.ge.0.475.and.accel.lt.0.5) then
      an20=an20+1
      goto 230
      endif
      print *,'acceleration more than 0.5g on line ',m,' of ',filname
      goto 230
  215 if (accel.gt.0.0.and.accel.lt.0.05) then
      an1=an1+1
      goto 230
      endif
      if (accel.ge.0.05.and.accel.lt.0.1) then
      an2=an2+1
      goto 230
      endif
      if (accel.ge.0.1.and.accel.lt.0.15) then
      an3=an3+1
      goto 230
      endif
      if (accel.ge.0.15.and.accel.lt.0.2) then
      an4=an4+1
      goto 230
      endif
      if (accel.ge.0.2.and.accel.lt.0.25) then
      an5=an5+1
      goto 230
      endif
      if (accel.ge.0.25.and.accel.lt.0.3) then
      an6=an6+1
      goto 230
      endif
      if (accel.ge.0.3.and.accel.lt.0.35) then
      an7=an7+1
      goto 230
      endif
      if (accel.ge.0.35.and.accel.lt.0.4) then
```

```
      an8=an8+1
      goto 230
      endif
      if (accel.ge.0.4.and.accel.lt.0.45) then
      an9=an9+1
      goto 230
      endif
      if (accel.ge.0.45.and.accel.lt.0.5) then
      an10=an10+1
      goto 230
      endif
      print *,'acceleration more than 0.5g on line ',m,' of ',filname
      goto 230
c     ******************************************************

c     ******************************************************
c     summation of columns for deccn. histogram
c     ******************************************************
  220 decn1=decn1+diff1
      z=z+1
      deccel=diff1*50/(calib*9.806)
      if (hist.eq.'l') goto 225
      if (deccel.lt.0.0.and.deccel.gt.-0.025) then
      dn1=dn1+1
      goto 230
      endif
      if (deccel.le.-0.025.and.deccel.gt.-0.05) then
      dn2=dn2+1
      goto 230
      endif
      if (deccel.le.-0.05.and.deccel.gt.-0.075) then
      dn3=dn3+1
      goto 230
      endif
      if (deccel.le.-0.075.and.deccel.gt.-0.1) then
      dn4=dn4+1
      goto230
      endif
      if (deccel.le.-0.1.and.deccel.gt.-0.125) then
      dn5=dn5+1
      goto 230
      endif
      if (deccel.le.-0.125.and.deccel.gt.-0.15) then
      dn6=dn6+1
      goto 230
      endif
      if (deccel.le.-0.15.and.deccel.gt.-0.175) then
      dn7=dn7+1
      goto 230
      endif
      if (deccel.le.-0.175.and.deccel.gt.-0.2) then
      dn8=dn8+1
      goto 230
      endif
      if (deccel.le.-0.2.and.deccel.gt.-0.225) then
      dn9=dn9+1
      goto 230
      endif
      if (deccel.le.-0.225.and.deccel.gt.-0.25) then
      dn10=dn10+1
```

```
      goto 230
      endif
      if (deccel.le.-0.25.and.deccel.gt.-0.275) then
      dn11=dn11+1
      goto 230
      endif
      if (deccel.le.-0.275.and.deccel.gt.-0.3) then
      dn12=dn12+1
      goto 230
      endif
      if (deccel.le.-0.3.and.deccel.gt.-0.325) then
      dn13=dn13+1
      goto 230
      endif
      if (deccel.le.-0.325.and.deccel.gt.-0.35) then
      dn14=dn14+1
      goto 230
      endif
      if (deccel.le.-0.35.and.deccel.gt.-0.375) then
      dn15=dn15+1
      goto 230
      endif
      if (deccel.le.-0.375.and.deccel.gt.-0.4) then
      dn16=dn16+1
      goto 230
      endif
      if (deccel.le.-0.4.and.deccel.gt.-0.425) then
      dn17=dn17+1
      goto 230
      endif
      if (deccel.le.-0.425.and.deccel.gt.-0.45) then
      dn18=dn18+1
      goto 230
      endif
      if (deccel.le.-0.45.and.deccel.gt.-0.475) then
      dn19=dn19+1
      goto 230
      endif
      if (deccel.le.-0.475.and.deccel.gt.-0.5) then
      dn20=dn20+1
      goto 230
      endif
      print *,'decceleration less than -0.5g on line ',m,' of ',filname
      goto 230
  225 if (deccel.lt.0.0.and.deccel.gt.-0.05) then
      dn1=dn1+1
      goto 230
      endif
      if (deccel.le.-0.05.and.deccel.gt.-0.1) then
      dn2=dn2+1
      goto 230
      endif
      if (deccel.le.-0.1.and.deccel.gt.-0.15) then
      dn3=dn3+1
      goto 230
      endif
      if (deccel.le.-0.15.and.deccel.gt.-0.2) then
      dn4=dn4+1
      goto230
      endif
```

```
      if (deccel.le.-0.2.and.deccel.gt.-0.25) then
      dn5=dn5+1
      goto 230
      endif
      if (deccel.le.-0.25.and.deccel.gt.-0.3) then
      dn6=dn6+1
      goto 230
      endif
      if (deccel.le.-0.3.and.deccel.gt.-0.35) then
      dn7=dn7+1
      goto 230
      endif
      if (deccel.le.-0.35.and.deccel.gt.-0.4) then
      dn8=dn8+1
      goto 230
      endif
      if (deccel.le.-0.4.and.deccel.gt.-0.45) then
      dn9=dn9+1
      goto 230
      endif
      if (deccel.le.-0.45.and.deccel.gt.-0.5) then
      dn10=dn10+1
      goto 230
      endif
      print *,'decceleration less than -0.5g on line ',m,' of ',filname
c     *****************************************************

c     *****************************************************
c     calculatons of throttle motion
c     *****************************************************
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 254
  230 diff2=p-(max2)
      max2=p
      if (diff2.gt.0.0) goto 240
      sdiff2=sdiff2+abs(diff2)
      l=l+1
  240 accn2=((diff2)*2)-pedal
      pedal=(diff2)*2
      if (accn2.gt.0.0) goto 250
      if (diff2.gt.0.0) goto 250
      saccn2=saccn2+abs(accn2)
      h=h+1
c     *****************************************************

c     *****************************************************
c     calculation of gear selection
c     *****************************************************
  250 if (o.eq.0) goto 251
      gear=q*calib*0.257*2*3.1416/(121*axle*50*o)
      if (gear.ge.3.4.and.gear.lt.3.8.and.o.lt.250) then
      cog='+0001'
      goto 253
      endif
      if (gear.ge.1.985.and.gear.lt.2.385.and.o.lt.400) then
      cog='+0002'
      goto 253
      endif
      if (gear.ge.1.25.and.gear.lt.1.60.and.o.gt.100) then
      cog='+0003'
      goto 253
```

```
      endif
      if (gear.ge.0.67.and.gear.lt.1.17.and.o.gt.150) then
      cog='+0004'
      goto 253
      endif
  251 cog='+NTRL'
  253 if (i.eq.1) goto 255
      if (cog.eq.clog) goto 255
      change=change+1.0
  255 clog=cog
c     ******************************************************

c     ******************************************************
c     calculations for initial vehicle state
c     ******************************************************
  254 flow=(f1+f2+f3+f4+f5+f6+f7+f8+f9+f10)*0.72
      ftot=ftot+flow
      fcount=fcount+1.0
      if (i.ne.1) goto 256
      speed1=x1+x2
      throt1=y1+y2
      eng1=w1+w2
      flow1=flow
      flow2=flow1/4.546
      temp1=u1+u2
      temp2=v1+v2
      select=clog
c     ******************************************************

c     ******************************************************
c     end of output file details written
c     ******************************************************
  256 if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 257
      write (3,260) a,b,c,d,e,f,g,cog
      goto 258
  257 write (3,259) a,d,e,f,g
  258 if (d(4:5).eq.y) goto 330
      i=i+1
      goto 40
  259 format (5(1x,a5))
  260 format (8(1x,a5))
  270 format (1x,a5)
  280 format (1x,a15)
  290 format (i5)
c     ******************************************************

c     ******************************************************
c     prompts for data reading problems
c     ******************************************************
  300 print *,'faulty column spacing on line ',m,' of ',filname
      print *,'and hence line No. ',i,' missing in ',results
      goto 40
  310 print *,'block of data less than ten lines, at line ',m
      print *,'in ',filname,' & line ',i,' of ',results
      j=0
      goto 40
  320 print *,'a fault has occured in closing file ',filname
c     ******************************************************

c     ******************************************************
```

```
c     calculation block with conversions
c     ********************************************************
  330 dist=sum1/(20*calib)
      vel=dist*7200/i
      accn=accn1*50/(n*calib)
      decn=decn1*50/(z*calib)
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 321
      denom=(pedoff+abs(pedon))
      fang=(90*pedoff/denom)-(90*(sum2/i)/denom)
      fvel=(90*(sdiff2/l)/denom)*2
      faccn=(90*(saccn2/h)/denom)*2
      chuck=change/2
      revs=sum3*120/(121*i)
  321 gas=sum5*0.001
      gast=sum6/(celcius*i)
      oilt=sum7/(centi*i)
      fcon=gas*100/dist
      walk=dist*0.62137
      whip=vel*0.62137
      petrol=gas/4.546
      fpet=282.475/fcon
      fuel=ftot/fcount
      flow3=flow/4.546
      fuel1=fuel/4.546
      derv=gas*7200/i
      derv1=derv/4.546
      speed2=speed1*180/calib
      speed4=speed2*0.62137
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 322
      throt2=(90*pedoff/denom)-(90*(throt1/2)/denom)
      eng2=eng1*60/121
  322 temp3=temp1/(celcius*2)
      temp4=temp2/(centi*2)
      speed3=(x1+x2)*180/calib
      speed5=speed3*0.62137
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 323
      throt3=(90*pedoff/denom)-(90*((y1+y2)/2)/denom)
      eng3=(w1+w2)*60/121
  323 temp5=(u1+u2)/(celcius*2)
      temp6=(v1+v2)/(centi*2)
c     ********************************************************

c     ********************************************************
c     data for %-g-level histogram plots
c     ********************************************************
      if (hist.eq.'l') goto 331
      asum1=an1+an2+an3+an4+an5+an6+an7+an8+an9+an10
      asum2=an11+an12+an13+an14+an15+an16+an17+an18+an19+an20
      asum=asum1+asum2
      dsum1=dn1+dn2+dn3+dn4+dn5+dn6+dn7+dn8+dn9+dn10
      dsum2=dn11+dn12+dn13+dn14+dn15+dn16+dn17+dn18+dn19+dn20
      dsum=dsum1+dsum2
      goto 332
  331 asum=an1+an2+an3+an4+an5+an6+an7+an8+an9+an10
      dsum=dn1+dn2+dn3+dn4+dn5+dn6+dn7+dn8+dn9+dn10
  332 a1=an1*100/asum
      a2=an2*100/asum
      a3=an3*100/asum
      a4=an4*100/asum
      a5=an5*100/asum
```

```
      a6=an6*100/asum
      a7=an7*100/asum
      a8=an8*100/asum
      a9=an9*100/asum
      a10=an10*100/asum
      d1=dn1*100/dsum
      d2=dn2*100/dsum
      d3=dn3*100/dsum
      d4=dn4*100/dsum
      d5=dn5*100/dsum
      d6=dn6*100/dsum
      d7=dn7*100/dsum
      d8=dn8*100/dsum
      d9=dn9*100/dsum
      d10=dn10*100/dsum
      if (hist.eq.'l') goto 333
      a11=an11*100/asum
      a12=an12*100/asum
      a13=an13*100/asum
      a14=an14*100/asum
      a15=an15*100/asum
      a16=an16*100/asum
      a17=an17*100/asum
      a18=an18*100/asum
      a19=an19*100/asum
      a20=an20*100/asum
      d11=dn11*100/dsum
      d12=dn12*100/dsum
      d13=dn13*100/dsum
      d14=dn14*100/dsum
      d15=dn15*100/dsum
      d16=dn16*100/dsum
      d17=dn17*100/dsum
      d18=dn18*100/dsum
      d19=dn19*100/dsum
      d20=dn20*100/dsum
c     ***********************************************************

c     ***********************************************************
c     data details written to file
c     ***********************************************************
  333 write (4,541)
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 338
      write (4,359)
      goto 339
  338 write (4,358)
  339 write (4,541)
      write (4,360) filname,vehicle
      write (4,541)
      write (4,370) x
      write (4,380) y
      if (count.ne.1) goto 340
      write (4,390)
      goto 350
  340 write (4,400)
  350 time=i/120.0
      write (4,410) time
      write (4,420) t,s
      write (4,541)
      write (4,430) dist,walk
```

```
      write (4,440) vel,whip
      write (4,450) accn
      write (4,540) decn
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 351
      write (4,460) fang
      write (4,470) fvel
      write (4,480) faccn
      write (4,485) chuck
      write (4,490) revs
  351 write (4,500) gas,petrol
      write (4,530) fcon,fpet
      write (4,550) fuel,fuel1
      write (4,551) derv,derv1
      write (4,510) gast
      write (4,520) oilt
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 354
      write (4,541)
      write (4,542)
      write (4,541)
      write (4,544)
      if (hist.eq.'1') goto 352
      write (4,545)
      goto 353
  352 write (4,546)
  353 write (4,547) a1,a2,a3,a4,a5,a6,a7,a8,a9,a10
      write (4,548) d1,d2,d3,d4,d5,d6,d7,d8,d9,d10
      if (hist.eq.'1') goto 354
      write (4,566)
      write (4,547) a11,a12,a13,a14,a15,a16,a17,a18,a19,a20
      write (4,548) d11,d12,d13,d14,d15,d16,d17,d18,d19,d20
  354 write (4,541)
      write (4,552)
      write (4,541)
      write (4,553) x
      write (4,554) speed2,speed4
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 355
      write (4,555) throt2
      write (4,556) eng2
  355 write (4,549) flow1,flow2
      write (4,557) temp3
      write (4,558) temp4
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 356
      write (4,559) select
  356 write (4,560) y
      write (4,554) speed3,speed5
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 357
      write (4,555) throt3
      write (4,556) eng3
  357 write (4,549) flow,flow3
      write (4,557) temp5
      write (4,558) temp6
      if (filname(2:4).eq.'014'.or.filname(2:4).eq.'015') goto 361
      write (4,559) clog
  361 write (4,541)
c     ***************************************************

c     ***************************************************
c     separating independent analysis by a clean page
c     ***************************************************
      write (4,*) char(12)
```

```
c       ****************************************************
c       ****************************************************
c       output formatting details
c       ****************************************************
 358 format (1x,'AUSTIN-ROVER MONTEGO FUEL CONSUMPTION TEST')
 359 format (1x,'VAUXHALL CAVALIER FUEL CONSUMPTION ROAD TEST')
 360 format (1x,'ANALYSIS FILE of ',a11,20x,a19)
 370 format (1x,'Commencing at mark No.',a)
 380 format (1x,'and terminating at mark No.',a)
 390 format (1x,'before the intermission ,with a')
 400 format (1x,'after the intermission ,with a')
 410 format (1x,'duration of ',f7.3,' minutes')
 420 format (1x,'from ',a15,' minus ',f4.1,' seconds')
 430 format (1x,'TOTAL DISTANCE          - ',f9.3,' KM.             { '
    *,f5.2,' miles }')
 440 format (1x,'AVE.VEHICLE SPEED       - ',f9.3,' KPH.            { '
    *,f5.2,' mph.  }')
 450 format (1x,'AVE.VEHICLE ACCN.       - ',f9.3,' M/S/S.')
 460 format (1x,'AVE.THROTTLE ANGLE      - ',f9.3,' DEG.')
 470 format (1x,'AVE.THROTTLE SPEED      - ',f9.3,' DEG/S.')
 480 format (1x,'AVE.THROTTLE ACCN.      - ',f9.3,' DEG/S/S.')
 485 format (1x,'GEAR CHANGES            - ',f9.1)
 490 format (1x,'AVE.ENGINE REVS         - ',f9.3,' R.P.M.')
 500 format (1x,'TOTAL FUEL USED         - ',f9.3,' LITRES          { '
    *,f5.2,' galls }')
 510 format (1x,'AVE.FUEL TEMP.          - ',f9.3,' DEG C.')
 520 format (1x,'AVE.OIL TEMP.           - ',f9.3,' DEG C.')
 530 format (1x,'AVE.FUEL CONSP.         - ',f9.3,' LIT./100KM.     { '
    *,f5.2,' mpg.  }')
 540 format (1x,'AVE.VEHICLE DECN.       - ',f9.3,' M/S/S.')
 541 format (1x,'*************************************************
    **************')
 542 format (1x,'VEHICLE ACCN/DECCN CHARACTERISTICS')
 545 format (1x,'g-level 0.025 0.050 0.075 0.100 0.125 0.150 0.175 0.20
    *0 0.225 0.250')
 566 format (1x,'g-level 0.275 0.300 0.325 0.350 0.375 0.400 0.425 0.45
    *0 0.475 0.500')
 546 format (1x,'level - 0.05g 0.10g 0.15g 0.20g 0.25g 0.30g 0.35g 0.40
    *g 0.45g 0.50g')
 544 format (1x,'% of vehicle-motion-time at g level')
 547 format (1x,'accn  -',10(1x,f5.2))
 548 format (1x,'decn  -',10(1x,f5.2))
 549 format (1x,'FUEL FLOW RATE          - ',f9.3,' LIT./HR.        { '
    *,f5.2,' gal/hr}')
 550 format (1x,'AVE.FUEL FLOW RATE      - ',f9.3,' LIT./HR.        { '
    *,f5.2,' gal/hr}')
 551 format (1x,'AVE.FUEL FLOW CHECK     - ',f9.3,' LIT./HR.        { '
    *,f5.2,' gal/hr}')
 552 format (1x,'VEHICLE STATE AT SECTION BOUNDARIES')
 553 format (1x,'Commencing at Event No.',a)
 554 format (1x,'VEHICLE SPEED           - ',f9.3,' KPH.            { '
    *,f5.2,' mph.  }')
 555 format (1x,'THROTTLE ANGLE          - ',f9.3,' DEG.')
 556 format (1x,'ENGINE REVS.            - ',f9.3,' RPM.')
 557 format (1x,'FUEL TEMP.              - ',f9.3,' DEG C.')
 558 format (1x,'OIL TEMP.               - ',f9.3,' DEG C.')
 559 format (1x,'GEAR SELECTION          -      ',a)
 560 format (1x,'Terminating at Event No.',a)
c       ****************************************************
```

```
c       **********************************************************
c       closure of input and output files
c       **********************************************************
  600 close (2)
      close (3)
      write (*,*) 'do you wish to analyse more data? (y/n) '
      read (5,*) quest
      if (quest.eq.'y') goto 5
  610 close (4)
c       **********************************************************

c       **********************************************************
c       end of program for analysing MICRODATA road test tapes
c       **********************************************************
      end
c       **********************************************************
```

APPENDIX C

LISTING OF DATA FILE ROADTEST.DATA

****

**********************LOUGHBOROUGH UNIVERSITY**************************

****************DEPARTMENT OF TRANSPORT TECHNOLOGY*******************

****

****

VAUXHALL CAVALIER AND AUSTIN-ROVER MONTEGO
FUEL CONSUMPTION TESTS SPRING/SUMMER 1985.

M.REDSELL - CONTRACT No.TRR/842/459

****

****

roadtest.data

****

"roadtest.data" contains descriptive data of all the test-drives conducted on the Leicestershire test route using the three Vauxhall Cavalier and two Austin-Rover Montego vehicles. All test-drives were conducted during the spring and summer of 1985.

Each test is summarised by 10 lines of data , each containing 21 variables and using the format;

```
0,1x,2(1x,f7.3),3(1x,f3.0),5(1x,f6.3),/,6(1x,f7.2),3(1x,f6.1),1x,f2.0
```

i.e.,20 printed lines are required for each test)

The ten lines of data denote ten different route sections coded y variable (5), defined as follows;

```
 value of                    description
ariable (5)                    of route

    1         -  data for complete test route
    2         -  data for Motorway section of test route
    3         -  data for first Urban Cycle (before break)
    4         -  data for second Urban Cycle (after break)
    5         -  data for first Suburban route section
    6         -  data for second Suburban route section
    7         -  data for average of Suburban routes
    8         -  data for "Urban Cycle No.2 to Motorway" route section
    9         -  data for "first mile" route section
   10         -  data for "50/40/10 %" route section (Urb/Suburb/M1)
```

Each line of data contains 21 test variables, namely;

```
number of                   description
variable                    of variable

 X(1)  - test     - number of test related to data logger tape
  (2)  - fuel     - average fuel consumption ( lit./100 Km.)
  (3)  - speed    - average speed for section ( Km./Hour )
 X(4)  - vehicle  - vehicle identification code;
                    1 - 1600 Petrol Cavalier - Montego (white)
                    2 - 1300 Petrol Cavalier - Montego (ivory)
                    3 - 1600 Diesel
 X(5)  - route    - route section identification ( as above )
 X(6)  - driver   - driver identification code;
                    1 - Male 37 years
```

2 - Male 70 years
3 - Male 49 years
4 - Male 27 years
5 - Female 36 years
6 - Female 25 years
7 - Male 45 years ('expert')
8 - Male 52 years ('supervisor')

(7)	- vacc	- average vehicle acceleration (m/s/sec.)
(8)	- vdec	- average vehicle deceleration (m/s/sec.)
(9)	- tpos	- average throttle position (degrees)
(10)	- tvel	- average throttle "on" velocity (deg./sec.)
(11)	- tacc	- average throttle "on" acceleration (deg./s/sec.)
(12)	- gear	- gear changes per Km. for route section
(13)	- revs	- average engine revs. for route section (r.p.m.)
(14)	- flow	- average fuel flow during section (lit./Hr.)
(15)	- tfuel	- average fuel supply temperature (deg. K.)
(16)	- toil	- average engine oil temperature (deg. K.)
(17)	- tamb	- average ambient temperature (deg. K.)
(18)	- traf	- hourly urban traffic flow (units/Hr.)
(19)	- press	- average ambient pressure for test (mBars.)
(20)	- humid	- average air humidity for section (%)
X (21)	- group	- identification code for test programme;

1 - main test programme (Cavalier/Spring)
2 - "expert" test drives (Cavalier/Spring)
3 - "extra motorway" tests (Cavalier/Spring)
4 - "time of day" tests (Cavalier/Spring)
5 - "hot start" tests (Cavalier/Spring)
6 - subsidory test programme (Cavalier/Summer)
7 - main test programme (Montego/Summer)

The weather variables of ambient temperature and humidity for ach section of the test route are averaged from a linear relation- hip of "variable vs. test time" , using the maximum and minimum alues recorded over the total test period.

The measures of hourly traffic flow were recorded by the eicester Traffic Control Office at the 'Holiday Inn' underpass n the A47. Urban Cycle 1 and Cycle 2 were conducted during he hours of 0900-1000 and 1000-1100 , respectively.

"roadtest.data" is formatted to be compatible with S.P.S.S. Statistical Package for the Social Sciences) for statistical nalysis, using the University's Honeywell "Multics" system.

****

9.268	34.676	1.	1.	1.	0.429	-0.584	6.935	3.897	7.479	
6.67	1899.00	3.22	288.85	370.35	280.00	0.0	1019.5	93.5	1.	
8.490	108.960	1.	2.	1.	0.207	-0.293	27.303	2.961	5.701	
0.00	4094.00	9.29	289.41	374.35	281.00	0.0	1019.5	93.8	1.	γ_{MOT}
11.597	19.507	1.	3.	1.	0.370	-0.595	3.271	2.771	5.210	
13.89	1508.30	2.26	288.90	370.48	279.30	1240.0	1019.5	93.3	1.	
11.508	22.204	1.	4.	1.	0.449	-0.751	4.398	3.136	6.359	γ_{URB}
13.27	1630.40	2.56	288.33	381.75	280.50	1072.0	1019.5	93.7	1.	
8.452	36.458	1.	5.	1.	0.416	-0.484	6.565	4.699	8.252	
5.81	1907.20	3.08	288.46	361.85	278.80	0.0	1019.5	93.1	1.	
8.285	45.527	1.	6.	1.	0.483	-0.591	9.159	4.345	8.592	
4.21	2159.40	3.78	289.55	371.32	281.30	0.0	1019.5	93.9	1.	
8.353	41.337	1.	7.	1.	0.452	-0.542	7.961	4.509	8.435	
4.86	2042.90	3.46	289.04	366.95	280.00	0.0	1019.5	93.5	1.	γ_{SUB}
9.524	31.066	1.	8.	1.	0.411	-0.592	6.301	3.700	7.329	
7.44	1796.50	2.95	289.31	371.17	280.80	0.0	1019.5	93.8	1.	

```
.   11.215   23.298  1.   9.  1.   0.478 -0.592  4.459  3.591  7.564
13.19 1687.90     2.59  288.77   348.88  278.50    0.0 1019.5   93.0 1.
.    9.966   28.928  1. 10.  1.   0.406 -0.582  7.832  3.576  6.836
 8.74 2011.20     3.51  288.87   372.27  280.00    0.0 1019.5   93.5 1.   γ%
.    8.738   38.526  1.   1.  1.   0.464 -0.611  7.860  3.518  6.608
 6.11 1938.90     3.36  287.78   364.59  277.80    0.0 1010.0   80.0 1.
.    9.878 111.067  1.   2.  1.   0.279 -0.351 32.555  5.247 11.370
 0.08 4179.90    10.96  287.68   374.27  278.90    0.0 1010.0   80.0 1.   γMOT
.   12.021   18.640  1.   3.  1.   0.403 -0.697  3.430  2.221  4.004
15.35 1533.30     2.24  287.72   370.22  276.90 1144.0 1010.0   80.0 1.   γURB
.    9.979   26.651  1.   4.  1.   0.538 -0.717  5.297  3.318  6.839
12.41 1663.40     2.66  287.71   368.56  278.30 1048.0 1010.0   80.0 1.
.    8.196   46.594  1.   5.  1.   0.470 -0.505  9.862  4.462  8.257
 4.29 2065.10     3.81  287.45   341.62  276.30    0.0 1010.0   80.0 1.
.    6.728   52.452  1.   6.  1.   0.440 -0.546  9.004  3.509  6.336
 2.99 2160.90     3.54  288.28   367.57  279.20    0.0 1010.0   80.0 1.
     7.331   49.879  1.   7.  1.   0.453 -0.528  9.381  3.928  7.180
 3.52 2118.90     3.66  287.92   356.17  277.80    0.0 1010.0   80.0 1.   γSUB
     8.739   35.956  1.   8.  1.   0.485 -0.647  7.383  3.837  7.675
 6.71 1861.60     3.13  288.11   369.47  278.60    0.0 1010.0   80.0 1.
    12.338   29.571  1.   9.  1.   0.555 -0.620  6.498  3.831  7.460
13.94 1672.90     3.63  288.27   302.15  276.00    0.0 1010.0   80.0 1.
     9.420   32.259  1. 10.  1.   0.444 -0.600  9.190  3.480  6.720
 8.36 2064.70     3.79  287.79   364.59  277.80    0.0 1010.0   80.0 1.   γ%
     8.945   34.444  1.   1.  2.   0.408 -0.573  6.586  2.593  4.474
 6.69 1881.50     3.07  284.19   364.75  275.50    0.0 1007.5   98.5 1.
     8.321 102.761  1.   2.  2.   0.209 -0.260 25.608  2.734  5.087
 0.25 3879.60     8.50  283.97   373.29  276.20    0.0 1007.5   98.8 1.
    12.352   18.541  1.   3.  2.   0.409 -0.651  3.181  2.260  4.323
16.06 1566.90     2.28  285.19   369.38  275.00 1184.0 1007.5   98.3 1.   β
    11.069   23.940  1.   4.  2.   0.437 -0.674  5.117  2.861  4.980
11.61 1618.30     2.64  283.38   370.36  275.80  992.0 1007.5   98.7 1.
     8.580   34.924  1.   5.  2.   0.352 -0.473  6.437  2.223  3.750
 5.39 1835.70     2.98  284.42   343.98  274.70    0.0 1007.5   98.1 1.
     6.845   52.644  1.   6.  2.   0.427 -0.503  9.227  2.642  3.994
 2.88 2253.80     3.59  283.99   368.09  276.30    0.0 1007.5   98.9 1.
     7.557   43.576  1.   7.  2.   0.389 -0.488  7.799  2.428  3.869
 3.91 2039.80     3.28  284.21   355.75  275.50    0.0 1007.5   98.5 1.
     9.574   29.712  1.   8.  2.   0.428 -0.648  5.833  2.842  4.856
 7.72 1761.10     2.83  283.93   370.55  276.00    0.0 1007.5   98.8 1.
    14.695   16.585  1.   9.  2.   0.347 -0.569  3.276  2.303  3.780
15.72 1406.40     2.40  284.63   313.74  274.50    0.0 1007.5   98.0 1.
     9.711   29.681  1. 10.  2.   0.388 -0.552  7.755  2.525  4.382
 8.51 2000.20     3.39  284.22   364.56  275.50    0.0 1007.5   98.5 1.
     8.798   36.004  1.   1.  2.   0.452 -0.621  7.337  2.694  4.591
 6.64 1941.40     3.16  287.46   368.77  277.50    0.0  975.5   98.0 1.
     8.043   98.316  1.   2.  2.   0.252 -0.307 25.210  1.503  2.484
 0.00 3684.20     7.88  287.94   375.24  278.50    0.0  975.5   98.0 1.
    11.805   22.482  1.   3.  2.   0.520 -0.754  5.061  2.980  5.177
13.63 1677.40     2.64  287.10   374.25  276.80 1152.0  975.5   98.0 1.   β
    11.179   22.753  1.   4.  2.   0.436 -0.744  4.503  2.743  5.040
12.58 1677.60     2.54  287.80   372.65  278.00 1112.0  975.5   98.0 1.
     8.434   36.645  1.   5.  2.   0.448 -0.494  7.555  2.487  4.010
 7.93 1928.20     3.08  286.27   351.78  276.30    0.0  975.5   98.0 1.
     6.745   47.707  1.   6.  2.   0.396 -0.523  7.855  2.328  3.576
 3.40 2098.70     3.22  287.88   370.03  278.80    0.0  975.5   98.0 1.
     7.438   42.451  1.   7.  2.   0.421 -0.509  7.712  2.404  3.782
 5.25 2017.70     3.16  287.12   361.36  277.50    0.0  975.5   98.0 1.
     9.630   32.459  1.   8.  2.   0.470 -0.720  7.247  2.944  4.900
 7.04 1865.40     3.13  288.25   374.00  278.30    0.0  975.5   98.0 1.
```

10.734	25.517	1.	9.	2.	0.550	-0.495	5.709	2.674	4.925	
15.08	1668.30	2.72	286.95	315.88	276.00	0.0	975.5	98.0	1.	
9.526	30.726	1.	10.	2.	0.432	-0.609	7.997	2.542	4.316	
8.66	2014.20	3.34	287.37	368.79	277.50	0.0	975.5	98.0	1.	
8.506	33.191	1.	1.	3.	0.385	-0.582	5.872	1.940	3.827	
6.67	1850.40	2.83	289.50	368.95	279.20	0.0	1018.0	85.0	1.	
8.812	105.664	1.	2.	3.	0.206	-0.330	28.112	2.006	3.748	
0.00	3959.60	9.34	289.88	378.44	280.00	0.0	1018.0	83.7	1.	
11.824	18.542	1.	3.	3.	0.356	-0.727	3.189	1.844	3.388	
13.83	1547.40	2.19	289.02	373.74	278.60	1228.0	1018.0	86.0	1.	R
10.750	20.582	1.	4.	3.	0.434	-0.654	3.261	1.976	3.852	
13.39	1607.20	2.21	289.81	373.55	279.60	1128.0	1018.0	84.3	1.	
7.480	38.990	1.	5.	3.	0.368	-0.488	6.661	1.921	4.008	
5.26	1947.20	2.91	288.42	348.16	278.20	0.0	1018.0	86.7	1.	
6.468	51.425	1.	6.	3.	0.396	-0.509	8.711	2.276	4.649	
2.46	2154.60	3.33	289.92	369.82	280.20	0.0	1018.0	83.3	1.	
6.884	45.476	1.	7.	3.	0.383	-0.499	7.730	2.106	4.342	
3.61	2055.40	3.13	289.20	359.46	279.20	0.0	1018.0	85.0	1.	
8.949	29.832	1.	8.	3.	0.432	-0.584	5.393	2.164	4.404	
8.48	1797.60	2.67	290.40	374.27	279.80	0.0	1018.0	84.0	1.	
11.492	21.371	1.	9.	3.	0.361	-0.575	3.777	1.859	5.194	
12.90	1456.30	2.43	289.05	311.62	278.00	0.0	1018.0	87.0	1.	
9.278	28.327	1.	10.	3.	0.371	-0.578	7.516	1.998	3.922	
8.25	2006.80	3.29	289.38	368.45	279.20	0.0	1018.0	85.0	1.	
7.899	35.757	1.	1.	3.	0.414	-0.568	6.192	2.285	4.568	
6.13	1938.90	2.93	290.69	370.92	281.10	0.0	1013.5	76.0	1.	
7.779	107.603	1.	2.	3.	0.208	-0.291	24.648	2.543	6.021	
0.00	4032.20	8.42	294.48	378.74	282.80	0.0	1013.5	70.0	1.	
10.466	21.604	1.	3.	3.	0.441	-0.707	3.339	1.981	3.851	
14.86	1639.20	2.26	288.47	374.42	279.80	1288.0	1013.5	80.5	1.	R
10.285	22.818	1.	4.	3.	0.454	-0.718	3.880	2.319	5.135	
12.51	1663.80	2.36	292.23	375.00	282.00	1032.0	1013.5	73.0	1.	
6.778	42.036	1.	5.	3.	0.337	-0.423	6.127	1.828	3.584	
4.45	1930.90	2.84	284.70	357.74	278.90	0.0	1013.5	83.5	1.	
5.827	55.736	1.	6.	3.	0.397	-0.441	8.142	2.437	4.670	
1.77	2232.00	3.28	293.81	371.38	283.30	0.0	1013.5	68.5	1.	
6.219	49.165	1.	7.	3.	0.368	-0.432	7.176	2.145	4.149	
2.87	2087.60	3.06	289.44	364.84	281.10	0.0	1013.5	76.0	1.	
9.476	29.455	1.	8.	3.	0.420	-0.643	5.938	2.653	5.132	
9.83	1816.50	2.80	293.69	375.44	282.40	0.0	1013.5	71.5	1.	
8.102	31.195	1.	9.	3.	0.534	-0.486	4.512	2.009	4.792	
10.47	1713.10	2.51	282.60	332.85	278.50	0.0	1013.5	85.0	1.	
8.454	31.669	1.	10.	3.	0.392	-0.558	7.140	2.187	4.508	
7.99	2064.00	3.22	290.40	371.17	281.10	0.0	1013.5	76.0	1.	
9.940	39.563	1.	1.	4.	0.489	-0.709	9.766	3.518	7.360	
6.37	2217.80	3.96	294.10	372.92	285.30	0.0	1005.0	83.5	1.	
13.773	141.692	1.	2.	4.	0.382	-0.519	60.627	4.443	10.501	
0.00	5309.70	19.60	296.22	391.68	286.80	0.0	1005.0	77.2	1.	4MOT
11.423	22.156	1.	3.	4.	0.448	-0.744	4.755	2.588	5.074	
3.32	1752.40	2.54	292.72	375.45	284.10	1168.0	1005.0	88.3	1.	4URB
11.143	25.818	1.	4.	4.	0.529	-0.843	5.734	3.464	7.700	
2.51	1854.50	2.90	294.46	376.56	286.00	968.0	1005.0	80.3	1.	
8.220	42.509	1.	5.	4.	0.427	-0.565	8.543	2.990	5.446	
4.86	2192.60	3.50	291.14	350.54	283.40	0.0	1005.0	91.4	1.	
8.356	58.692	1.	6.	4.	0.577	-0.728	13.684	4.731	11.210	
3.39	2704.80	4.97	297.30	380.01	287.10	0.0	1005.0	75.6	1.	
8.305	50.754	1.	7.	4.	0.503	-0.648	11.162	3.877	8.383	
3.99	2453.60	4.25	294.28	365.55	285.30	0.0	1005.0	83.5	1.	
10.661	33.278	1.	8.	4.	0.516	-0.781	8.845	4.034	8.388	
8.11	2106.60	3.57	295.79	377.62	286.40	0.0	1005.0	78.8	1.	

.	11.347	32.493	1.	9.	4.	0.753	-0.636	8.293	4.236	8.633	
10.51	1982.20	3.67	290.93	306.91	283.00	0.0	1005.0	93.0	1.		
.	10.341	33.977	1.	10.	4.	0.484	-0.708	13.150	3.508	7.597	
8.05	2414.10	5.02	294.13	373.39	285.30	0.0	1005.0	83.5	1.		
.	9.353	43.589	1.	1.	4.	0.494	-0.683	10.185	3.694	8.138	
5.44	2268.20	4.09	292.49	369.22	283.70	0.0	1004.0	73.5	1.		
.	12.805	138.791	1.	2.	4.	0.260	-0.397	52.722	5.082	12.726	
0.00	5201.00	17.93	293.83	385.90	285.20	0.0	1004.0	66.5	1.		4мот
.	10.359	28.771	1.	3.	4.	0.561	-0.856	6.439	3.385	7.216	
11.38	1913.40	2.99	291.21	372.06	282.50	1176.0	1004.0	78.8	1.		4игв
.	10.588	27.219	1.	4.	4.	0.541	-0.838	5.838	3.822	8.435	
12.18	1882.80	2.89	292.51	373.08	284.50	1040.0	1004.0	70.0	1.		
.	7.997	49.583	1.	5.	4.	0.444	-0.554	9.985	3.376	7.158	
3.39	2290.80	3.97	290.01	346.75	281.80	0.0	1004.0	82.3	1.		
.	7.934	54.714	1.	6.	4.	0.468	-0.610	11.735	4.123	9.438	
3.12	2586.50	4.38	295.16	376.32	285.60	0.0	1004.0	64.8	1.		
.	7.960	52.484	1.	7.	4.	0.458	-0.586	10.975	3.798	8.448	
3.23	2458.00	4.20	292.92	363.47	283.70	0.0	1004.0	73.5	1.		
.	9.899	36.190	1.	8.	4.	0.523	-0.681	8.997	3.759	8.268	
7.28	2064.00	3.57	293.49	373.55	284.90	0.0	1004.0	68.3	1.		
.	9.884	42.646	1.	9.	4.	0.658	-0.643	9.797	3.976	9.173	
8.39	2081.80	4.20	290.30	305.53	281.40	0.0	1004.0	84.0	1.		
.	9.702	38.165	1.	10.	4.	0.485	-0.697	12.731	3.829	8.564	
7.18	2452.30	4.94	292.48	370.26	283.70	0.0	1004.0	73.5	1.		
.	8.319	34.929	1.	1.	5.	0.356	-0.609	6.116	1.910	4.169	
6.28	1842.50	2.90	287.43	367.78	278.60	0.0	1018.5	67.5	1.		
.	9.428	109.823	1.	2.	5.	0.199	-0.298	30.597	2.207	5.557	
0.00	4115.40	10.33	287.50	378.68	279.40	0.0	1018.5	63.8	1.		
.	10.257	20.127	1.	3.	5.	0.335	-0.645	2.736	1.513	3.447	
12.55	1542.60	2.06	287.30	372.33	278.00	1168.0	1018.5	70.3	1.		
.	10.693	19.398	1.	4.	5.	0.330	-0.745	2.851	1.531	3.385	
14.12	1448.60	2.07	286.96	370.91	279.00	968.0	1018.5	65.7	1.		
.	7.864	37.388	1.	5.	5.	0.356	-0.539	6.554	1.867	3.491	
5.73	1875.60	2.93	287.80	350.78	277.60	0.0	1018.5	72.1	1.		
.	6.366	51.407	1.	6.	5.	0.380	-0.553	8.072	2.127	4.820	
2.73	2153.40	3.28	287.97	369.67	279.60	0.0	1018.5	62.9	1.		
.	6.982	44.543	1.	7.	5.	0.368	-0.546	7.329	2.000	4.169	
3.97	2017.40	3.11	287.89	360.42	278.60	0.0	1018.5	67.5	1.		
.	8.795	34.162	1.	8.	5.	0.486	-0.727	6.726	2.857	6.654	
8.36	1846.50	2.99	287.67	373.28	279.20	0.0	1018.5	64.8	1.		
.	11.413	27.801	1.	9.	5.	0.582	-0.670	6.716	2.536	3.914	
14.48	1586.80	3.13	289.18	309.63	277.40	0.0	1018.5	73.0	1.		
.	8.973	28.417	1.	10.	5.	0.333	-0.596	7.388	1.782	3.931	
8.25	1966.30	3.31	287.47	367.85	278.60	0.0	1018.5	67.5	1.		
.	7.699	35.867	1.	1.	5.	0.367	-0.578	5.462	1.757	3.591	
6.24	1861.40	2.76	288.59	365.33	277.70	0.0	991.5	89.5	1.		
.	8.567	107.596	1.	2.	5.	0.198	-0.258	27.003	1.267	2.943	
0.00	4031.90	9.23	289.04	374.17	278.70	0.0	991.5	86.5	1.		
.	9.283	22.765	1.	3.	5.	0.367	-0.642	2.921	1.644	3.368	
11.90	1536.20	2.11	288.09	368.88	276.90	1192.0	991.5	91.8	1.		
.	8.977	23.481	1.	4.	5.	0.413	-0.682	3.038	1.781	3.785	
13.57	1567.50	2.11	288.46	368.23	278.20	1120.0	991.5	88.0	1.		
.	7.978	35.111	1.	5.	5.	0.388	-0.557	5.562	2.023	4.247	
6.45	1841.70	2.79	287.80	349.05	276.40	0.0	991.5	93.3	1.		
.	6.234	43.649	1.	6.	5.	0.322	-0.526	5.602	1.386	2.616	
3.88	2003.00	2.73	289.71	368.32	278.90	0.0	991.5	85.8	1.		
.	6.950	39.687	1.	7.	5.	0.353	-0.540	5.583	1.682	3.373	
4.94	1928.10	2.76	288.82	359.38	277.70	0.0	991.5	89.5	1.		
.	7.628	32.845	1.	8.	5.	0.359	-0.574	4.792	1.846	3.759	
6.38	1809.70	2.50	289.15	370.99	278.40	0.0	991.5	87.3	1.		

10.919	30.140	1.	9.	5.	0.649	-0.706	6.107	3.464	7.632	
16.41	1711.20	3.27	288.78	307.84	276.20	0.0	991.5	94.0	1.	
8.202	30.645	1.	10.	5.	0.356	-0.573	6.423	1.656	3.432	
8.34	1950.40	3.08	288.57	365.44	277.70	0.0	991.5	89.5	1.	
9.547	36.251	1.	1.	6.	0.455	-0.710	7.821	2.486	5.252	
7.62	2250.60	3.47	290.71	374.25	277.70	0.0	1020.5	68.5	1.	
9.444	118.488	1.	2.	6.	0.275	-0.418	32.856	1.910	4.379	
0.[illegible]2	4446.00	11.26	292.72	384.64	280.30	0.0	1020.5	54.2	1.	
12.614	18.664	1.	3.	6.	0.372	-0.772	3.821	1.943	3.964	
15.28	1772.90	2.35	288.73	377.06	275.80	1232.0	1020.5	79.3	1.	
11.480	22.282	1.	4.	6.	0.472	-0.773	4.216	2.027	4.438	α
16.50	1968.20	2.57	291.78	379.66	279.00	984.0	1020.5	61.3	1.	
8.758	40.878	1.	5.	6.	0.410	-0.617	9.175	2.553	5.219	
4.73	2229.70	3.58	288.03	352.62	274.50	0.0	1020.5	86.4	1.	
7.629	58.552	1.	6.	6.	0.544	-0.693	11.731	3.315	7.470	
3.84	2808.60	4.50	293.53	377.52	280.90	0.0	1020.5	50.6	1.	
8.095	49.727	1.	7.	6.	0.477	-0.655	10.455	2.935	6.346	
4.21	2519.60	4.04	290.78	365.09	277.70	0.0	1020.5	68.5	1.	
9.562	34.360	1.	8.	6.	0.492	-0.738	7.206	2.865	6.155	
9.01	2241.60	3.29	292.94	379.45	279.60	0.0	1020.5	57.8	1.	
13.781	27.622	1.	9.	6.	0.596	-0.835	8.432	4.020	8.619	
12.65	2043.50	3.76	288.93	312.63	273.80	0.0	1020.5	90.0	1.	
10.205	30.021	1.	10.	6.	0.429	-0.690	9.477	2.357	5.077	
9.64	2387.70	3.97	290.71	373.68	277.70	0.0	1020.5	68.5	1.	
9.444	35.923	1.	1.	6.	0.455	-0.665	7.122	2.467	5.296	
7.81	2350.40	3.42	295.12	376.58	284.50	0.0	1023.0	71.0	1.	
9.778	121.669	1.	2.	6.	0.325	-0.388	34.576	2.160	5.484	
0.00	4559.30	11.97	296.93	386.50	285.80	0.0	1023.0	68.3	1.	
12.323	18.187	1.	3.	6.	0.359	-0.709	3.002	1.697	3.740	
18.38	1783.60	2.26	294.10	378.08	283.50	1272.0	1023.0	73.0	1.	α
11.838	20.533	1.	4.	6.	0.421	-0.721	3.443	1.809	3.617	
16.98	1994.10	2.45	295.30	380.39	285.20	1008.0	1023.0	69.7	1.	
8.228	41.445	1.	5.	6.	0.441	-0.570	7.622	3.036	6.376	
5.48	2341.90	3.42	292.83	358.36	282.80	0.0	1023.0	74.3	1.	
7.445	59.180	1.	6.	6.	0.556	-0.658	11.523	3.547	7.809	
3.35	2947.50	4.46	297.55	380.58	286.20	0.0	1023.0	67.7	1.	
7.768	50.344	1.	7.	6.	0.499	-0.614	9.580	3.292	7.095	
4.23	2645.80	3.94	295.20	369.51	284.50	0.0	1023.0	71.0	1.	
10.752	33.663	1.	8.	6.	0.526	-0.725	6.691	2.758	6.480	
10.95	2380.20	3.32	296.25	381.83	285.50	0.0	1023.0	69.0	1.	
11.313	30.640	1.	9.	6.	0.735	-0.696	8.257	4.123	10.868	
12.87	2308.90	3.74	292.69	320.15	282.50	0.0	1023.0	75.0	1.	
10.125	28.907	1.	10.	6.	0.427	-0.642	8.901	2.409	5.226	
10.53	2458.70	3.95	295.12	376.07	284.50	0.0	1023.0	71.0	1.	
8.031	34.560	2.	1.	1.	0.376	-0.532	8.345	3.652	7.765	
10.01	1734.50	2.77	287.07	367.65	278.50	0.0	1020.5	95.0	1.	
7.113	94.566	2.	2.	1.	0.154	-0.216	21.516	2.699	6.002	
0.00	3540.10	6.73	287.76	378.69	279.00	0.0	1020.5	94.3	1.	
10.439	19.497	2.	3.	1.	0.371	-0.618	5.340	3.294	7.059	
21.80	1359.40	2.03	287.12	369.36	278.10	1216.0	1020.5	95.5	1.	
9.830	22.103	2.	4.	1.	0.396	-0.640	6.118	3.196	7.047	
19.87	1477.10	2.17	287.22	372.03	278.70	1008.0	1020.5	94.7	1.	
8.296	36.661	2.	5.	1.	0.310	-0.422	8.602	3.178	6.170	
7.36	1684.30	3.03	285.90	353.44	277.90	0.0	1020.5	95.8	1.	
6.196	51.975	2.	6.	1.	0.390	-0.459	11.170	4.468	9.377	
3.93	2094.60	3.22	287.41	370.43	279.10	0.0	1020.5	94.2	1.	
7.059	44.367	2.	7.	1.	0.350	-0.441	9.894	3.827	7.784	
5.33	1890.80	3.13	286.66	361.99	278.50	0.0	1020.5	95.0	1.	
8.531	29.814	2.	8.	1.	0.389	-0.574	7.900	3.810	8.304	
12.60	1659.30	2.54	287.88	372.36	278.80	0.0	1020.5	94.5	1.	

19.838	25.611	2.	9.	1.	0.370	-0.569	9.562	2.253	4.071
11.85	1636.80	5.06	285.08	324.97	277.80	0.0	1020.5	96.0	1.
8.603	29.316	2.	10.	1.	0.347	-0.512	8.974	3.423	7.240
12.55	1819.40	2.97	287.02	368.02	278.50	0.0	1020.5	95.0	1.
8.452	38.445	2.	1.	1.	0.417	-0.603	10.998	3.494	6.890
8.36	1933.00	3.24	284.46	366.90	275.40	0.0	980.0	75.0	1.
8.441	113.680	2.	2.	1.	0.149	-0.247	29.385	2.116	4.793
0.00	4255.60	9.59	284.64	382.06	276.80	0.0	980.0	65.0	1.
10.453	21.867	2.	3.	1.	0.365	-0.663	7.222	2.755	5.009
16.82	1542.90	2.27	284.16	368.80	274.30	1144.0	980.0	82.5	1.
10.852	24.966	2.	4.	1.	0.469	-0.817	9.230	3.669	7.584
17.95	1652.20	2.70	284.22	369.19	276.10	1048.0	980.0	70.0	1.
7.851	39.899	2.	5.	1.	0.365	-0.468	10.393	2.979	5.328
6.83	1888.90	3.11	283.63	350.77	273.60	0.0	980.0	87.5	1.
6.716	50.950	2.	6.	1.	0.414	-0.514	12.151	3.876	7.689
4.67	2156.50	3.42	285.58	372.06	277.10	0.0	980.0	62.5	1.
7.183	45.748	2.	7.	1.	0.391	-0.492	11.324	3.454	6.578
5.56	2030.50	3.27	284.66	362.03	275.40	0.0	980.0	75.0	1.
9.231	34.930	2.	8.	1.	0.459	-0.704	11.977	3.831	7.865
9.83	1833.90	3.19	285.09	370.25	276.40	0.0	980.0	67.5	1.
13.895	19.943	2.	9.	1.	0.359	-0.571	7.358	2.319	5.169
18.29	1582.80	2.73	284.04	321.56	273.30	0.0	980.0	90.0	1.
9.043	32.284	2.	10.	1.	0.380	-0.592	11.581	3.199	6.259
10.91	2036.60	3.51	284.43	367.52	275.40	0.0	980.0	75.0	1.
8.204	38.527	2.	1.	2.	0.439	-0.608	9.712	3.067	5.444
8.62	1975.40	3.15	286.35	370.16	277.70	0.0	1007.0	77.5	1.
8.696	107.065	2.	2.	2.	0.173	-0.246	28.351	2.046	3.912
0.00	4008.00	9.28	286.88	382.19	279.00	0.0	1007.0	66.5	1.
10.907	21.524	2.	3.	2.	0.438	-0.727	6.637	2.877	4.984
21.61	1587.00	2.34	286.15	373.79	276.70	1192.0	1007.0	85.8	1.
10.082	26.028	2.	4.	2.	0.506	-0.777	7.884	3.130	5.715
17.55	1697.30	2.62	286.00	373.52	278.30	992.0	1007.0	72.0	1.
7.561	37.643	2.	5.	2.	0.372	-0.478	8.517	2.389	4.251
8.59	1858.50	2.84	286.11	354.20	276.00	0.0	1007.0	91.3	1.
6.486	54.813	2.	6.	2.	0.427	-0.521	11.739	3.556	6.150
3.57	2326.80	3.56	286.78	373.39	279.30	0.0	1007.0	63.8	1.
6.927	46.182	2.	7.	2.	0.399	-0.499	10.119	2.969	5.195
5.63	2091.40	3.20	286.44	363.75	277.70	0.0	1007.0	77.5	1.
8.516	35.178	2.	8.	2.	0.473	-0.652	9.642	3.169	5.276
9.72	1914.40	2.99	286.64	375.14	278.60	0.0	1007.0	69.3	1.
12.169	19.077	2.	9.	2.	0.401	-0.534	5.842	1.938	3.789
22.85	1445.70	2.30	287.13	320.20	275.70	0.0	1007.0	94.0	1.
8.887	32.653	2.	10.	2.	0.413	-0.600	10.513	2.894	5.144
2.04	2058.40	3.44	286.30	370.54	277.70	0.0	1007.0	77.5	1.
7.936	36.722	2.	1.	2.	0.406	-0.596	8.982	2.988	5.318
9.82	1922.30	2.93	291.70	372.80	283.10	0.0	996.0	86.0	1.
7.275	108.571	2.	2.	2.	0.153	-0.244	24.321	1.978	3.863
0.00	4064.40	7.93	293.15	385.20	284.00	0.0	996.0	83.3	1.
10.640	21.779	2.	3.	2.	0.408	-0.715	6.760	2.693	4.394
7.32	1570.60	2.32	291.33	375.33	282.30	1424.0	996.0	88.0	1.
10.351	21.759	2.	4.	2.	0.419	-0.751	6.233	2.934	5.546
4.23	1591.00	2.26	291.54	376.82	283.50	848.0	996.0	84.7	1.
7.262	45.911	2.	5.	2.	0.387	-0.493	11.317	3.425	6.669
6.17	2069.90	3.33	290.45	353.23	281.80	0.0	996.0	89.3	1.
6.107	51.562	2.	6.	2.	0.401	-0.500	10.266	2.897	4.734
4.51	2207.80	3.17	292.61	376.30	284.30	0.0	996.0	82.7	1.
6.581	49.083	2.	7.	2.	0.395	-0.497	10.727	3.129	5.583
5.19	2147.30	3.24	291.66	366.18	283.10	0.0	996.0	86.0	1.
9.145	28.786	2.	8.	2.	0.443	-0.697	7.940	3.049	5.345
5.16	1741.10	2.64	292.69	376.94	283.80	0.0	996.0	84.0	1.

```
    9.834  33.318  2.   9.  2.   0.631 -0.642 10.456  3.892  8.524
17.51 1903.60     3.24   291.17   313.33  281.60     0.0  996.0    90.0 1.
    8.608  31.212  2.  10.  2.   0.380 -0.590  9.971  2.856  5.104
12.46 2055.80     3.23   291.70   373.03  283.10     0.0  996.0    86.0 1.
    7.595  35.811  2.   1.  3.   0.348 -0.541  8.080  3.183 10.021
 9.63 1845.10     2.72   287.89   366.82  280.00     0.0  994.0    83.0 1.
    7.483  96.606  2.   2.  3.   0.176 -0.234 23.283  1.945  4.542
 0.00 3616.50     7.23   288.95   375.93  281.00     0.0  994.0    83.0 1.
   10.103  19.357  2.   3.  3.   0.340 -0.642  5.173  1.824  4.516
27.10 1506.40     1.95   287.20   369.97  279.30 1264.0  994.0    83.0 1.
    9.777  22.964  2.   4.  3.   0.407 -0.688  4.504  8.214 32.712
18.87 1613.20     2.25   287.98   370.72  280.50 1064.0  994.0    83.0 1.
    7.442  39.516  2.   5.  3.   0.270 -0.431  8.824  1.584  3.899
 7.40 1867.90     2.94   286.66   350.73  278.80     0.0  994.0    83.0 1.
    5.820  48.426  2.   6.  3.   0.328 -0.476  9.425  2.367  5.643
 4.60 2048.90     2.83   289.28   369.85  281.30     0.0  994.0    83.0 1.
    6.485  44.325  2.   7.  3.   0.301 -0.455  9.148  2.007  4.840
 5.75 1965.60     2.88   288.07   361.05  280.00     0.0  994.0    83.0 1.
    7.830  33.120  2.   8.  3.   0.395 -0.558  8.240  2.925  7.084
 9.88 1768.80     2.59   288.77   370.67  280.80     0.0  994.0    83.0 1.
   13.892  20.676  2.   9.  3.   0.353 -0.513  6.052  1.451  3.115
30.09 1661.30     2.87   286.71   318.51  278.50     0.0  994.0    83.0 1.
    8.311  29.684  2.  10.  3.   0.325 -0.538  8.407  3.507 11.697
13.79 1927.80     2.92   287.92   367.19  280.00     0.0  994.0    83.0 1.
    7.671  35.472  2.   1.  3.   0.359 -0.529  8.713  2.457  5.345
10.23 1840.90     2.73   292.82   368.10  286.40     0.0  994.0    78.5 1.
    7.010 104.303  2.   2.  3.   0.126 -0.207 22.971  1.620  3.881
 0.00 3904.60     7.41   294.07   381.79  287.50     0.0  994.0    70.2 1.
   10.094  20.024  2.   3.  3.   0.369 -0.603  5.742  1.995  4.364
23.52 1526.80     2.03   292.44   370.17  285.50 1248.0  994.0    84.8 1.
   10.342  22.193  2.   4.  3.   0.419 -0.712  7.392  2.778  5.827
20.70 1571.30     2.30   292.35   371.65  286.90  880.0  994.0    74.3 1.
    6.523  39.191  2.   5.  3.   0.239 -0.368  8.260  1.358  3.185
 4.61 1794.90     2.56   291.57   350.42  284.90     0.0  994.0    88.9 1.
    6.165  46.159  2.   6.  3.   0.335 -0.463  9.489  2.517  5.407
 6.02 2034.00     2.87   294.61   373.09  287.80     0.0  994.0    68.1 1.
    6.312  43.020  2.   7.  3.   0.292 -0.420  8.935  1.995  4.406
 5.44 1926.30     2.73   293.24   362.88  286.40     0.0  994.0    78.5 1.
    9.072  33.509  2.   8.  3.   0.437 -0.613 10.643  3.634  7.603
 2.82 1828.10     3.03   293.24   371.73  287.20     0.0  994.0    72.3 1.
    9.082  26.035  2.   9.  3.   0.357 -0.563  7.082  2.018  5.545
 1.32 1526.70     2.34   291.53   315.08  284.60     0.0  994.0    91.0 1.
    8.334  29.461  2.  10.  3.   0.326 -0.518  9.155  2.153  4.698
 3.23 1935.50     2.92   292.90   368.79  286.40     0.0  994.0    78.5 1.
    9.068  37.052  2.   1.  4.   0.417 -0.649 10.234  3.266  7.470
 9.57 1386.40     3.36   287.61   372.24  278.40     0.0 1016.0    81.5 1.
   10.897 131.241  2.   2.  4.   0.181 -0.303 41.749  2.836  7.820
 0.00 4982.70    14.36   289.30   390.09  280.40     0.0 1016.0    74.5 1.
   10.604  21.901  2.   3.  4.   0.406 -0.698  6.368  2.691  6.144
 2.77 1666.70     2.32   285.90   374.20  277.00 1168.0 1016.0    86.8 1.
   10.244  25.036  2.   4.  4.   0.461 -0.757  7.276  3.527  8.239
 1.12 1821.90     2.56   287.87   376.18  279.40  968.0 1016.0    78.0 1.
    8.312  35.570  2.   5.  4.   0.313 -0.479  9.429  2.347  4.958
 0.66 1893.10     2.94   285.71   356.01  276.00     0.0 1016.0    90.3 1.
    7.578  46.167  2.   6.  4.   0.419 -0.634 11.251  3.591  7.618
 4.13 2588.70     3.51   290.87   378.17  280.90     0.0 1016.0    72.8 1.
    7.881  41.134  2.   7.  4.   0.369 -0.560 10.386  3.000  6.355
 6.81 2258.30     3.24   288.42   367.65  278.40     0.0 1016.0    81.5 1.
    9.780  35.985  2.   8.  4.   0.479 -0.792 11.366  4.063  9.821
 9.72 1419.80     3.50   289.09   376.28  279.90     0.0 1016.0    76.3 1.
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13.128	25.695	2.	9.	4.	0.474	-0.545	8.955	2.827	6.992
22.17	1887.40	3.35	285.91	318.17	275.50	0.0	1016.0	92.0	1.
9.454	31.456	2.	10.	4.	0.382	-0.618	11.740	3.038	6.920
13.69	2273.80	3.95	287.74	373.66	278.40	0.0	1016.0	81.5	1.
9.218	40.280	2.	1.	4.	0.450	-0.677	11.676	4.006	9.041
8.88	2107.50	3.70	284.69	371.47	275.30	0.0	1013.0	83.5	1.
10.885	129.923	2.	2.	4.	0.139	-0.201	40.161	2.073	5.763
0.00	4863.80	14.09	285.68	390.71	277.90	0.0	1013.0	76.5	1.
11.751	23.482	2.	3.	4.	0.519	-0.783	8.516	4.060	9.320
21.09	1724.90	2.74	283.58	375.26	273.40	1248.0	1013.0	88.8	1.
10.591	25.294	2.	4.	4.	0.524	-0.822	8.133	3.821	8.626
20.95	1722.10	2.67	284.76	374.51	276.60	1096.0	1013.0	80.0	1.
9.247	36.764	2.	5.	4.	0.339	-0.496	10.085	3.173	6.709
8.05	1995.80	3.38	283.49	353.64	272.10	0.0	1013.0	92.3	1.
7.371	56.836	2.	6.	4.	0.454	-0.650	13.958	4.473	10.248
4.23	2496.90	4.20	287.01	378.32	278.60	0.0	1013.0	74.8	1.
8.143	46.431	2.	7.	4.	0.394	-0.570	11.950	3.799	8.413
5.80	2237.10	3.78	285.18	365.53	275.30	0.0	1013.0	83.5	1.
8.692	39.335	2.	8.	4.	0.500	-0.740	11.224	4.459	10.423
9.72	2113.00	3.39	285.92	376.85	277.30	0.0	1013.0	78.3	1.
18.366	19.701	2.	9.	4.	0.346	-0.491	8.357	1.891	3.150
17.28	1776.40	3.60	285.15	316.07	271.50	0.0	1013.0	94.0	1.
9.930	33.460	2.	10.	4.	0.432	-0.649	12.958	3.697	8.428
12.83	2243.00	4.27	284.73	372.72	275.30	0.0	1013.0	83.5	1.
7.569	36.676	2.	1.	5.	0.343	-0.577	8.458	2.065	4.753
10.37	1856.10	2.76	284.72	368.91	273.50	0.0	1007.5	75.0	1.
8.620	108.693	2.	2.	5.	0.155	-0.222	28.548	2.345	5.923
0.00	4069.00	9.32	284.47	381.89	275.20	0.0	1007.5	62.3	1.
9.504	21.609	2.	3.	5.	0.386	-0.704	5.868	2.178	5.097
27.03	1492.50	2.04	283.76	371.13	272.20	1264.0	1007.5	84.5	1.
8.653	22.324	2.	4.	5.	0.319	-0.610	5.176	1.678	3.830
19.18	1552.00	1.93	285.35	371.15	274.30	1024.0	1007.5	68.7	1.
7.276	44.032	2.	5.	5.	0.393	-0.562	10.442	2.666	6.169
9.09	1972.20	3.19	284.19	356.85	271.40	0.0	1007.5	90.8	1.
6.019	50.159	2.	6.	5.	0.324	-0.499	9.665	1.971	4.301
4.58	2128.90	3.02	285.31	372.05	275.60	0.0	1007.5	59.2	1.
6.535	47.447	2.	7.	5.	0.355	-0.527	10.009	2.279	5.128
6.43	2059.60	3.09	284.81	365.33	273.50	0.0	1007.5	75.0	1.
7.612	32.877	2.	8.	5.	0.322	-0.590	7.722	1.940	4.236
8.34	1721.20	2.49	286.02	371.74	274.80	0.0	1007.5	65.5	1.
9.509	29.828	2.	9.	5.	0.546	-0.707	8.949	3.043	6.475
31.52	1688.90	2.80	285.95	327.89	271.00	0.0	1007.5	94.0	1.
8.015	31.141	2.	10.	5.	0.334	-0.561	9.619	2.110	4.875
14.13	1991.80	3.16	284.65	369.89	273.50	0.0	1007.5	75.0	1.
7.332	38.058	2.	1.	5.	0.345	-0.598	8.680	2.145	4.911
9.21	1881.00	2.81	294.22	371.45	285.50	0.0	1020.0	77.0	1.
8.281	112.813	2.	2.	5.	0.176	-0.270	28.471	2.274	5.498
0.00	4223.20	9.41	295.49	384.28	286.90	0.0	1020.0	72.3	1.
9.623	20.480	2.	3.	5.	0.343	-0.722	5.465	1.849	4.414
22.33	1455.60	1.98	293.03	373.67	284.50	1208.0	1020.0	80.5	1.
8.443	23.988	2.	4.	5.	0.367	-0.706	5.794	1.818	4.042
21.47	1571.60	2.04	294.96	374.71	286.20	1096.0	1020.0	74.7	1.
7.096	46.295	2.	5.	5.	0.341	-0.565	11.145	2.603	5.626
5.30	2058.60	3.29	291.43	354.42	283.80	0.0	1020.0	82.8	1.
5.476	53.605	2.	6.	5.	0.332	-0.487	9.625	2.170	4.890
3.97	2180.50	2.97	296.17	375.73	287.30	0.0	1020.0	71.2	1.
6.140	50.348	2.	7.	5.	0.336	-0.522	10.303	2.363	5.218
4.51	2126.20	3.11	294.05	366.23	285.50	0.0	1020.0	77.0	1.
7.358	35.887	2.	8.	5.	0.369	-0.591	8.308	2.575	6.271
8.64	1778.60	2.65	295.80	374.52	286.60	0.0	1020.0	73.5	1.

9.020	36.029	2.	9.	5.	0.579	-0.714	10.382	3.534	9.144
16.42	1869.70	3.24	291.54	313.40	283.40	0.0	1020.0	84.0	1.
7.800	31.929	2.	10.	5.	0.330	-0.593	9.783	2.089	4.751
12.75	2029.60	3.19	294.17	372.01	285.50	0.0	1020.0	77.0	1.
8.064	37.033	2.	1.	6.	0.363	-0.559	8.814	2.678	5.856
12.18	2067.20	2.99	288.08	372.12	279.90	0.0	1017.0	88.0	1.
8.616	113.542	2.	2.	6.	0.133	-0.218	28.474	2.499	5.948
0.00	4250.40	9.83	289.03	383.73	281.00	0.0	1017.0	84.0	1.
10.075	20.525	2.	3.	6.	0.331	-0.618	5.401	1.908	4.047
28.19	1748.50	2.07	287.42	376.12	279.10	1184.0	1017.0	91.0	1.
9.528	23.830	2.	4.	6.	0.411	-0.668	6.132	2.637	5.840
25.48	1714.10	2.27	287.64	375.40	280.40	1064.0	1017.0	86.0	1.
7.702	37.976	2.	5.	6.	0.320	-0.440	8.946	2.591	5.322
9.27	2034.80	2.92	287.69	355.26	278.60	0.0	1017.0	93.0	1.
6.520	57.432	2.	6.	6.	0.441	-0.570	12.165	3.540	7.956
5.54	2549.00	3.76	290.24	376.37	281.20	0.0	1017.0	83.0	1.
7.007	47.449	2.	7.	6.	0.379	-0.503	10.513	3.053	6.604
7.07	2285.10	3.33	288.93	365.54	279.90	0.0	1017.0	88.0	1.
8.341	34.443	2.	8.	6.	0.369	-0.601	8.885	3.072	6.838
9.97	1944.10	2.85	288.53	375.16	280.70	0.0	1017.0	85.0	1.
12.434	28.774	2.	9.	6.	0.568	-0.587	9.871	4.395	8.318
19.91	1894.60	3.61	288.27	313.13	278.30	0.0	1017.0	94.0	1.
8.565	31.392	2.	10.	6.	0.350	-0.545	9.936	2.607	5.708
16.25	2204.80	3.40	288.24	372.47	279.90	0.0	1017.0	88.0	1.
7.858	39.967	2.	1.	6.	0.379	-0.586	9.793	2.752	6.267
11.05	2169.10	3.16	293.78	374.03	287.10	0.0	1001.5	76.5	1.
7.553	110.946	2.	2.	6.	0.166	-0.275	25.200	1.706	3.778
0.00	4153.30	8.43	295.42	386.65	288.50	0.0	1001.5	72.2	1.
9.498	23.185	2.	3.	6.	0.344	-0.648	6.061	2.081	4.655
21.10	1741.20	2.22	293.13	375.45	286.00	1256.0	1001.5	79.8	1.
9.540	22.934	2.	4.	6.	0.376	-0.659	5.732	2.260	5.194
24.39	1778.50	2.20	293.78	377.19	287.80	1144.0	1001.5	74.3	1.
7.364	48.273	2.	5.	6.	0.368	-0.478	12.129	2.876	6.269
5.74	2333.00	3.57	292.03	356.90	285.30	0.0	1001.5	81.9	1.
6.647	53.898	2.	6.	6.	0.409	-0.565	12.387	3.503	8.538
7.83	2503.50	3.62	295.23	379.77	288.80	0.0	1001.5	71.1	1.
6.942	51.439	2.	7.	6.	0.391	-0.527	12.274	3.229	7.546
6.97	2429.00	3.59	293.83	369.77	287.00	0.0	1001.5	76.5	1.
8.454	37.870	2.	8.	6.	0.437	-0.600	10.238	3.178	7.259
12.68	2130.00	3.21	294.98	377.54	288.10	0.0	1001.5	73.3	1.
11.165	37.163	2.	9.	6.	0.619	-0.726	12.146	4.367	9.887
12.99	2478.80	4.15	291.61	318.59	284.90	0.0	1001.5	83.0	1.
8.291	32.938	2.	10.	6.	0.353	-0.565	10.378	2.547	5.858
14.16	2266.90	3.38	293.80	374.73	287.10	0.0	1001.5	76.5	1.
6.651	38.672	3.	1.	1.	0.411	-0.550	16.512	5.612	10.682
6.31	1931.40	2.56	283.95	357.69	277.70	0.0	1007.0	77.5	1.
8.690	108.371	3.	2.	1.	0.136	-0.253	53.385	1.339	1.927
0.00	4061.00	9.39	283.13	373.82	279.00	0.0	1007.0	66.5	1.
7.716	21.260	3.	3.	1.	0.367	-0.627	10.139	4.757	8.871
13.80	1537.60	1.64	285.63	359.96	276.70	1160.0	1007.0	85.8	1.
7.230	25.261	3.	4.	1.	0.467	-0.645	11.400	5.252	9.403
14.01	1619.10	1.82	284.29	359.80	278.30	1072.0	1007.0	72.0	1.
6.146	41.692	3.	5.	1.	0.450	-0.467	17.844	7.246	13.876
4.51	1979.80	2.53	282.81	338.42	276.00	0.0	1007.0	91.3	1.
5.393	51.052	3.	6.	1.	0.386	-0.494	17.744	5.330	10.261
3.27	2149.90	2.74	281.94	364.02	279.30	0.0	1007.0	63.8	1.
5.702	46.748	3.	7.	1.	0.415	-0.482	17.790	6.211	11.923
3.78	2071.70	2.64	282.34	352.25	277.70	0.0	1007.0	77.5	1.
6.924	33.593	3.	8.	1.	0.421	-0.592	15.373	5.595	11.116
8.19	1805.50	2.31	285.80	361.18	278.60	0.0	1007.0	69.3	1.

8.255	24.367	3.	9.	1.	0.477	-0.495	13.156	5.610	11.985
15.15	1566.90	2.00	284.76	298.40	275.70	0.0	1007.0	94.0	1.
6.887	32.285	3.	10.	1.	0.388	-0.536	17.839	5.121	9.530
8.47	2024.00	2.86	283.73	358.22	277.70	0.0	1007.0	77.5	1.
6.605	34.671	3.	1.	1.	0.408	-0.559	14.682	5.142	10.449
8.12	1806.60	2.30	292.40	361.87	284.50	0.0	1023.0	71.0	1.
8.010	110.994	3.	2.	1.	0.159	-0.246	50.341	2.306	3.807
0.00	4157.50	8.96	290.90	375.93	285.80	0.0	1023.0	68.3	1.
8.294	17.495	3.	3.	1.	0.339	-0.625	8.426	3.918	8.144
18.52	1409.70	1.45	293.90	363.60	283.50	1272.0	1023.0	73.0	1.
7.370	21.254	3.	4.	1.	0.401	-0.646	9.933	4.580	8.930
16.96	1436.90	1.58	294.04	363.62	285.20	1008.0	1023.0	69.7	1.
6.051	40.776	3.	5.	1.	0.407	-0.480	16.845	6.495	13.220
5.90	1924.90	2.46	289.17	344.04	282.80	0.0	1023.0	74.3	1.
5.281	55.919	3.	6.	1.	0.461	-0.507	18.838	6.098	12.041
3.28	2285.60	2.96	290.08	368.68	286.20	0.0	1023.0	67.7	1.
5.597	48.523	3.	7.	1.	0.435	-0.494	17.865	6.292	12.617
4.35	2109.50	2.71	289.64	356.64	284.50	0.0	1023.0	71.0	1.
6.972	31.464	3.	8.	1.	0.483	-0.588	14.974	6.079	12.727
9.89	1742.00	2.18	293.31	364.77	285.50	0.0	1023.0	69.0	1.
6.951	30.317	3.	9.	1.	0.511	-0.487	14.032	5.128	11.423
11.06	1602.50	2.11	290.73	302.13	282.50	0.0	1023.0	75.0	1.
6.958	28.612	3.	10.	1.	0.375	-0.540	16.770	4.872	9.696
10.61	1971.20	2.74	291.93	362.06	284.50	0.0	1023.0	71.0	1.
6.561	35.037	3.	1.	2.	0.388	-0.573	14.273	3.943	6.714
6.28	1913.30	2.30	287.91	362.21	280.00	0.0	1026.0	89.0	1.
6.387	90.038	3.	2.	2.	0.112	-0.172	36.014	0.910	1.446
0.00	3374.10	5.71	285.51	371.63	281.00	0.0	1026.0	85.7	1.
8.706	18.422	3.	3.	2.	0.369	-0.622	8.340	4.902	11.081
13.35	1610.50	1.61	289.68	364.91	279.30	1200.0	1026.0	91.5	1.
7.747	25.937	3.	4.	2.	0.512	-0.772	12.532	4.894	8.295
12.76	1720.70	2.00	288.34	364.99	280.50	1072.0	1026.0	87.3	1.
6.046	39.852	3.	5.	2.	0.353	-0.433	15.468	2.968	4.202
4.39	1969.80	2.40	285.90	346.79	278.80	0.0	1026.0	93.2	1.
5.385	43.435	3.	6.	2.	0.319	-0.502	15.046	3.110	4.169
3.49	2005.60	2.34	286.26	364.71	281.30	0.0	1026.0	84.8	1.
5.656	41.889	3.	7.	2.	0.334	-0.472	15.228	3.049	4.183
3.86	1990.10	2.37	286.10	356.98	280.00	0.0	1026.0	89.0	1.
7.088	31.063	3.	8.	2.	0.375	-0.638	13.780	3.886	5.801
6.83	1831.70	2.20	289.17	365.57	280.80	0.0	1026.0	86.5	1.
8.220	24.157	3.	9.	2.	0.502	-0.518	12.427	3.889	5.770
12.71	1727.50	1.95	289.10	314.20	278.50	0.0	1026.0	94.0	1.
7.017	30.118	3.	10.	2.	0.365	-0.555	14.911	3.759	6.662
8.07	1966.30	2.42	287.50	362.43	280.00	0.0	1026.0	89.0	1.
6.807	38.318	3.	1.	2.	0.432	-0.597	15.688	4.225	6.739
5.72	2002.60	2.60	284.72	361.35	277.80	0.0	1010.0	80.0	1.
7.760	97.660	3.	2.	2.	0.162	-0.321	43.752	1.788	2.736
0.17	3699.10	7.52	283.25	371.22	278.90	0.0	1010.0	80.0	1.
8.594	19.812	3.	3.	2.	0.393	-0.677	9.305	3.636	5.656
3.09	1584.80	1.71	286.90	364.53	276.90	1144.0	1010.0	80.0	1.
8.210	25.297	3.	4.	2.	0.525	-0.780	11.639	4.865	8.099
3.34	1763.20	2.07	285.40	364.24	278.30	1040.0	1010.0	80.0	1.
6.084	46.077	3.	5.	2.	0.399	-0.460	17.310	4.363	6.696
3.51	2096.30	2.78	283.72	343.11	276.30	0.0	1010.0	80.0	1.
5.397	51.096	3.	6.	2.	0.401	-0.489	17.426	4.010	6.337
2.92	2211.10	2.74	282.25	365.16	279.20	0.0	1010.0	80.0	1.
5.678	48.914	3.	7.	2.	0.400	-0.476	17.376	4.164	6.493
3.16	2161.20	2.76	282.89	355.57	277.80	0.0	1010.0	80.0	1.
7.491	32.126	3.	8.	2.	0.469	-0.662	14.841	4.529	7.392
7.70	1906.40	2.40	286.19	365.65	278.60	0.0	1010.0	80.0	1.

7.867	37.265	3.	9.	2.	0.610	-0.591	17.970	5.280	9.181
8.12	1919.90	2.92	285.90	298.49	276.00	0.0	1010.0	80.0	1.
7.249	31.878	3.	10.	2.	0.406	-0.587	16.561	3.969	6.310
7.89	2071.40	2.80	284.56	361.54	277.80	0.0	1010.0	80.0	1.
6.572	35.058	3.	1.	3.	0.376	-0.525	15.883	3.934	8.128
7.04	1889.40	2.30	286.17	360.40	277.90	0.0	1036.5	71.5	1.
7.851	101.539	3.	2.	3.	0.110	-0.199	47.339	0.963	1.840
0.00	3805.00	7.98	285.73	374.04	280.60	0.0	1036.5	63.8	1.
7.979	20.030	3.	3.	3.	0.360	-0.604	10.060	4.022	8.398
14.46	1587.60	1.60	286.99	363.22	275.90	1264.0	1036.5	77.3	1.
7.597	22.780	3.	4.	3.	0.430	-0.663	11.735	4.164	8.969
13.88	1640.20	1.73	287.93	363.52	279.30	1032.0	1036.5	67.7	1.
6.129	34.601	3.	5.	3.	0.351	-0.429	14.737	3.397	6.522
5.38	1839.90	2.09	283.14	343.88	274.50	0.0	1036.5	81.1	1.
5.305	48.601	3.	6.	3.	0.374	-0.481	19.014	4.172	9.063
4.49	2104.20	2.58	285.38	365.54	281.30	0.0	1036.5	61.9	1.
5.644	41.677	3.	7.	3.	0.363	-0.455	16.898	3.789	7.806
4.86	1973.40	2.34	284.27	354.82	277.90	0.0	1036.5	71.5	1.
6.625	33.638	3.	8.	3.	0.395	-0.501	16.853	4.310	8.874
7.62	1829.90	2.21	288.53	363.72	280.00	0.0	1036.5	65.8	1.
8.310	23.036	3.	9.	3.	0.442	-0.510	11.623	3.853	8.150
13.18	1567.00	1.91	285.33	300.84	273.80	0.0	1036.5	83.0	1.
6.939	29.462	3.	10.	3.	0.354	-0.519	16.942	3.658	7.648
9.03	1976.80	2.56	286.01	361.01	277.90	0.0	1036.5	71.5	1.
6.315	35.720	3.	1.	3.	0.391	-0.519	15.103	3.603	7.372
6.94	1900.90	2.25	286.78	360.58	279.40	0.0	991.5	76.0	1.
6.638	101.648	3.	2.	3.	0.145	-0.229	41.032	1.570	2.748
0.00	3809.10	6.75	286.49	375.05	281.60	0.0	991.5	65.3	1.
7.877	19.414	3.	3.	3.	0.417	-0.587	9.828	3.808	7.457
15.40	1528.80	1.53	286.83	362.68	277.70	1248.0	991.5	84.0	1.
7.499	22.294	3.	4.	3.	0.423	-0.648	10.805	3.738	7.833
13.34	1640.80	1.67	289.21	364.34	280.50	1096.0	991.5	70.7	1.
6.064	39.088	3.	5.	3.	0.352	-0.431	16.656	3.415	7.285
5.45	1908.00	2.34	282.54	341.17	276.60	0.0	991.5	89.3	1.
5.005	51.323	3.	6.	3.	0.357	-0.438	17.925	3.555	6.824
2.92	2181.60	2.57	285.97	366.57	282.10	0.0	991.5	62.7	1.
5.440	45.479	3.	7.	3.	0.355	-0.435	17.319	3.488	7.044
3.96	2051.00	2.46	284.33	354.44	279.40	0.0	991.5	76.0	1.
6.675	35.606	3.	8.	3.	0.423	-0.534	16.458	3.992	8.202
7.16	1908.50	2.35	288.52	365.03	281.00	0.0	991.5	68.0	1.
7.840	24.490	3.	9.	3.	0.441	-0.477	11.940	3.141	7.948
4.73	1582.20	1.92	285.66	303.80	276.00	0.0	991.5	92.0	1.
6.686	29.615	3.	10.	3.	0.366	-0.506	16.189	3.439	6.915
8.77	1993.70	2.46	286.39	361.04	279.40	0.0	991.5	76.0	1.
7.550	41.746	3.	1.	4.	0.455	-0.662	19.720	6.307	14.870
6.29	2199.00	3.13	281.68	361.11	273.50	0.0	1007.5	75.0	1.
10.393	123.249	3.	2.	4.	0.160	-0.342	77.348	3.530	8.716
0.12	4688.30	12.72	280.99	383.69	275.20	0.0	1007.5	62.3	1.
8.873	25.912	3.	3.	4.	0.514	-0.820	13.795	6.269	15.236
2.95	1877.80	2.30	282.85	363.60	272.20	1264.0	1007.5	84.5	1.
7.646	30.897	3.	4.	4.	0.548	-0.779	15.307	7.466	17.455
1.03	1933.60	2.35	282.64	362.90	274.30	1024.0	1007.5	68.7	1.
6.588	43.511	3.	5.	4.	0.404	-0.524	18.280	5.587	12.543
4.45	2108.00	2.84	278.83	341.00	271.40	0.0	1007.5	90.8	1.
6.402	54.777	3.	6.	4.	0.450	-0.607	22.480	6.660	16.255
4.24	2449.90	3.49	280.49	369.26	275.60	0.0	1007.5	59.2	1.
6.479	49.513	3.	7.	4.	0.429	-0.568	20.518	6.159	14.521
4.32	2290.10	3.18	279.71	356.06	273.50	0.0	1007.5	75.0	1.
7.827	37.842	3.	8.	4.	0.530	-0.779	18.326	6.662	16.354
7.76	2165.50	2.94	283.33	366.19	274.80	0.0	1007.5	65.5	1.

9.965 27.559 3. 9. 4. 0.581 -0.692 16.341 6.506 16.160
13.44 1880.50 2.71 280.20 300.14 271.00 0.0 1007.5 94.0 1.
7.762 37.746 3. 10. 4. 0.453 -0.661 23.217 6.250 14.853
7.74 2337.80 3.71 281.36 362.42 273.50 0.0 1007.5 75.0 1.
7.292 40.201 3. 1. 4. 0.389 -0.627 18.713 5.015 11.451
6.07 2203.40 2.94 293.36 367.48 285.50 0.0 1020.0 77.0 1.
9.639 124.790 3. 2. 4. 0.173 -0.231 73.620 1.964 4.414
0.00 4676.30 12.11 292.28 384.23 286.90 0.0 1020.0 72.3 1.
9.127 19.177 3. 3. 4. 0.357 -0.655 10.761 3.971 8.178
14.15 1692.10 1.77 296.03 370.03 284.50 1208.0 1020.0 80.5 1.
8.011 27.492 3. 4. 4. 0.504 -0.768 13.666 6.505 15.118
13.26 1964.50 2.21 293.69 369.07 286.20 1096.0 1020.0 74.7 1.
6.351 46.020 3. 5. 4. 0.342 -0.535 19.018 4.243 9.812
4.45 2273.10 2.92 290.48 349.80 283.80 0.0 1020.0 82.8 1.
6.033 60.891 3. 6. 4. 0.369 -0.566 24.026 5.459 12.974
2.65 2717.00 3.69 291.67 375.43 287.30 0.0 1020.0 71.2 1.
6.164 53.753 3. 7. 4. 0.356 -0.551 21.622 4.875 11.456
3.39 2503.90 3.32 291.10 363.13 285.50 0.0 1020.0 77.0 1.
7.492 37.891 3. 8. 4. 0.426 -0.721 18.549 5.712 13.552
6.80 2130.30 2.82 294.21 369.65 286.60 0.0 1020.0 73.5 1.
8.580 33.754 3. 9. 4. 0.526 -0.688 17.301 5.123 12.796
9.67 2202.60 2.78 291.09 309.46 283.40 0.0 1020.0 84.0 1.
7.716 33.704 3. 10. 4. 0.375 -0.599 22.118 4.766 10.848
8.21 2383.30 3.53 293.10 368.45 285.50 0.0 1020.0 77.0 1.
6.460 35.905 3. 1. 5. 0.342 -0.575 14.189 3.348 5.805
5.83 1918.90 2.31 285.13 359.86 277.30 0.0 1028.0 77.0 1.
7.243 95.438 3. 2. 5. 0.169 -0.270 42.076 1.928 3.971
0.00 3576.40 6.88 285.23 371.99 279.80 0.0 1028.0 68.3 1.
7.944 21.118 3. 3. 5. 0.371 -0.706 9.562 3.404 6.022
12.54 1589.00 1.67 284.61 362.47 275.50 1184.0 1028.0 83.5 1.
7.282 23.157 3. 4. 5. 0.368 -0.681 9.941 3.568 5.855
12.16 1630.30 1.68 287.42 363.28 278.50 1024.0 1028.0 72.7 1.
6.699 35.126 3. 5. 5. 0.318 -0.555 14.575 2.537 3.607
5.61 1868.00 2.34 281.60 341.28 274.20 0.0 1028.0 87.8 1.
4.972 51.410 3. 6. 5. 0.307 -0.449 16.121 3.249 5.560
2.47 2230.90 2.55 284.31 365.97 280.40 0.0 1028.0 66.2 1.
5.681 43.191 3. 7. 5. 0.313 -0.502 15.341 2.890 4.574
3.76 2047.70 2.44 282.94 353.50 277.30 0.0 1028.0 77.0 1.
6.859 29.985 3. 8. 5. 0.335 -0.589 12.292 3.280 5.874
6.76 1770.10 2.05 288.63 364.06 279.20 0.0 1028.0 70.5 1.
9.590 18.308 3. 9. 5. 0.256 -0.619 9.057 2.086 2.435
10.79 1453.10 1.73 283.71 301.61 273.60 0.0 1028.0 90.0 1.
6.804 30.400 3. 10. 5. 0.327 -0.575 15.220 3.092 5.196
7.68 1981.50 2.50 284.71 360.04 277.30 0.0 1028.0 77.0 1.
6.413 39.130 3. 1. 5. 0.376 -0.581 16.035 3.556 6.442
5.39 1999.50 2.51 290.43 361.82 283.70 0.0 1004.0 73.5 1.
8.393 107.239 3. 2. 5. 0.156 -0.267 54.860 2.066 4.547
0.00 4018.60 9.07 290.35 375.00 285.20 0.0 1004.0 66.5 1.
7.594 23.536 3. 3. 5. 0.423 -0.698 10.534 3.420 6.013
1.29 1667.30 1.80 290.01 363.46 282.50 1176.0 1004.0 78.8 1.
6.770 25.984 3. 4. 5. 0.416 -0.638 11.090 3.850 6.587
9.73 1695.70 1.77 292.38 365.31 284.50 1040.0 1004.0 70.0 1.
5.837 43.464 3. 5. 5. 0.356 -0.490 17.139 3.272 6.618
3.48 2060.70 2.53 287.56 345.25 281.80 0.0 1004.0 82.3 1.
4.970 52.568 3. 6. 5. 0.323 -0.509 17.519 3.430 6.199
2.58 2236.30 2.62 289.99 369.30 285.60 0.0 1004.0 64.8 1.
5.326 48.402 3. 7. 5. 0.338 -0.500 17.345 3.358 6.391
2.95 2155.90 2.58 288.88 358.29 283.70 0.0 1004.0 73.5 1.
6.649 36.868 3. 8. 5. 0.387 -0.605 15.841 3.973 7.443
6.61 1927.50 2.44 292.15 364.99 284.90 0.0 1004.0 68.3 1.

7.983	34.541	3.	9.	5.	0.605	-0.730	16.935	4.649	7.805
9.91	1986.50	2.74	288.96	303.04	281.40	0.0	1004.0	84.0	1.
6.562	34.025	3.	10.	5.	0.361	-0.561	17.830	3.367	6.161
6.44	2105.00	2.83	290.18	363.01	283.70	0.0	1004.0	73.5	1.
6.695	37.316	3.	1.	6.	0.376	-0.569	15.586	5.066	10.297
6.95	2128.10	2.49	286.02	363.46	278.30	0.0	1022.0	85.0	1.
7.074	110.027	3.	2.	6.	0.150	-0.274	45.012	2.781	5.894
0.00	4123.10	7.74	286.82	378.42	281.40	0.0	1022.0	79.7	1.
8.659	18.278	3.	3.	6.	0.299	-0.591	8.861	3.273	6.331
13.78	1709.00	1.58	287.42	365.38	275.90	1384.0	1022.0	89.0	1.
7.184	28.670	3.	4.	6.	0.492	-0.617	13.304	6.102	13.060
13.23	2028.90	2.06	287.72	366.82	279.80	1024.0	1022.0	82.3	1.
6.170	37.927	3.	5.	6.	0.364	-0.472	14.685	4.744	9.104
5.57	2022.00	2.31	280.85	346.00	274.30	0.0	1022.0	91.7	1.
5.570	49.634	3.	6.	6.	0.393	-0.574	18.291	6.750	14.126
4.36	2356.40	2.77	286.32	370.50	282.20	0.0	1022.0	78.3	1.
5.818	44.095	3.	7.	6.	0.379	-0.525	16.571	5.793	11.730
4.86	2196.90	2.56	283.71	358.81	278.30	0.0	1022.0	85.0	1.
7.339	36.022	3.	8.	6.	0.410	-0.660	17.135	5.312	11.448
8.27	2131.50	2.63	288.08	367.19	280.60	0.0	1022.0	81.0	1.
9.023	20.506	3.	9.	6.	0.372	-0.599	10.182	4.032	6.767
15.67	1576.90	1.82	282.88	312.79	273.50	0.0	1022.0	93.0	1.
6.997	31.969	3.	10.	6.	0.364	-0.540	16.671	4.939	10.129
8.70	2225.60	2.71	285.95	364.42	278.30	0.0	1022.0	85.0	1.
6.987	39.254	3.	1.	6.	0.404	-0.575	18.077	5.131	9.903
6.25	2193.40	2.75	292.48	366.95	286.40	0.0	994.0	78.5	1.
8.859	120.383	3.	2.	6.	0.174	-0.256	65.075	1.923	3.523
0.00	4511.20	10.68	291.46	381.79	287.50	0.0	994.0	70.2	1.
8.188	20.885	3.	3.	6.	0.341	-0.604	9.674	3.435	6.385
13.24	1768.30	1.72	292.88	367.71	285.50	1248.0	994.0	84.8	1.
7.733	24.079	3.	4.	6.	0.473	-0.599	12.100	5.293	10.495
13.71	1824.60	1.87	294.40	369.80	286.90	880.0	994.0	74.3	1.
6.271	46.096	3.	5.	6.	0.356	-0.491	19.840	5.453	11.084
3.82	2220.70	2.89	289.94	348.37	284.90	0.0	994.0	88.9	1.
5.455	56.852	3.	6.	6.	0.410	-0.580	22.577	6.140	12.039
3.16	2485.40	3.12	291.04	374.49	287.80	0.0	994.0	68.1	1.
5.789	51.884	3.	7.	6.	0.385	-0.539	21.313	5.823	11.598
3.44	2363.20	3.01	290.53	362.43	286.40	0.0	994.0	78.5	1.
7.199	37.449	3.	8.	6.	0.441	-0.635	19.297	6.332	12.250
6.98	2113.30	2.69	293.43	369.33	287.20	0.0	994.0	72.3	1.
7.148	43.701	3.	9.	6.	0.677	-0.581	21.492	8.684	21.263
8.35	2186.90	3.12	290.88	303.46	284.60	0.0	994.0	91.0	1.
7.183	32.488	3.	10.	6.	0.375	-0.542	20.476	4.703	9.211
8.11	2294.60	3.17	292.18	367.53	286.40	0.0	994.0	78.5	1.
7.559	36.083	1.	1.	7.	0.383	-0.562	5.588	1.876	3.892
6.79	1827.90	2.75	296.34	365.75	287.20	0.0	1022.5	59.5	2.
6.975	88.757	1.	2.	7.	0.177	-0.262	19.035	0.889	1.557
0.00	3326.00	6.25	297.54	371.81	288.50	0.0	1022.5	56.5	2.
9.869	20.286	1.	3.	7.	0.393	-0.614	2.502	1.666	3.549
7.61	1479.70	2.01	295.06	370.52	286.20	0.0	1022.5	61.8	2.
9.285	23.663	1.	4.	7.	0.388	-0.640	3.284	1.862	4.065
3.45	1524.40	2.22	296.98	369.87	287.90	0.0	1022.5	58.0	2.
7.025	43.821	1.	5.	7.	0.338	-0.482	7.342	2.023	4.124
3.82	1929.30	3.09	293.61	340.51	285.50	0.0	1022.5	63.3	2.
6.550	46.769	1.	6.	7.	0.397	-0.540	6.910	1.929	3.582
3.86	2080.00	3.10	298.45	368.39	288.90	0.0	1022.5	55.8	2.
6.745	45.511	1.	7.	7.	0.372	-0.515	7.094	1.969	3.813
3.84	2015.70	3.10	296.38	356.50	287.20	0.0	1022.5	59.5	2.
7.813	31.551	1.	8.	7.	0.387	-0.594	4.658	2.071	4.688
7.73	1687.80	2.49	297.39	370.22	288.20	0.0	1022.5	57.3	2.

10.448	28.826	1.	9.	7.	0.472	-0.576	5.817	2.280	5.278	
12.01	1530.70	3.00	294.40	301.74	285.20	0.0	1022.5	64.0	2.	
8.184	30.610	1.	10.	7.	0.362	-0.546	6.188	1.759	3.584	
9.30	1889.90	2.92	296.31	364.88	287.20	0.0	1022.5	59.5	2.	
7.082	34.246	2.	1.	7.	0.327	-0.501	7.391	1.889	4.331	
11.34	1739.40	2.45	296.26	372.08	286.70	0.0	1020.5	59.5	2.	
6.292	88.822	2.	2.	7.	0.101	-0.178	18.931	1.101	2.269	
0.00	3325.10	5.65	298.54	379.83	288.00	0.0	1020.5	56.5	2.	
9.304	20.231	2.	3.	7.	0.346	-0.578	5.166	1.650	3.448	
21.62	1408.30	1.89	294.57	374.71	285.80	0.0	1020.5	61.8	2.	
9.569	18.223	2.	4.	7.	0.336	-0.542	4.589	1.662	4.056	
31.30	1364.10	1.76	296.92	375.20	287.30	0.0	1020.5	58.0	2.	
6.317	41.143	2.	5.	7.	0.293	-0.404	8.570	1.940	4.199	
7.86	1813.50	2.60	292.72	352.53	285.10	0.0	1020.5	63.3	2.	
5.755	51.743	2.	6.	7.	0.329	-0.460	9.719	2.273	4.945	
5.02	2171.90	3.02	298.82	374.89	288.30	0.0	1020.5	55.8	2.	
5.986	46.793	2.	7.	7.	0.312	-0.434	9.182	2.117	4.597	
6.19	2004.50	2.82	295.97	364.45	286.70	0.0	1020.5	59.5	2.	
8.060	27.206	2.	8.	7.	0.325	-0.534	6.243	1.799	4.434	
16.29	1575.30	2.21	298.12	375.90	287.60	0.0	1020.5	57.3	2.	
8.057	33.246	2.	9.	7.	0.500	-0.477	9.121	3.378	8.439	
7.16	1549.70	2.66	292.79	310.76	284.80	0.0	1020.5	64.0	2.	
7.742	28.028	2.	10.	7.	0.305	-0.471	8.005	1.785	3.942	
5.70	1827.40	2.61	296.11	371.24	286.70	0.0	1020.5	59.5	2.	
6.067	36.282	3.	1.	7.	0.365	-0.514	13.415	3.153	5.436	
7.51	1851.80	2.20	287.13	359.21	278.40	0.0	1003.5	94.0	2.	
6.454	83.917	3.	2.	7.	0.120	-0.192	33.657	1.692	2.965	
0.00	3144.70	5.38	285.66	365.76	279.90	0.0	1003.5	93.3	2.	
7.812	18.924	3.	3.	7.	0.353	-0.613	8.257	2.945	5.085	
9.08	1478.90	1.48	289.62	362.61	277.30	0.0	1003.5	94.5	2.	
7.020	24.598	3.	4.	7.	0.464	-0.605	9.993	3.707	6.304	
7.51	1625.80	1.73	287.76	362.55	279.20	0.0	1003.5	93.7	2.	
5.538	39.304	3.	5.	7.	0.300	-0.419	14.066	2.467	3.974	
5.07	1845.30	2.16	285.81	340.57	276.50	0.0	1003.5	94.8	2.	
5.207	51.977	3.	6.	7.	0.335	-0.453	16.554	3.233	5.494	
3.25	2164.20	2.71	284.63	361.87	280.30	0.0	1003.5	93.2	2.	
5.343	45.906	3.	7.	7.	0.318	-0.437	15.362	2.866	4.766	
4.00	2011.40	2.45	285.20	351.67	278.40	0.0	1003.5	94.0	2.	
6.068	33.554	3.	8.	7.	0.433	-0.534	12.605	3.506	6.027	
9.14	1784.40	2.02	288.18	362.80	279.60	0.0	1003.5	93.5	2.	
7.379	29.774	3.	9.	7.	0.497	-0.470	13.488	3.931	7.433	
2.28	1606.60	2.19	286.83	299.94	276.10	0.0	1003.5	95.0	2.	
6.492	30.412	3.	10.	7.	0.344	-0.498	14.073	2.979	5.050	
0.75	1895.20	2.32	286.99	358.53	278.40	0.0	1003.5	94.0	2.	
8.563	44.673	1.	1.	1.	0.456	-0.599	9.351	3.331	6.255	
4.99	2145.30	3.86	296.20	372.91	286.70	0.0	1013.5	58.5	3.	
8.325	109.935	1.	2.	1.	0.301	-0.373	27.115	3.034	5.800	
0.05	4158.90	9.26	298.74	384.15	288.50	0.0	1013.5	55.5	3.	γ_{MOT}
11.452	19.003	1.	3.	1.	0.388	-0.685	3.400	2.221	4.094	
7.22	1446.10	2.19	293.88	373.92	285.40	1200.0	1013.5	60.8	3.	
10.688	23.935	1.	4.	1.	0.487	-0.747	4.755	3.206	6.066	γ_{URB}
3.09	1623.60	2.58	296.18	376.57	287.60	1104.0	1013.5	57.0	3.	
7.707	45.396	1.	5.	1.	0.457	-0.477	9.040	4.109	7.338	
3.98	1995.20	3.51	292.79	349.01	284.50	0.0	1013.5	62.3	3.	
6.789	52.257	1.	6.	1.	0.500	-0.589	8.812	3.683	6.873	
3.76	2229.90	3.59	299.73	375.25	289.00	0.0	1013.5	54.8	3.	
7.159	49.250	1.	7.	1.	0.481	-0.540	8.912	3.870	7.077	
3.85	2127.00	3.56	296.69	363.75	286.70	0.0	1013.5	58.5	3.	γ_{SUB}
9.828	34.615	1.	8.	1.	0.573	-0.728	8.245	3.906	7.280	
7.45	1937.30	3.42	297.35	377.07	288.10	0.0	1013.5	56.3	3.	

9.416	27.235	1.	9.	1.	0.447	-0.525	5.266	2.824	5.068	
10.54	1461.30	2.57	292.99	312.46	284.00	0.0	1013.5	63.0	3.	
9.229	30.940	1.	10.	1.	0.441	-0.611	8.315	3.208	5.951	γ%
9.12	2034.10	3.54	296.07	371.54	286.70	0.0	1013.5	58.5	3.	
8.182	45.269	2.	1.	1.	0.381	-0.523	11.342	3.818	7.960	
0.00	0.00	3.70	287.97	370.11	278.30	0.0	1022.0	85.0	3.	
8.018	110.402	2.	2.	1.	0.184	-0.262	26.257	2.928	6.919	
0.00	0.00	8.87	290.12	386.31	281.40	0.0	1022.0	79.7	3.	
10.573	18.317	2.	3.	1.	0.312	-0.574	5.037	2.753	5.658	
0.00	0.00	1.93	285.94	369.80	275.90	1384.0	1022.0	89.0	3.	
9.813	24.256	2.	4.	1.	0.451	-0.706	6.889	3.408	6.975	
0.00	0.00	2.38	288.29	371.99	279.80	1024.0	1022.0	82.3	3.	
7.926	45.652	2.	5.	1.	0.367	-0.374	11.220	4.009	7.869	
0.00	0.00	3.60	284.49	347.78	274.30	0.0	1022.0	91.7	3.	
6.672	52.128	2.	6.	1.	0.443	-0.556	11.616	4.398	9.059	
0.00	0.00	3.50	291.19	373.81	282.20	0.0	1022.0	78.3	3.	
7.179	49.300	2.	7.	1.	0.410	-0.477	11.443	4.228	8.539	
0.00	0.00	3.54	288.26	362.45	278.30	0.0	1022.0	85.0	3.	
9.030	35.423	2.	8.	1.	0.517	-0.652	10.406	4.804	10.635	
0.00	0.00	3.20	289.45	372.69	280.60	0.0	1022.0	81.0	3.	
17.099	33.456	2.	9.	1.	0.594	-0.513	11.819	3.287	6.910	
0.00	0.00	5.66	285.48	307.26	273.50	0.0	1022.0	93.0	3.	
8.769	30.761	2.	10.	1.	0.373	-0.537	10.184	3.524	7.266	
0.00	0.00	3.38	287.87	369.06	278.30	0.0	1022.0	85.0	3.	
7.337	45.634	3.	1.	1.	0.383	-0.555	20.893	5.061	9.393	
5.06	2180.90	3.33	28[illegible].37	361.48	272.90	0.0	994.0	81.5	3.	
8.545	118.857	3.	2.	1.	0.181	-0.285	61.293	3.269	6.002	
0.04	4485.80	10.09	280.13	383.45	274.10	0.0	994.0	73.2	3.	
8.778	18.551	3.	3.	1.	0.350	-0.713	9.423	4.396	8.107	
16.29	1509.10	1.62	284.37	361.96	272.10	1200.0	994.0	87.8	3.	
7.861	24.856	3.	4.	1.	0.466	-0.721	12.086	5.421	10.433	
14.15	1637.10	1.94	282.64	361.17	273.50	1072.0	994.0	77.3	3.	
6.029	43.180	3.	5.	1.	0.396	-0.418	18.109	6.077	10.584	
3.98	1910.80	2.57	278.61	336.48	271.60	0.0	994.0	91.9	3.	
5.482	56.700	3.	6.	1.	0.394	-0.549	19.681	5.082	9.691	
3.12	2339.20	3.08	278.60	366.21	274.30	0.0	994.0	71.1	3.	
5.703	50.337	3.	7.	1.	0.395	-0.487	18.941	5.550	10.111	
3.47	2137.60	2.84	278.61	352.22	273.00	0.0	994.0	81.5	3.	
7.264	31.501	3.	8.	1.	0.378	-0.619	14.994	5.169	9.238	
8.91	1737.80	2.25	282.60	361.06	273.80	0.0	994.0	75.3	3.	
7.181	30.810	3.	9.	1.	0.513	-0.457	14.822	5.463	9.573	
10.00	1599.50	2.19	282.13	295.12	271.30	0.0	994.0	94.0	3.	
7.298	31.421	3.	10.	1.	0.380	-0.582	19.083	5.001	9.280	
9.00	2090.20	3.04	281.21	360.01	272.90	0.0	994.0	81.5	3.	
8.094	38.346	1.	1.	1.	0.467	-0.577	6.867	2.942	5.509	
6.67	1929.90	3.13	295.50	368.06	287.10	0.0	1001.5	76.5	4.	
7.493	103.963	1.	2.	1.	0.237	-0.293	23.150	3.734	6.801	
0.00	3895.80	7.87	297.50	376.73	288.50	0.0	1001.5	72.2	4.	γMOT
9.986	23.735	1.	3.	1.	0.515	-0.652	3.905	2.577	4.883	
4.71	1614.20	2.39	294.84	370.63	286.00	1256.0	1001.5	79.8	4.	
9.147	23.635	1.	4.	1.	0.451	-0.595	3.064	2.212	4.386	γCARB
4.37	1589.40	2.18	295.45	372.48	287.80	1144.0	1001.5	74.3	4.	
8.085	48.430	1.	5.	1.	0.489	-0.528	10.733	4.630	8.354	
3.92	2109.50	3.93	293.30	348.81	285.30	0.0	1001.5	81.9	4.	
6.033	55.699	1.	6.	1.	0.397	-0.486	8.298	2.822	5.248	
2.69	2231.60	3.40	297.30	371.45	288.80	0.0	1001.5	71.1	4.	
6.874	52.466	1.	7.	1.	0.438	-0.505	9.381	3.626	6.630	
3.19	2177.30	3.64	295.52	361.38	287.00	0.0	1001.5	76.5	4.	γUMR
9.259	30.494	1.	8.	1.	0.458	-0.604	5.585	2.596	5.012	
8.52	1763.00	2.84	296.34	370.89	288.10	0.0	1001.5	73.3	4.	

10.908	27.739	1.	9.	1.	0.579	-0.666	5.792	2.960	5.538	
11.82	1705.40	3.00	293.24	317.91	284.90	0.0	1001.5	83.0	4.	
8.288	33.674	1.	10.	1.	0.440	-0.543	7.810	3.021	5.649	
8.55	2061.40	3.38	295.53	368.00	287.10	0.0	1001.5	76.5	4.	γ%
8.003	39.140	2.	1.	1.	0.424	-0.565	10.023	3.468	6.748	
9.20	1893.90	3.13	288.16	368.01	278.80	0.0	1005.5	75.0	4.	
8.756	103.258	2.	2.	1.	0.139	-0.204	28.591	1.497	3.240	
0.00	3865.50	9.07	288.36	379.91	279.60	0.0	1005.5	75.7	4.	
9.534	24.363	2.	3.	1.	0.462	-0.641	6.846	3.146	6.263	
20.57	1557.80	2.32	288.27	370.54	278.20	1248.0	1005.5	74.5	4.	
8.921	24.714	2.	4.	1.	0.459	-0.632	6.448	2.954	5.939	
19.26	1521.80	2.20	288.12	370.44	279.20	1096.0	1005.5	75.3	4.	
7.915	40.354	2.	5.	1.	0.366	-0.485	10.746	4.113	7.237	
7.59	1916.00	3.19	288.04	355.25	277.80	0.0	1005.5	74.2	4.	
6.303	53.140	2.	6.	1.	0.411	-0.473	11.288	3.046	5.942	
3.84	2173.30	3.35	287.97	370.77	279.80	0.0	1005.5	75.8	4.	
6.964	47.026	2.	7.	1.	0.389	-0.479	11.029	3.556	6.561	
5.38	2050.30	3.27	288.01	363.35	278.80	0.0	1005.5	75.0	4.	
8.598	36.263	2.	8.	1.	0.469	-0.663	10.071	4.051	8.145	
11.34	1839.90	3.10	288.95	371.77	279.40	0.0	1005.5	75.5	4.	
8.401	34.726	2.	9.	1.	0.592	-0.480	9.765	3.931	8.767	
14.18	1681.40	2.91	288.77	317.76	277.60	0.0	1005.5	74.0	4.	
8.275	33.500	2.	10.	1.	0.400	-0.530	10.594	3.097	5.999	
12.11	1976.60	3.35	288.13	368.58	278.80	0.0	1005.5	75.0	4.	
6.151	37.887	3.	1.	1.	0.395	-0.567	15.301	5.185	10.600	
6.71	1874.80	2.34	294.31	362.63	285.40	0.0	1021.5	69.5	4.	
6.746	106.673	3.	2.	1.	0.133	-0.245	42.806	1.748	3.305	
0.00	3997.40	7.30	295.00	376.53	287.80	0.0	1021.5	59.2	4.	
7.528	20.575	3.	3.	1.	0.388	-0.695	9.547	4.456	9.282	
16.06	1469.30	1.55	294.40	364.27	283.60	1224.0	1021.5	77.3	4.	
7.437	22.113	3.	4.	1.	0.414	-0.706	10.748	4.842	10.432	
16.91	1502.10	1.66	296.96	364.69	286.60	1080.0	1021.5	64.3	4.	
5.787	46.326	3.	5.	1.	0.346	-0.439	18.397	5.622	10.684	
3.35	2026.60	2.67	288.72	342.04	282.40	0.0	1021.5	82.4	4.	
4.965	53.931	3.	6.	1.	0.406	-0.487	17.538	5.980	12.181	
2.82	2179.20	2.69	293.81	369.10	288.40	0.0	1021.5	56.6	4.	
5.303	50.525	3.	7.	1.	0.379	-0.466	17.923	5.820	11.511	
3.04	2110.90	2.68	291.53	356.98	285.40	0.0	1021.5	69.5	4.	
6.599	36.052	3.	8.	1.	0.449	-0.606	16.478	5.702	11.301	
7.35	1832.50	2.37	296.38	365.88	287.20	0.0	1021.5	61.8	4.	
6.498	30.400	3.	9.	1.	0.329	-0.418	13.916	4.344	8.282	
7.79	1552.40	1.95	288.81	301.39	281.80	0.0	1021.5	85.0	4.	
6.539	30.979	3.	10.	1.	0.365	-0.561	16.523	4.827	9.863	
9.46	1986.90	2.60	293.95	362.69	285.40	0.0	1021.5	69.5	4.	
8.108	35.365	1.	1.	3.	0.396	-0.580	6.189	2.051	4.058	
6.34	1883.60	2.87	289.67	372.45	279.20	0.0	1012.5	69.0	5.	
7.862	104.729	1.	2.	3.	0.183	-0.296	24.421	1.317	2.787	
0.00	3924.50	8.31	291.46	377.85	280.90	0.0	1012.5	64.3	5.	
10.516	21.763	1.	3.	3.	0.446	-0.668	4.001	2.042	3.882	
4.48	1602.70	2.28	288.03	373.36	277.90	1160.0	1012.5	72.5	5.	
10.187	22.252	1.	4.	3.	0.407	-0.645	3.763	2.115	3.911	
2.36	1607.80	2.27	290.02	374.11	280.00	1032.0	1012.5	66.7	5.	
7.053	38.333	1.	5.	3.	0.377	-0.478	5.775	1.704	3.165	
5.33	1876.10	2.70	287.14	371.12	277.00	0.0	1012.5	74.8	5.	
6.488	47.537	1.	6.	3.	0.385	-0.531	7.208	2.074	4.207	
3.34	2126.70	3.10	292.38	372.99	281.30	0.0	1012.5	63.2	5.	
6.721	43.275	1.	7.	3.	0.381	-0.506	6.544	1.903	3.724	
4.16	2010.60	2.91	289.95	372.12	279.20	0.0	1012.5	69.0	5.	
9.481	28.443	1.	8.	3.	0.362	-0.651	5.702	2.232	4.810	
7.38	1733.40	2.69	291.23	373.76	280.40	0.0	1012.5	65.5	5.	

8.199	26.093	1.	9.	3.	0.442	-0.569	3.014	1.526	3.367	
10.30	1662.30	2.12	287.04	373.48	276.60	0.0	1012.5	76.0	5.	
8.649	30.379	1.	10.	3.	0.384	-0.560	7.001	1.932	3.717	
8.37	1999.30	3.14	289.64	373.50	279.20	0.0	1012.5	69.0	5.	
7.606	34.530	2.	1.	3.	0.341	-0.532	8.463	1.893	3.980	
10.50	1832.30	2.62	286.85	371.30	277.80	0.0	1015.5	83.5	5.	
7.809	101.745	2.	2.	3.	0.133	-0.203	26.427	1.134	2.895	
0.00	3808.80	7.93	286.22	379.09	278.60	0.0	1015.5	82.5	5.	
9.325	19.519	2.	3.	3.	0.306	-0.566	5.218	1.488	3.180	
22.56	1480.90	1.82	287.71	372.64	277.20	1248.0	1015.5	84.3	5.	
9.835	20.692	2.	4.	3.	0.355	-0.657	5.888	1.936	3.776	
20.28	1541.30	2.03	286.44	370.86	278.20	1016.0	1015.5	83.0	5.	
6.603	36.719	2.	5.	3.	0.299	-0.440	7.950	1.322	2.741	
7.70	1829.10	2.42	287.40	371.16	276.80	0.0	1015.5	84.8	5.	
6.235	49.700	2.	6.	3.	0.357	-0.483	11.035	2.186	4.589	
6.08	2104.70	3.10	285.81	370.04	278.80	0.0	1015.5	82.3	5.	
6.385	43.405	2.	7.	3.	0.329	-0.462	9.539	1.767	3.693	
6.75	1971.00	2.77	286.58	370.59	277.80	0.0	1015.5	83.5	5.	
8.184	30.862	2.	8.	3.	0.384	-0.596	8.261	2.444	5.093	
13.33	1752.90	2.51	286.40	372.87	278.40	0.0	1015.5	82.8	5.	
8.865	18.508	2.	9.	3.	0.357	-0.562	4.478	1.387	3.564	
28.43	1384.80	1.63	287.34	371.64	276.60	0.0	1015.5	85.0	5.	
8.125	28.517	2.	10.	3.	0.310	-0.511	9.235	1.676	3.506	
13.41	1924.80	2.86	286.79	372.02	277.80	0.0	1015.5	83.5	5.	
6.531	33.570	3.	1.	3.	0.341	-0.530	13.620	3.102	5.605	
6.45	1836.40	2.19	286.63	363.22	278.00	0.0	1005.5	91.5	5.	
7.333	105.439	3.	2.	3.	0.117	-0.200	44.086	0.599	1.270	
0.00	3951.10	7.72	283.92	372.07	279.30	0.0	1005.5	90.5	5.	
7.532	21.860	3.	3.	3.	0.342	-0.625	9.642	3.368	5.478	
12.69	1539.70	1.65	286.27	362.71	277.00	1288.0	1005.5	92.3	5.	
7.993	20.246	3.	4.	3.	0.379	-0.636	9.100	3.271	6.007	
14.79	1576.50	1.61	287.68	363.39	278.70	1032.0	1005.5	91.0	5.	
6.410	27.018	3.	5.	3.	0.279	-0.437	10.263	2.025	3.405	
7.53	1620.10	1.73	287.61	362.65	276.30	0.0	1005.5	92.8	5.	
4.997	53.917	3.	6.	3.	0.342	-0.469	18.040	3.155	5.764	
2.27	2259.00	2.69	283.48	364.80	279.70	0.0	1005.5	90.3	5.	
5.576	38.262	3.	7.	3.	0.305	-0.450	13.514	2.497	4.391	
4.43	1887.10	2.13	285.89	363.55	278.00	0.0	1005.5	91.5	5.	
7.020	28.094	3.	8.	3.	0.328	-0.514	12.394	2.931	5.823	
7.47	1686.40	1.96	288.26	363.38	279.00	0.0	1005.5	90.8	5.	
7.250	22.854	3.	9.	3.	0.408	-0.708	10.417	3.814	6.645	
13.96	1556.00	1.61	296.48	362.62	276.00	0.0	1005.5	93.0	5.	
6.845	28.448	3.	10.	3.	0.314	-0.515	14.500	2.719	4.755	
8.64	1929.00	2.44	286.24	364.15	278.00	0.0	1005.5	91.5	5.	
7.558	36.492	1.	1.	3.	0.387	-0.544	6.099	2.239	4.623	
6.92	1837.60	2.78	296.59	369.79	290.10	0.0	1014.5	88.5	6.	
7.603	105.507	1.	2.	3.	0.213	-0.283	24.279	1.223	2.585	
0.00	3953.80	8.16	299.37	377.64	292.00	0.0	1014.5	84.2	6.	
10.059	20.560	1.	3.	3.	0.370	-0.628	3.116	1.993	4.135	
5.97	1492.10	2.09	295.59	374.44	288.70	0.0	1014.5	91.8	6.	
9.090	23.837	1.	4.	3.	0.428	-0.616	3.446	2.368	4.598	R
4.97	1539.00	2.19	297.24	374.86	291.00	0.0	1014.5	86.3	6.	
7.061	40.781	1.	5.	3.	0.355	-0.486	6.979	1.883	3.876	
4.98	1878.60	2.89	293.35	350.45	287.80	0.0	1014.5	93.9	6.	
5.463	52.235	1.	6.	3.	0.327	-0.420	7.127	2.254	4.249	
2.68	2133.90	2.89	298.42	371.62	292.40	0.0	1014.5	83.1	6.	
6.119	46.839	1.	7.	3.	0.340	-0.451	7.057	2.079	4.073	
3.62	2013.60	2.89	296.03	361.65	290.10	0.0	1014.5	88.5	6.	
8.518	33.169	1.	8.	3.	0.489	-0.638	6.785	2.695	6.253	
9.70	1793.70	2.85	298.38	374.65	291.50	0.0	1014.5	85.3	6.	

11.046	24.489	1.	9.	3.	0.524	-0.671	5.603	3.073	8.016	
16.42	1606.80	2.69	292.41	320.08	287.30	0.0	1014.5	95.0	6.	
7.995	31.239	1.	10.	3.	0.357	-0.520	6.891	2.044	4.071	
9.18	1958.60	3.04	296.56	369.75	290.10	0.0	1014.5	88.5	6.	
7.605	37.013	1.	1.	3.	0.413	-0.541	5.412	2.852	6.222	
6.59	1856.40	2.83	293.33	367.47	284.40	0.0	1010.0	79.5	6.	
7.829	105.322	1.	2.	3.	0.224	-0.326	25.481	1.951	3.770	
0.00	3946.80	8.33	295.44	375.06	286.10	0.0	1010.0	76.5	6.	
9.950	23.719	1.	3.	3.	0.449	-0.657	4.380	2.767	5.588	
12.10	1598.90	2.37	291.80	371.40	283.00	0.0	1010.0	81.8	6.	R
9.704	21.516	1.	4.	3.	0.418	-0.620	3.389	2.026	3.710	
15.70	1508.70	2.10	293.57	373.93	285.20	0.0	1010.0	78.0	6.	
7.212	37.691	1.	5.	3.	0.354	-0.440	-0.127	4.942	12.812	
5.70	1798.70	2.72	290.71	348.08	282.10	0.0	1010.0	83.3	6.	
5.745	48.859	1.	6.	3.	0.386	-0.477	6.609	2.248	4.642	
3.29	2072.30	2.84	296.16	369.85	286.60	0.0	1010.0	75.8	6.	
6.348	43.560	1.	7.	3.	0.371	-0.459	3.412	3.527	8.519	
4.28	1942.40	2.78	293.57	359.52	284.40	0.0	1010.0	79.5	6.	
8.407	34.357	1.	8.	3.	0.484	-0.593	7.676	3.131	6.215	
7.75	1770.40	2.90	294.76	373.21	285.70	0.0	1010.0	77.3	6.	
9.552	23.738	1.	9.	3.	0.374	-0.511	-1.352	7.592	24.135	
11.24	1459.50	2.27	290.72	312.83	281.70	0.0	1010.0	84.0	6.	
8.235	31.018	1.	10.	3.	0.387	-0.536	5.855	2.804	6.109	
8.66	1948.60	3.06	293.31	367.65	284.40	0.0	1010.0	79.5	6.	
7.582	36.469	1.	1.	3.	0.404	-0.527	6.023	2.310	4.806	
6.64	1877.70	2.79	295.66	366.83	287.90	0.0	1011.0	75.5	6.	
7.390	99.844	1.	2.	3.	0.235	-0.271	24.512	2.761	5.431	
0.00	3741.50	7.42	297.38	373.92	289.30	0.0	1011.0	69.2	6.	
10.555	20.344	1.	3.	3.	0.413	-0.659	3.488	2.115	4.456	
14.25	1556.20	2.16	294.54	371.40	286.80	0.0	1011.0	80.3	6.	R
9.244	23.577	1.	4.	3.	0.445	-0.621	3.357	1.853	3.713	
14.78	1616.90	2.19	296.16	372.16	288.60	0.0	1011.0	72.3	6.	
7.112	38.183	1.	5.	3.	0.347	-0.416	5.203	2.690	7.294	
5.82	1833.80	2.73	293.00	346.29	286.10	0.0	1011.0	83.4	6.	
6.014	46.101	1.	6.	3.	0.311	-0.446	6.226	1.737	3.295	
3.53	2033.70	2.81	297.70	369.25	289.60	0.0	1011.0	67.6	6.	
6.464	42.486	1.	7.	3.	0.327	-0.432	5.759	2.172	5.121	
4.47	1942.40	2.77	295.55	358.77	287.90	0.0	1011.0	75.5	6.	
8.093	36.930	1.	8.	3.	0.517	-0.568	7.489	3.178	5.766	
6.74	1899.70	3.02	296.90	372.42	288.90	0.0	1011.0	70.8	6.	
10.556	23.101	1.	9.	3.	0.562	-0.549	-1.282	7.587	24.939	
21.42	1547.40	2.44	292.63	311.64	285.70	0.0	1011.0	85.0	6.	
8.274	30.135	1.	10.	3.	0.369	-0.520	6.466	2.137	4.634	
9.05	1944.40	2.94	295.63	366.79	287.90	0.0	1011.0	75.5	6.	
7.617	36.651	1.	1.	3.	0.395	-0.544	6.048	2.279	4.745	
6.79	1860.80	2.82	298.28	367.46	291.00	0.0	1019.5	80.0	6.	
7.258	105.380	1.	2.	3.	0.224	-0.293	23.319	1.701	3.491	
0.00	3948.90	7.78	301.06	376.20	293.10	0.0	1019.5	73.3	6.	
9.763	21.835	1.	3.	3.	0.429	-0.633	3.367	2.295	4.821	
4.62	1542.00	2.15	296.52	371.97	289.40	0.0	1019.5	85.0	6.	R
9.807	21.875	1.	4.	3.	0.406	-0.622	3.104	2.048	4.178	
4.56	1540.70	2.17	299.12	373.81	292.10	0.0	1019.5	76.7	6.	
7.377	35.398	1.	5.	3.	0.341	-0.508	5.471	1.625	3.372	
7.33	1750.90	2.63	294.40	347.46	288.30	0.0	1019.5	88.3	6.	
5.820	50.616	1.	6.	3.	0.348	-0.438	7.399	2.419	4.582	
2.68	2117.70	3.00	301.82	370.52	293.70	0.0	1019.5	71.7	6.	
6.461	43.025	1.	7.	3.	0.345	-0.473	6.437	2.023	3.978	
4.59	1934.80	2.81	298.12	359.02	291.00	0.0	1019.5	80.0	6.	
8.623	36.676	1.	8.	3.	0.487	-0.595	7.798	3.294	6.709	
7.44	1909.40	3.18	300.33	373.13	292.60	0.0	1019.5	75.0	6.	

10.321	22.280	1.	9.	3.	0.340	-0.545	3.613	1.955	4.586	
13.44	1395.80	2.29	293.68	311.48	287.80	0.0	1019.5	90.0	6.	
8.202	30.190	1.	10.	3.	0.369	-0.532	6.525	2.065	4.190	
9.13	1939.50	2.98	298.26	367.67	291.00	0.0	1019.5	80.0	6.	
7.640	34.631	1.	1.	8.	0.370	-0.566	5.174	1.497	2.921	
7.35	1871.00	2.68	300.74	369.08	294.20	0.0	1008.0	68.0	6.	
7.364	108.463	1.	2.	8.	0.194	-0.276	24.063	1.083	2.082	
0.00	4064.50	8.13	303.86	378.67	296.10	0.0	1008.0	58.7	6.	
10.702	16.900	1.	3.	8.	0.329	-0.630	1.841	1.151	2.372	
19.17	1481.40	1.83	298.98	373.42	292.70	0.0	1008.0	75.0	6.	
9.788	22.755	1.	4.	8.	0.455	-0.715	3.247	1.753	3.387	Burr
17.86	1644.30	2.26	301.60	374.67	295.10	0.0	1008.0	63.3	6.	
7.105	38.156	1.	5.	8.	0.300	-0.434	5.916	1.437	3.032	
3.35	1890.30	2.73	296.40	346.64	291.70	0.0	1008.0	79.7	6.	
5.952	49.539	1.	6.	8.	0.345	-0.522	6.672	1.369	2.612	
2.88	2176.30	3.01	304.66	373.36	296.60	0.0	1008.0	56.3	6.	
6.427	44.129	1.	7.	8.	0.324	-0.480	6.313	1.401	2.812	
3.07	2040.40	2.88	300.74	360.66	294.10	0.0	1008.0	68.0	6.	
7.934	34.160	1.	8.	8.	0.443	-0.610	5.284	1.960	3.968	
8.93	1818.10	2.74	303.08	373.83	295.60	0.0	1008.0	61.0	6.	
12.393	19.616	1.	9.	8.	0.342	-0.570	3.830	1.889	4.464	
9.07	1576.10	2.43	295.37	313.68	291.20	0.0	1008.0	82.0	6.	
8.429	28.406	1.	10.	8.	0.345	-0.556	6.203	1.395	2.773	
10.49	2004.00	2.99	300.83	369.16	294.20	0.0	1008.0	68.0	6.	
6.403	34.687	3.	1.	3.	0.349	-0.523	14.863	3.113	5.880	
6.73	1834.90	2.24	297.47	363.88	291.40	0.0	1009.0	83.0	6.	
8.073	107.329	3.	2.	3.	0.122	-0.192	49.699	1.149	2.242	
0.00	4022.00	8.73	296.57	376.65	292.10	0.0	1009.0	78.3	6.	
7.952	18.998	3.	3.	3.	0.339	-0.578	9.550	2.968	5.544	
13.45	1524.50	1.53	299.14	367.02	290.90	0.0	1009.0	86.5	6.	
7.281	21.934	3.	4.	3.	0.393	-0.595	10.773	3.416	6.164	
13.77	1535.60	1.61	298.33	367.08	291.70	0.0	1009.0	80.7	6.	
5.660	39.066	3.	5.	3.	0.294	-0.412	15.220	2.067	3.828	
4.57	1870.00	2.21	294.92	344.10	290.60	0.0	1009.0	88.8	6.	
4.748	50.435	3.	6.	3.	0.323	-0.477	16.961	3.012	5.723	
3.41	2111.00	2.42	295.92	368.84	292.20	0.0	1009.0	77.2	6.	
5.123	45.048	3.	7.	3.	0.309	-0.446	16.136	2.564	4.825	
3.89	1996.80	2.32	295.45	357.12	291.40	0.0	1009.0	83.0	6.	
6.992	32.483	3.	8.	3.	0.397	-0.590	16.094	3.921	8.142	
7.81	1794.90	2.27	298.29	367.17	291.90	0.0	1009.0	79.5	6.	
7.772	21.169	3.	9.	3.	0.315	-0.479	9.578	2.281	4.211	
12.57	1445.70	1.61	294.14	309.57	290.40	0.0	1009.0	90.0	6.	
6.667	29.204	3.	10.	3.	0.319	-0.491	16.505	2.737	5.081	
8.36	1966.00	2.59	297.20	364.04	291.40	0.0	1009.0	83.0	6.	
6.186	34.985	3.	1.	3.	0.347	-0.523	14.680	3.270	6.358	
6.58	1826.90	2.18	296.65	363.24	289.80	0.0	1001.0	84.5	6.	
7.542	105.882	3.	2.	3.	0.141	-0.262	46.992	2.004	3.631	
0.00	3967.80	8.05	295.63	376.15	290.60	0.0	1001.0	76.2	6.	
7.810	19.639	3.	3.	3.	0.343	-0.625	9.821	3.472	6.822	
3.40	1522.80	1.55	298.59	366.21	289.20	0.0	1001.0	90.8	6.	
6.853	22.636	3.	4.	3.	0.364	-0.598	10.295	3.181	6.245	
3.55	1472.40	1.56	297.68	365.25	290.20	0.0	1001.0	80.3	6.	
5.509	36.462	3.	5.	3.	0.292	-0.418	13.790	2.270	4.039	
5.70	1785.70	2.00	293.58	344.43	288.80	0.0	1001.0	94.9	6.	
4.825	47.566	3.	6.	3.	0.338	-0.448	16.500	3.155	6.006	
3.42	2053.90	2.31	294.46	368.43	290.80	0.0	1001.0	74.1	6.	
5.106	42.281	3.	7.	3.	0.316	-0.434	15.210	2.734	5.070	
4.36	1926.20	2.17	294.04	357.01	289.80	0.0	1001.0	84.5	6.	
6.918	31.624	3.	8.	3.	0.372	-0.559	15.410	3.783	7.554	
7.07	1783.00	2.19	298.20	366.87	290.40	0.0	1001.0	78.3	6.	

7.536	27.330	3.	9.	3.	0.475	-0.524	13.304	3.578	7.151	
13.95	1698.10	2.07	293.15	305.78	288.60	0.0	1001.0	97.0	6.	
6.464	29.360	3.	10.	3.	0.317	-0.505	15.812	2.957	5.658	
8.48	1916.10	2.45	296.24	363.28	289.80	0.0	1001.0	84.5	6.	
5.948	36.938	3.	1.	3.	0.355	-0.497	15.307	3.241	5.916	
5.96	1866.40	2.21	295.13	363.98	287.50	0.0	1010.0	79.0	6.	
6.972	102.489	3.	2.	3.	0.144	-0.235	43.305	0.984	1.912	
0.08	3863.00	7.17	294.93	376.47	288.10	0.0	1010.0	73.0	6.	
7.580	22.500	3.	3.	3.	0.449	-0.658	11.476	4.097	7.253	
13.47	1584.70	1.72	295.32	366.64	286.90	0.0	1010.0	83.5	6.	
6.852	23.060	3.	4.	3.	0.372	-0.599	11.358	3.668	6.982	
12.97	1527.70	1.59	297.10	367.04	287.80	0.0	1010.0	76.0	6.	
5.466	41.380	3.	5.	3.	0.264	-0.385	16.327	1.935	3.457	
3.72	1901.10	2.25	291.50	342.74	286.60	0.0	1010.0	86.5	6.	
4.705	47.327	3.	6.	3.	0.307	-0.410	15.324	2.737	4.662	
3.01	2044.70	2.24	293.72	369.51	288.30	0.0	1010.0	71.5	6.	
5.017	44.691	3.	7.	3.	0.288	-0.399	15.769	2.381	4.128	
3.30	1981.00	2.25	292.74	357.64	287.40	0.0	1010.0	79.0	6.	
6.513	32.544	3.	8.	3.	0.442	-0.573	14.902	4.011	7.808	
8.37	1803.60	2.13	296.70	367.55	288.00	0.0	1010.0	74.5	6.	
7.961	22.522	3.	9.	3.	0.413	-0.561	11.095	3.087	6.858	
14.53	1515.20	1.73	291.38	308.12	286.40	0.0	1010.0	88.0	6.	
6.313	31.372	3.	10.	3.	0.335	-0.497	16.347	2.992	5.401	
7.94	1956.80	2.44	294.69	364.12	287.50	0.0	1010.0	79.0	6.	
6.047	37.026	3.	1.	3.	0.344	-0.554	15.038	3.111	6.593	
6.60	1848.50	2.25	295.41	365.03	287.60	0.0	1013.0	86.0	6.	
7.266	106.991	3.	2.	3.	0.115	-0.225	44.528	1.074	2.121	
0.00	4009.30	7.83	294.68	377.14	289.10	0.0	1013.0	83.3	6.	
7.292	19.705	3.	3.	3.	0.342	-0.652	9.299	3.104	6.437	
16.02	1447.10	1.45	296.78	367.24	286.50	0.0	1013.0	88.0	6.	
6.899	23.732	3.	4.	3.	0.409	-0.624	11.146	3.903	8.461	
14.80	1542.00	1.65	297.33	368.13	288.30	0.0	1013.0	84.7	6.	
5.256	43.538	3.	5.	3.	0.288	-0.434	16.513	2.243	4.743	
3.70	1902.90	2.29	291.45	344.89	285.80	0.0	1013.0	89.3	6.	
4.945	55.152	3.	6.	3.	0.320	-0.512	18.137	2.638	5.028	
2.77	2226.90	2.75	293.62	370.67	289.40	0.0	1013.0	82.7	6.	
5.073	49.710	3.	7.	3.	0.305	-0.475	17.376	2.453	4.894	
3.15	2075.10	2.53	292.60	358.59	287.60	0.0	1013.0	86.0	6.	
6.513	34.413	3.	8.	3.	0.432	-0.585	16.237	4.126	9.532	
7.86	1814.30	2.24	296.60	368.72	288.70	0.0	1013.0	84.0	6.	
6.574	31.905	3.	9.	3.	0.384	-0.525	14.641	3.363	7.048	
8.57	1579.10	2.10	292.04	307.15	285.40	0.0	1013.0	90.0	6.	
6.306	31.247	3.	10.	3.	0.321	-0.532	16.514	2.840	5.894	useless
8.97	1978.20	2.57	295.03	364.99	287.60	0.0	1013.0	86.0	6.	
8.915	41.076	1.	1.	6.	0.348	-0.749	0.000	0.000	0.000	
0.00	0.00	3.70	297.17	367.69	289.50	0.0	1015.0	70.0	7.	
9.885	133.009	1.	2.	6.	0.350	-0.721	0.000	0.000	0.000	
0.00	0.00	13.36	297.00	377.34	291.40	0.0	1015.0	60.7	7.	
11.122	24.177	1.	3.	6.	0.330	-0.764	0.000	0.000	0.000	
0.00	0.00	2.68	297.36	370.69	288.00	0.0	1015.0	77.0	7.	
10.841	25.393	1.	4.	6.	0.314	-0.752	0.000	0.000	0.000	α
0.00	0.00	2.78	297.01	371.47	290.40	0.0	1015.0	65.3	7.	
7.698	46.414	1.	5.	6.	0.363	-0.731	0.000	0.000	0.000	
0.00	0.00	3.60	297.53	343.62	287.00	0.0	1015.0	81.7	7.	
7.421	51.619	1.	6.	6.	0.380	-0.755	0.000	0.000	0.000	
0.00	0.00	3.87	297.00	374.35	291.90	0.0	1015.0	58.3	7.	
7.535	49.349	1.	7.	6.	0.372	-0.745	0.000	0.000	0.000	
0.00	0.00	3.75	297.23	360.95	289.50	0.0	1015.0	70.0	7.	
9.767	34.274	1.	8.	6.	0.330	-0.760	0.000	0.000	0.000	
0.00	0.00	3.35	297.00	373.08	290.90	0.0	1015.0	63.0	7.	

12.469	24.257	1.	9.	6.	0.288	-0.748	0.000	0.000	0.000
0.00	0.00	3.01	297.69	314.28	286.50	0.0	1015.0	84.0	7.
9.494	34.446	1.	10.	6.	0.345	-0.749	0.000	0.000	0.000
0.00	0.00	4.20	297.19	367.65	289.50	0.0	1015.0	70.0	7.
9.141	41.229	1.	1.	6.	0.344	-0.759	0.000	0.000	0.000
0.00	0.00	3.81	298.99	369.89	290.90	0.0	1016.0	84.0	7.
10.235	134.280	1.	2.	6.	0.350	-0.721	0.000	0.000	0.000
0.00	0.00	13.96	298.99	380.31	291.40	0.0	1016.0	82.7	7.
11.441	22.826	1.	3.	6.	0.288	-0.765	0.000	0.000	0.000
0.00	0.00	2.64	299.00	371.50	290.50	0.0	1016.0	85.0	7.
10.502	25.283	1.	4.	6.	0.301	-0.765	0.000	0.000	0.000
0.00	0.00	2.69	299.00	373.71	291.20	0.0	1016.0	83.3	7.
8.056	49.516	1.	5.	6.	0.378	-0.748	0.000	0.000	0.000
0.00	0.00	4.03	299.01	345.76	290.20	0.0	1016.0	85.7	7.
7.471	52.915	1.	6.	6.	0.389	-0.757	0.000	0.000	0.000
0.00	0.00	3.99	298.96	376.18	291.60	0.0	1016.0	82.3	7.
7.712	51.463	1.	7.	6.	0.385	-0.753	0.000	0.000	0.000
0.00	0.00	4.01	298.98	363.18	290.90	0.0	1016.0	84.0	7.
9.552	38.377	1.	8.	6.	0.350	-0.764	0.000	0.000	0.000
0.00	0.00	3.69	299.00	375.57	291.30	0.0	1016.0	83.0	7.
11.812	33.355	1.	9.	6.	0.380	-0.754	0.000	0.000	0.000
0.00	0.00	3.97	299.03	309.01	290.10	0.0	1016.0	86.0	7.
9.594	34.126	1.	10.	6.	0.336	-0.756	0.000	0.000	0.000
0.00	0.00	4.33	298.99	369.60	290.90	0.0	1016.0	84.0	7.
9.449	41.439	2.	1.	6.	0.348	-0.760	0.000	0.000	0.000
0.00	0.00	3.95	295.88	319.19	288.60	0.0	1004.0	75.5	7.
9.414	134.285	2.	2.	6.	0.365	-0.715	0.000	0.000	0.000
0.00	0.00	12.84	298.56	305.71	289.50	0.0	1004.0	73.8	7.
12.559	24.377	2.	3.	6.	0.293	-0.750	0.000	0.000	0.000
0.00	0.00	3.08	294.97	326.54	287.90	0.0	1004.0	76.8	7.
11.126	28.984	2.	4.	6.	0.356	-0.790	0.000	0.000	0.000
0.00	0.00	3.24	296.06	323.35	289.00	0.0	1004.0	74.7	7.
8.012	49.331	2.	5.	6.	0.376	-0.740	0.000	0.000	0.000
0.00	0.00	3.96	291.81	310.66	287.50	0.0	1004.0	77.6	7.
7.327	55.095	2.	6.	6.	0.418	-0.759	0.000	0.000	0.000
0.00	0.00	4.09	298.70	314.25	289.70	0.0	1004.0	73.4	7.
7.609	52.570	2.	7.	6.	0.399	-0.750	0.000	0.000	0.000
0.00	0.00	4.03	295.69	312.68	288.60	0.0	1004.0	75.5	7.
11.307	33.289	2.	8.	6.	0.327	-0.770	0.000	0.000	0.000
0.00	0.00	3.79	297.12	323.64	289.30	0.0	1004.0	74.3	7.
11.107	33.216	2.	9.	6.	0.415	-0.776	0.000	0.000	0.000
0.00	0.00	3.68	290.67	310.63	287.30	0.0	1004.0	78.0	7.
9.906	36.909	2.	10.	6.	0.359	-0.757	0.000	0.000	0.000
0.00	0.00	4.48	295.88	318.11	288.60	0.0	1004.0	75.5	7.
9.529	41.112	2.	1.	6.	0.344	-0.754	0.000	0.000	0.000
0.00	0.00	3.95	296.24	318.81	287.60	0.0	995.5	95.0	7.
9.943	126.987	2.	2.	6.	0.310	-0.712	0.000	0.000	0.000
0.00	0.00	12.81	299.27	304.98	287.90	0.0	995.5	93.0	7.
12.203	24.169	2.	3.	6.	0.295	-0.756	0.000	0.000	0.000
0.00	0.00	2.96	294.51	326.38	287.30	0.0	995.5	96.5	7.
12.550	25.053	2.	4.	6.	0.316	-0.777	0.000	0.000	0.000
0.00	0.00	3.15	296.81	327.25	287.70	0.0	995.5	94.0	7.
8.187	45.202	2.	5.	6.	0.370	-0.738	0.000	0.000	0.000
0.00	0.00	3.72	293.04	309.19	287.20	0.0	995.5	97.5	7.
7.552	57.415	2.	6.	6.	0.396	-0.756	0.000	0.000	0.000
0.00	0.00	4.38	299.07	310.21	287.90	0.0	995.5	92.5	7.
7.815	51.672	2.	7.	6.	0.384	-0.748	0.000	0.000	0.000
0.00	0.00	4.07	296.24	309.73	287.60	0.0	995.5	95.0	7.
10.860	34.974	2.	8.	6.	0.338	-0.753	0.000	0.000	0.000
0.00	0.00	3.85	298.17	326.95	287.80	0.0	995.5	93.5	7.

```
75.    11.501  35.052  2.   9.  6.   0.380 -0.752  0.000  0.000  0.000
   0.00     0.00     4.02  292.81   294.63  287.10    0.0  995.5    98.0 7.
75.    10.308  34.668  2.  10.  6.   0.337 -0.754  0.000  0.000  0.000
   0.00     0.00     4.44  296.25   317.80  287.60    0.0  995.5    95.0 7.
71.     7.752 999.000  2.   1.  7.   0.339 -0.740  0.000  0.000  0.000
   0.00     0.00     2.96  301.65   321.89  294.80    0.0 1010.5    66.0 7.
71.     6.344  99.807  2.   2.  7.   0.387 -0.713  0.000  0.000  0.000
   0.00     0.00     6.44  304.74   312.75  296.80    0.0 1010.5    60.0 7.
71.    11.257  23.167  2.   3.  7.   0.304 -0.752  0.000  0.000  0.000
   0.00     0.00     2.61  299.21   327.83  293.30    0.0 1010.5    70.5 7.
71.    10.617  24.882  2.   4.  7.   0.310 -0.752  0.000  0.000  0.000
   0.00     0.00     2.69  302.63   330.44  295.80    0.0 1010.5    63.0 7.
71.     6.002  43.903  2.   5.  7.   0.363 -0.724  0.000  0.000  0.000
   0.00     0.00     2.66  297.31   307.61  292.30    0.0 1010.5    73.5 7.
71.     6.198  46.898  2.   6.  7.   0.370 -0.729  0.000  0.000  0.000
   0.00     0.00     2.95  304.63   317.58  297.30    0.0 1010.5    58.5 7.
71.     6.119  45.617  2.   7.  7.   0.367 -0.727  0.000  0.000  0.000
   0.00     0.00     2.83  301.50   313.32  294.80    0.0 1010.5    66.0 7.
71.     8.680  34.428  2.   8.  7.   0.328 -0.745  0.000  0.000  0.000
   0.00     0.00     3.04  304.11   327.54  296.30    0.0 1010.5    61.5 7.
71.     8.802  29.308  2.   9.  7.   0.398 -0.768  0.000  0.000  0.000
   0.00     0.00     2.60  297.28   297.81  291.80    0.0 1010.5    75.0 7.
71.     8.549  32.699  2.  10.  7.   0.339 -0.738  0.000  0.000  0.000
   0.00     0.00     3.10  301.53   321.17  294.80    0.0 1010.5    66.0 7.

*************************************************************************
```

APPENDIX D

EXAMPLES OF INPUT & OUTPUT FILES FROM THE RUNNING OF ROADTEST.FORTRAN

Example of terminal prompts and replies when
using "ROADTEST.FORTRAN" from a VDU.

```
roadtest
 has the input data been previously analysed? (y/n)
n
 enter name of input file
test1
 enter name of output file
L132021001
 if data errors are present in test1
 answer "n" to the following question and
 use the edit facility to correct file contents.
 do you wish to continue data analysis? (y/n)
y
 enter name of raw-data file
L132021001
 enter two figure event No. to commence data transfer
01
 enter two figure event No. to end data transfer
04
 do the markers come before the break? (y/n)
y
 high or low histogram resolution? (h/l)
l
 enter name of data output file
output
 enter name of data analysis file
analysis
 does the data begin with a header code? (y/n)
y
 do you wish to analyse more data? (y/n)
n
```

replies prompts

Example content of an input data file for "ROADTEST.FORTRAN".

```
L132021001
10+0000 11+0435 12+2047 14+0000 15+0001 16+0125 18+0382
10+0000 11+0435 12+2030 15+0000 16+0124
10+0000 11+0435 12+2083 15+0001 16+0125
10+0000 11+0435 12+2081
10+0000 11+0435 12+2077 16+0124
10+0000 11+0435 12+2066 15+0000 18+0383
10+0000 11+0435 12+2039 15+0001
10+0000 11+0435 12+2140
10+0000 11+0435 12+2156 14+0001
10+0000 11+0435 12+2127 15+0000
D059H08M27S57·9
10+0001 11+0433 12+2165 15+0001 18+0384
10+0001 11+0433 12+2128
10+0001 11+0418 12+2133
10+0002 11+0358 12+2296 15+0000 18+0385
10+0002 11+0349 12+2821 15+0001
10+0013 11+0376 12+2483 16+0123
10+0028 11+0372 12+1984
10+0047 11+0362 12+1425 15+0002 18+0386
10+0069 11+0345 12+1574 15+0001 18+0387
10+0087 11+0319 12+1992 18+0388
S02·9
10+0101 11+0308 12+2334 18+0389
10+0111 11+0433 12+2329 18+0391
10+0113 11+0435 12+1782 16+0122 18+0393
10+0114 11+0424 12+1760 15+0002 16+0123 18+0394
10+0114 11+0399 12+1598 15+0000 16+0122 18+0395
10+0122 11+0292 12+1705 15+0001 18+0396
10+0134 11+0261 12+1881 18+0397
10+0151 11+0241 12+2104 15+0002 18+0398
10+0167 11+0220 12+2331 15+0001 18+0399
10+0185 11+0208 12+2579 18+0400
S07·9
10+0201 11+0205 12+2814 15+0002 16+0120 18+0401
10+0210 11+0432 12+2627 15+0001 16+0121
10+0213 11+0435 12+1798 15+0002 18+0402
10+0211 11+0434 12+1747 15+0001
10+0210 11+0423 12+1893 16+0118 18+0403
10+0208 11+0423 12+1877 16+0121
10+0205 11+0418 12+1859
10+0207 11+0399 12+1868 16+0120 18+0404
10+0208 11+0382 12+1873
10+0211 11+0361 12+1903
S12·9
10+0216 11+0347 12+1948
10+0219 11+0331 12+1982
10+0227 11+0316 12+2045 18+0405
10+0231 11+0405 12+2083 18+0404
10+0230 11+0422 12+2071
                *  <--------- approximately 3000 additional
                *                          lines for the
10+0011 11+0436 12+1873 15+0000 18+0405    complete section
10+0006 11+0410 12+1189 15+0001 16+0123    of "raw" data
10+0000 11+0410 12+1234 14+0004
L132021999
```

D(iii)

Example content of a formatted data file output from "ROADTEST.FORTRAN".

```
L132021001
 dist  foot  revs  mark  fuel  tmpf  tmpo  gear
+0000 +0435 +2156 +0001 +0001 +0124 +0383 +NTRL
+0000 +0435 +2127 +0001 +0000 +0124 +0383 +NTRL
+0001 +0433 +2165 +0001 +0001 +0124 +0384 +NTRL
+0001 +0433 +2128 +0001 +0001 +0124 +0384 +NTRL
+0001 +0418 +2133 +0001 +0001 +0124 +0384 +NTRL
+0002 +0358 +2296 +0001 +0000 +0124 +0385 +NTRL
+0002 +0349 +2821 +0001 +0001 +0124 +0385 +NTRL
+0013 +0376 +2483 +0001 +0001 +0123 +0385 +NTRL
+0028 +0372 +1984 +0001 +0001 +0123 +0385 +NTRL
+0047 +0362 +1425 +0001 +0002 +0123 +0386 +NTRL
+0069 +0345 +1574 +0001 +0001 +0123 +0387 +NTRL
+0087 +0319 +1992 +0001 +0001 +0123 +0388 +0001
+0101 +0308 +2334 +0001 +0001 +0123 +0389 +NTRL
+0111 +0433 +2329 +0001 +0001 +0123 +0391 +NTRL
+0113 +0435 +1782 +0001 +0001 +0122 +0393 +0002
+0114 +0424 +1760 +0001 +0002 +0123 +0394 +0002
+0114 +0399 +1598 +0001 +0000 +0122 +0395 +0002
+0122 +0292 +1705 +0001 +0001 +0122 +0396 +NTRL
+0134 +0261 +1881 +0001 +0001 +0122 +0397 +0002
+0151 +0241 +2104 +0001 +0002 +0122 +0398 +NTRL
+0167 +0220 +2331 +0001 +0001 +0122 +0399 +NTRL
+0185 +0208 +2579 +0001 +0001 +0122 +0400 +NTRL
+0201 +0205 +2814 +0001 +0002 +0120 +0401 +0002
+0210 +0432 +2627 +0001 +0001 +0121 +0401 +NTRL
+0213 +0435 +1798 +0001 +0002 +0121 +0402 +NTRL
+0211 +0434 +1747 +0001 +0001 +0121 +0402 +NTRL
+0210 +0423 +1893 +0001 +0001 +0118 +0403 +0003
+0208 +0423 +1877 +0001 +0001 +0121 +0403 +0003
+0205 +0418 +1859 +0001 +0001 +0121 +0403 +0003
+0207 +0399 +1868 +0001 +0001 +0120 +0404 +0003
+0208 +0382 +1873 +0001 +0001 +0120 +0404 +0003
+0211 +0361 +1903 +0001 +0001 +0120 +0404 +0003
+0216 +0347 +1948 +0001 +0001 +0120 +0404 +0003
+0219 +0331 +1982 +0001 +0001 +0120 +0404 +0003
+0227 +0316 +2045 +0001 +0001 +0120 +0405 +0003
+0231 +0405 +2083 +0001 +0001 +0120 +0404 +0003
+0230 +0422 +2071 +0001 +0001 +0120 +0404 +0003
                    *
                    *
                    *
                    *
                    *
                    *
                    *
                    *   <---------- approximately 3000 additional
                    *               lines to complete the data file
                    *
                    *
                    *
                    *
+0011 +0436 +1873 +0003 +0000 +0122 +0405 +NTRL
+0006 +0436 +1189 +0003 +0001 +0123 +0405 +NTRL
+0000 +0436 +1234 +0004 +0001 +0123 +0405 +NTRL
L132021001
```

Example of output from "ROADTEST.FORTRAN".

```
*****************************************************************
VAUXHALL CAVALIER FUEL CONSUMPTION ROAD TEST
*****************************************************************
ANALYSIS FILE of L132021001                  1300 Petrol  (BLUE)
*****************************************************************
Commencing at mark No.01
and terminating at mark No.04
before the intermission, with a
duration of  26·133 minutes
from D059H08M27S52·9 minus 56·0 seconds
*****************************************************************
TOTAL DISTANCE       -    15·968 KM.           {  9·92 miles }
AVE.VEHICLE SPEED    -    36·661 KPH           { 22·78 mph.  }
AVE.VEHICLE ACCN.    -     0·310 M/S/S.
AVE.VEHICLE DECN.    -    -0·422 M/S/S.
AVE.THROTTLE ANGLE   -     8·602 DEG.
AVE.THROTTLE SPEED   -     3·178 DEG/S.
AVE.THROTTLE ACCN.   -     6·170 DEG/S/S.
GEAR CHANGES         -     117·5
AVE.ENGINE REVS      -  1684·332 R.P.M.
TOTAL FUEL USED      -     1·321 LITRES        {  0·29 galls }
AVE.FUEL CONSP.      -     8·273 LIT./100KM.   { 34·14 mpg.  }
AVE.FUEL FLOW RATE   -     3·032 LIT./HR.      {  0·67 gal/hr}
AVE.FUEL FLOW CHECK  -     3·033 LIT./HR.      {  0·67 gal/hr}
AVE.FUEL TEMP.       -    12·902 DEG C.
AVE.OIL TEMP.        -    80·445 DEG C.
*****************************************************************
VEHICLE ACCN/DECCN CHARACTERISTICS
*****************************************************************
% of vehicle-motion-time at g level
level - 0·05g 0·10g 0·15g 0·20g 0·25g 0·30g 0·35g 0·40g 0·45g 0·50g
accn  - 69·69 18·33  7·88  2·89  0·80  0·24  0·16  0·00  0·00  0·00
decn  - 74·66 15·01  7·12  2·30  0·69  0·15  0·08  0·00  0·00  0·00
*****************************************************************
VEHICLE STATE AT SECTION BOUNDARIES
*****************************************************************
Commencing at Event No.01
VEHICLE SPEED        -     0·081 KPH.          {  0·05 mph.  }
THROTTLE ANGLE       -     7·663 DEG.
ENGINE REVS.         -  2130·248 RPM.
FUEL FLOW RATE       -     4·320 LIT./HR.      {  0·95 gal/hr}
FUEL TEMP.           -    12·400 DEG C.
OIL TEMP.            -    38·300 DEG C.
GEAR SELECTION       -     +NTRL
Terminating at Event No.04
VEHICLE SPEED        -    25·453 KPH.          { 15·82 mph.  }
THROTTLE ANGLE       -    32·356 DEG.
ENGINE REVS.         -  3564·793 RPM.
FUEL FLOW RATE       -     3·600 LIT./HR.      {  0·79 gal/hr}
FUEL TEMP.           -    14·000 DEG C.
OIL TEMP.            -    92·000 DEG C.
GEAR SELECTION       -     +NTRL
*****************************************************************
```

APPENDIX E

LISTING OF FORTRAN PROGRAM DYNO.FORTRAN
WITH AN EXAMPLE OF THE INPUT & OUTPUT FILES USED

```
c       *********************************************************
c       *****************LOUGHBOROUGH UNIVERSITY*****************
c       ***********DEPARTMENT OF TRANSPORT TECHNOLOGY************
c       *********************************************************
c       *********************************************************
c              VAUXHALL CAVALIER AND AUSTIN-ROVER MONTEGO
c              FUEL CONSUMPTION TESTS SPRING/SUMMER 1985.
c                 M.REDSELL - CONTRACT No.TRR/842/459
c       *********************************************************
c       *********************************************************
        program dyno
c       *********************************************************
c        Program "dyno.fortran" is a piece of software written to
c       convert the formatted output files from "roadtest.fortran"
c       into data files suitable for drive-cycle applications on
c       the Chassis Dynomometer in the Department of Transport
c       Technology, Loughborough University of Technology.
c        The program reads in the "raw" (7 column) data files of
c       integer values, informing of distance travelled, throttle
c       position, engine speed, event marker, fuel used, fuel and
c       oil temperatures for each half-second interval of the test
c       and calculates corresponding values of distance travelled,
c       time elapsed from start of test, vehicle speed, engine
c       speed, event marker, fuel used, fuel and oil temperatures,
c       and gear selection.
c        The gear selection data read from the input file is
c       smoothed to allow for errors in gear calculation, due to
c       "clutch-slip", to be omitted.
c        The output file contains a header block detailing the
c       parameters listed and their units of measure.
c       *********************************************************
        character *1 gear,cog1,cog2,cog3
        character *4 a,b,c,d,e,f,g
        character *15 filename,results,header
        character *48 data,labels
c       *********************************************************
        integer dist,revs,count,fuel,tfuel,toil,a4,a5,b4,b5,c4,c5
c       *********************************************************
c       control parameters set to initial conditions
c       *********************************************************
        road1=Ø.Ø
        k=Ø
        time=-Ø.5
        a5=Ø
        b1=Ø.Ø
        b2=Ø.Ø
        b3=Ø.Ø
        b4=Ø.Ø
        b5=Ø
        b6=Ø.Ø
        b7=Ø.Ø
        c1=Ø.Ø
        c2=Ø.Ø
        c3=Ø.Ø
```

```
      c4=Ø.Ø
      c5=Ø
      c6=Ø.Ø
      c7=Ø.Ø
      gear(1:1)='N'
      cog2='N'
      cog3='N'
c     ************************************************************
c     prompts to terminal for file names
c     ************************************************************
      write (*,*) 'enter input data filename'
      read (5,1Ø) filename
      write (*,*) 'enter output data filename'
      read (5,1Ø) results
c     ************************************************************
c     open output and input files and read header labels
c     ************************************************************
      open (2,file=filename,form='formatted')
      open (3,file=results,form='formatted')
      read (2,1Ø) header
      read (2,1Ø) labels
   1Ø format (a)
c     ************************************************************
c     format output file header block
c     ************************************************************
      write (3,25)
   25 format ('*************************************************************
     ***************')
   26 format ('*-----------------------------------------------------------
     *-------------*')
      write (3,11) filename
   11 format ('*',1x,'DATA FILE OF TEST ',a15,35x,'*')
      write (3,25)
      write (3,15)
   15 format ('*',1x,'DISTANCE|',2x,'TIME',2x,'|',2x,
     *'CAR',2x,'|',1x,'ENGINE',1x,'|',1x,'MK',1x,'|',1x,'FUEL'
     *,1x,'|',1x,'FUEL',1x,'|',2x,'OIL',2x,'|',1x,'GEAR',1x,'*')
      write (3,16)
   16 format ('*',2x,'DRIVER',1x,'|',1x,'PASSED',1x,'|',1x,'SPEED'
     *,1x,'|',2x,'REVS',2x,'|',4x,'|',1x,'USED',1x,'|',1x,'TEMP'
     *,1x,'|',2x,'TEMP',1x,'|',1x,'USED',1x,'*')
      write (3,26)
      write (3,17)
   17 format ('*',4x,'Km',3x,'|',2x,'secs',2x,'|',2x,'m/s',2x,'|'
     *,2x,'rpm',3x,'|',1x,'No',1x,'|',2x,'cc',2x,'|',1x,'degC',1x
     *,'|',2x,'degC',1x,'|',2x,'No',2x,'*')
      write (3,26)
c     ************************************************************
c     read line of input file as character string
c     ************************************************************
   20 read (2,1Ø,end=7Ø) data
c     ************************************************************
c     increment time parameter and segment string into integers
c     ************************************************************
      time=time+Ø.5
      a=data(3:6)
      b=data(15:18)
      c=data(21:24)
      d=data(27:3Ø)
      e=data(33:36)
```

```
      f=data(39:42)
      g=data(45:48)
c     ***********************************************************
c     conversion of strings to numerical values
c     ***********************************************************
      read (a,4Ø) dist
      read (b,4Ø) revs
      read (c,4Ø) count
      read (d,4Ø) fuel
      read (e,4Ø) tfuel
      read (f,4Ø) toil
   4Ø format (i4)
c     ***********************************************************
c     notation check of neutral gear selection
c     ***********************************************************
      if (g.eq.'NTRL') then
      g='ØØØN'
      endif
      if (g(4:4).eq.gear(1:1)) goto 6Ø
      if (g(4:4).eg.'N'.or.gear(1:1).eq.'N') goto 6Ø
      g(4:4)='N'
   6Ø gear(1:1)=g(4:4)
c     ***********************************************************
c     calculation block
c     ***********************************************************
      road1=road1+(dist/(2Ø*222Ø.6)
      a1=time
      a2=dist*1ØØ/222Ø.6
      a3=revs*12Ø/121.Ø
      a4=count
      a5=fuel+a5
      a6=tfuel/1Ø.Ø
      a7=toil/1Ø.Ø
      cog1=g(4:4)
      k=k+1
c     ***********************************************************
c     smoothing of gear change data from input data file
c     ***********************************************************
      if (cog1.eq.'N'.and.cog3.eq.'N') then
      cog2='N'
      endif
      if (cog3.eq.'N'.and.cog2.ne.cog1.and.cog1.ne.'N'
     *.and.cog2.ne.'N') then
      cog2=cog1
      endif
c     ***********************************************************
c     temporary storage of data values for differencing
c     ***********************************************************
      cog3=cog2
      road3=road2
      c1=b1
      c2=b2
      c3=b3
      c4=b4
      c5=b5
      c6=b6
      c7=b7
      cog2=cog1
      road2=road1
      b1=a1
```

```
      b2=a2
      b3=a3
      b4=a4
      b5=a5
      b6=a6
      b7=a7
      if (k.lt.2) goto 2Ø
c     ***********************************************************
c     write calculated values to output file and return
c     ***********************************************************
      write (3,5Ø) road3,c1,c2,c3,c4,c5,c6,c7,cog3
      goto 2Ø
   5Ø format ('*',1x,f7.4,1x,'|',1x,f6.1,1x,'|',1x,f5.2,1x,'|',1x
     *,f6.1,1x,'|',1x,i2,1x,'|',1x,i4,1x,'|',1x,f4.1,1x,'|',1x
     *,f5.1,1x,'|',3x,a1,2x,'*')
   7Ø write (3,5Ø) road2,b1,b2,b3,b4,b5,b6,b7,cog2
c     ***********************************************************
c     inform of successful conversion and close both files
c     ***********************************************************
      print *,'conversion completed'
      write (3,25)
      close (2)
      close (3)
c     ***********************************************************
      end
c     ***********************************************************
```

Example of a data input file for "DYNO.FORTRAN".
(i.e., a formatted data file output from "ROADTEST.FORTRAN).

```
L132021001
 dist  foot  revs  mark  fuel  tmpf  tmpo  gear
+0000 +0435 +2156 +0001 +0001 +0124 +0383 +NTRL
+0000 +0435 +2127 +0001 +0000 +0124 +0383 +NTRL
+0001 +0433 +2165 +0001 +0001 +0124 +0384 +NTRL
+0001 +0433 +2128 +0001 +0001 +0124 +0384 +NTRL
+0001 +0418 +2133 +0001 +0001 +0124 +0384 +NTRL
+0002 +0358 +2296 +0001 +0000 +0124 +0385 +NTRL
+0002 +0349 +2821 +0001 +0001 +0124 +0385 +NTRL
+0013 +0376 +2483 +0001 +0001 +0123 +0385 +NTRL
+0028 +0372 +1984 +0001 +0001 +0123 +0385 +NTRL
+0047 +0362 +1425 +0001 +0002 +0123 +0386 +NTRL
+0069 +0345 +1574 +0001 +0001 +0123 +0387 +0001
+0087 +0319 +1992 +0001 +0001 +0123 +0388 +0001
+0101 +0308 +2334 +0001 +0001 +0123 +0389 +NTRL
+0111 +0433 +2329 +0001 +0001 +0123 +0391 +NTRL
+0113 +0435 +1782 +0001 +0001 +0122 +0393 +0002
+0114 +0424 +1760 +0001 +0002 +0123 +0394 +0002
+0114 +0399 +1598 +0001 +0000 +0122 +0395 +0002
+0122 +0292 +1705 +0001 +0001 +0122 +0396 +NTRL
+0134 +0261 +1881 +0001 +0001 +0122 +0397 +0002
+0151 +0241 +2104 +0001 +0002 +0122 +0398 +NTRL
+0167 +0220 +2331 +0001 +0001 +0122 +0399 +NTRL
+0185 +0208 +2579 +0001 +0001 +0122 +0400 +NTRL
+0201 +0205 +2814 +0001 +0002 +0120 +0401 +0002
+0210 +0432 +2627 +0001 +0001 +0121 +0401 +NTRL
+0213 +0435 +1798 +0001 +0002 +0121 +0402 +NTRL
+0211 +0434 +1747 +0001 +0001 +0121 +0402 +NTRL
+0210 +0423 +1893 +0001 +0001 +0118 +0403 +0003
+0208 +0423 +1877 +0001 +0001 +0121 +0403 +0003
+0205 +0418 +1859 +0001 +0001 +0121 +0403 +0003
+0207 +0399 +1868 +0001 +0001 +0120 +0404 +0003
+0208 +0382 +1873 +0001 +0001 +0120 +0404 +0003
+0211 +0361 +1903 +0001 +0001 +0120 +0404 +0003
+0216 +0347 +1948 +0001 +0001 +0120 +0404 +0003
+0219 +0331 +1982 +0001 +0001 +0120 +0404 +0003
+0227 +0316 +2045 +0001 +0001 +0120 +0405 +0003
+0231 +0405 +2083 +0001 +0001 +0120 +0404 +0003
+0230 +0422 +2071 +0001 +0001 +0120 +0404 +0003
+0011 +0436 +1873 +0003 +0000 +0122 +0405 +NTRL
+0006 +0436 +1189 +0003 +0001 +0123 +0405 +NTRL
+0000 +0436 +1234 +0004 +0001 +0123 +0405 +NTRL
```

Example of a data output file from "DYNO.FORTRAN".
(obtained when using Appendix E(ii) as input file)

```
************************************************************************
* DATA FILE OF TEST dyno.input                                         *
************************************************************************
```

DISTANCE DRIVEN	TIME PASSED	CAR SPEED	ENGINE REVS	MK	FUEL USED	FUEL TEMP	OIL TEMP	GEAR USED
Km	secs	m/s	rpm	No	cc	degC	degC	No
0.0000	0.0	0.00	2138.2	1	1	12.4	38.3	N
0.0000	0.5	0.00	2109.4	1	1	12.4	38.3	N
0.0000	1.0	0.05	2147.1	1	2	12.4	38.4	N
0.0000	1.5	0.05	2110.4	1	3	12.4	38.4	N
0.0001	2.0	0.05	2115.4	1	4	12.4	38.4	N
0.0001	2.5	0.09	2277.0	1	4	12.4	38.5	N
0.0002	3.0	0.09	2797.7	1	5	12.4	38.5	N
0.0005	3.5	0.59	2462.5	1	6	12.3	38.5	N
0.0011	4.0	1.26	1967.6	1	7	12.3	38.5	N
0.0021	4.5	2.12	1413.2	1	9	12.3	38.6	N
0.0037	5.0	3.11	1561.0	1	10	12.3	38.7	1
0.0057	5.5	3.92	1975.5	1	11	12.3	38.8	1
0.0079	6.0	4.55	2314.7	1	12	12.3	38.9	N
0.0104	6.5	5.00	2309.8	1	13	12.3	39.1	N
0.0130	7.0	5.09	1767.3	1	14	12.2	39.3	2
0.0155	7.5	5.13	1745.5	1	16	12.3	39.4	2
0.0181	8.0	5.13	1584.8	1	16	12.2	39.5	2
0.0209	8.5	5.49	1690.9	1	17	12.2	39.6	N
0.0239	9.0	6.03	1865.5	1	18	12.2	39.7	N
0.0273	9.5	6.80	2086.6	1	20	12.2	39.8	N
0.0310	10.0	7.52	2311.7	1	21	12.2	39.9	N
0.0352	10.5	8.33	2557.7	1	22	12.2	40.0	N
0.0397	11.0	9.05	2790.7	1	24	12.0	40.1	N
0.0444	11.5	9.46	2605.3	1	25	12.1	40.1	N
0.0492	12.0	9.59	1783.1	1	27	12.1	40.2	N
0.0540	12.5	9.50	1732.6	1	28	12.1	40.2	N
0.0587	13.0	9.46	1877.4	1	29	11.8	40.3	3
0.0634	13.5	9.37	1861.5	1	30	12.1	40.3	3
0.0680	14.0	9.23	1843.6	1	31	12.1	40.3	3
0.0727	14.5	9.32	1852.6	1	32	12.0	40.4	3
0.0774	15.0	9.37	1857.5	1	33	12.0	40.4	3
0.0821	15.5	9.50	1887.3	1	34	12.0	40.4	3
0.0870	16.0	9.73	1931.9	1	35	12.0	40.4	3
0.0919	16.5	9.86	1965.6	1	36	12.0	40.4	3
0.0970	17.0	10.22	2028.1	1	37	12.0	40.5	3
0.1022	17.5	10.40	2065.8	1	38	12.0	40.4	3
0.1074	18.0	10.36	2053.9	1	39	12.0	40.4	3
0.1077	18.5	0.50	1857.5	3	39	12.2	40.4	N
0.1078	19.0	0.27	1179.2	3	40	12.3	40.5	N
0.1078	19.5	0.00	1223.8	4	41	12.3	40.5	N

APPENDIX F

EXAMPLES OF A TEST DATA SHEET, QUESTIONNAIRES FOR DRIVERS PARTICIPATING IN BOTH TEST PROGRAMMES AND A TEST PROCEDURE SHEET FOR THE TEST OBSERVER.

F(i)

Example of a test data sheet as completed by the test observer.

VAUXHALL CAVALIER ROAD TESTING

Vehicle Number:	Tape Number:
Program Number:	Track Numbers:
Driver/Observer: /	Date of test: / /1985.
Calibration checks: start end	Conditions: start end
Distance monitor (50m): Throttle angle - closed: - open: Engine speed: Fuel counter O.K.? Fuel temp. °C: Oil temp. °C:	Time (hrs./min.): Dry bulb temp. °C: Wet bulb temp. °C: Relative humidity %: Air pressure (mBars.): Wind direction: Wind speed (k.p.h.):
General comments:	
Road test checklist:	Road condition -

Event No.	Description	Time (hrs./min.)	Comments
1	Start; Ashleigh Drive	/	
2	On joining the A6	/	Put choke in
3	Through road sign	/	
4	On joining roundabout	/	
5	On joining Urban Cycle	/	
6	On passing Event No.5	/	
7	On passing Event No.6	/	
8	At service area junction	/	Switch off scan
9	On passing Event No.8	/	Switch on scan
10	On joining Urban Cycle	/	
11	On passing Event No.10	/	
12	On passing Event No.11	/	
13	On joining M1 motorway	/	
14*	Motorway marker No.1	/	
15*	Motorway marker No.2	/	
16**	On exit at junction 24	/	
17**	On entry at junction 24	/	
18	On exit at junction 22	/	
19	Coalville junction	/	
20	On joining the A512	/	
21	End; Ashleigh Drive	/	

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

Department of Transport Technology

VAUXHALL CAVALIER ROAD TESTS - SPRING TEST PROGRAMME, 1985.
DRIVER QUESTIONNAIRE:

a) DRIVER

1. Name: ....
2. Age: (years/months) ....
3. How long have you been driving? (years) ....
4. Approximately how many miles do you drive a year? ....
   Could you divide this total into the following categories by percent;
   Business .... i.e., 30
   Domestic .... i.e., 25
   Pleasure .... i.e., 45%
5. What type of vehicle are you used to driving at home?
   ....

b) VEHICLES

The vehicles you have driven were as follows:

1600cc petrol Vauxhall Cavalier GL - colour red
1300cc petrol Vauxhall Cavalier GL - colour blue
1600cc diesel Vauxhall Cavalier LD - colour green

Could you answer the following questions by ranking the vehicles 1, 2 or 3 (1 for the most preferred vehicle). If there is no preference put NP by the appropriate vehicles.

1. Which colour did you prefer? red.... blue.... green....
2. Which vehicle did you find most comfortable to drive?
   red.... blue.... green....
3. Rank vehicles in terms of performance:
   red.... blue.... green....
4. Rank the vehicles in terms of road and engine noise:
   (1 for quietest vehicle) red.... blue.... green....
5. Given the choice of all three vehicles (money no object!) which vehicle would you choose for your personal use?
   (tick vehicle preferred) red.... blue.... green....

6. If the answer to (5) is not the diesel (green) vehicle, indicate why, and comment on any improvements that in your view could be made to this car: ....
....
....
....
....
....
....
....

c) ROAD TESTS

Could you tick the appropriate answer to the following:

1. Did you find the length of test you were asked to drive:
   too long ..... a comfortable length ..... too short.....
2. Did you find the time you were asked to drive:
   too long ..... a comfortable time ..... too short.....
3. Did you find the half-way break useful for a rest etc.?
   required ..... not required ..... no preference .....
   If the answer to (3) is "not required" indicate why you felt no half-way break was required during the test route: ....
   ....
   ....
   ....

Thankyou for participating in the test drives, your help has been greatly appreciated.

Mark Redsell
Research Assistant.

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

Department of Transport Technology

AUSTIN-ROVER MONTEGO ROAD TESTS - SUMMER TEST PROGRAMME, 1985.
DRIVER QUESTIONNAIRE:

a) DRIVER

1. Name: ....
2. Age: (years/months) ....
3. How long have you been driving? (years) ....
4. Approximately how many miles do you drive a year? ....

   Could you divide this total into the following categories by percent;
   Business .... i.e., 30
   Domestic .... i.e., 25
   Pleasure .... i.e., 45%
5. What type of vehicle are you used to driving at home?

   ....

b) VEHICLES

The vehicles you have driven were as follows:

1600cc petrol Austin Montego HL - colour white

1600cc petrol Austin Montego HL - colour ivory

Could you answer the following questions by ranking the vehicles 1 or 2 (1 for the preferred vehicle).

1. Which colour did you prefer? white.... ivory....
2. Which vehicle did you find most comfortable to drive?

   white.... ivory....

   Explain the failings of vehicle ranked 2 in question (2) above: ....

   ....

   ....

   ....

   ....
3. Rank vehicles in terms of performance:

   (if no preference put NP) white.... ivory....

4. Rank vehicles in terms of road and engine noise:
   (if no preference put NP) white.... ivory....
5. How do the Montego vehicles compare to the 1600cc petrol Vauxhall Cavalier (red) in your opinion?
   Performance: ....
   Ride and comfort: ....
   Driveability: (gear changing etc.) ....
   ....

c) ROAD TESTS

Please try to answer sincerely with YES or NO.

1. Having already driven a number of road tests did you find the length of test too long? timewise: ....
   distance: ....
2. Did you find driving the same test route a tedious task?
   ....
3. Did you feel a need for the half-way break? ....
4. With respect to the above questions, do you think your driving ability, technique or confidence changed over the course of test drives? ....
5. Do you feel that you drove the vehicles in a similar manner to the way you drive at home? ....
   If the answer to (5) is "no" please explain why: ....
   ....
   ....
   ....

Thankyou for participating in the test drives, your help has been greatly appreciated.

Mark Redsell
Research Assistant.

PROCEDURE FOR TEST OBSERVER.

1. Position the test vehicle in Ashleigh Drive with its rear adjacent to the University gates. Have the driver ready to go and the car engine on idle. Seat belts on, of course!
2. Switch on "scan" and tell the driver to "go". As the vehicle starts to move, switch the "event" on and off, quickly. Note the approximate time of day.
3. Repeat the latter part of (2) each time you pass an "event marker" shown on Map 1 enclosed* and described on the test data sheet.
4. From Loughborough the car is driven to Leicester on the A6. You will eventually come to the "Dysart Way" roundabout - this is where the Urban Cycle starts and finishes.
5. Drive once around the Urban Cycle, as shown on Map 2**.
6. On completion of the Urban Cycle, take the car to Leicester Forest East services by returning back down the A6, turning right at the first roundabout for the A46, and following the signs for "Hinckley A47".
7. Turn left just before the "Moat House" hotel for the "Welcome Break" motorway services. Follow the service road across the motorway bridge for the northbound service area.
8. At the T-junction on the staff road, switch the "event" on and off quickly, then switch the "scan" off. Drive through the petrol station and across to the lorry park to the clearing behind the "Happy Eater" cafe. Watch out for drivers who think the road system is one-way.
9. After $\frac{1}{2}$ - $\frac{3}{4}$ hour break return to the vehicle and switch the "scan" on. Switch "event" on and off as you return through the T-junction. Drive back to the "Dysart Way" roundabout to begin the final circuit of the Urban Cycle.
10. With the Cycle completed, head for the M1 motorway. Follow the usual Cycle route until adjacent to the British Rail station where you turn right into Waterloo Way, keeping in the left lane. Follow signs for "A426" and remain on that road until a right turning for the B5418.
11. At the end of the B5418 filter left onto the A46 for the M1 motorway.

12. Leave out "event" Nos.14, 15, 16 & 17.
13. Exit at Junction 22 for Ashby along the A50. At Coalville turn right at the clocktower, following signs to Loughborough.
14. Drive through Thringstone and pick up the A512 to Loughborough at the "Bulls Head" public house.
15. At the "Epinal Way" roundabout turn right along Epinal Way and right at the next roundabout for Forest Road. Turn into Ashleigh Drive and stop the test vehicle with its nose next to the University gates.
16. As vehicle stops switch "event" on and off, and then switch off "scan".
17. Throughout the test route note any general comments that may affect travel of vehicle (i.e. roadworks and weather), overall road condition, and note also observations between "event markers" (i.e. use of auxiliary units on vehicle) in the appropriate boxes on the data sheet.
18. If an "event" is missed, make a note of the approximate time it should have occurred.
19. Finally, at the beginning of the test the operation of the manual choke on the 1300cc Petrol vehicle is governed by the driver; however, if by "event" No.2 the choke is still out, ask for it to be returned.

* (identical to Figure No.8 contained in this thesis)

** (identical to Figure No.9 contained in this thesis)

PLATES

Index to Plates.

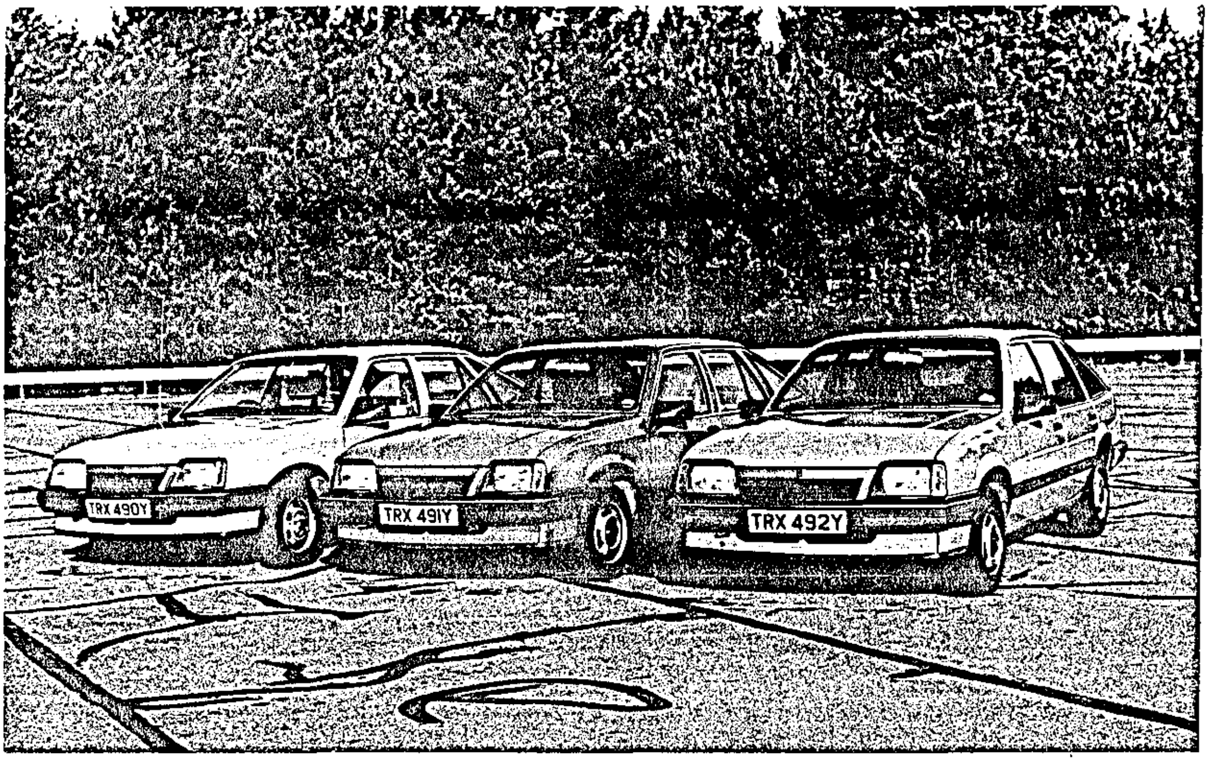


Plate No.1 - Vauxhall Cavalier test vehicles.
(left to right 1600 diesel, 1600 & 1300 petrol)

Plate No.2 - Austin-Rover Montego test vehicles.
(left to right "white" & "ivory" 1600 petrol)

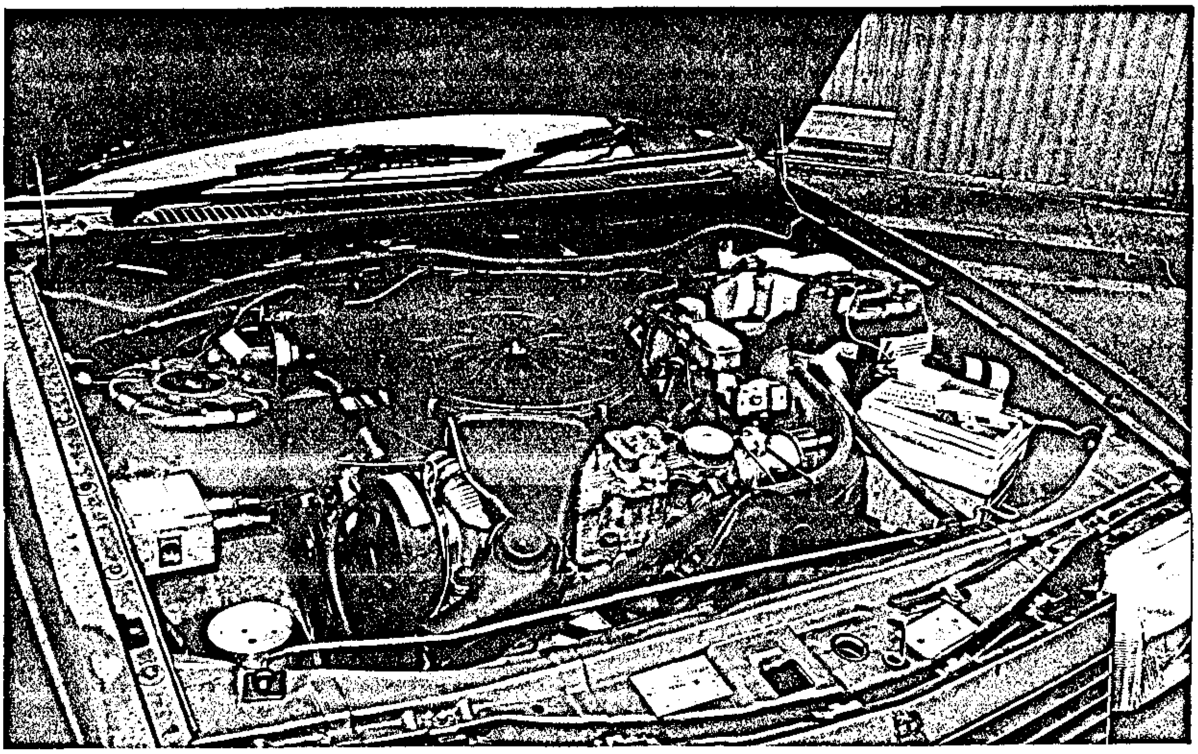


Plate No.3 - Under-bonnet view of 1600 petrol car.
Note location of speedometer cable transducer in
space left of air filter moulding.

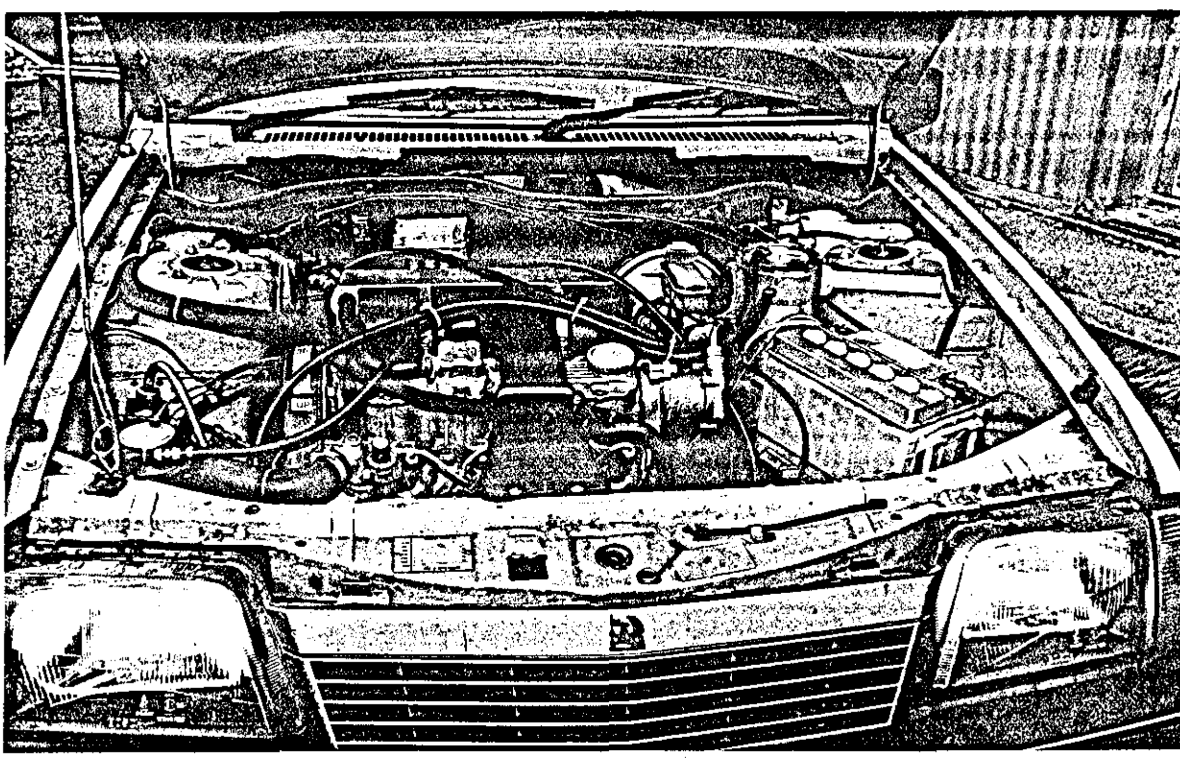


Plate No.4 - Under-bonnet view of 1600 diesel car.
Note position of fuel reservoir behind the battery.

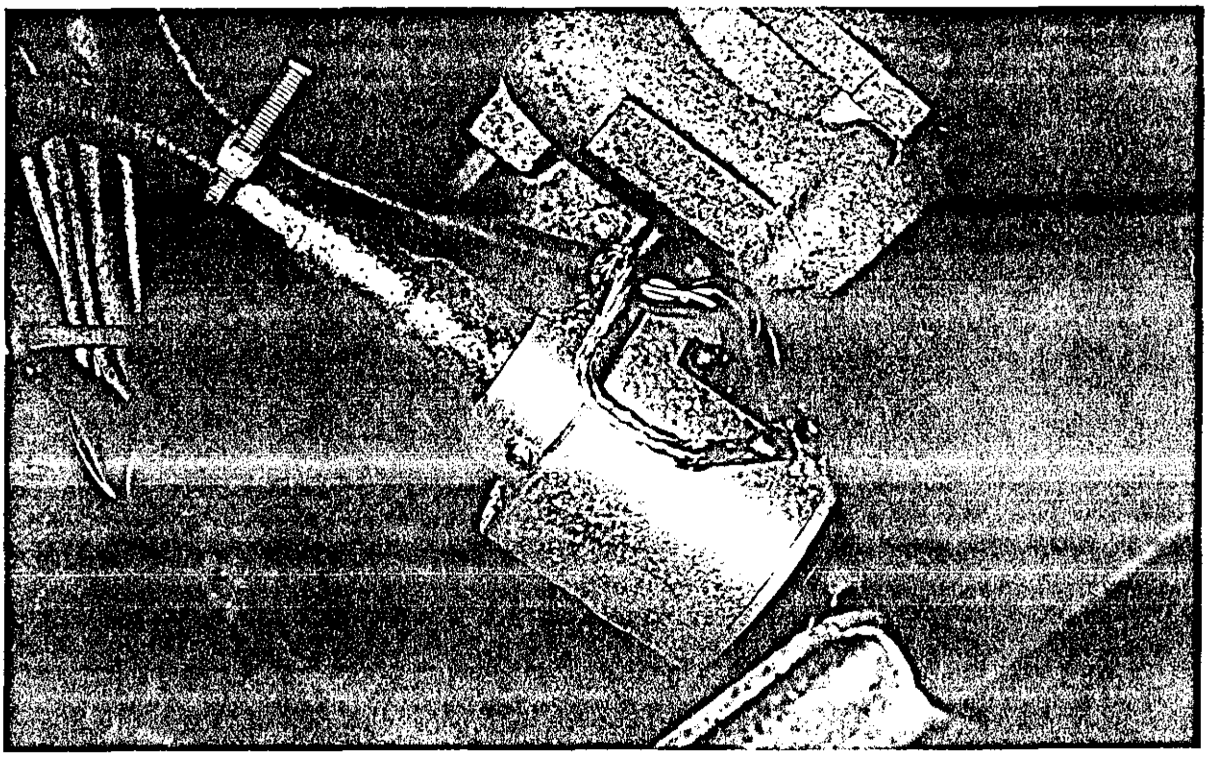


Plate No.5 - "Optoswitch" slotted disc transducer fitted in speedometer cable of each test vehicle for measurement of distanced travelled.

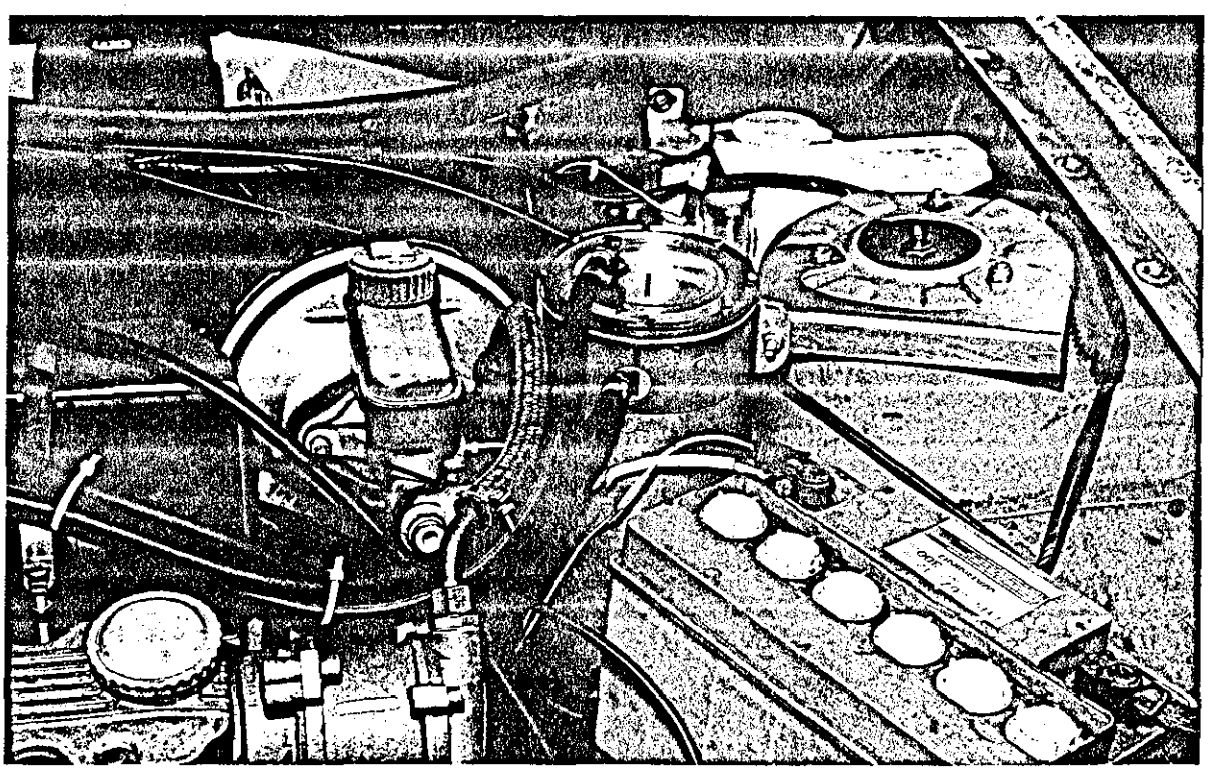


Plate No.6 - Diesel fuel supply reservoir used to achieve a measure of net fuel consumption.

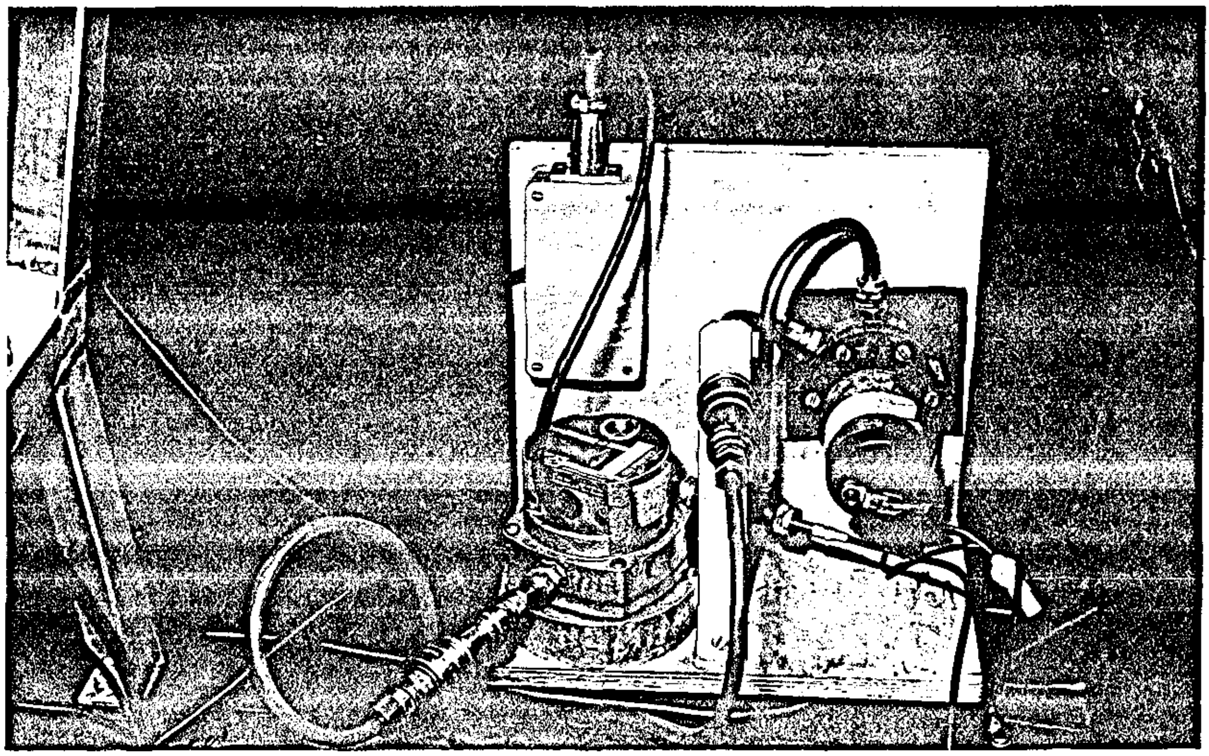


Plate No.7 - Layout of fuel pump, "Transflo" fuel flowmeter and fuel temperature transducer in the rear compartment of each petrol vehicle.

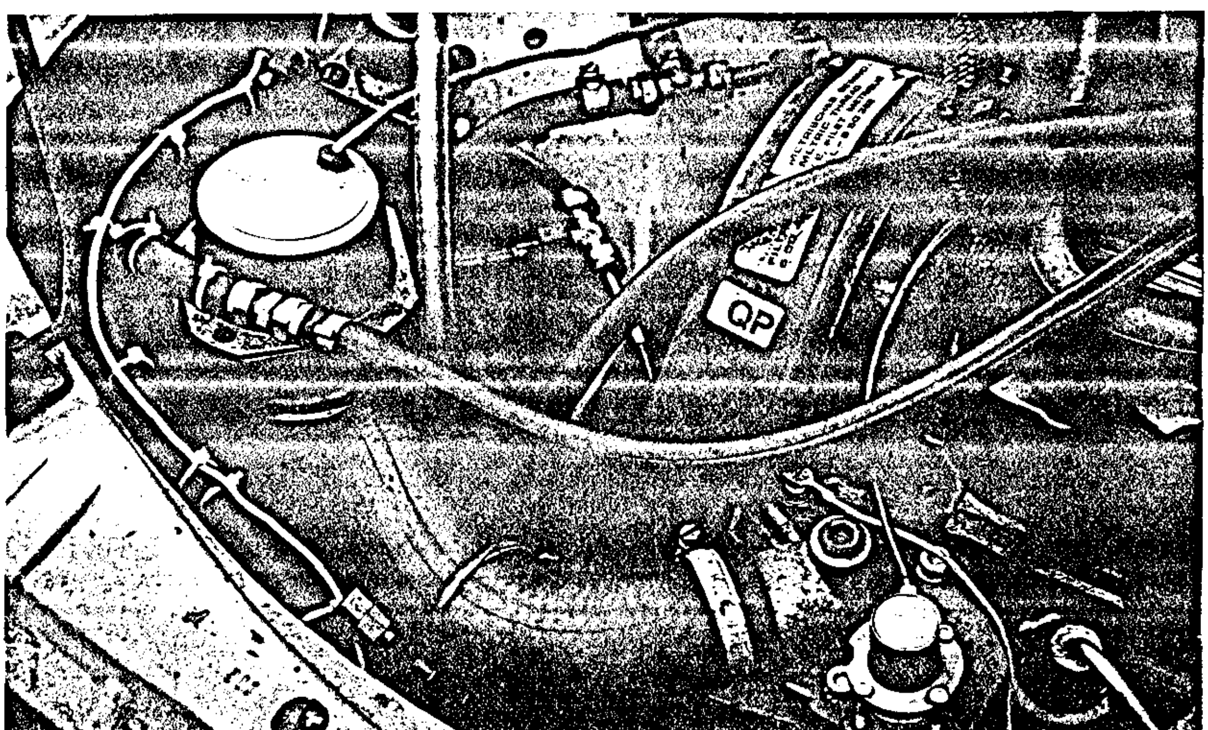


Plate No.8 - Location of "Transflo" fuel flowmeter and fuel temperature transducer (bottom right) in the engine compartment of the diesel vehicle.

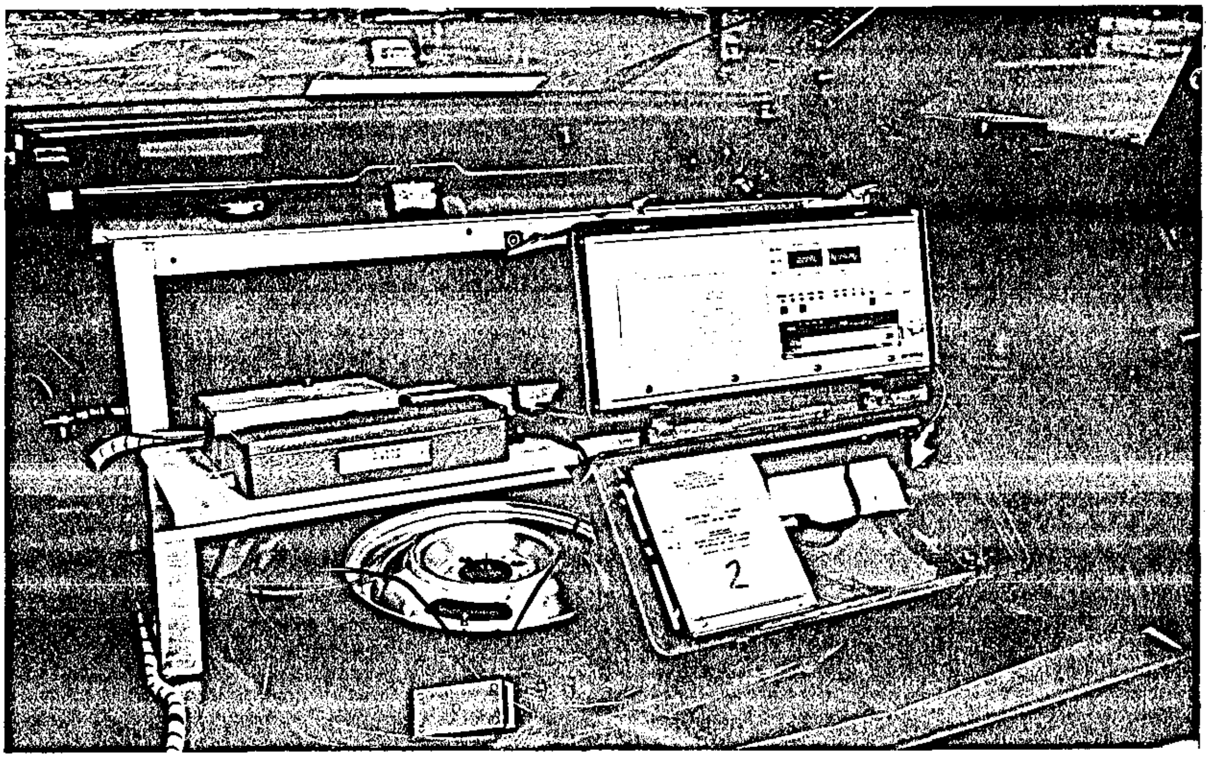


Plate No.9 - Front view of on-board data logger installed in the rear compartment of each vehicle (concealed from drivers during testing).

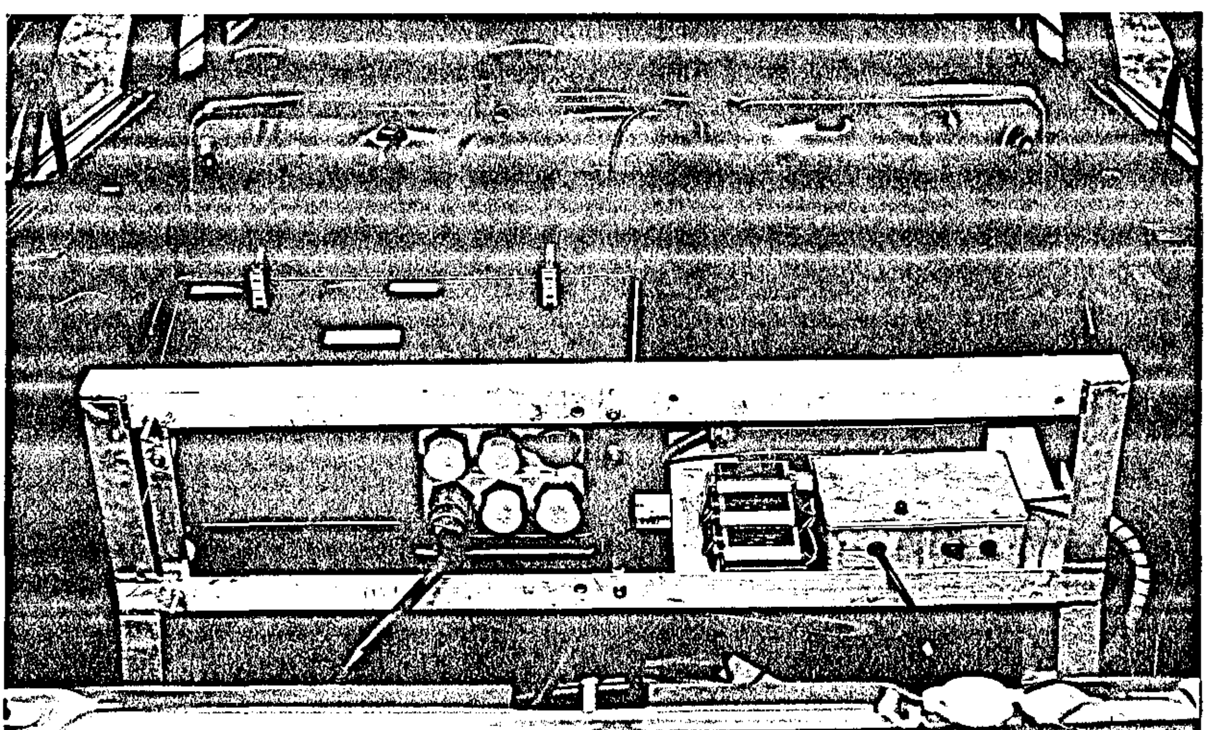


Plate No.10 - Rear view of on-board data logger showing position of "d.c. to d.c." convertors and concealment of logger behind passenger seat.

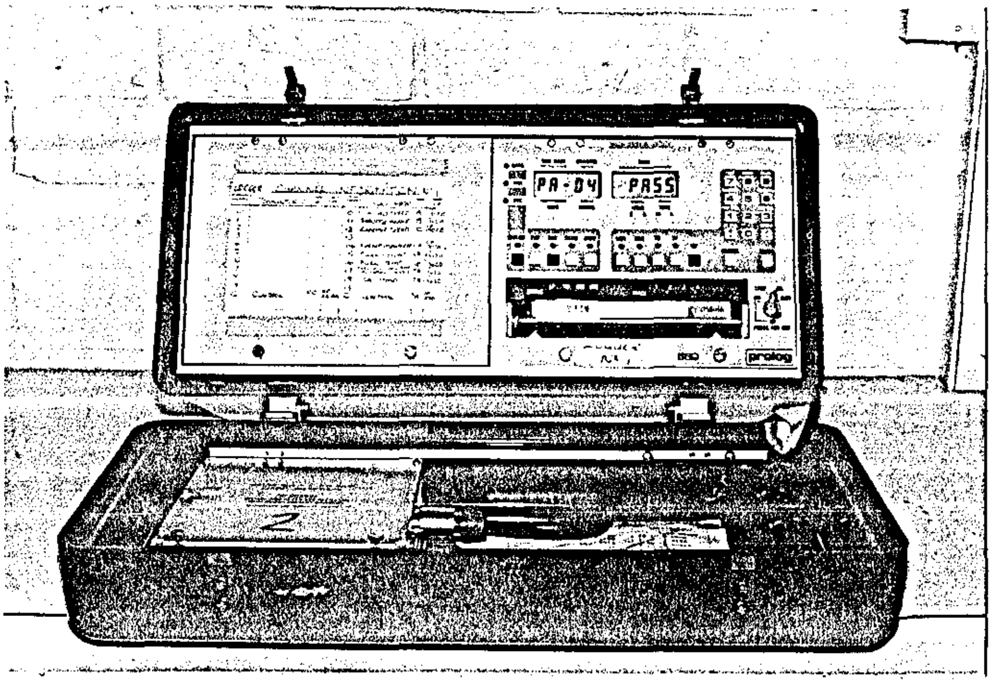


Plate No.11 - MICRODATA M1680 data logger.
(Prolog portable model)

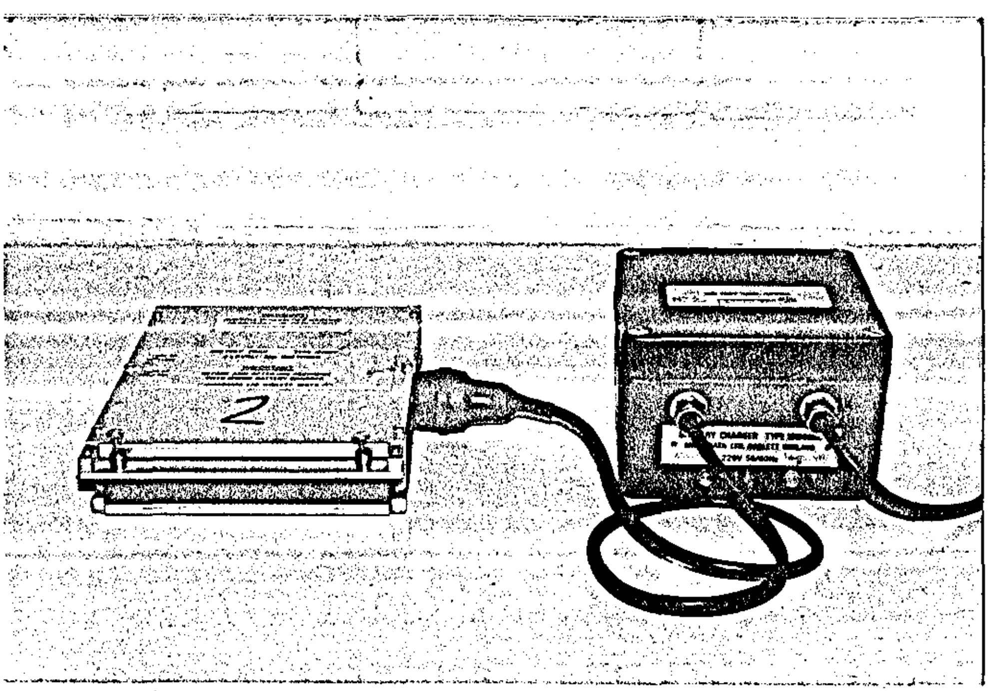


Plate No.12 - Rechargeable lead acid battery ±6V.
& 3Ah. sealed (shown with laboratory charger unit).

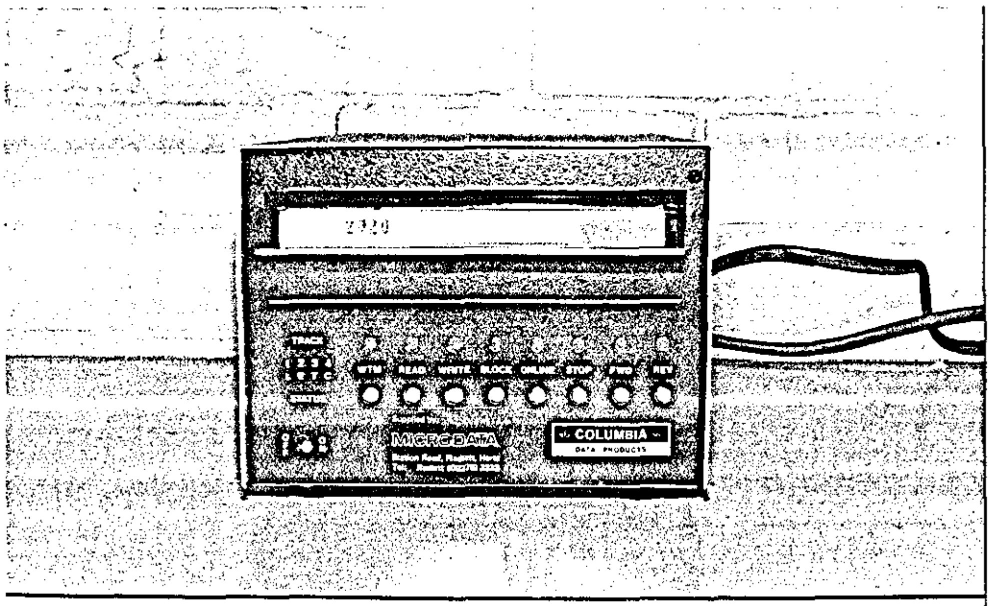


Plate No.13 - COLUMBIA data cartridge recorder.
Used to "down-load" test data from $\frac{1}{4}$-inch tape
to a main-frame computer file.

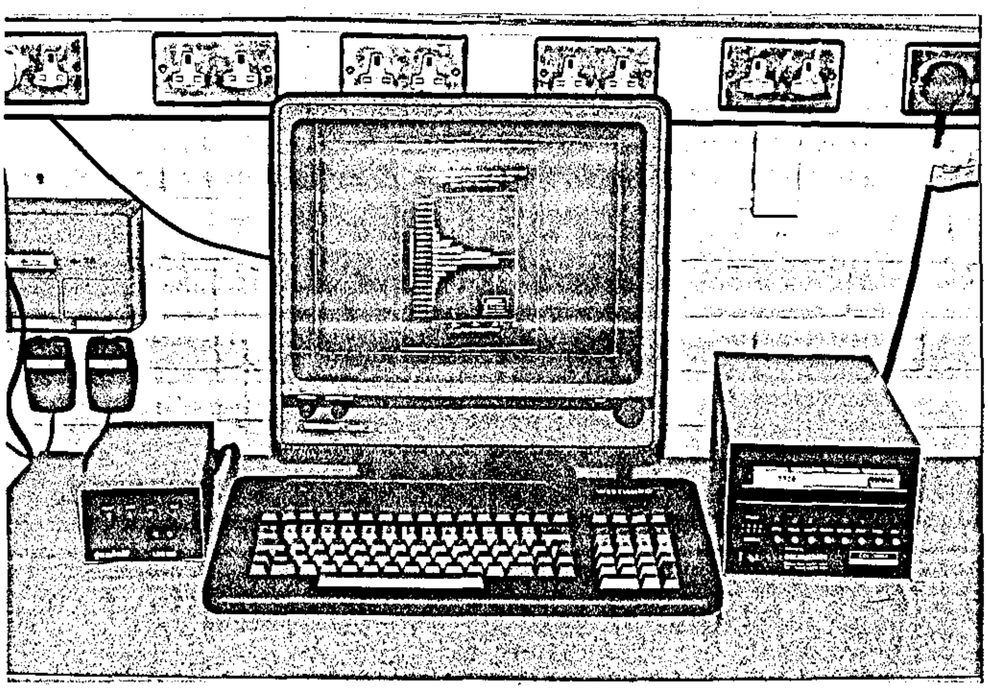


Plate No.14 - V.D.U. terminal for communication to
and from main-frame computer system.
(gandalf LDS125 to left; COLUMBIA recorder to right)

FIGURES

Index to Figures.

Figure No.1

PETROLEUM CONSUMPTION IN THE UNITED KINGDOM BY THE TRANSPORT SECTOR

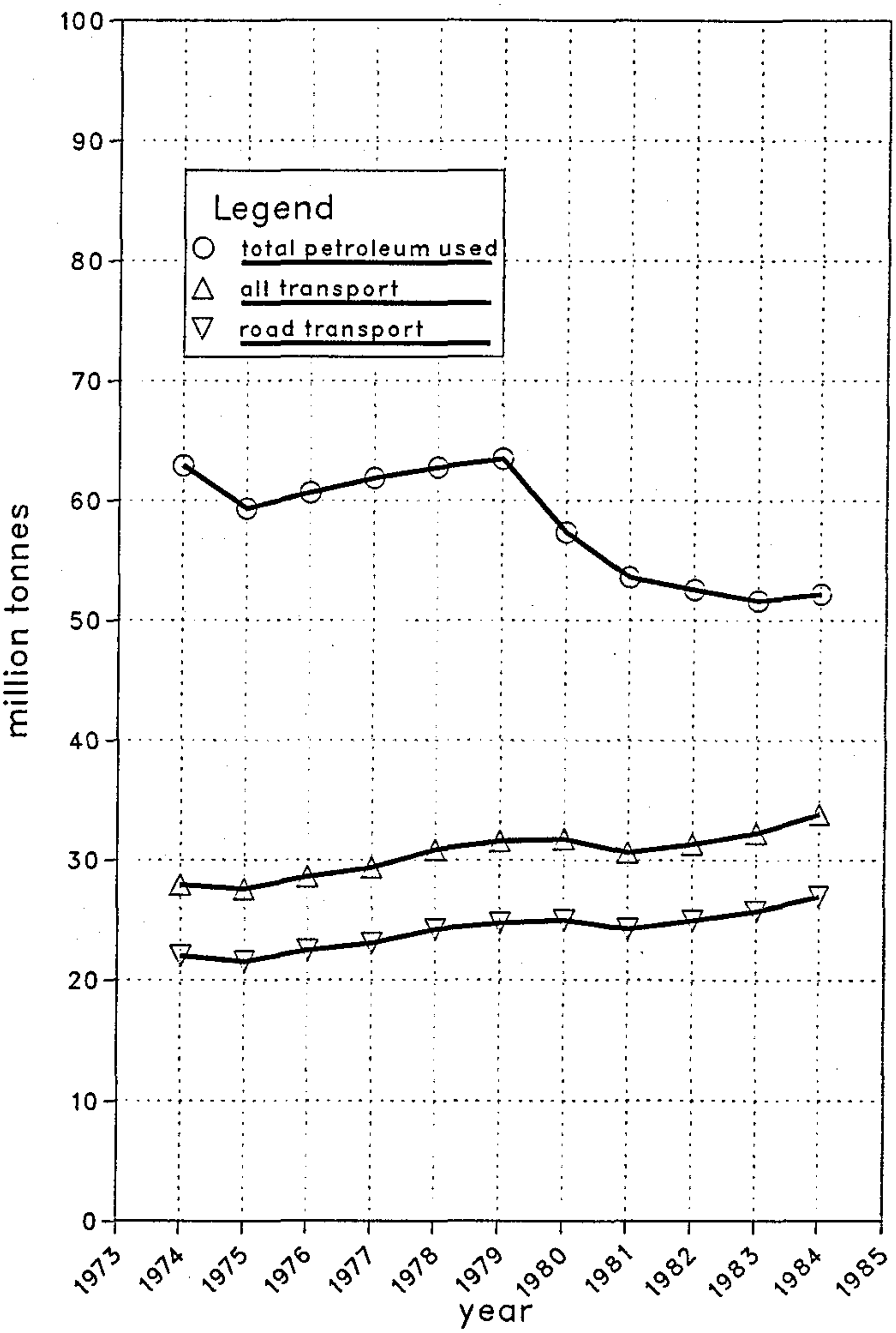
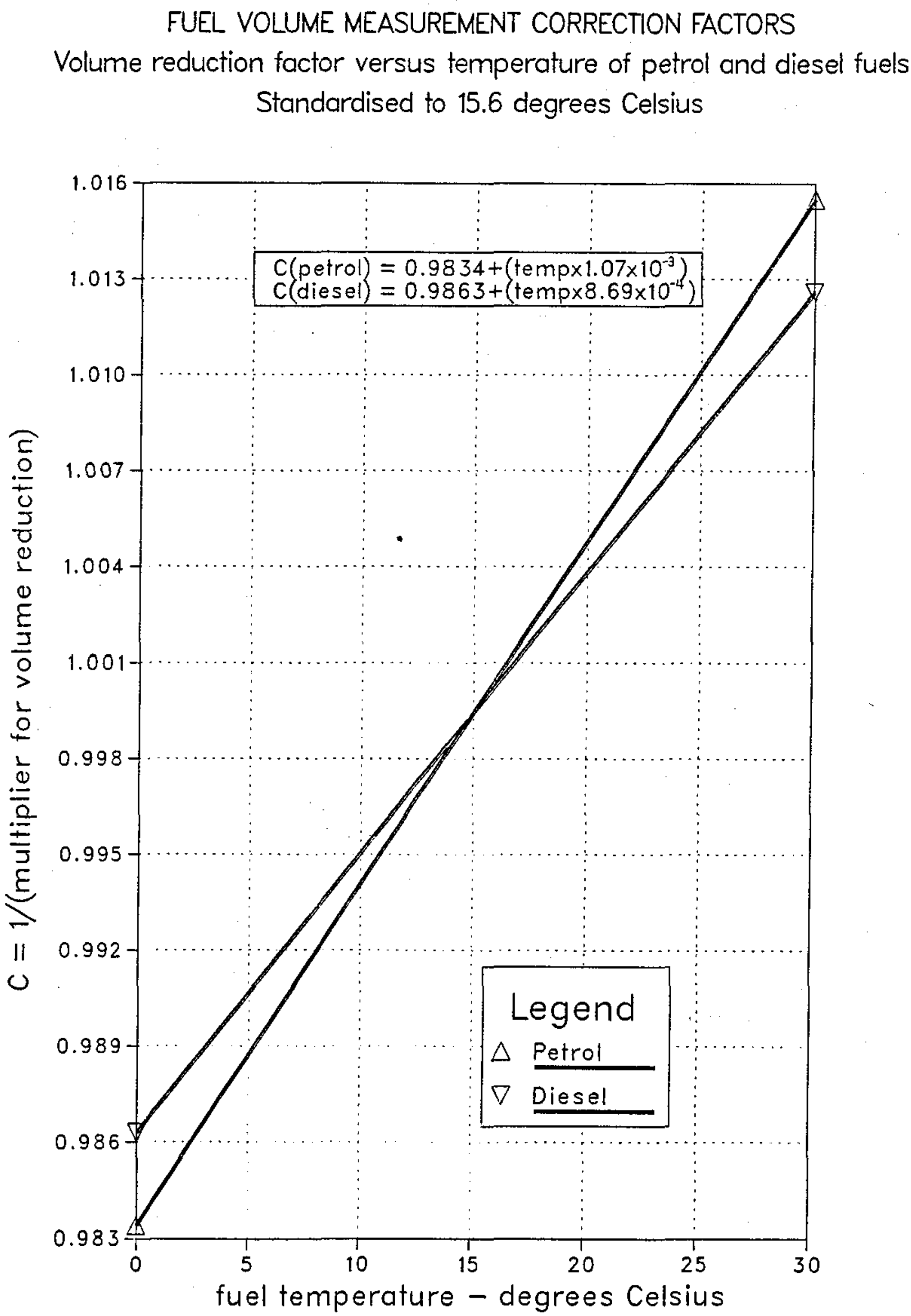


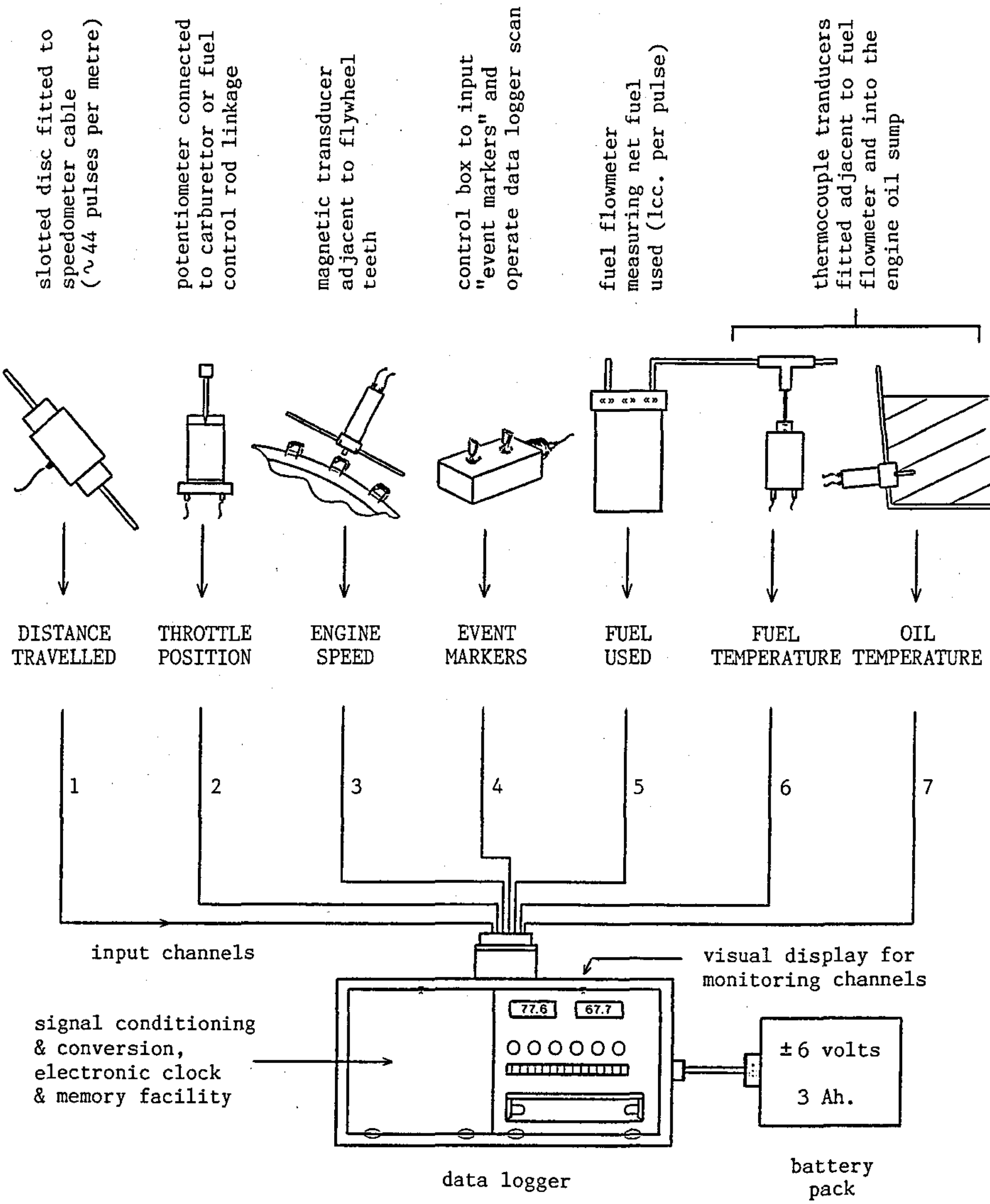
Figure No.2



FUEL VOLUME MEASUREMENT CORRECTION FACTORS
Volume reduction factor versus temperature of petrol and diesel fuels
Standardised to 15.6 degrees Celsius
C(petrol) = 0.9834+(tempx1.07x10^-3)
C(diesel) = 0.9863+(tempx8.69x10^-4)
C = 1/(multiplier for volume reduction)
1.016
1.013
1.010
1.007
1.004
1.001
0.998
0.995
0.992
0.989
0.986
0.983
0
5
10
15
20
25
30
fuel temperature - degrees Celsius
Legend
Petrol
Diesel

Figure No.3

Vehicle instrumentation system using an on-board MICRODATA M1680 Data Logger.



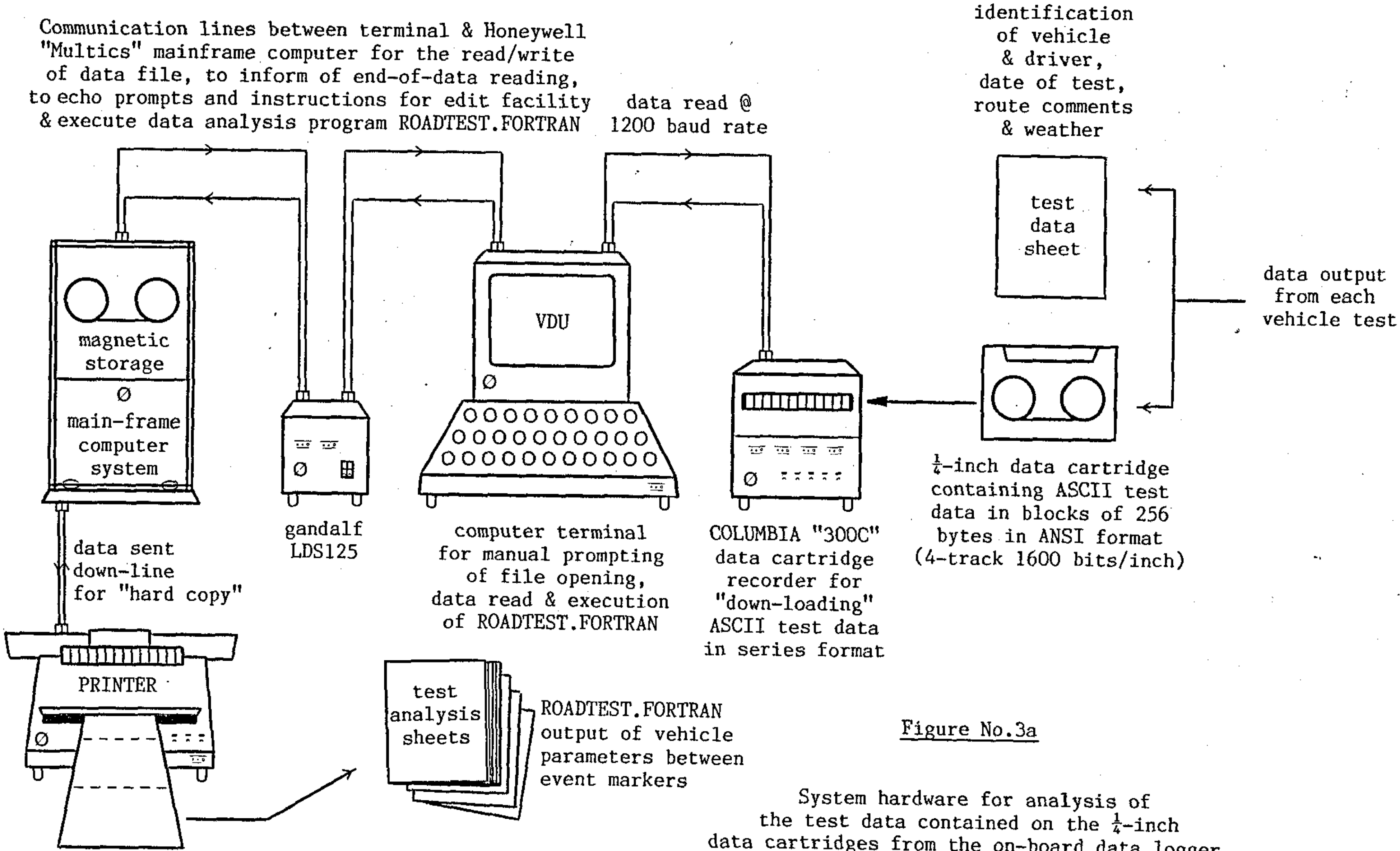


Figure No.3a

System hardware for analysis of the test data contained on the ¼-inch data cartridges from the on-board data logger.

Figure No.4

Fuel supply and monitoring system for
the 1300cc and 1600cc Vauxhall Cavalier cars.

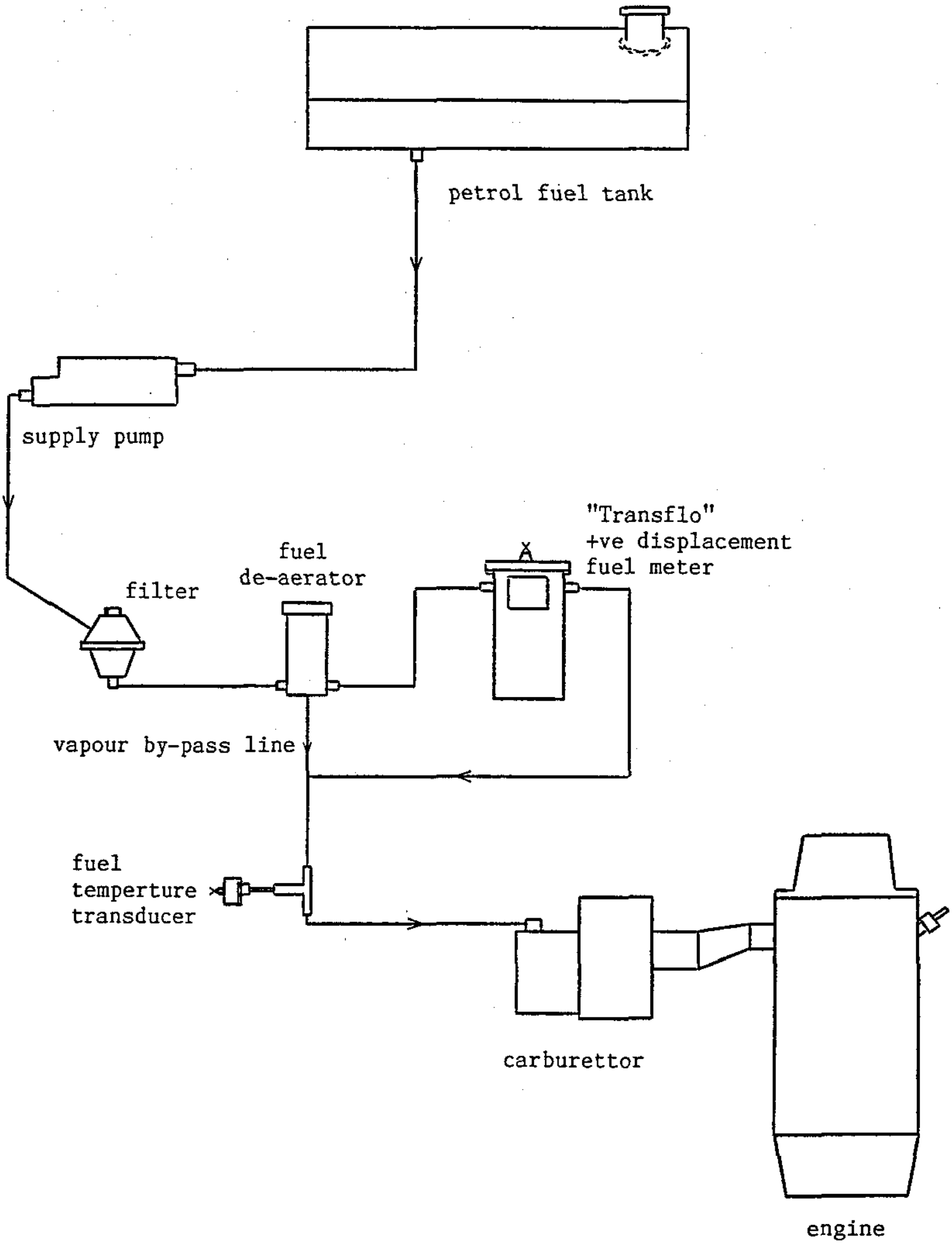


Figure No.5

Fuel supply and monitoring system for
the 1600cc diesel Vauxhall Cavalier car.

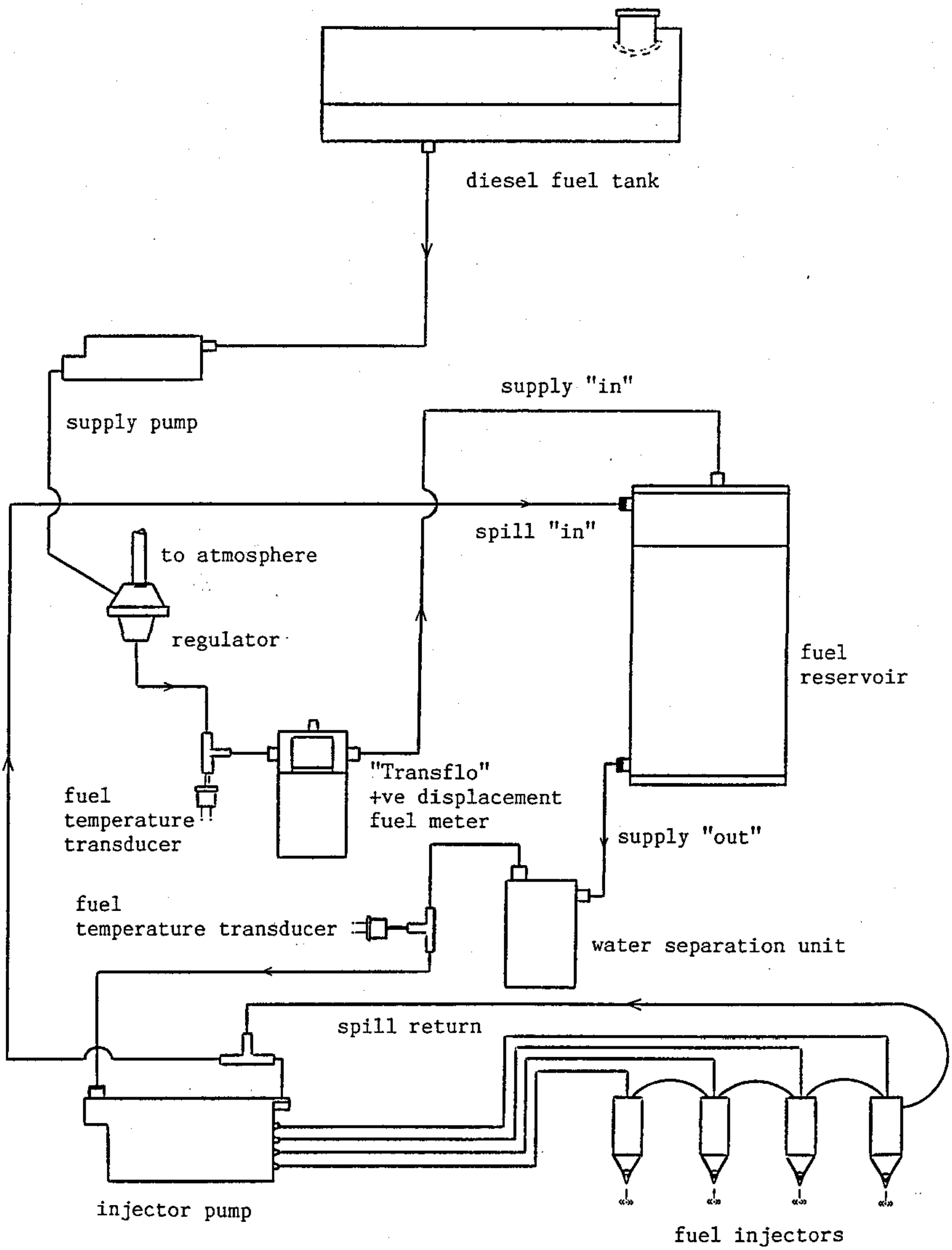


Figure No.6

The Leicestershire test route.

(showing built-up areas and direction of travel)

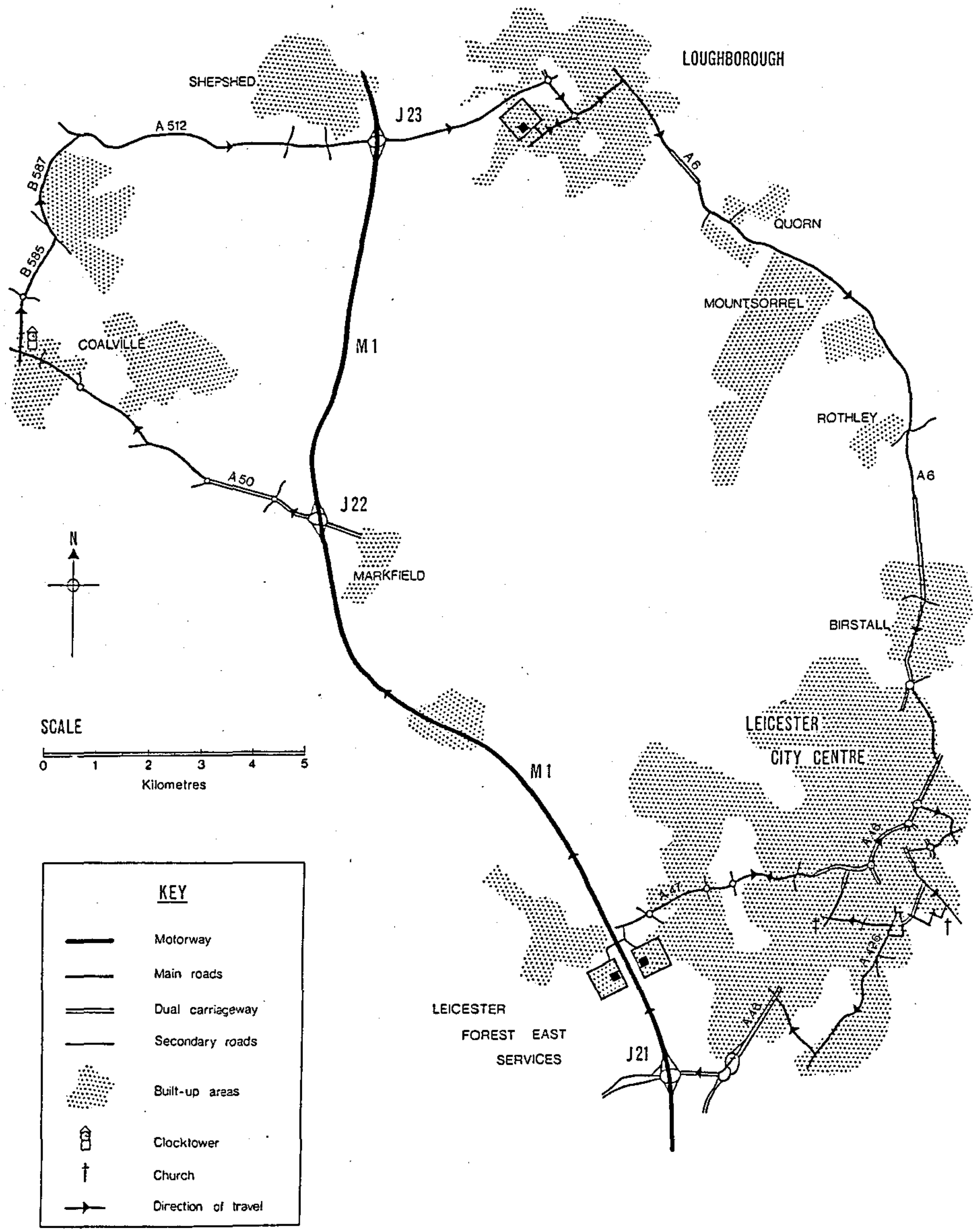


Figure No.7

The Leicestershire test route.

(showing local speed limits and height of road)

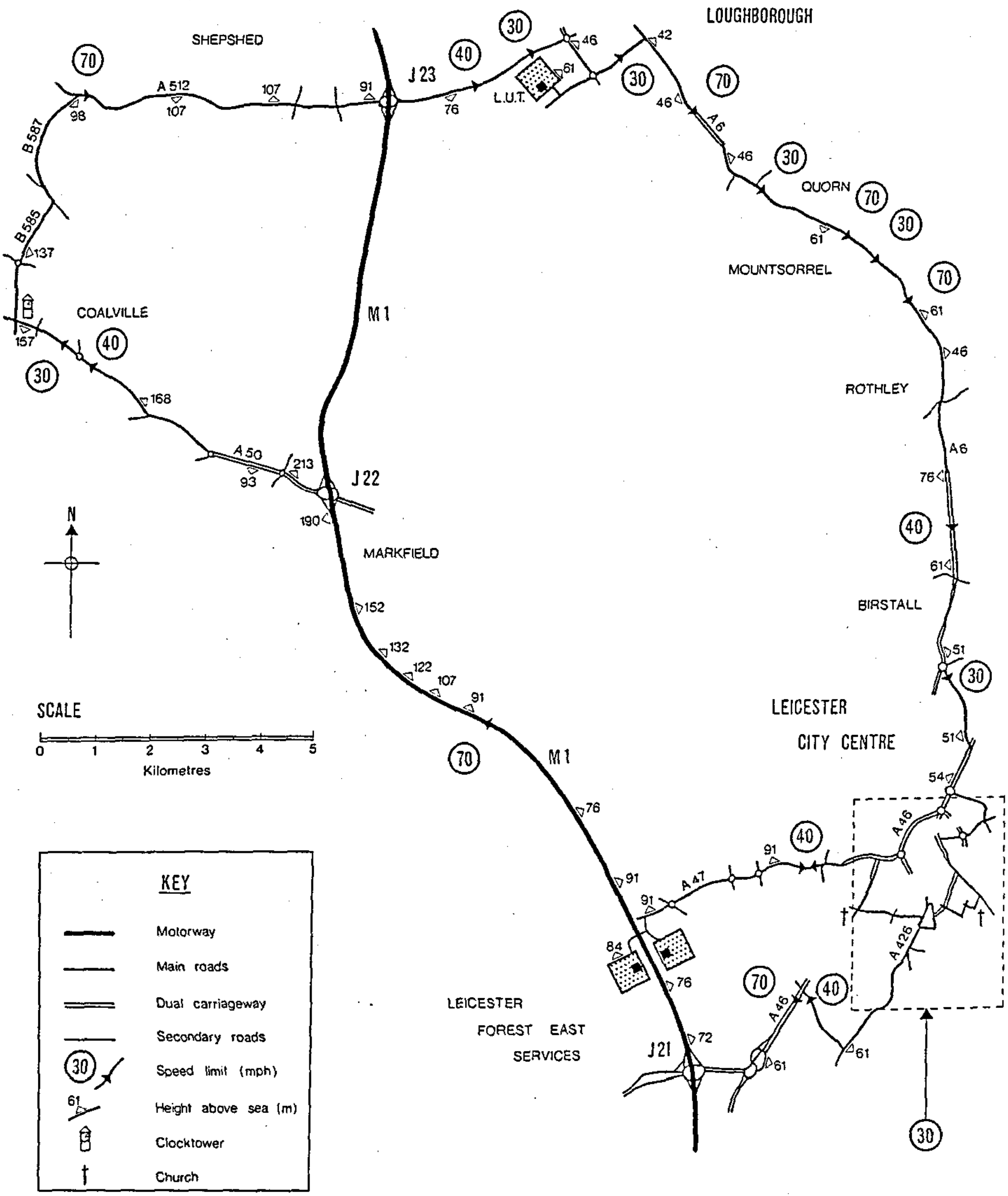


Figure No.8

The Leicestershire test route.

(showing event marker numbers)

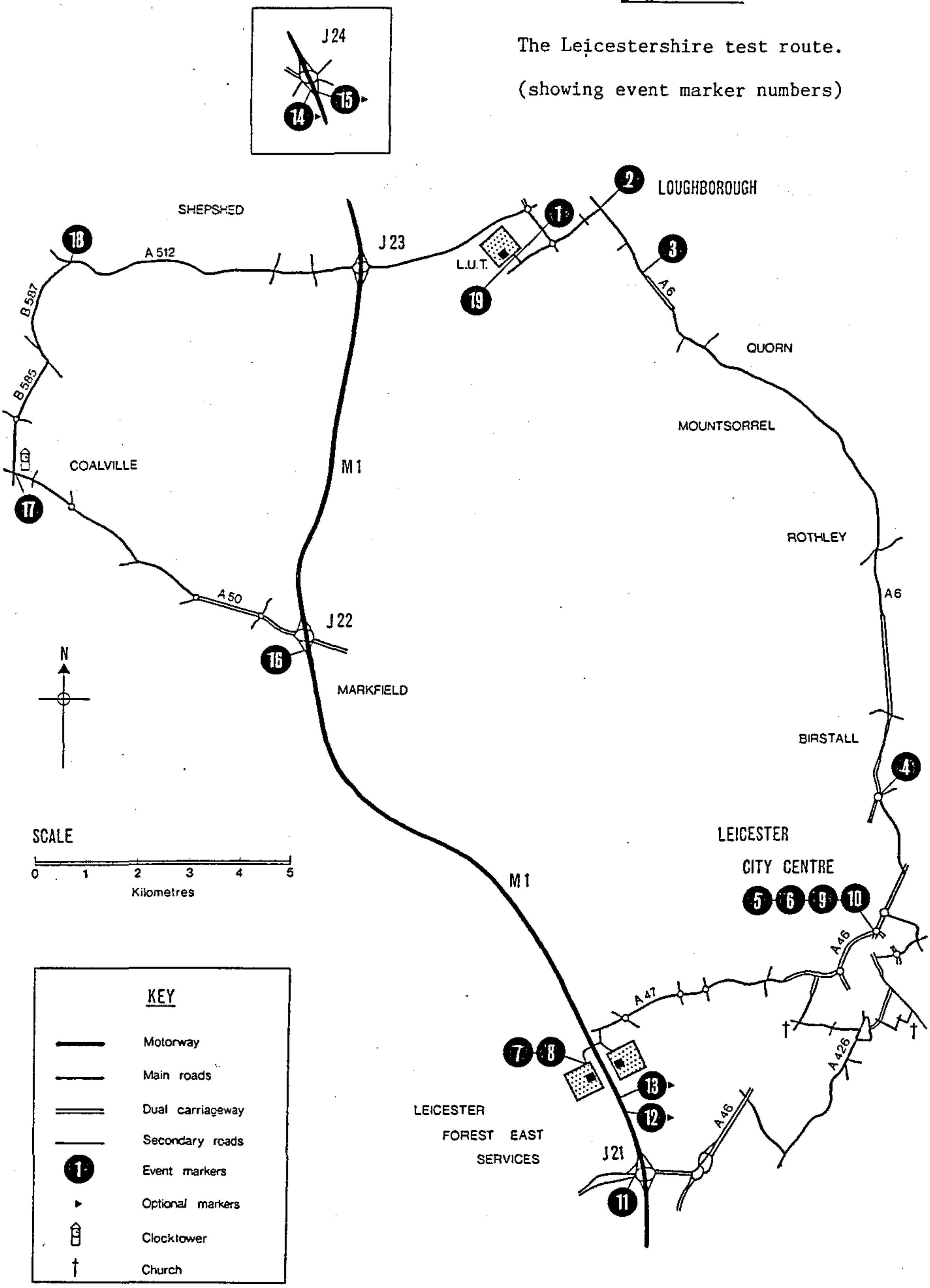


Figure No.9

The Urban Cycle.

(showing event marker numbers)

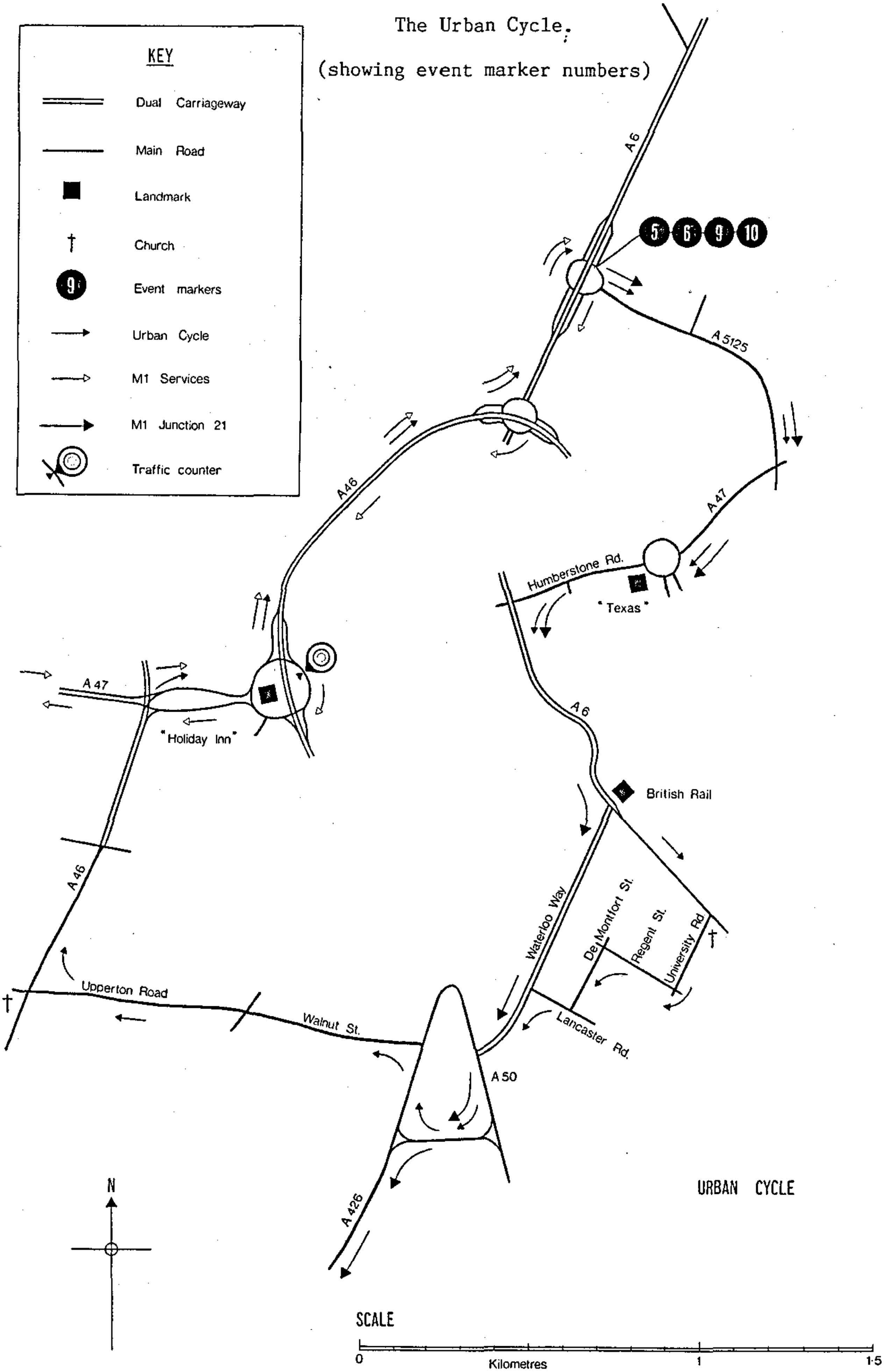


Figure No.9a

The Leicestershire test route.

(showing photograph locations)

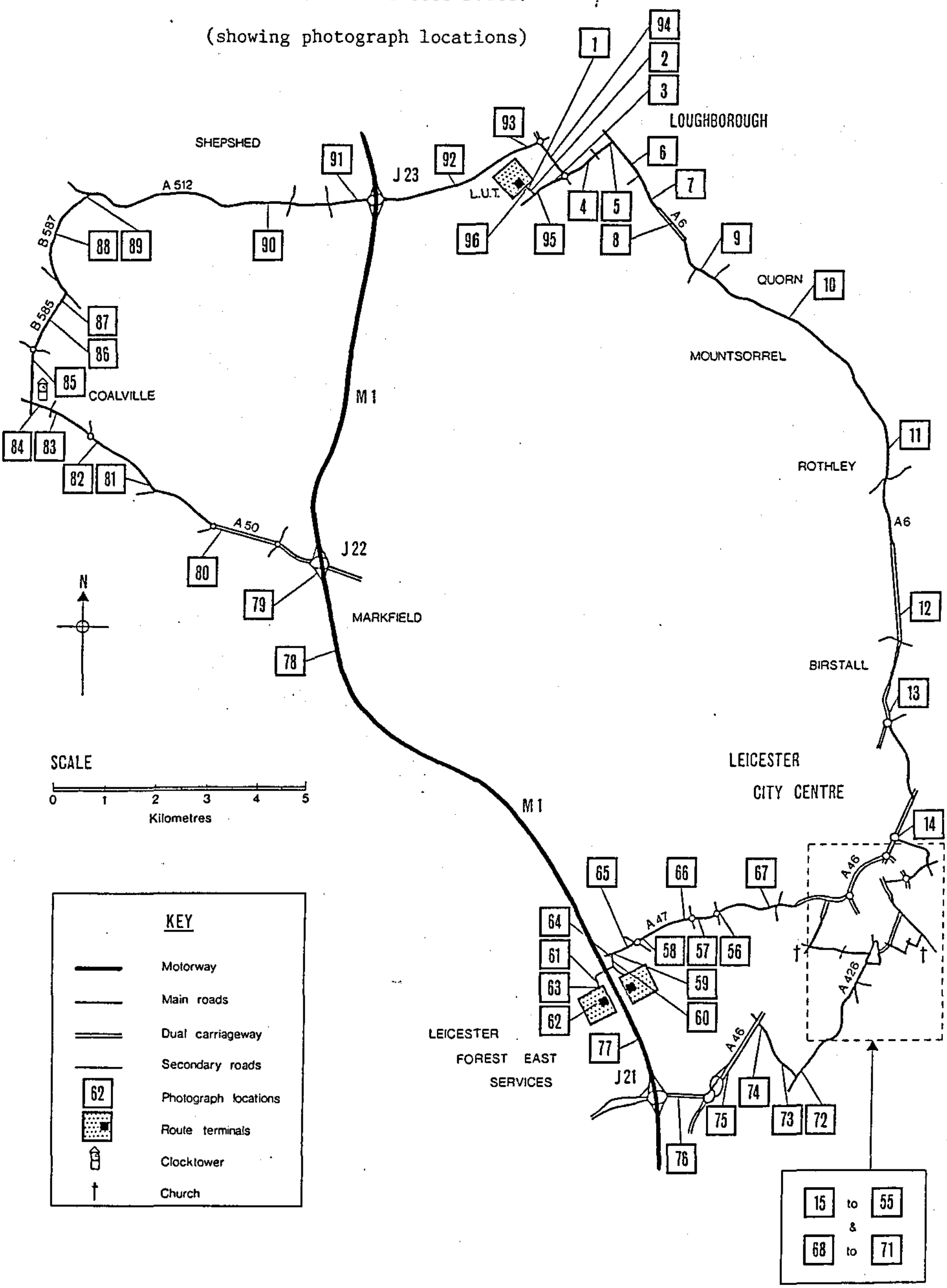


Figure No.9b

The Urban Cycle.

(photograph locations)

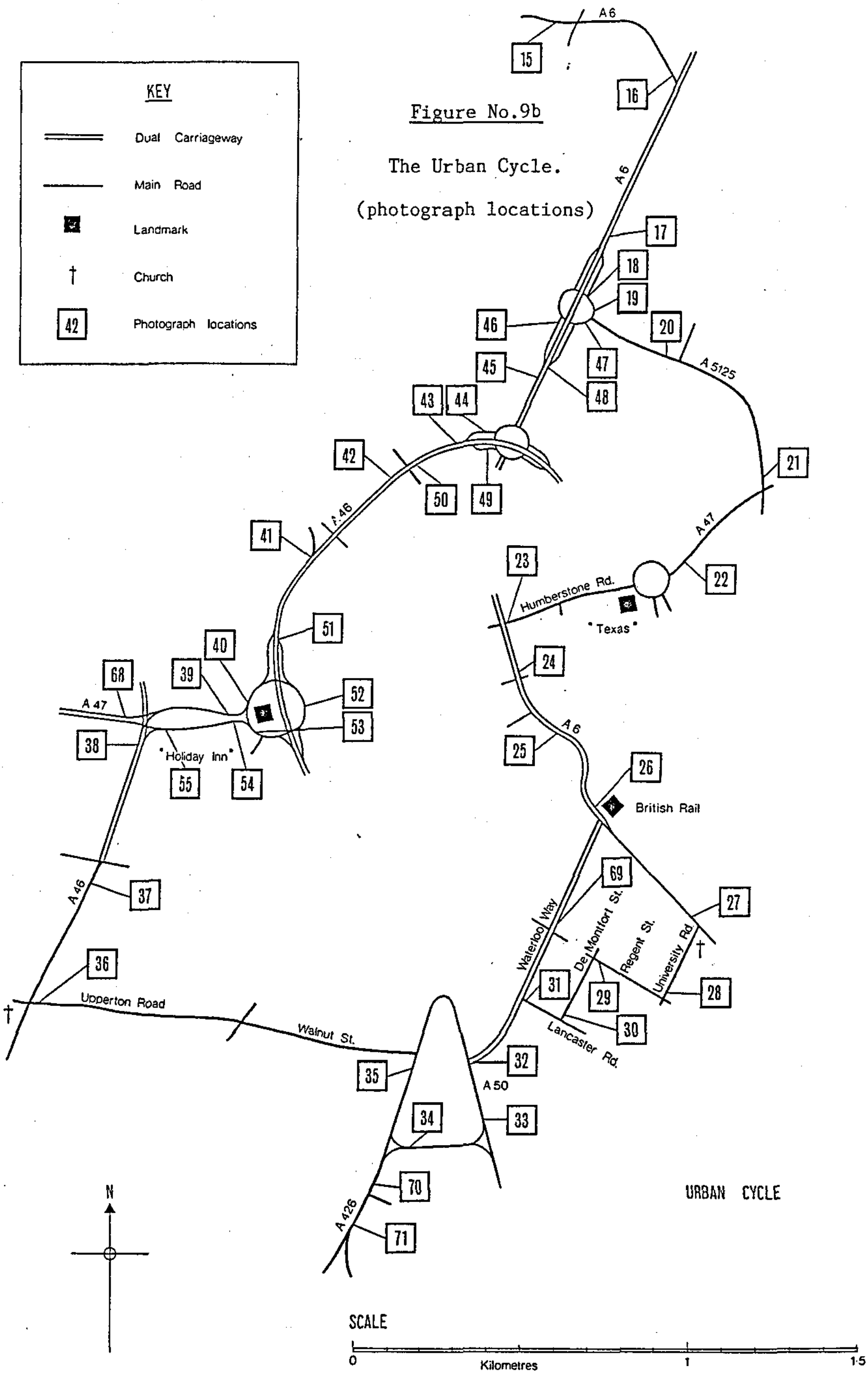


Figure No.10

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Average fuel consumption with standard error for each vehicle and route section
Driver Nos. 1 to 6

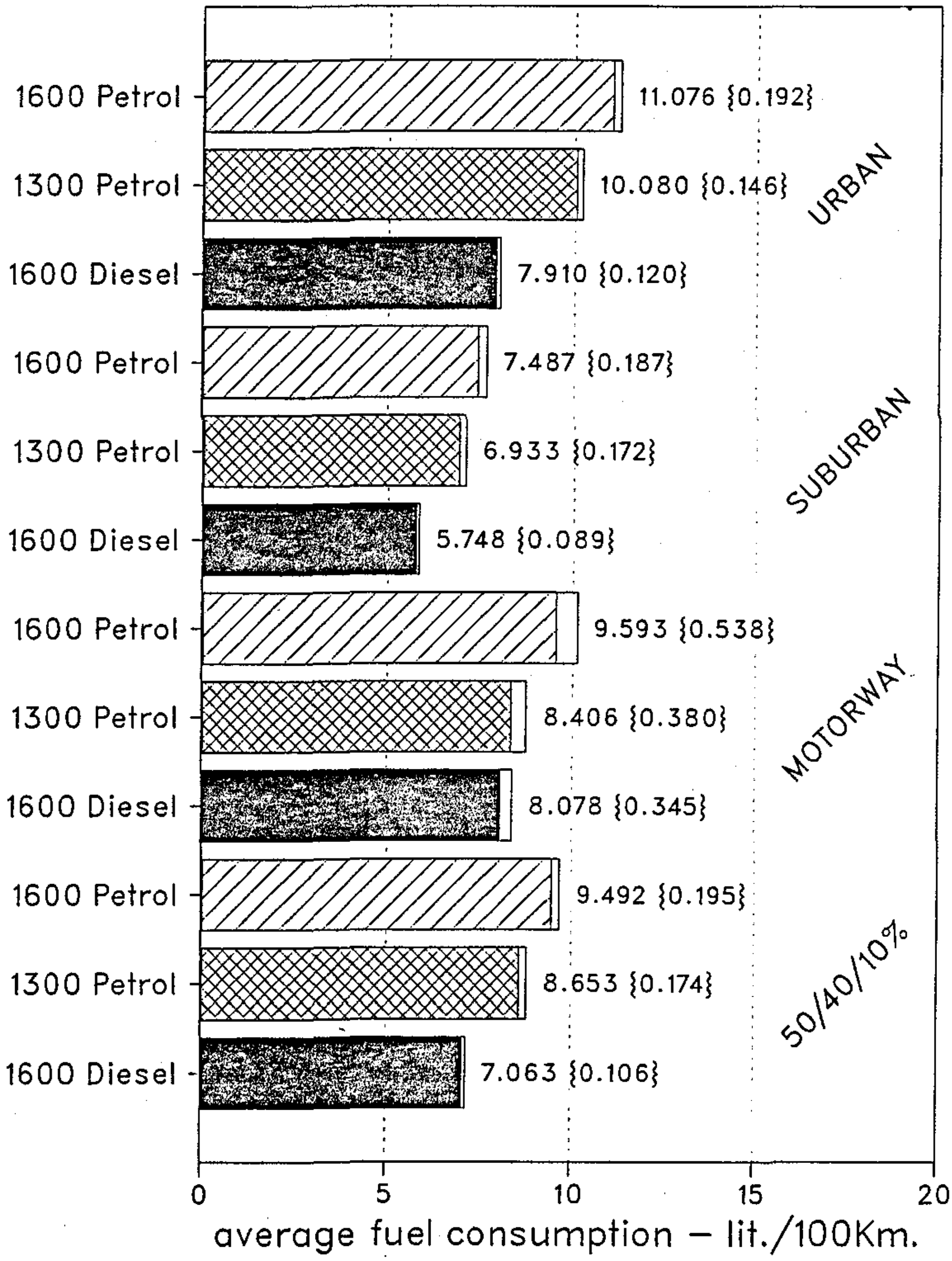


Figure No.11

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Average speed with standard error for each vehicle and route section
Driver Nos. 1 to 6

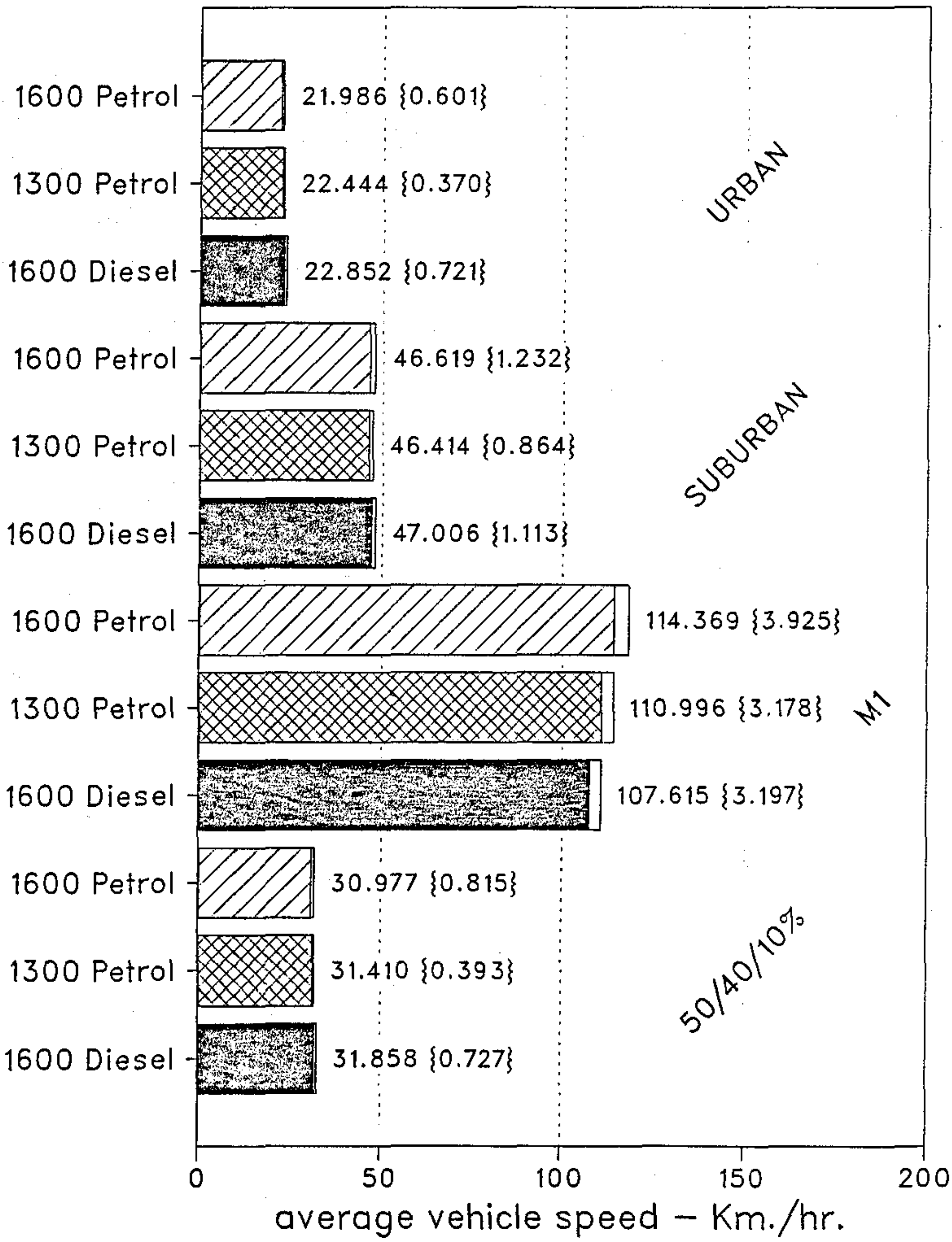


Figure No.12

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985.
Average fuel consumption for each driver – all vehicles

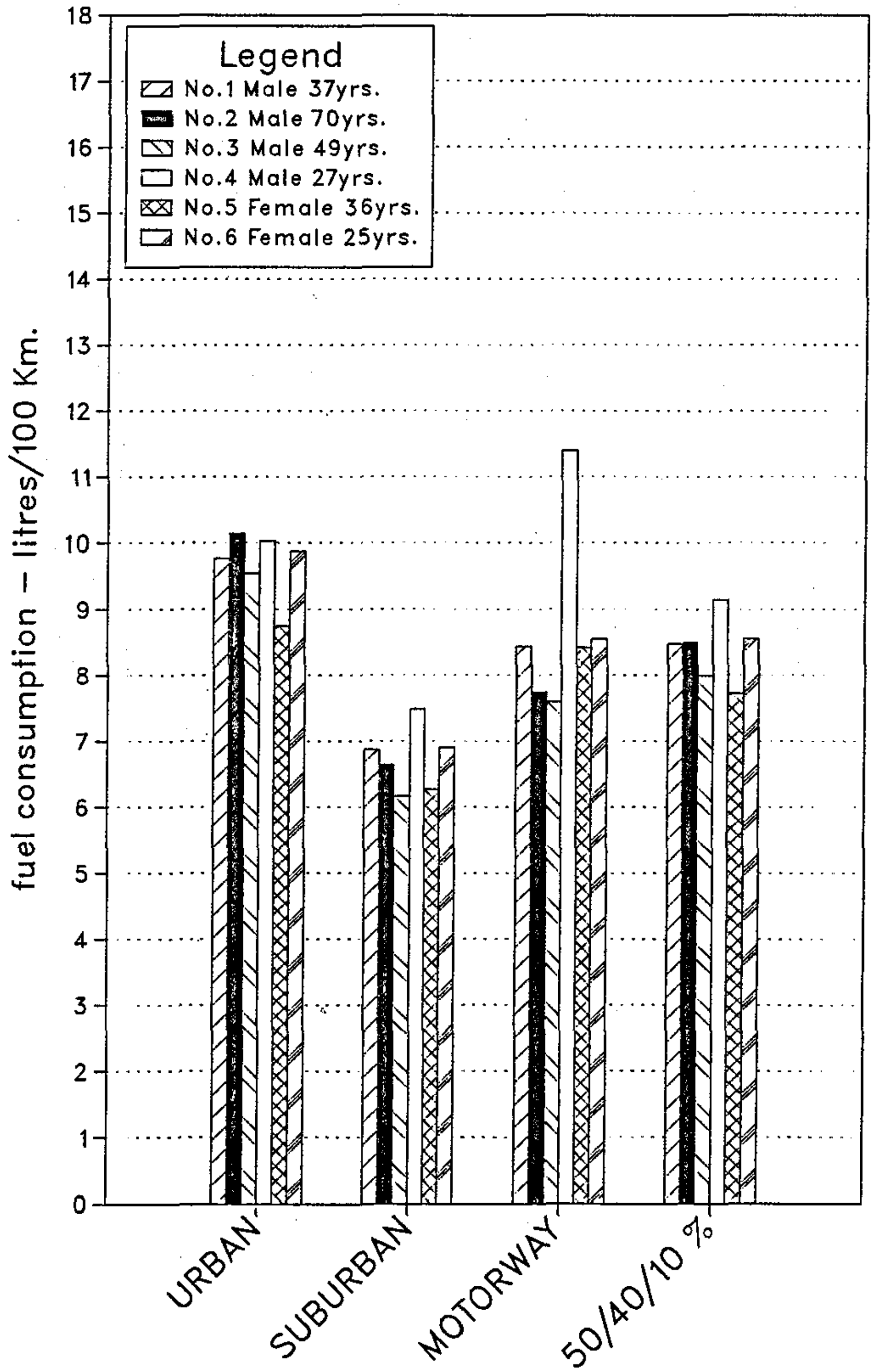


Figure No.13

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Average vehicle speed for each driver – all vehicles

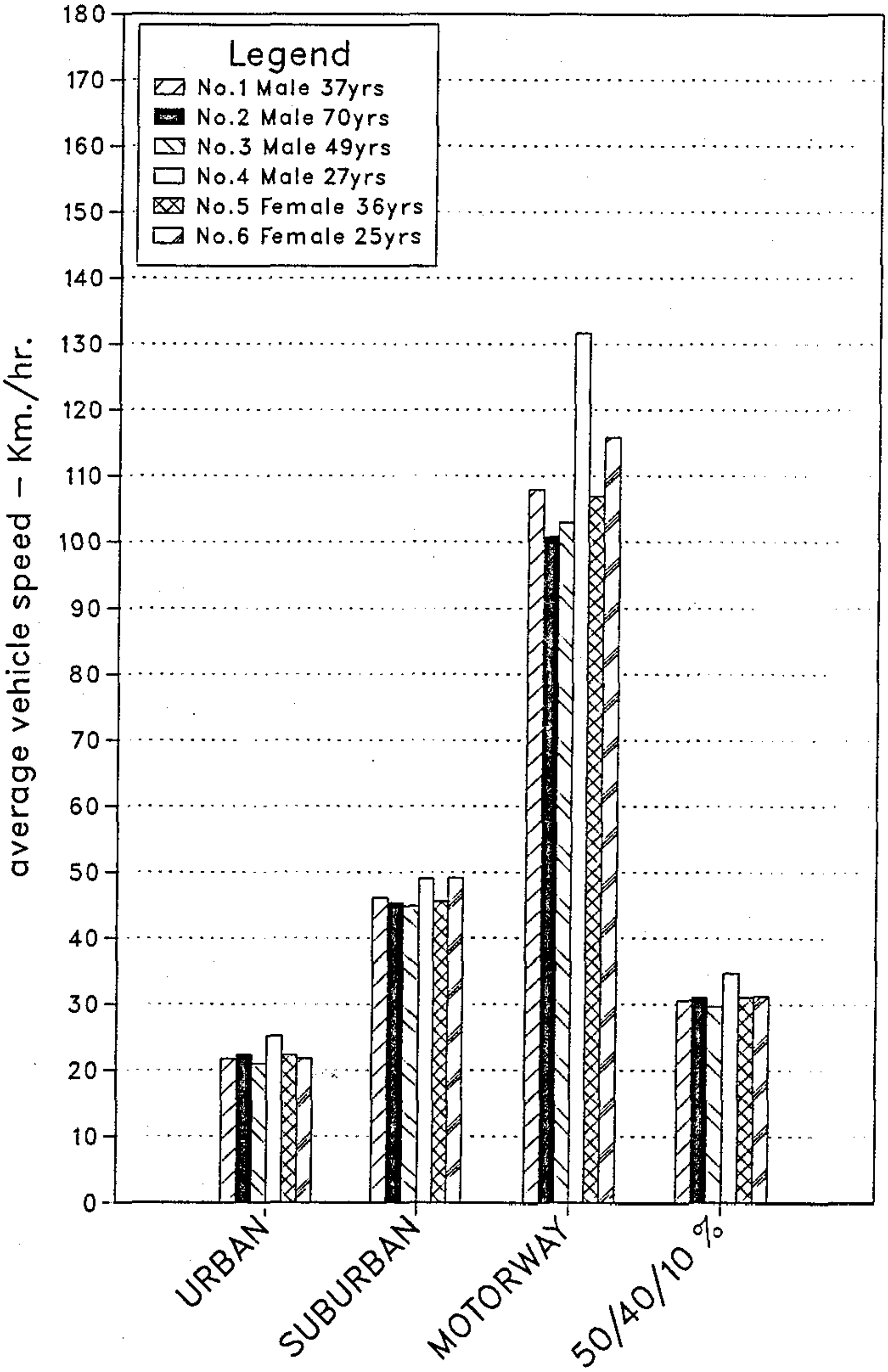


Figure No.14

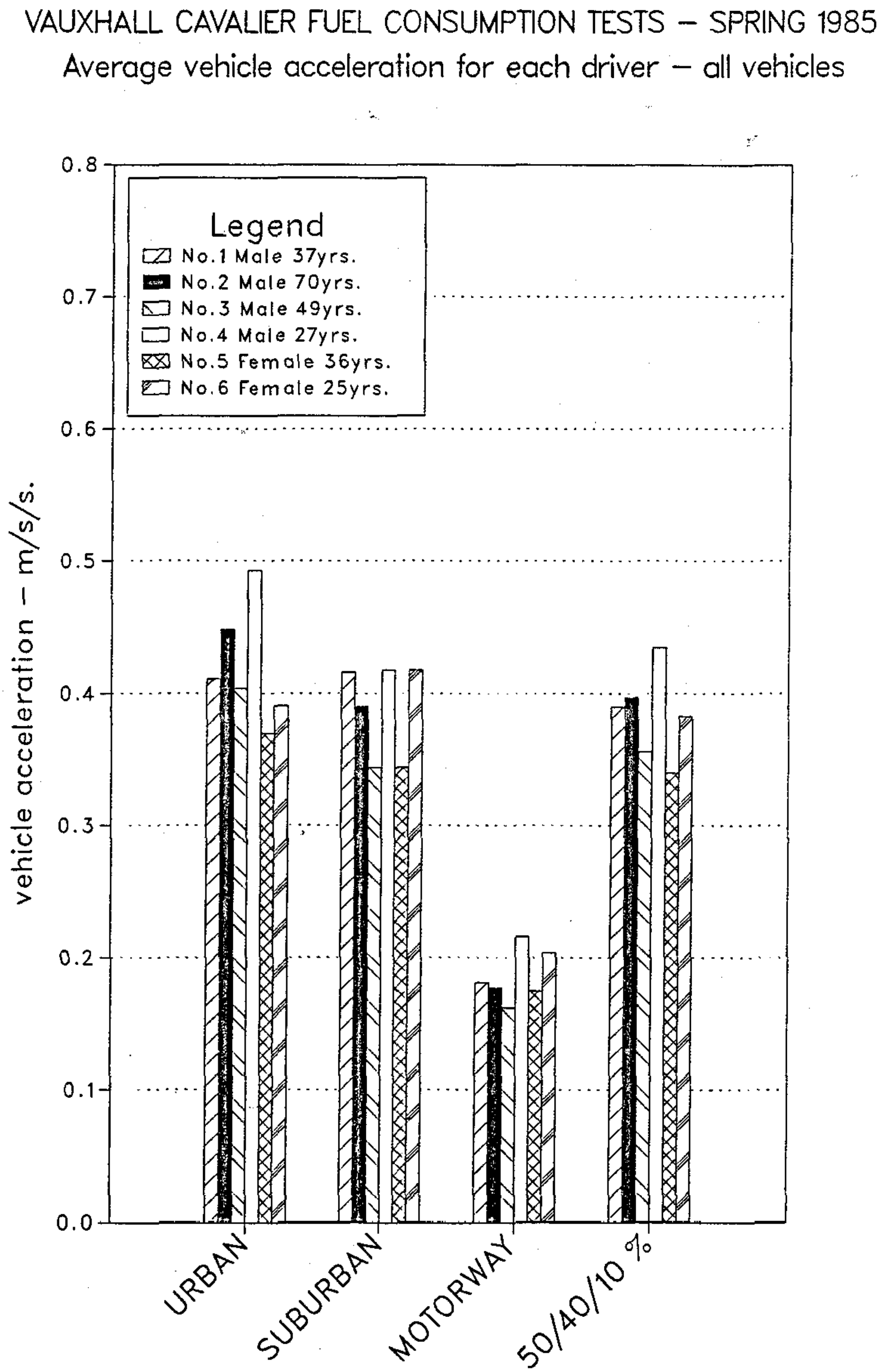

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985.
Average vehicle acceleration for each driver – all vehicles
Legend
No.1 Male 37yrs.
No.2 Male 70yrs.
No.3 Male 49yrs.
No.4 Male 27yrs.
No.5 Female 36yrs.
No.6 Female 25yrs.
vehicle acceleration – m/s/s.
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
URBAN
SUBURBAN
MOTORWAY
50/40/10 %

Figure No.15

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985.
Average vehicle deceleration for each driver – all vehicles

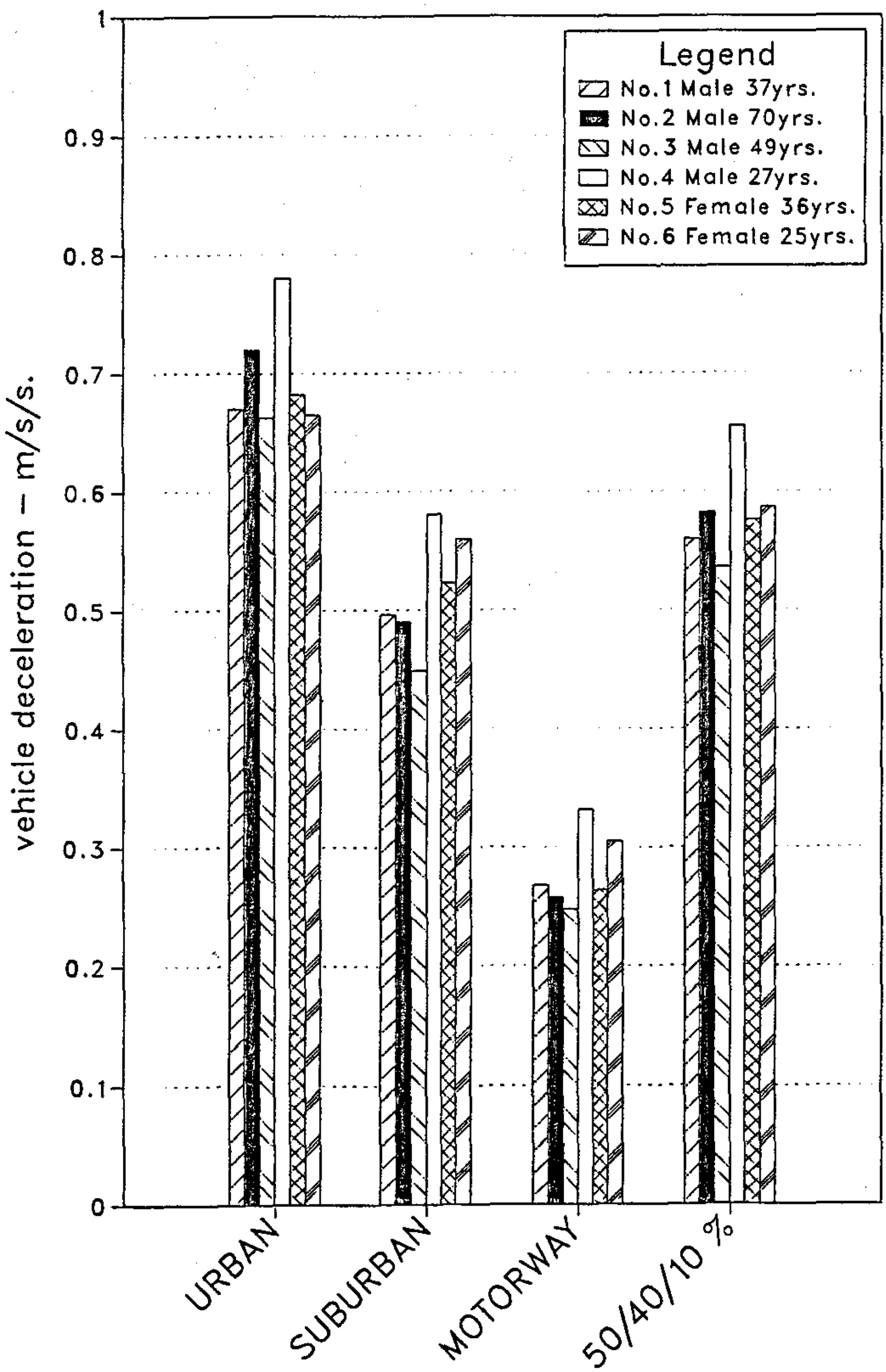


Figure No.16

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985.
Average throttle position for each driver – all vehicles

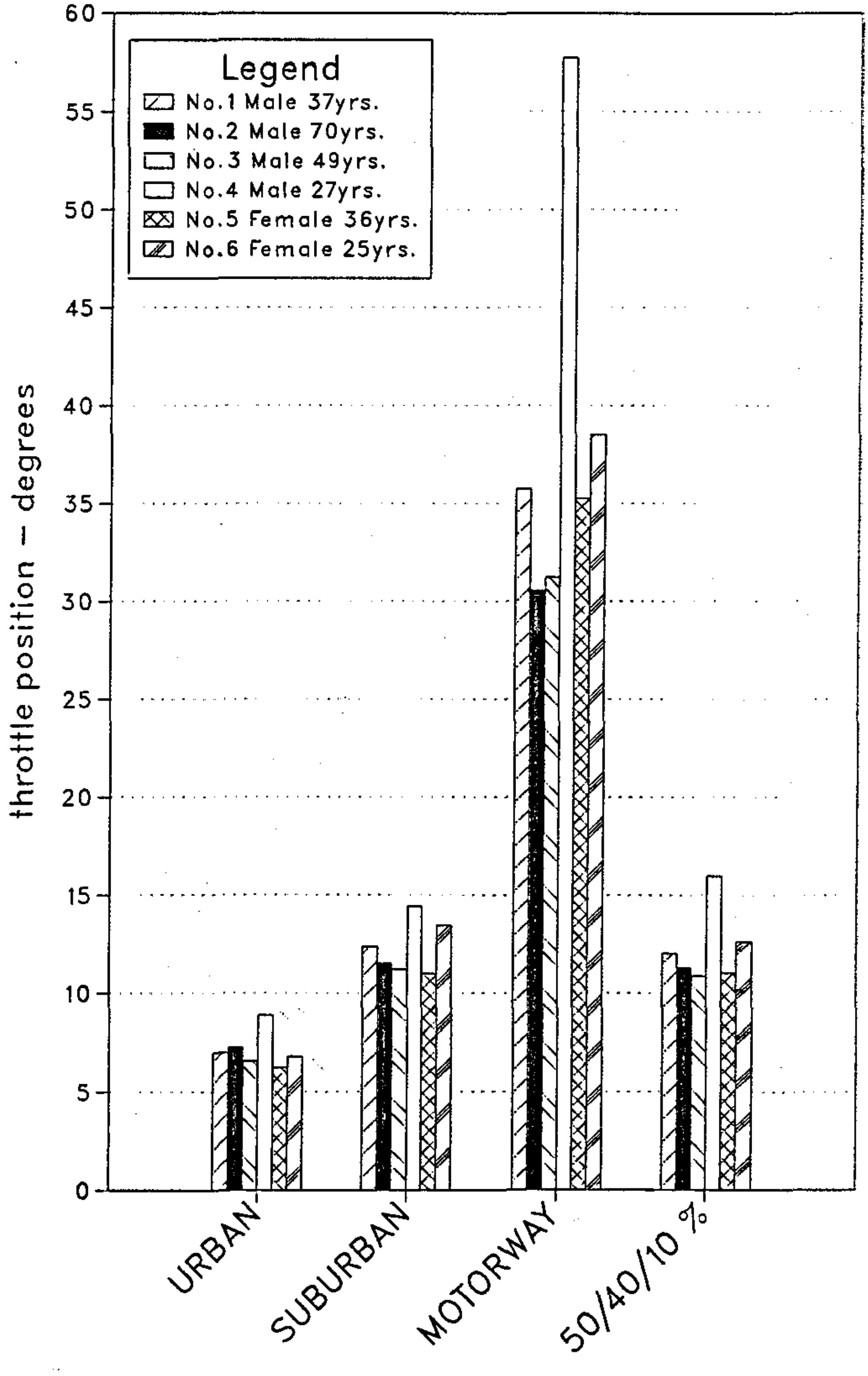


Figure No.17

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985.
Average throttle acceleration for each driver – all vehicles

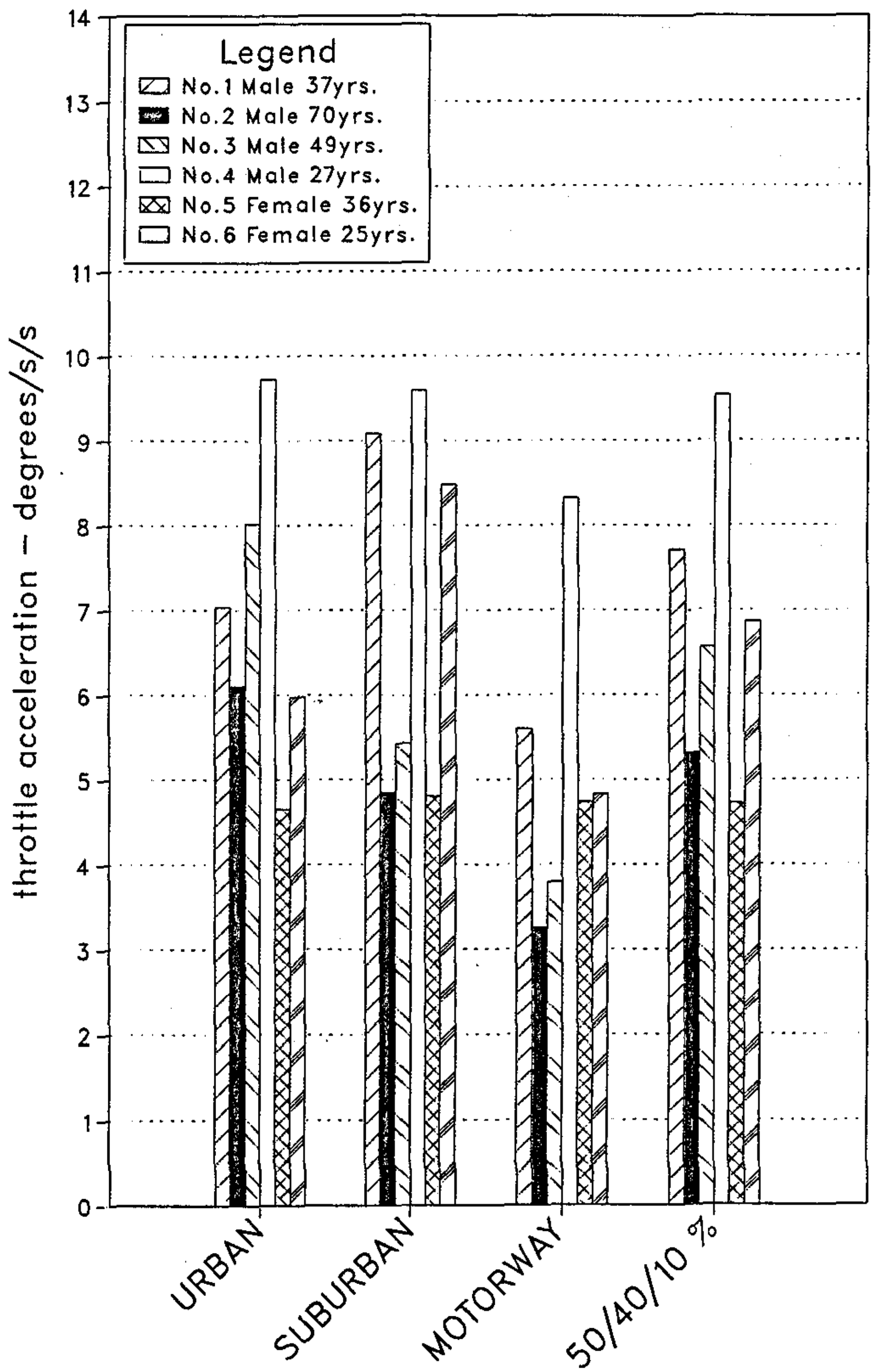


Figure No.18

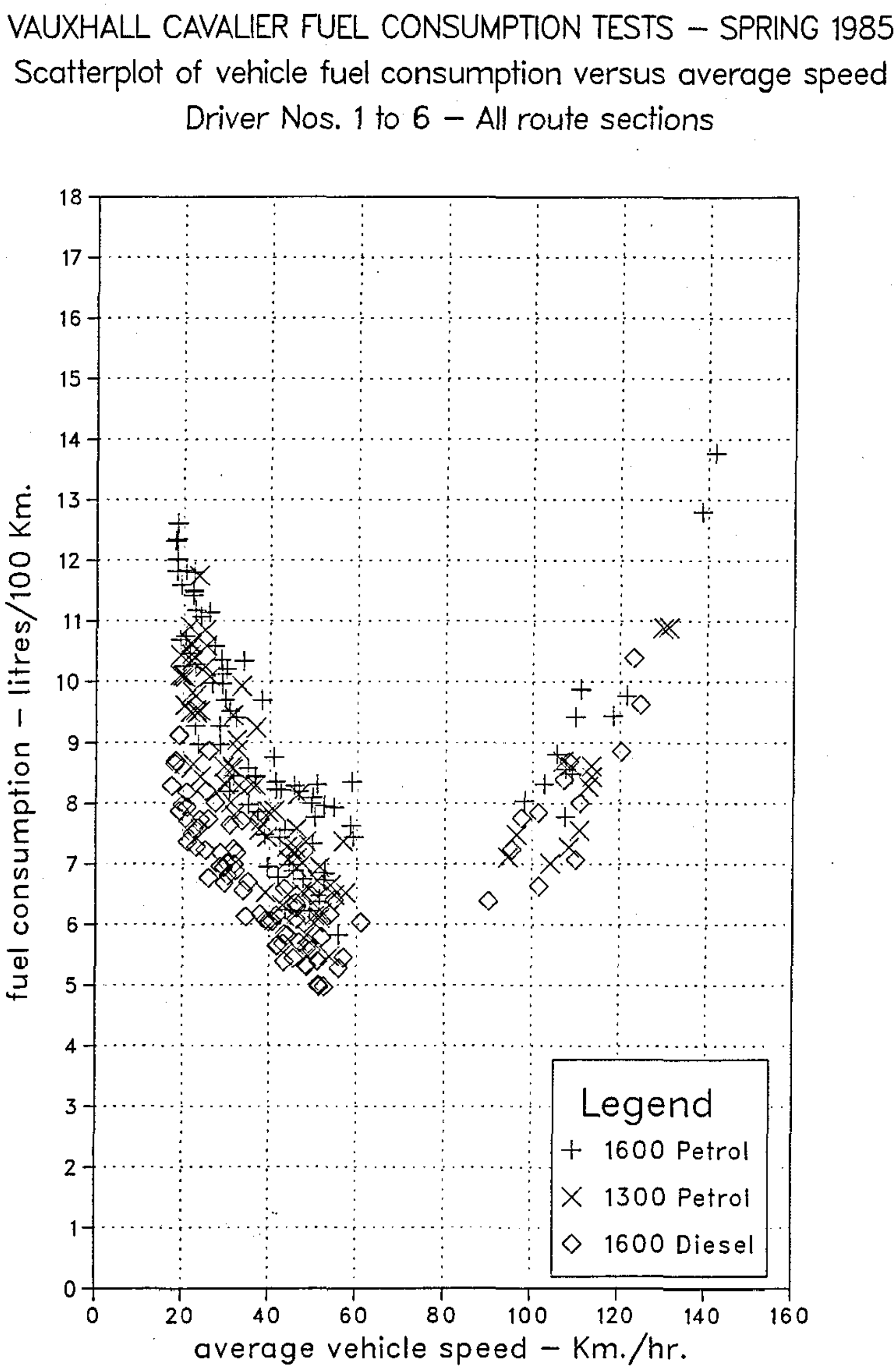

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Scatterplot of vehicle fuel consumption versus average speed
Driver Nos. 1 to 6 – All route sections
fuel consumption – litres/100 Km.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
average vehicle speed – Km./hr.
0
20
40
60
80
100
120
140
160
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.19

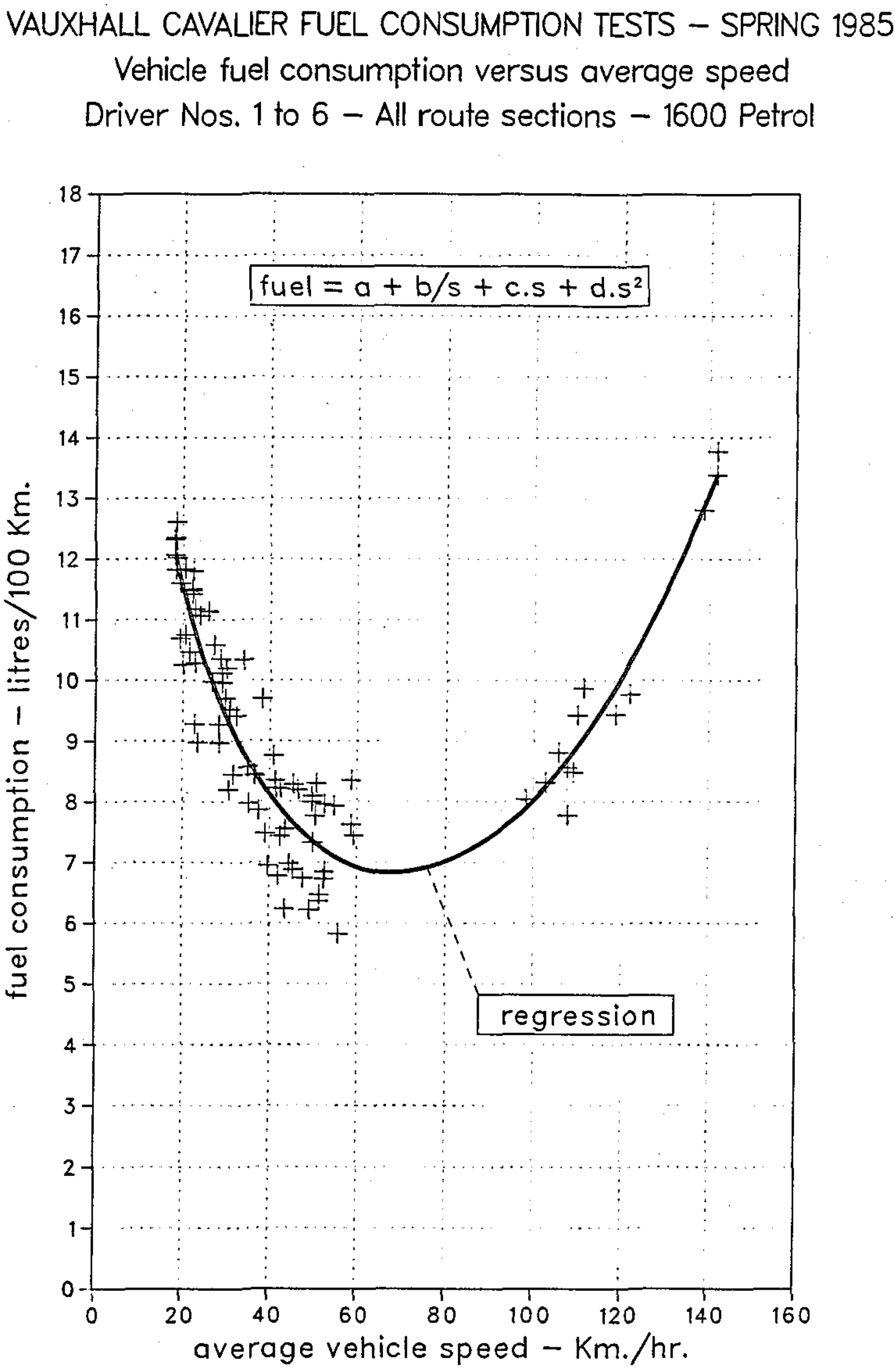

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle fuel consumption versus average speed
Driver Nos. 1 to 6 – All route sections – 1600 Petrol
fuel = a + b/s + c.s + d.s²
regression
fuel consumption – litres/100 Km.
average vehicle speed – Km./hr.
0
20
40
60
80
100
120
140
160
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Figure No.20

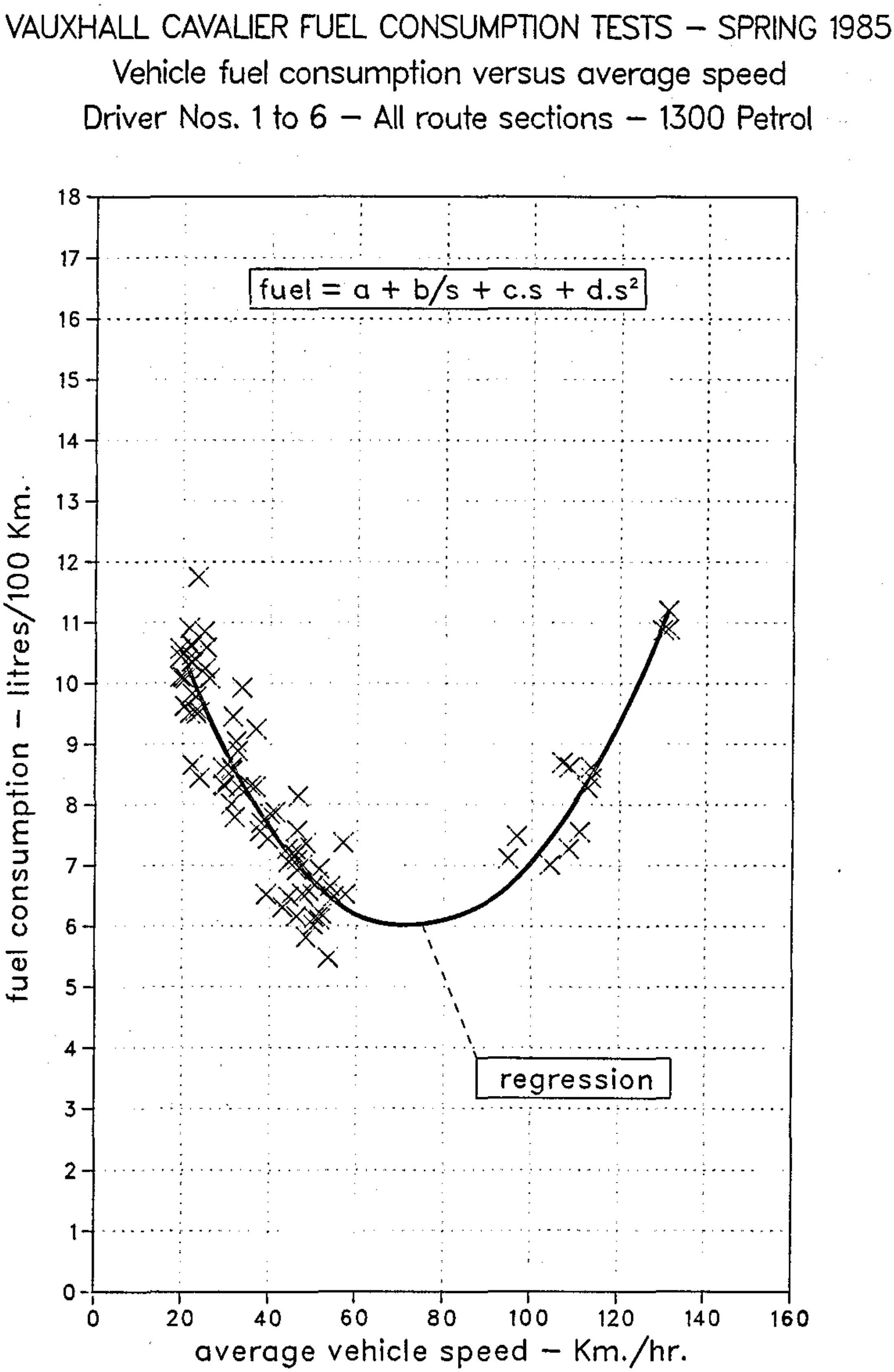
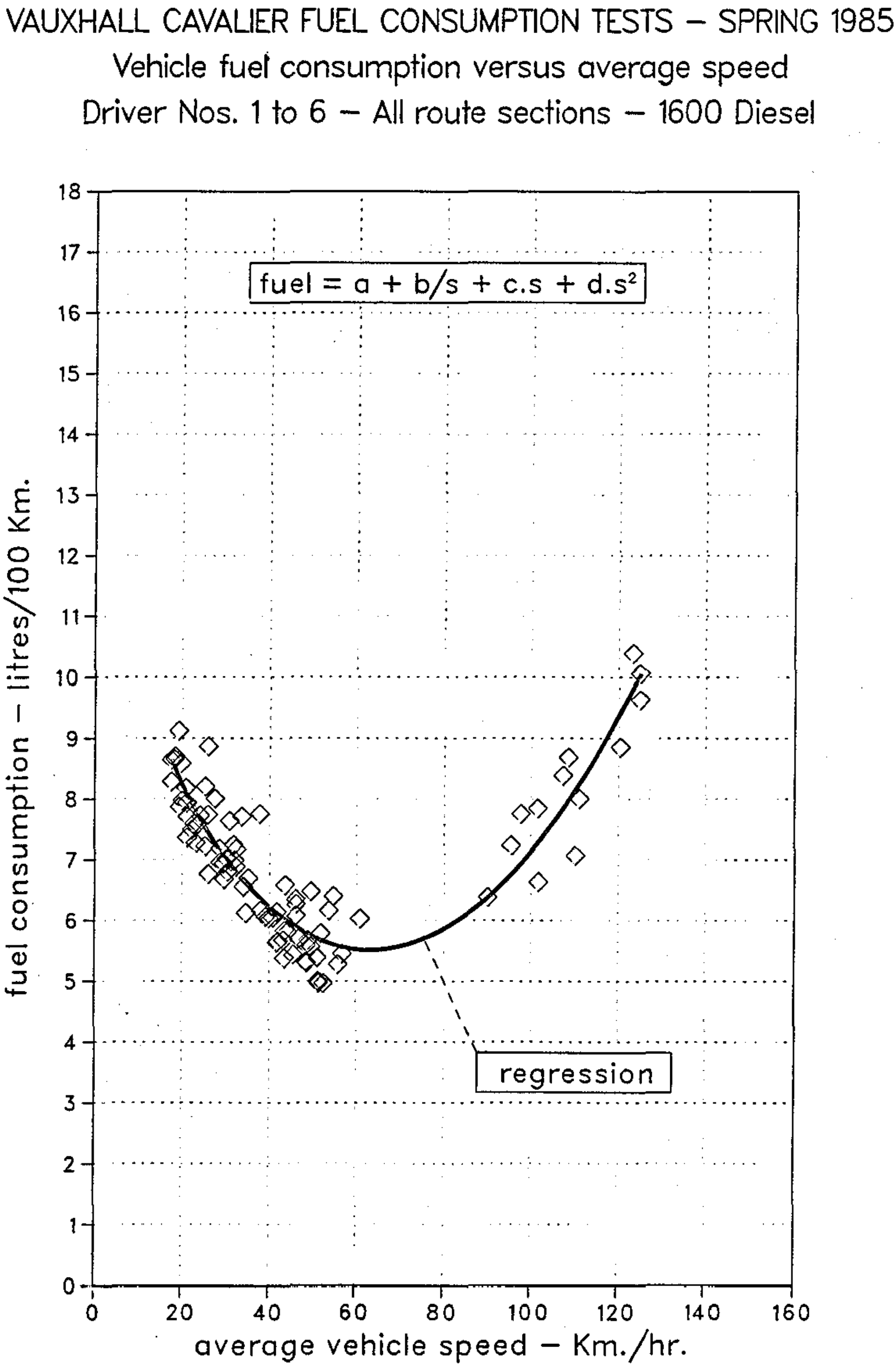

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle fuel consumption versus average speed
Driver Nos. 1 to 6 – All route sections – 1300 Petrol
fuel = a + b/s + c.s + d.s²
regression
fuel consumption – litres/100 Km.
average vehicle speed – Km./hr.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
20
40
60
80
100
120
140
160

Figure No.21



VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle fuel consumption versus average speed
Driver Nos. 1 to 6 – All route sections – 1600 Diesel
fuel = a + b/s + c.s + d.s²
regression
fuel consumption – litres/100 Km.
average vehicle speed – Km./hr.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
20
40
60
80
100
120
140
160

Figure No.22

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Regression of vehicle fuel consumption with average speed
Driver Nos. 1 to 6 – All route sections

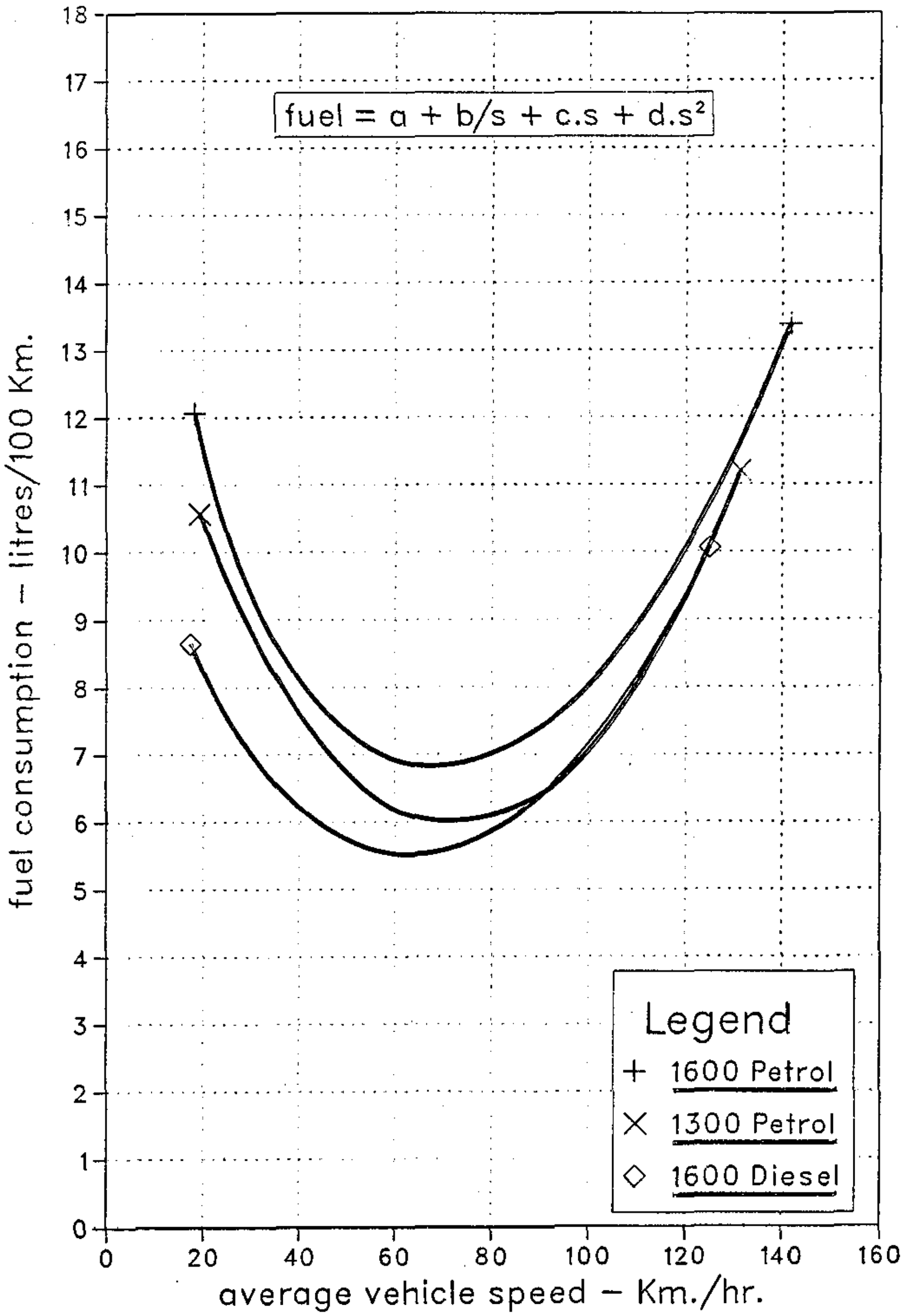


Figure No.23

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Regression of vehicle fuel consumption with average speed
Driver Nos. 1 to 6 – Urban and Suburban route sections

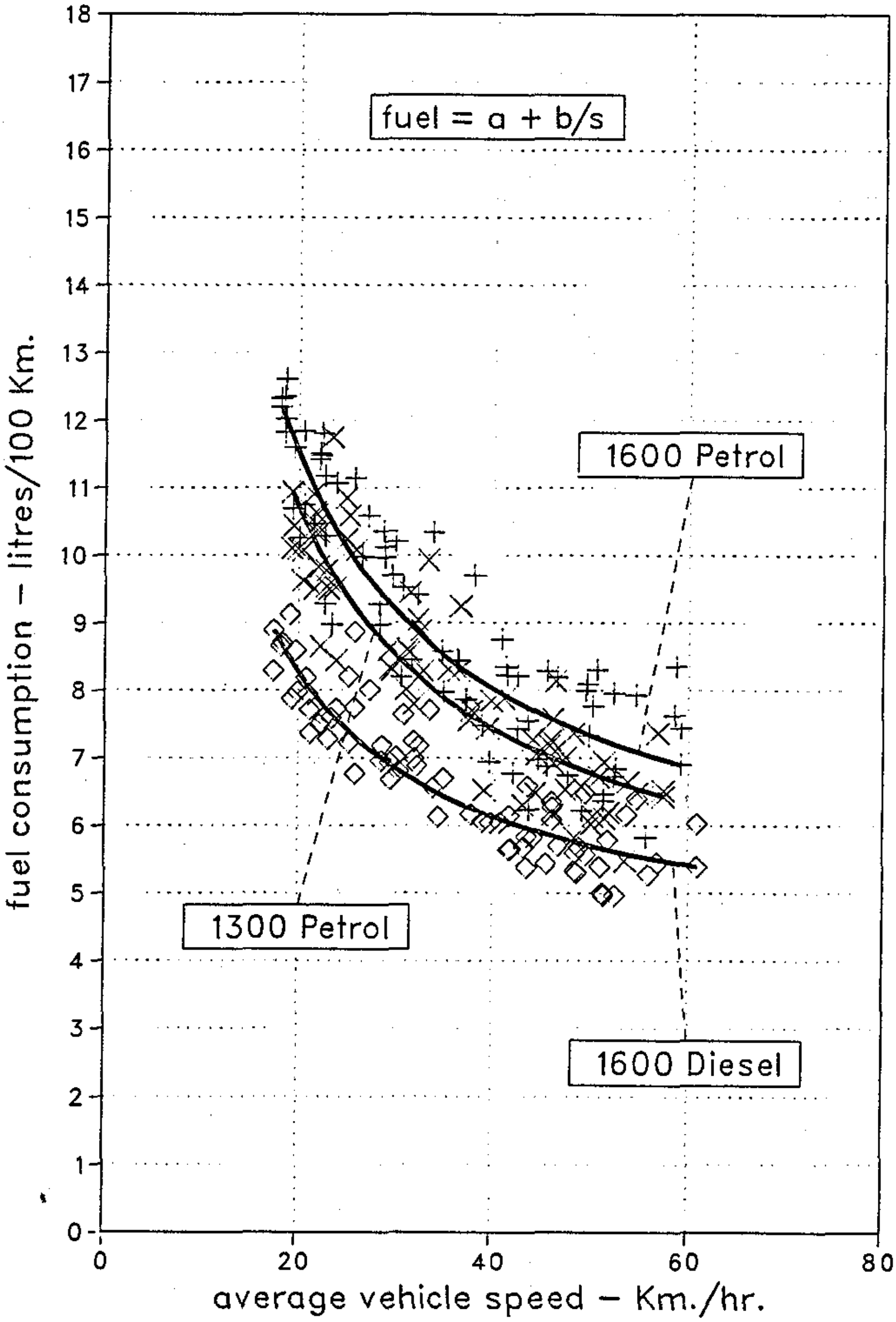


Figure No.24

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Regression of vehicle fuel consumption with average speed
Driver Nos. 1 to 6 – Motorway route section

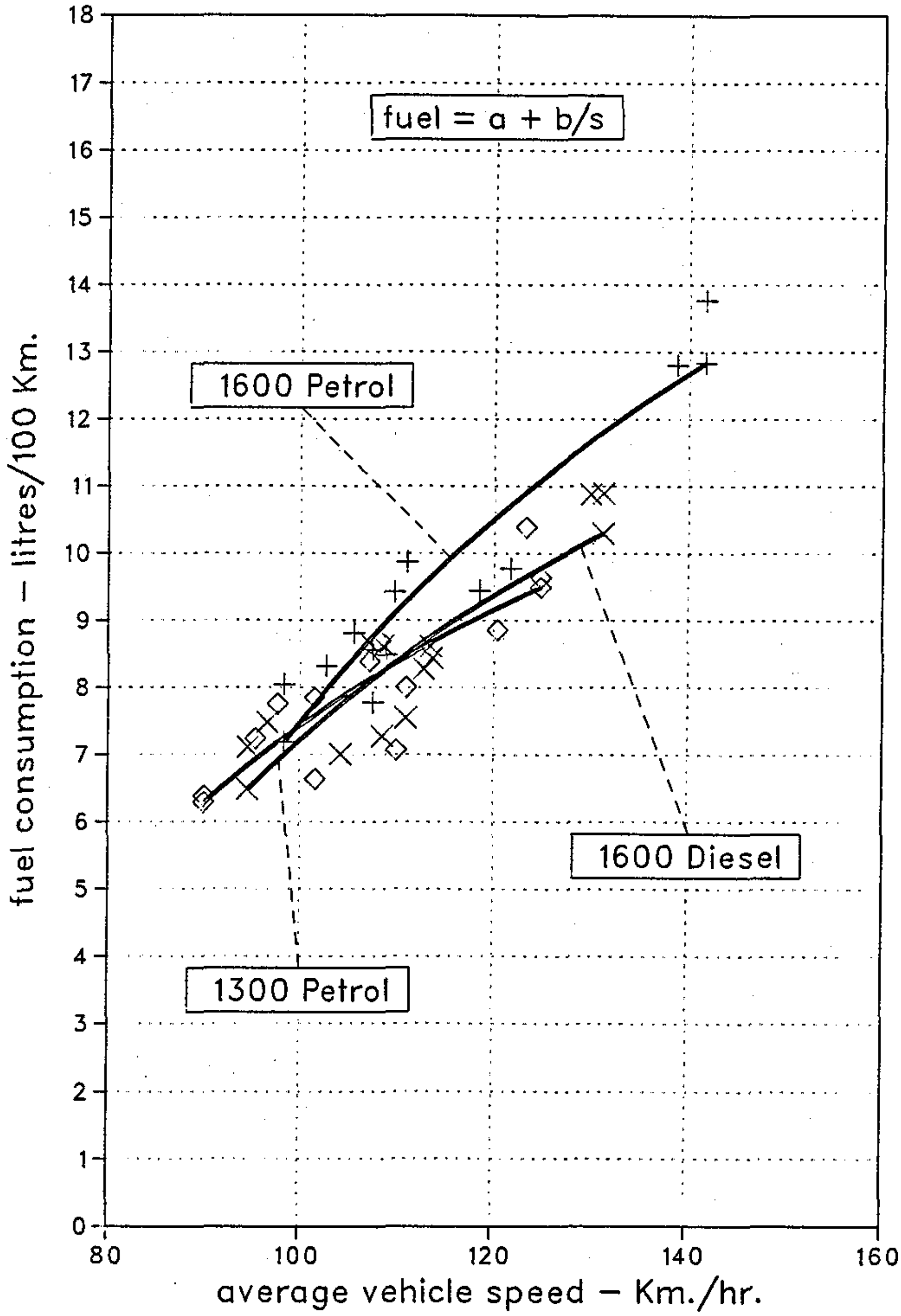
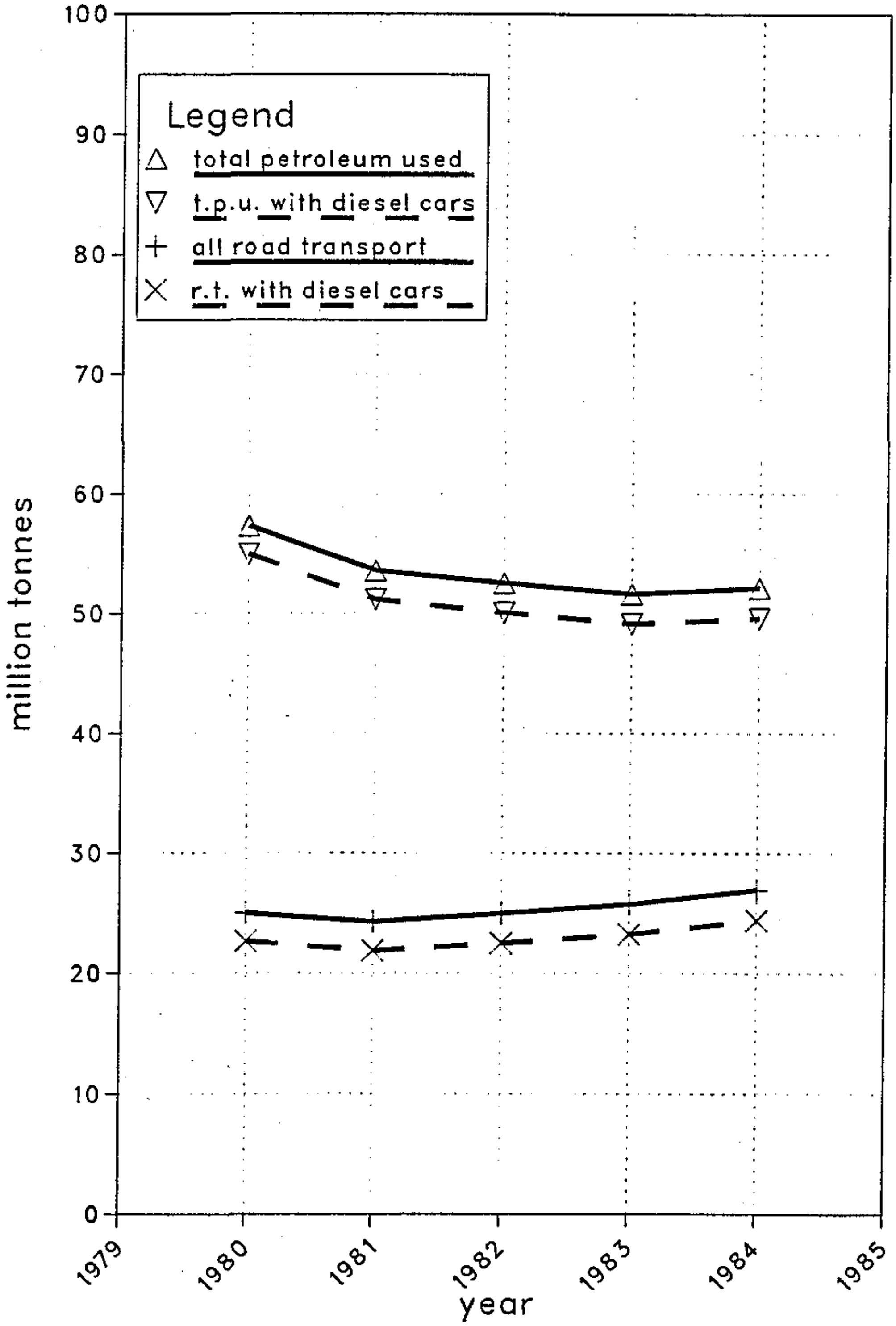


Figure No.25

EFFECT OF DIESEL CAR SUBSTITUTION ON PETROLEUM CONSUMPTION OF U.K.



Comparisons of the fuel and total annual costs between the diesel and 1300cc petrol cars and the two petrol vehicles, versus annual mileage, for all drivers

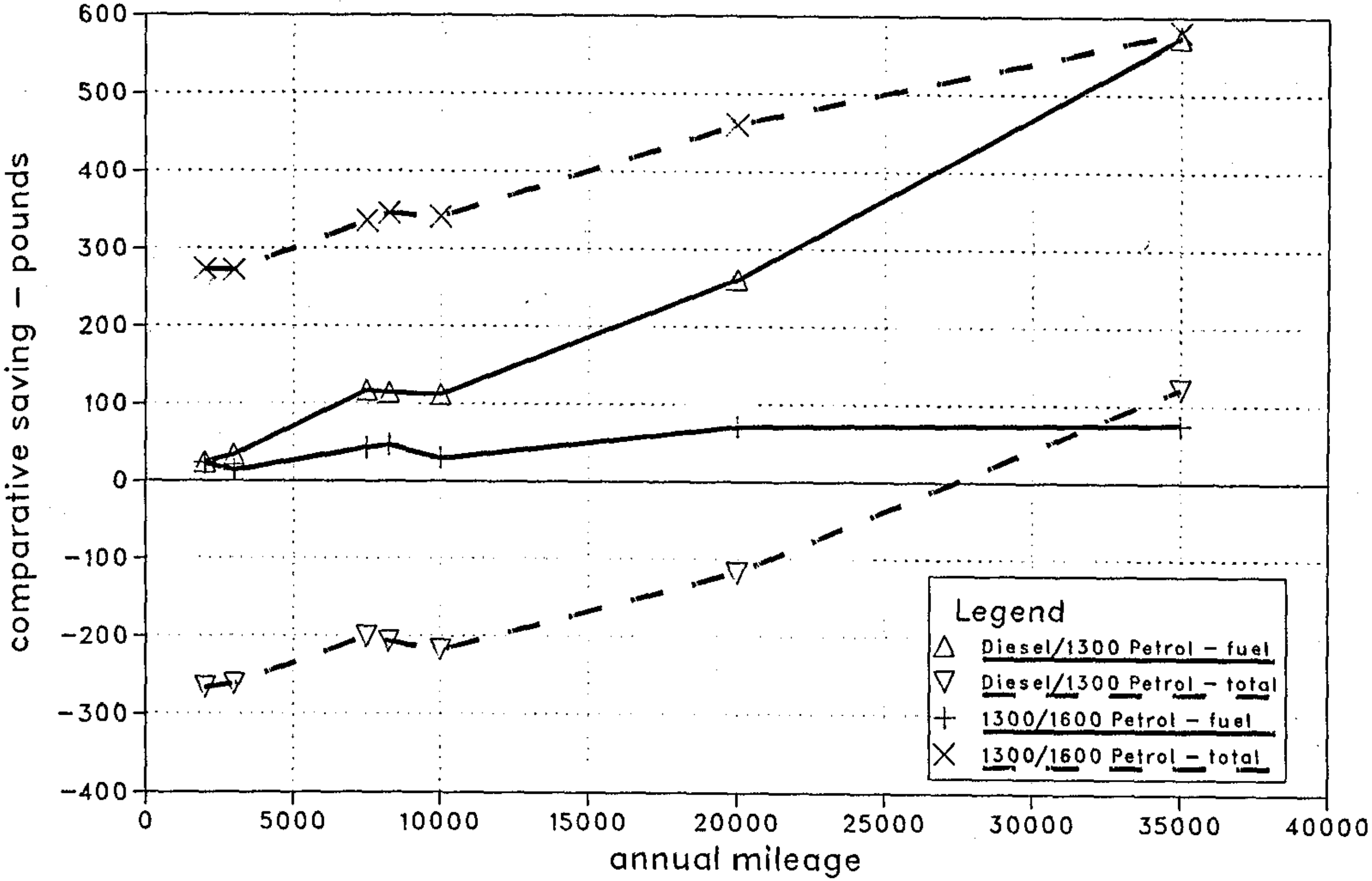
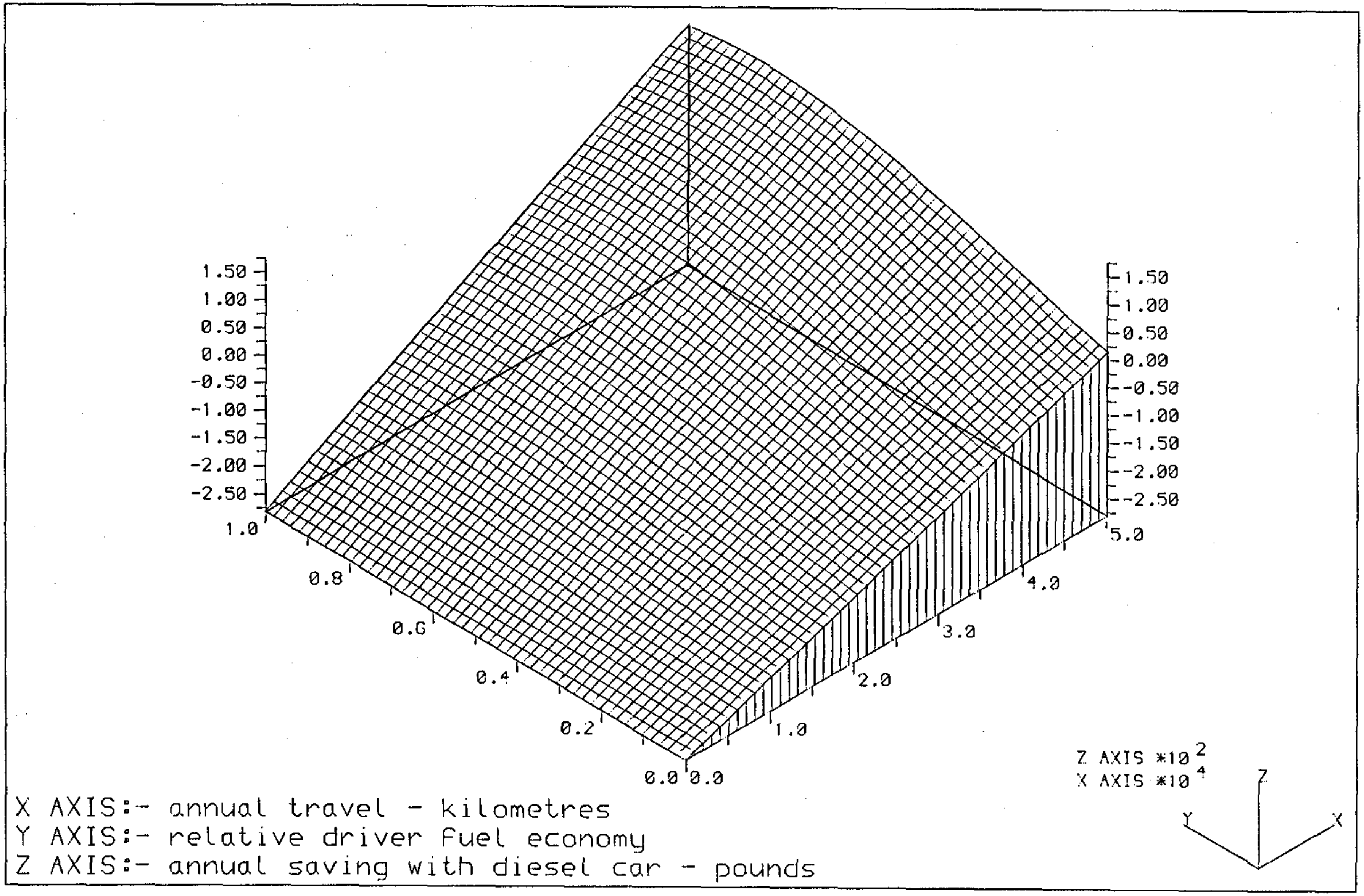
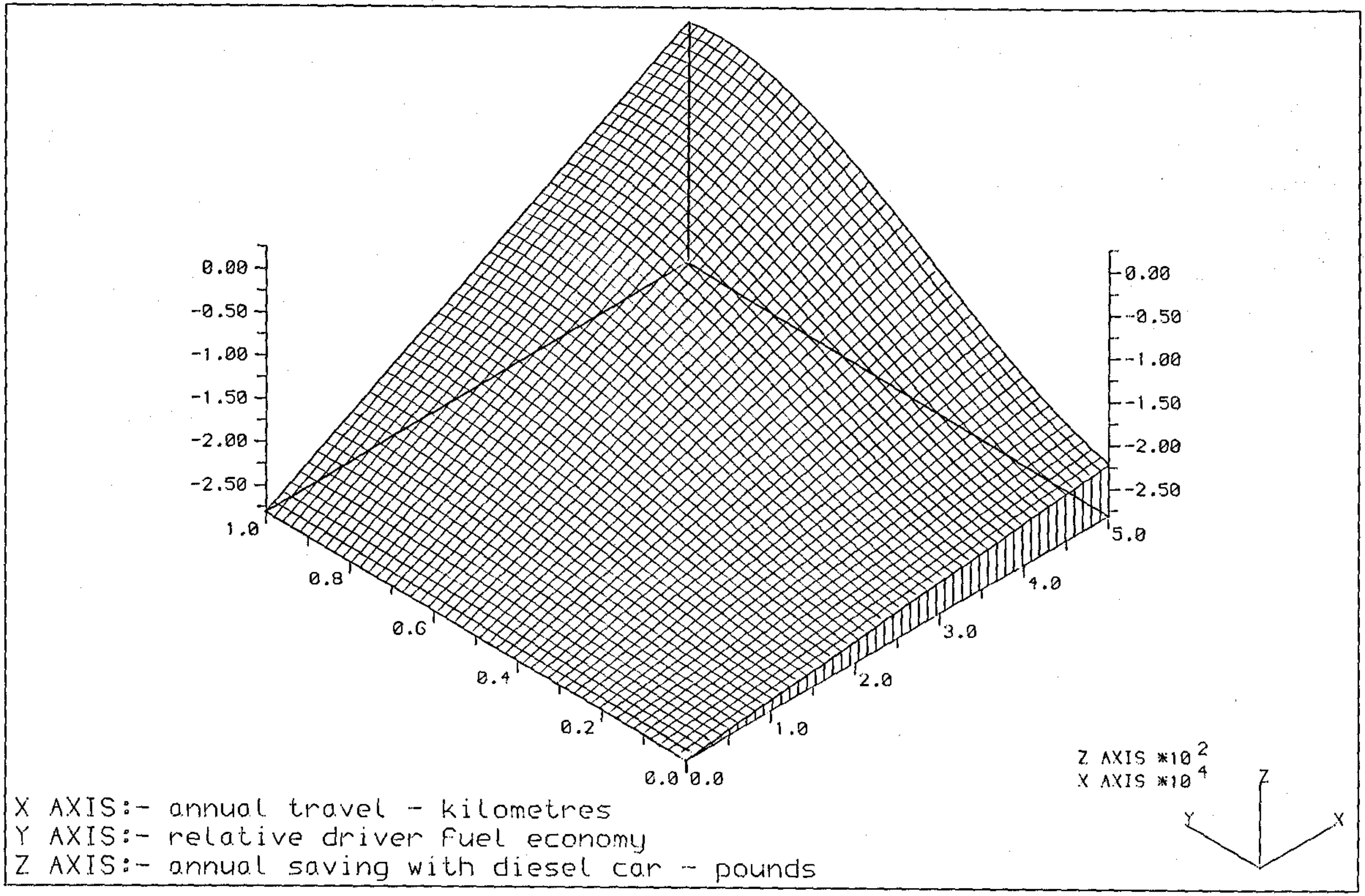


Figure No.26



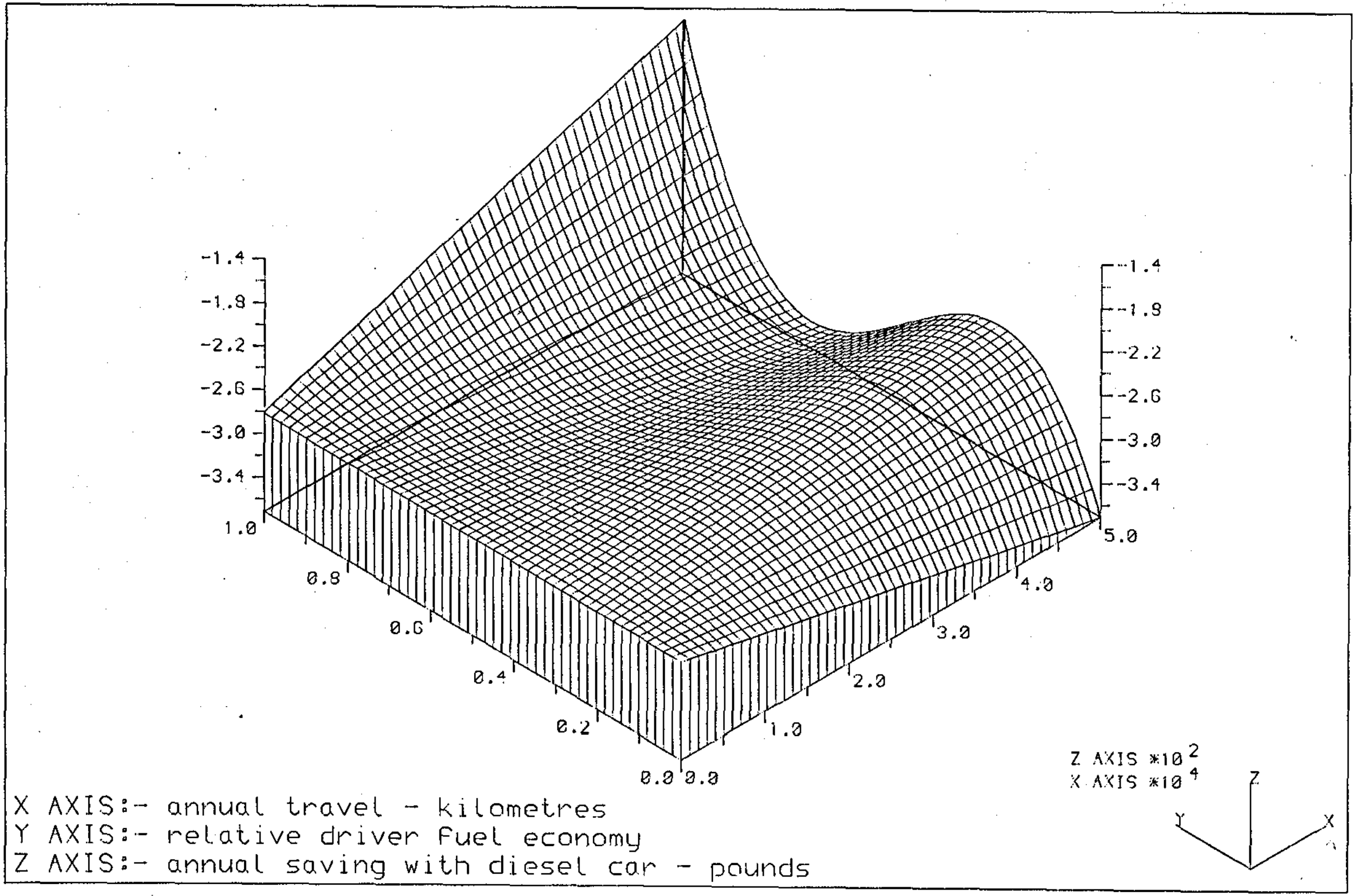
Diesel-1300 Petrol annual cost comparison for urban driving

Figure No.27



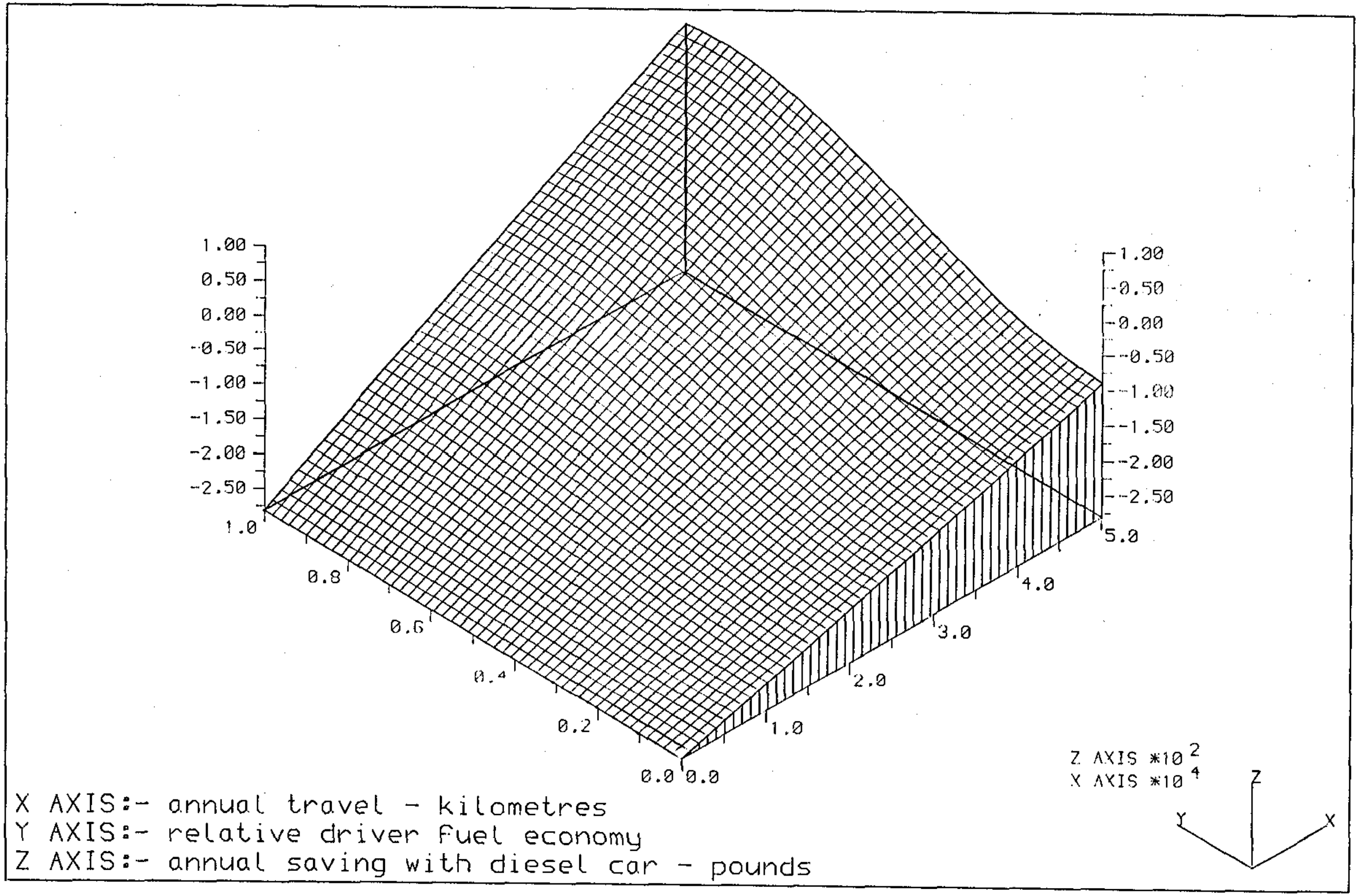
Diesel-1300 Petrol annual cost comparison for suburban driving

Figure No.28



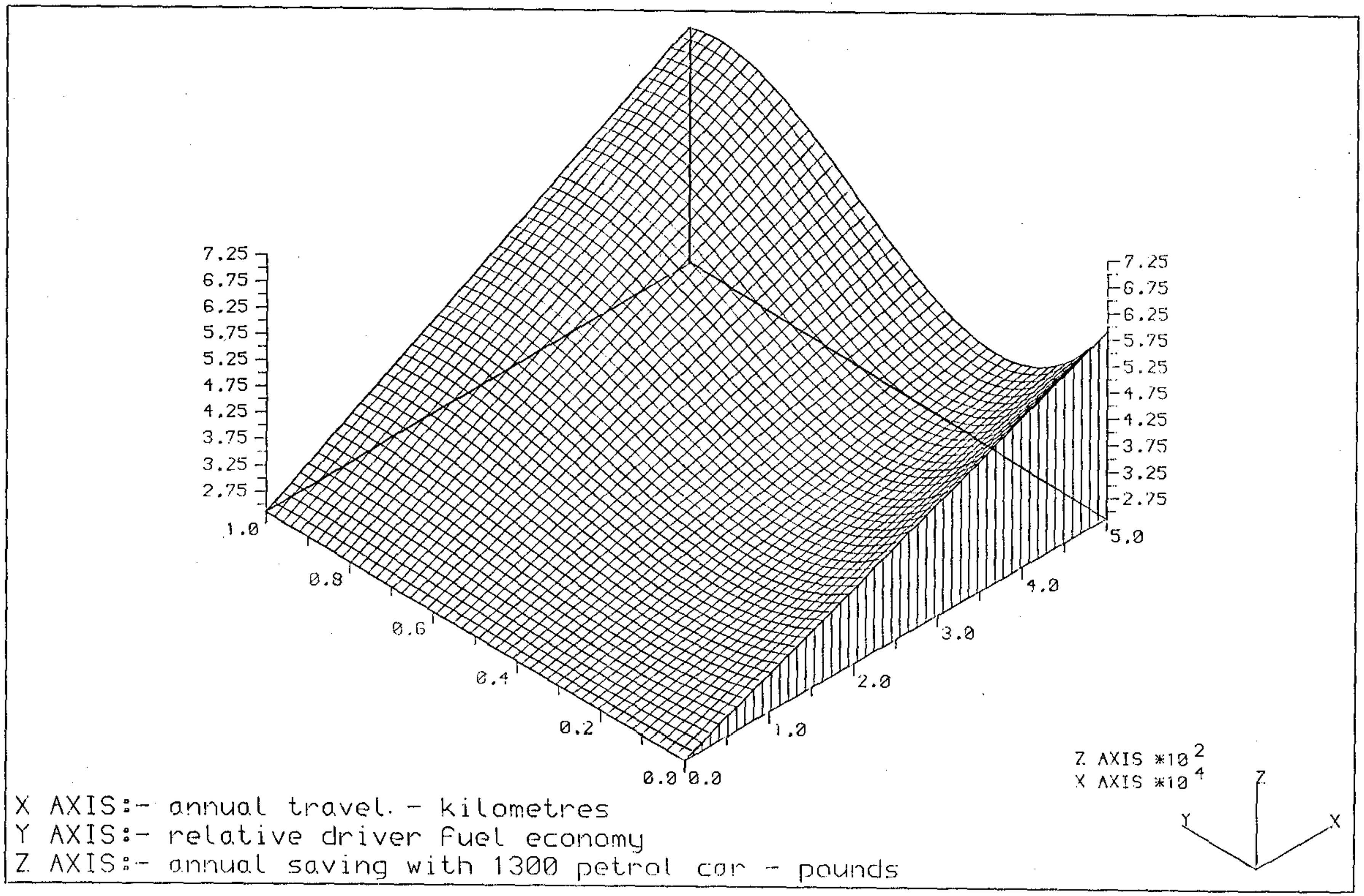
Diesel-1300 Petrol annual cost comparison for motorway driving

Figure No.30

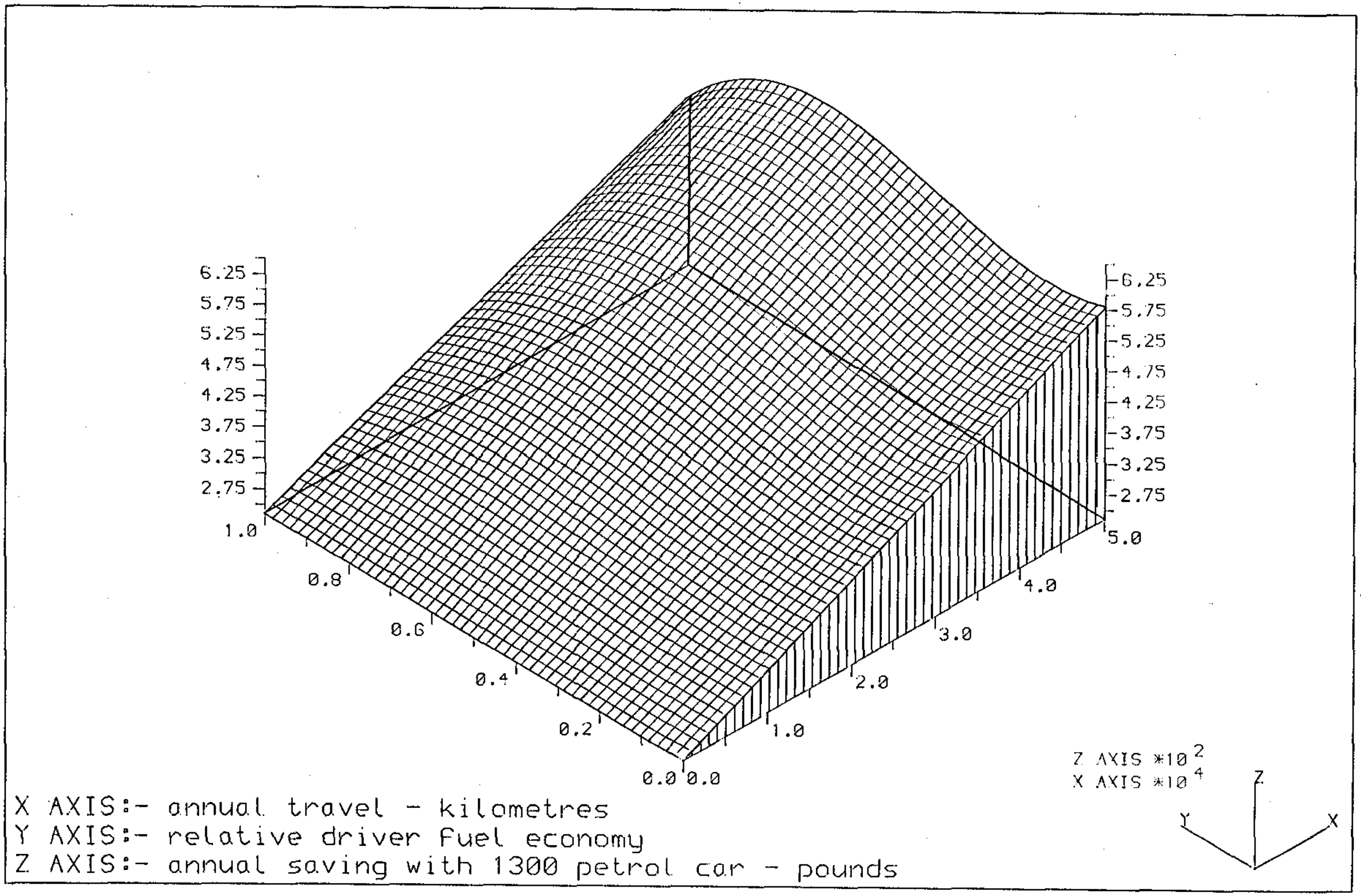


Diesel-1300 Petrol annual cost comparison for 50/40/10% driving

Figure No.31

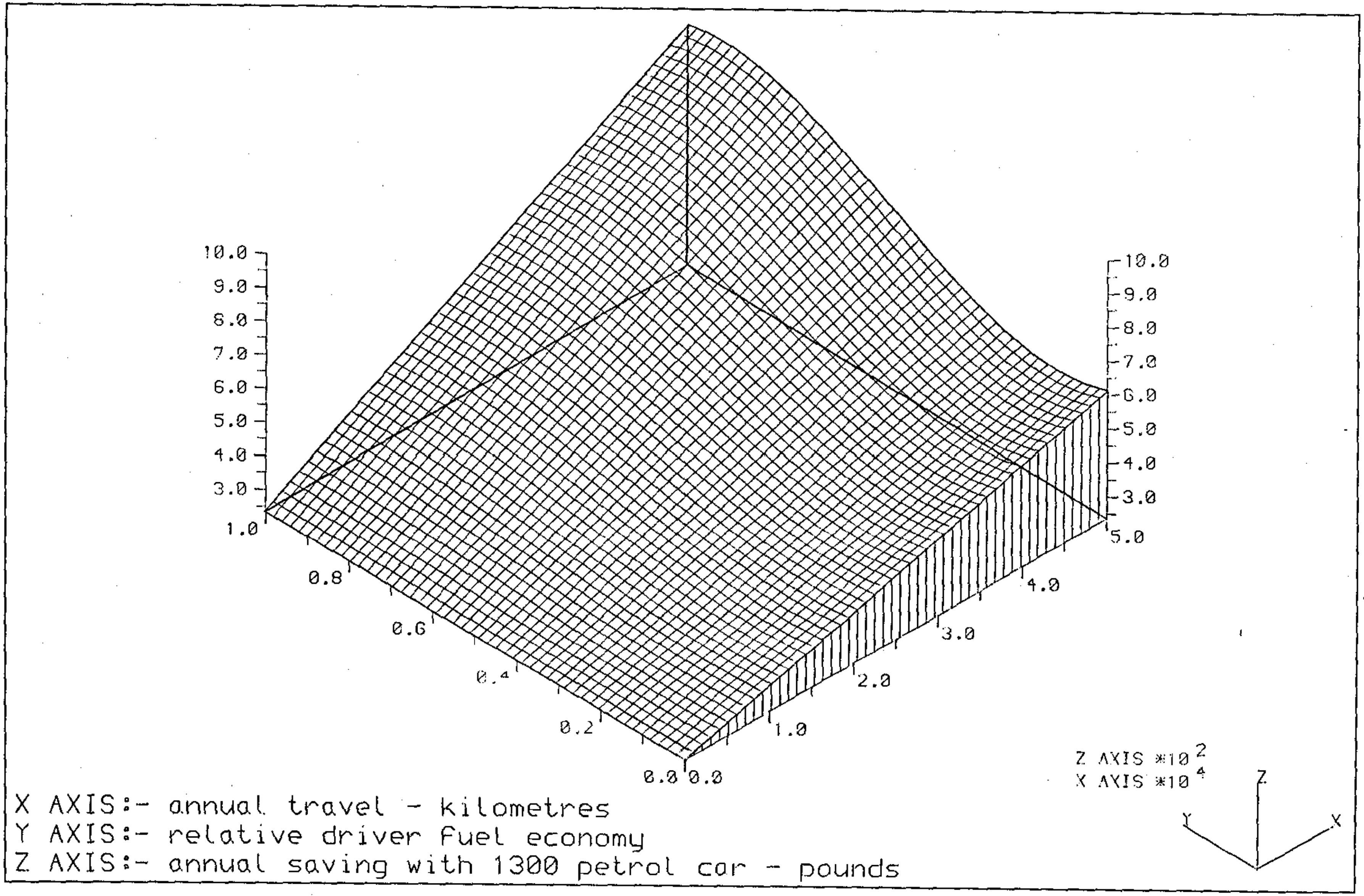


1300-1600 Petrol annual cost comparison for urban driving



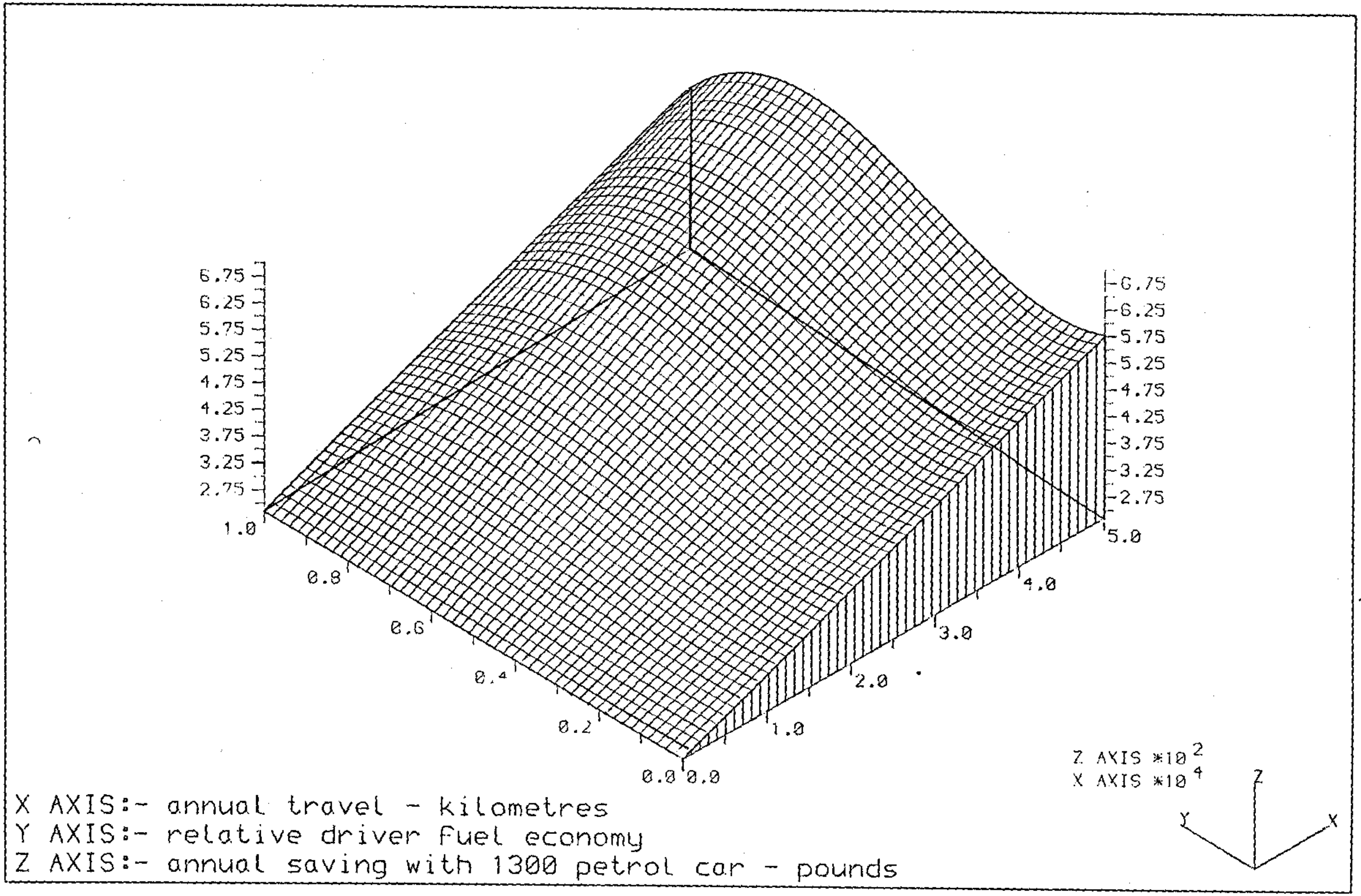
1300-1600 Petrol annual cost comparison for suburban driving

Figure No.32



1300-1600 Petrol annual cost comparison for motorway driving

Figure No.33



1300-1600 Petrol annual cost comparison for 50/40/10% driving

Figure No.34

Figure No.35

AUSTIN–ROVER MONTEGO FUEL CONSUMPTION TESTS – SUMMER 1985
Fuel consumption with standard error for each vehicle and route section
Driver Nos. 6 and 7

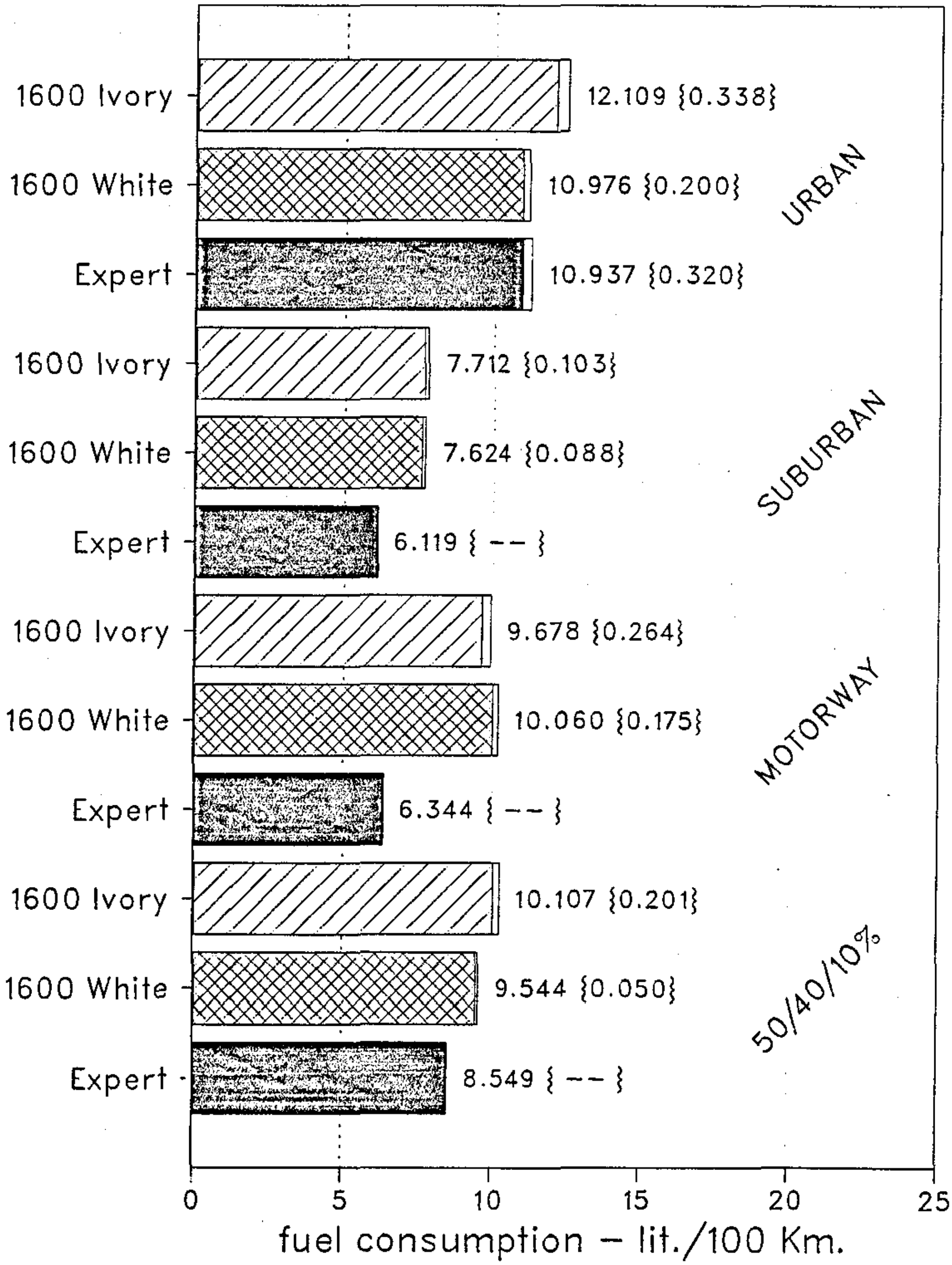


Figure No.36

AUSTIN–ROVER MONTEGO FUEL CONSUMPTION TESTS – SUMMER 1985
Average vehicle speed with standard error for each vehicle and route section
Driver Nos. 6 and 7

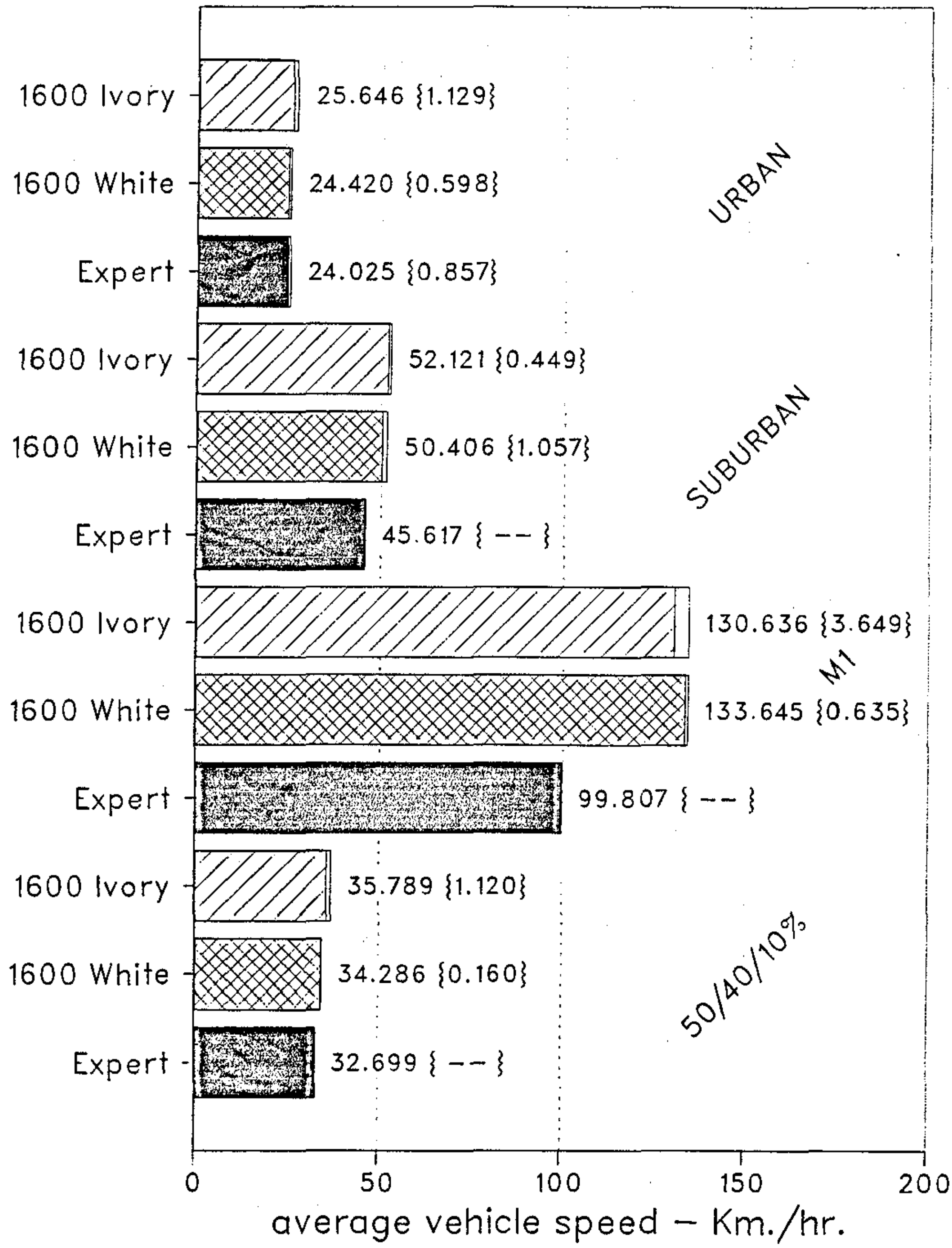


Figure No.37

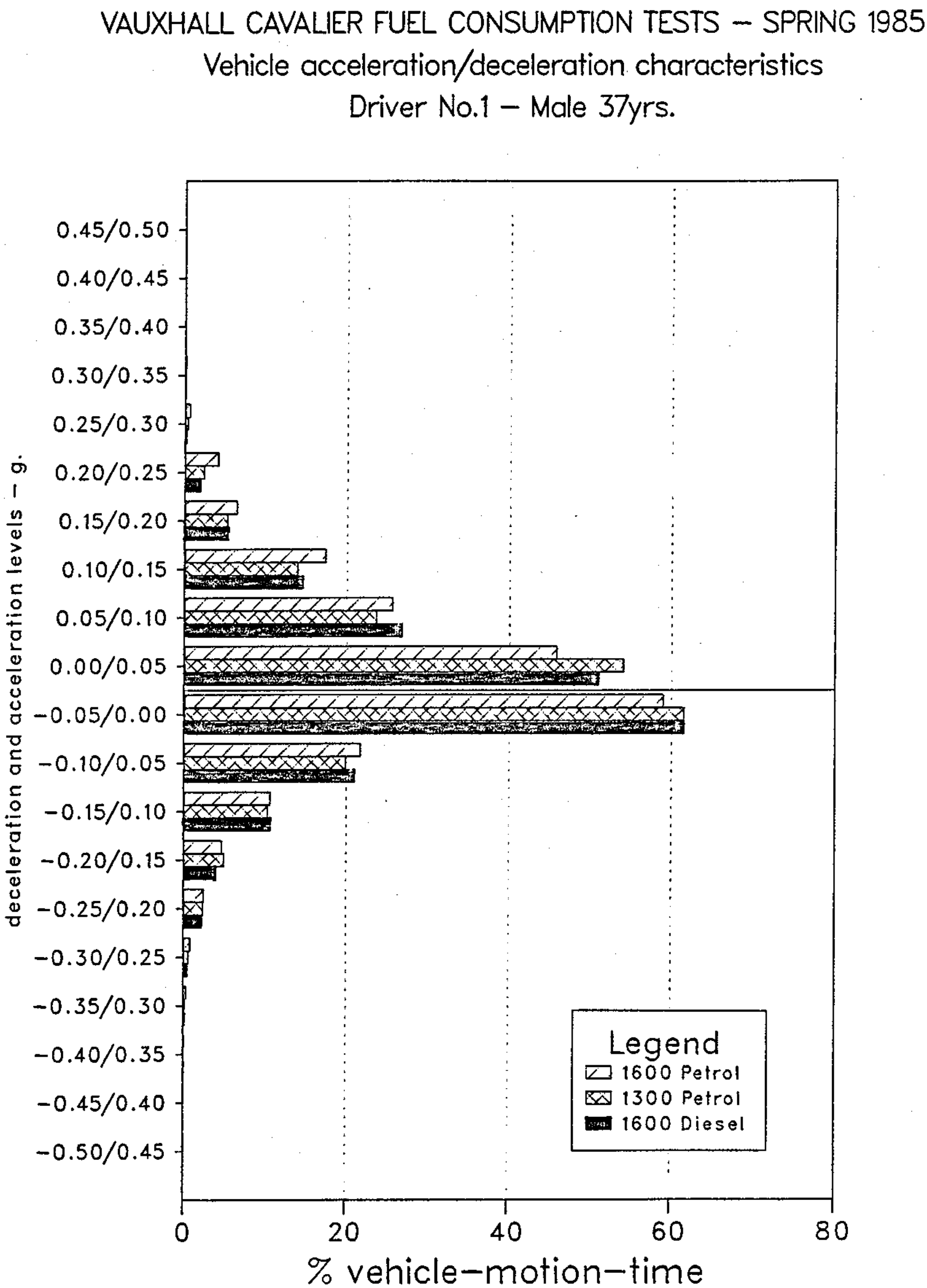

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.1 – Male 37yrs.
0.45/0.50
0.40/0.45
0.35/0.40
0.30/0.35
0.25/0.30
0.20/0.25
0.15/0.20
0.10/0.15
0.05/0.10
0.00/0.05
−0.05/0.00
−0.10/0.05
−0.15/0.10
−0.20/0.15
−0.25/0.20
−0.30/0.25
−0.35/0.30
−0.40/0.35
−0.45/0.40
−0.50/0.45
deceleration and acceleration levels – g.
0
20
40
60
80
% vehicle–motion–time
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.38

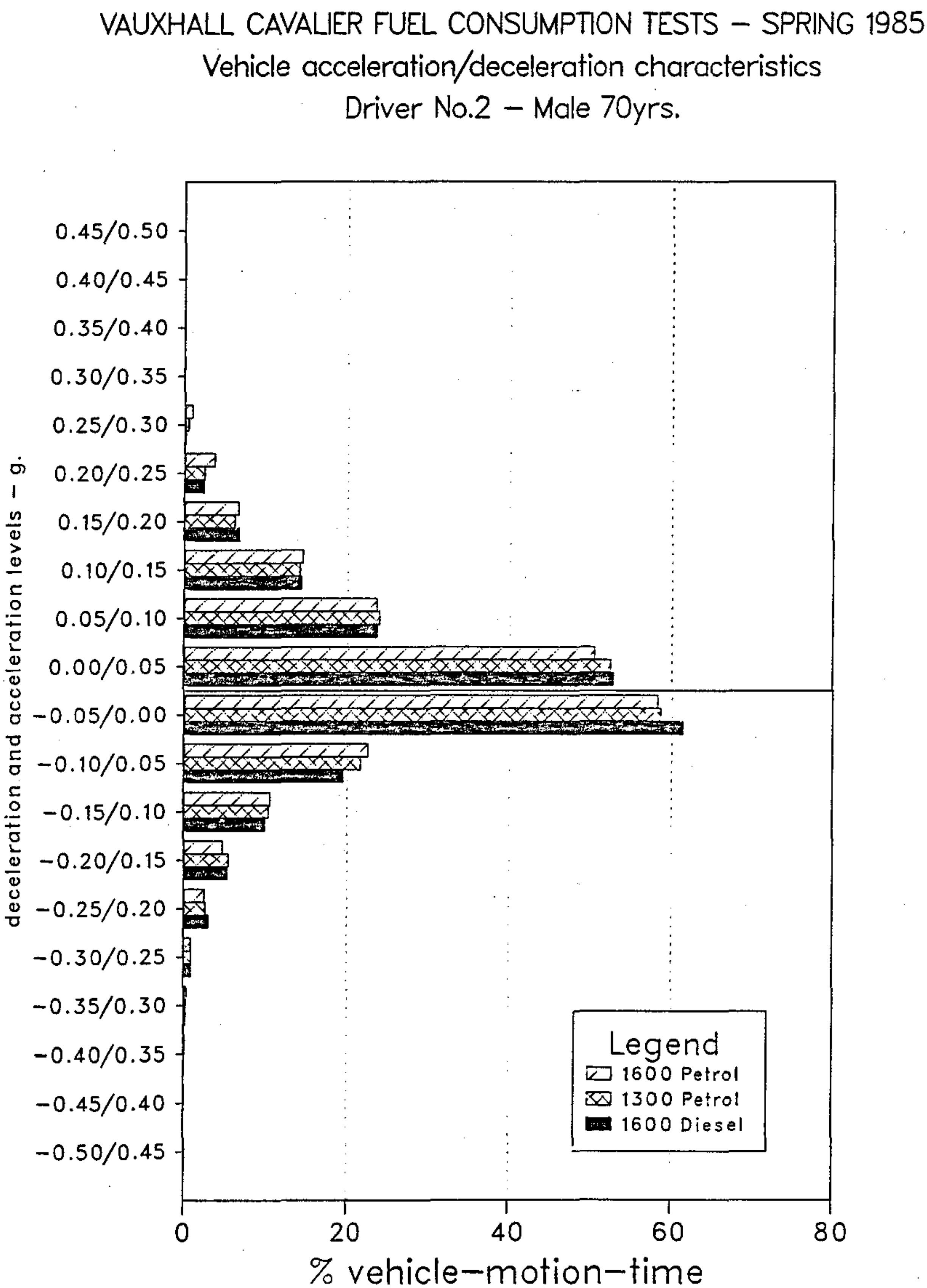

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.2 – Male 70yrs.
0.45/0.50
0.40/0.45
0.35/0.40
0.30/0.35
0.25/0.30
0.20/0.25
0.15/0.20
0.10/0.15
0.05/0.10
0.00/0.05
−0.05/0.00
−0.10/0.05
−0.15/0.10
−0.20/0.15
−0.25/0.20
−0.30/0.25
−0.35/0.30
−0.40/0.35
−0.45/0.40
−0.50/0.45
deceleration and acceleration levels – g.
0
20
40
60
80
% vehicle–motion–time
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.39

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.3 – Male 49yrs.

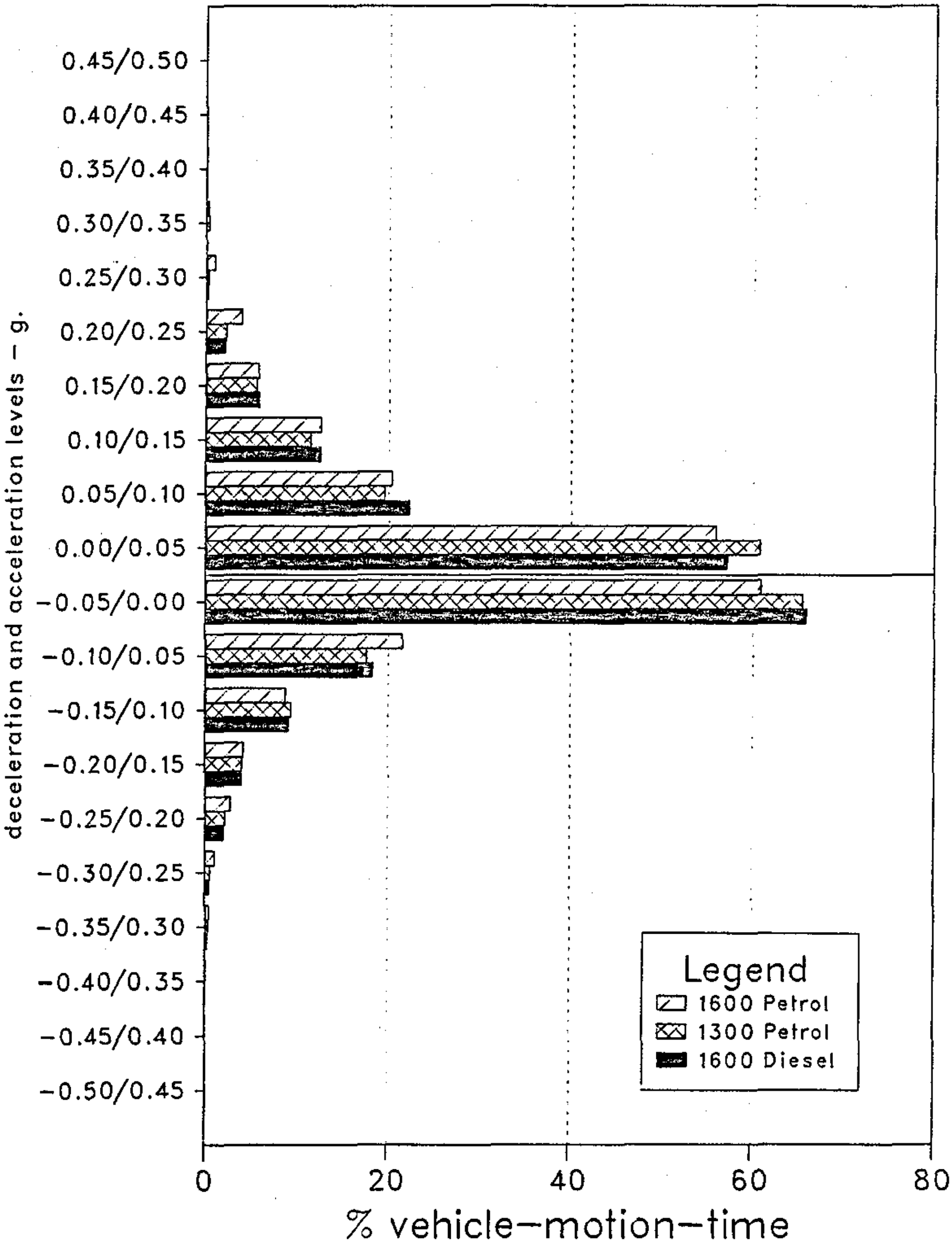


Figure No.40

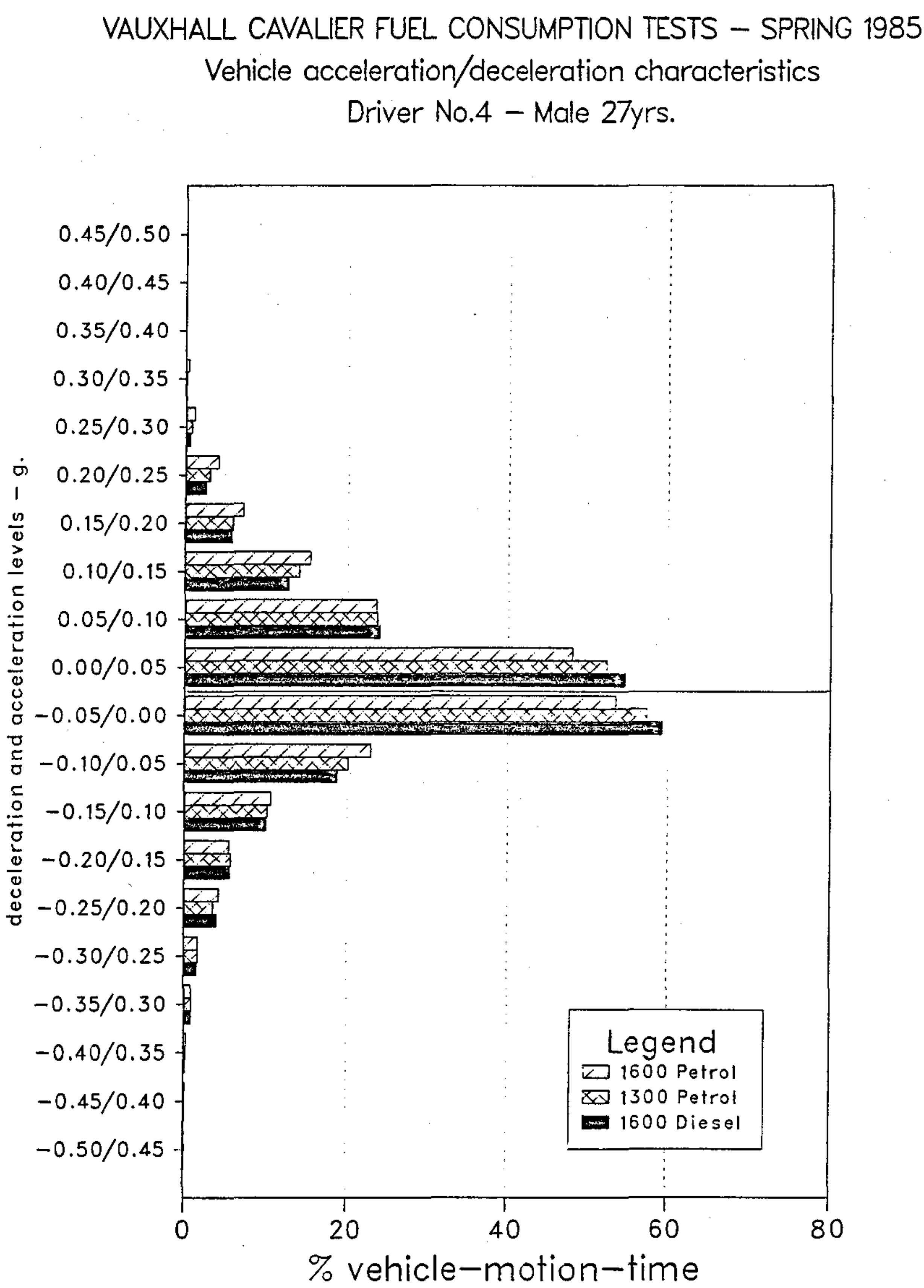

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.4 – Male 27yrs.
deceleration and acceleration levels – g.
0.45/0.50
0.40/0.45
0.35/0.40
0.30/0.35
0.25/0.30
0.20/0.25
0.15/0.20
0.10/0.15
0.05/0.10
0.00/0.05
–0.05/0.00
–0.10/0.05
–0.15/0.10
–0.20/0.15
–0.25/0.20
–0.30/0.25
–0.35/0.30
–0.40/0.35
–0.45/0.40
–0.50/0.45
0
20
40
60
80
% vehicle–motion–time
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.41

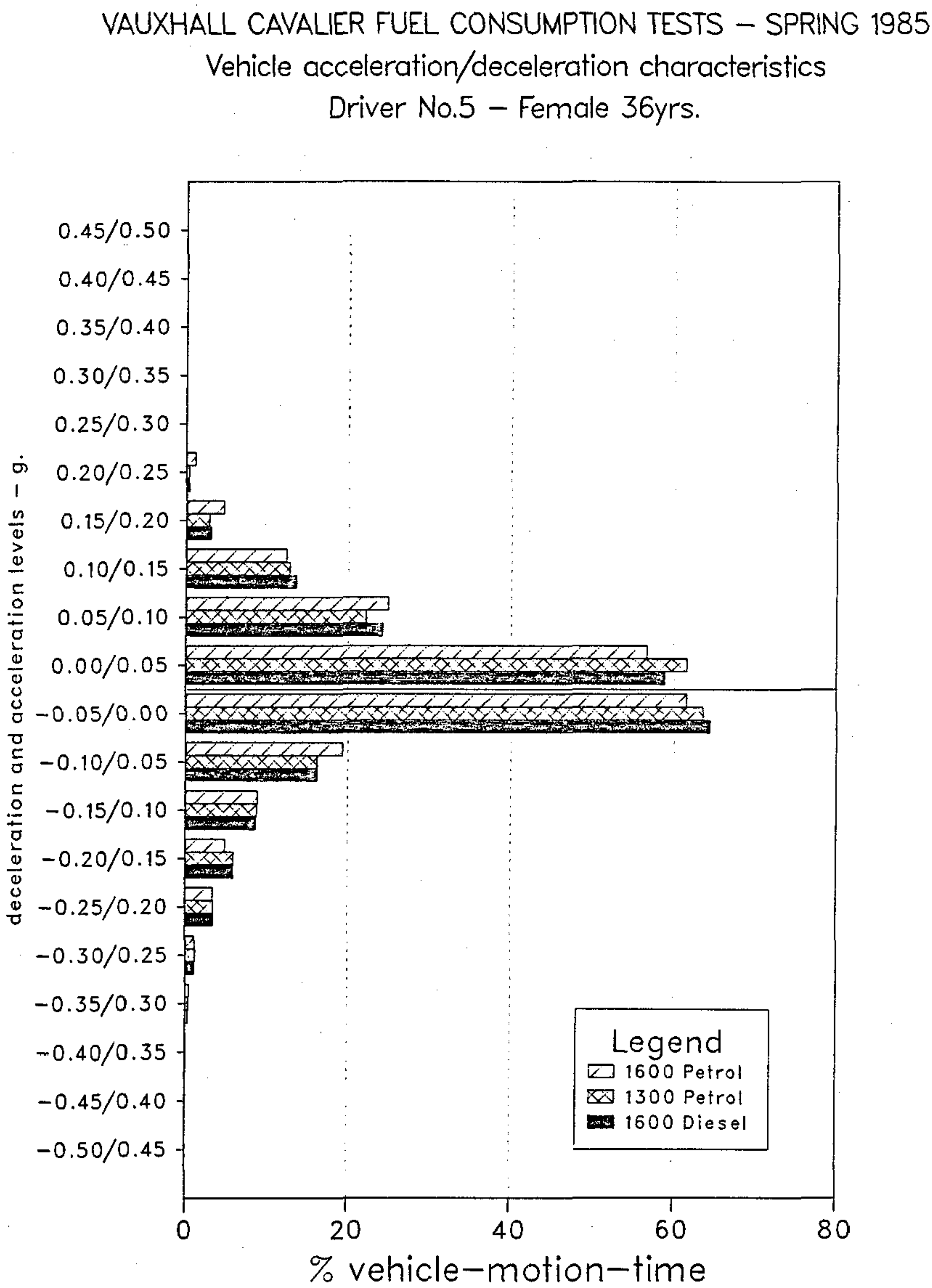

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.5 – Female 36yrs.
0.45/0.50
0.40/0.45
0.35/0.40
0.30/0.35
0.25/0.30
0.20/0.25
0.15/0.20
0.10/0.15
0.05/0.10
0.00/0.05
−0.05/0.00
−0.10/0.05
−0.15/0.10
−0.20/0.15
−0.25/0.20
−0.30/0.25
−0.35/0.30
−0.40/0.35
−0.45/0.40
−0.50/0.45
deceleration and acceleration levels – g.
0
20
40
60
80
% vehicle–motion–time
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.42

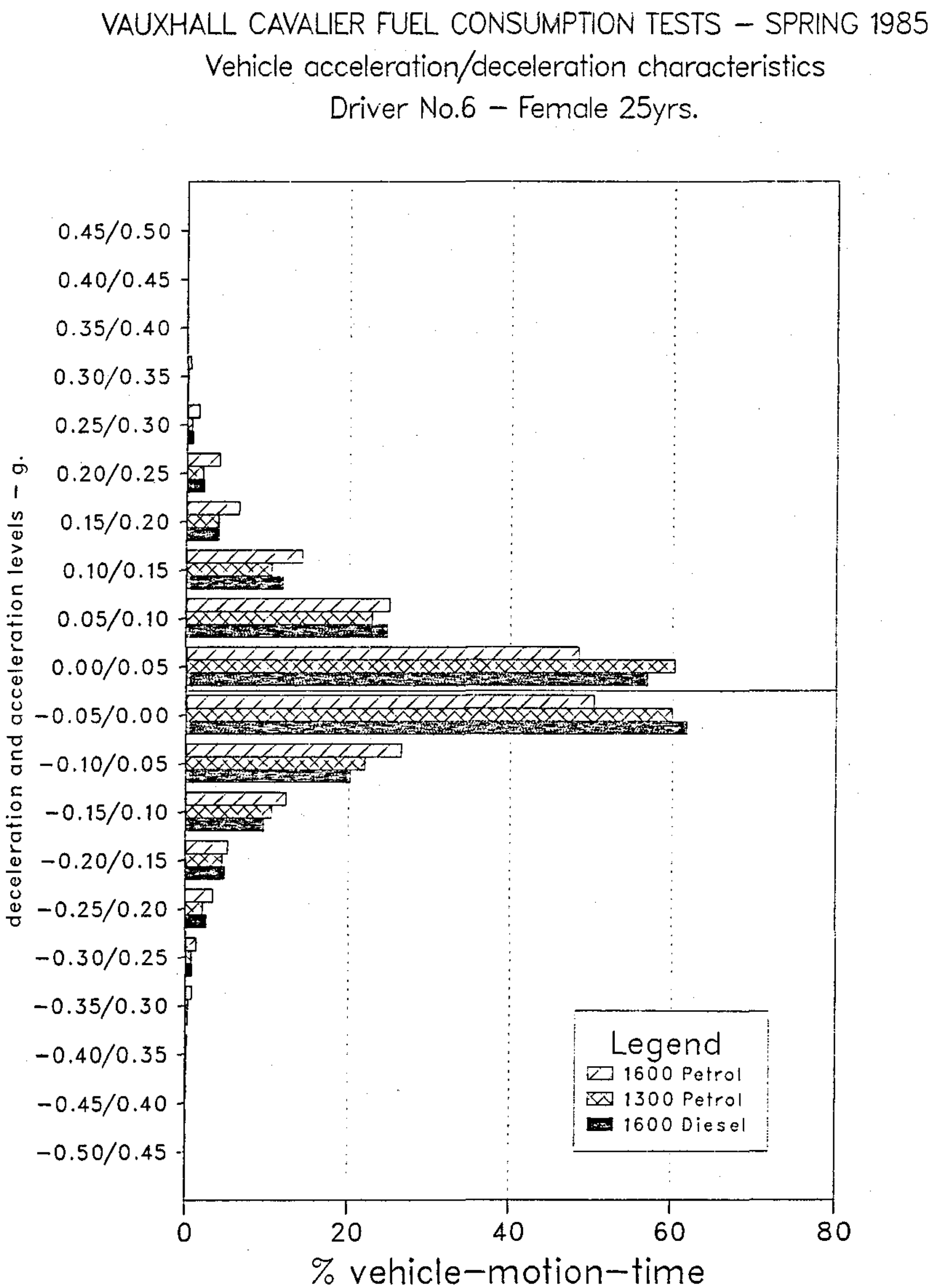

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.6 – Female 25yrs.
0.45/0.50
0.40/0.45
0.35/0.40
0.30/0.35
0.25/0.30
0.20/0.25
0.15/0.20
0.10/0.15
0.05/0.10
0.00/0.05
–0.05/0.00
–0.10/0.05
–0.15/0.10
–0.20/0.15
–0.25/0.20
–0.30/0.25
–0.35/0.30
–0.40/0.35
–0.45/0.40
–0.50/0.45
deceleration and acceleration levels – g.
0
20
40
60
80
% vehicle–motion–time
Legend
1600 Petrol
1300 Petrol
1600 Diesel

Figure No.43

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.1 – Male 37yrs.– 1600cc Petrol – Urban Cycle
Resolution 0.05g

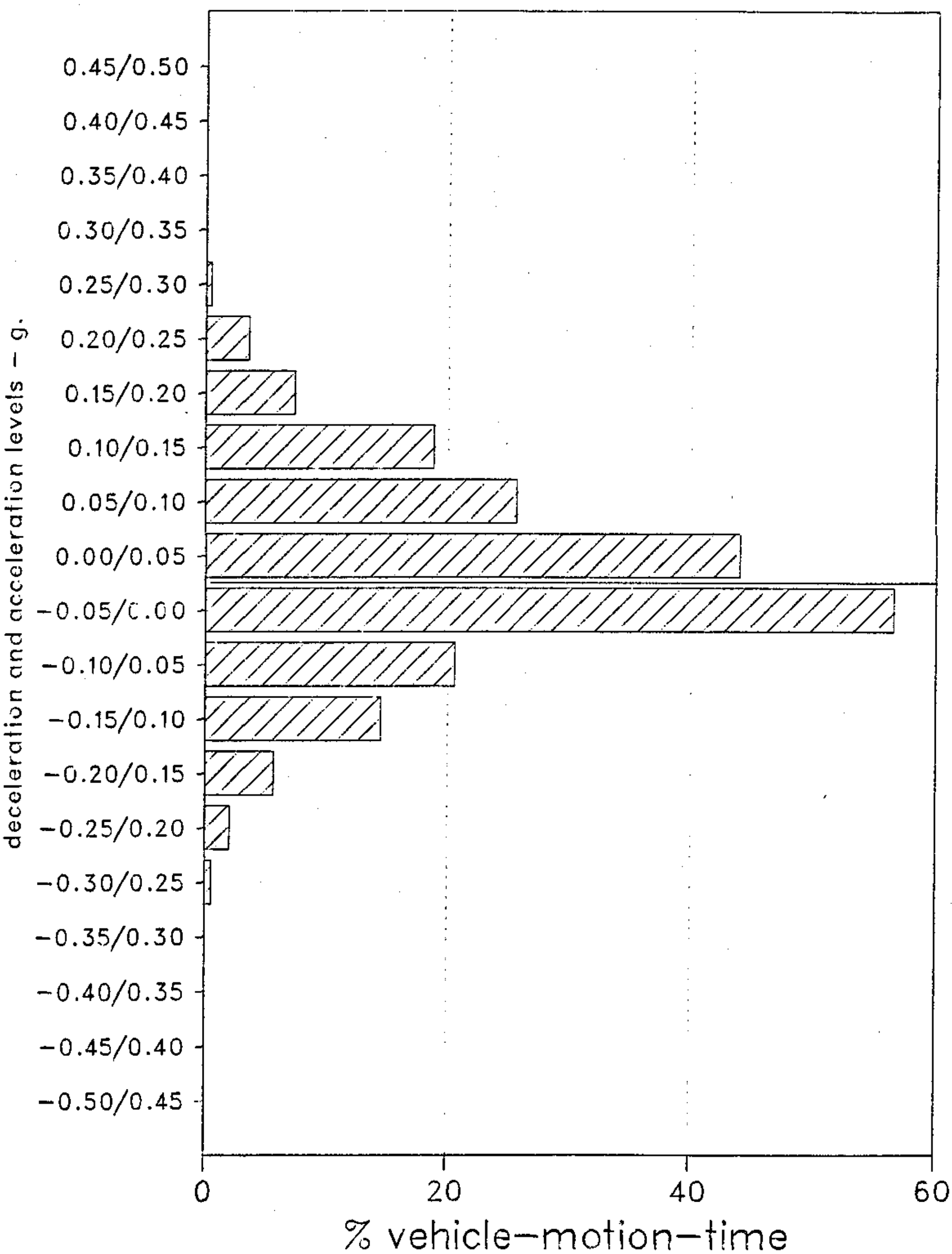
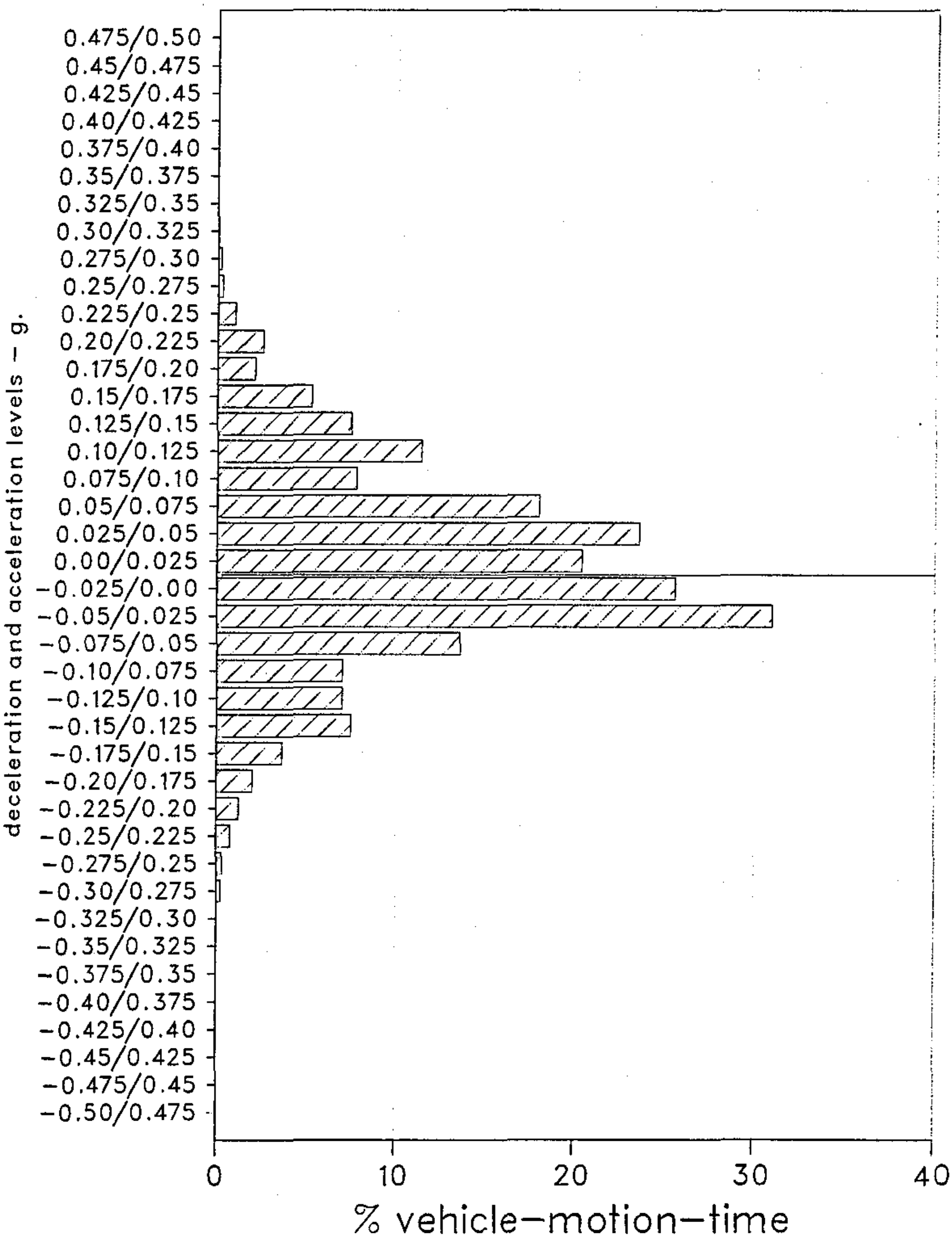


Figure No.44

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985
Vehicle acceleration/deceleration characteristics
Driver No.1 – Male 37yrs.– 1600cc Petrol – Urban Cycle
Resolution 0.025g



VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985

Vehicle deceleration and acceleration characteristics

Data for Driver No.1 – 1600 Petrol – Urban Cycle

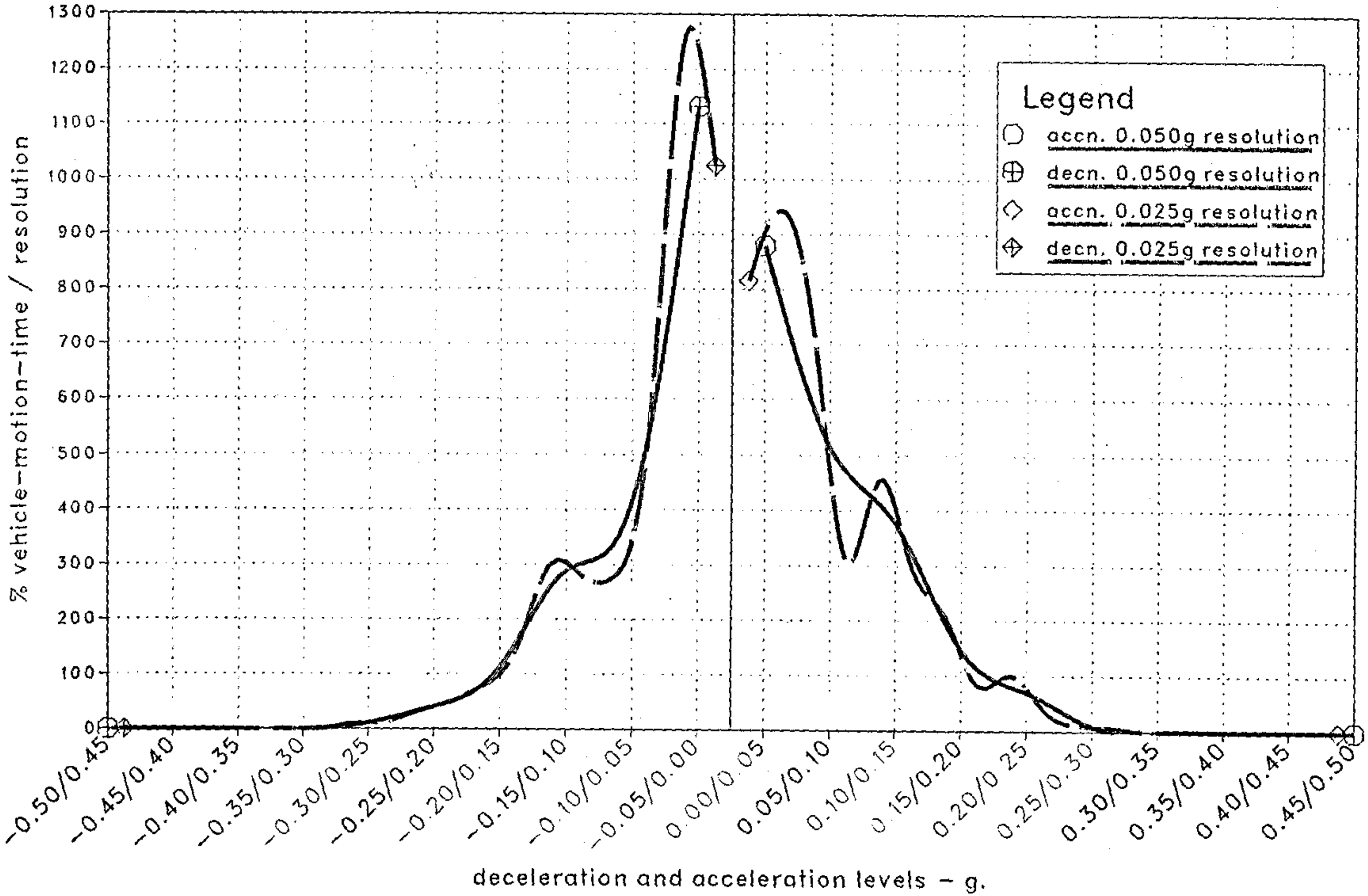


Figure No.45

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985

Vehicle deceleration and acceleration characteristics

Data for Driver No.1 – 1600 Petrol – Urban Cycle

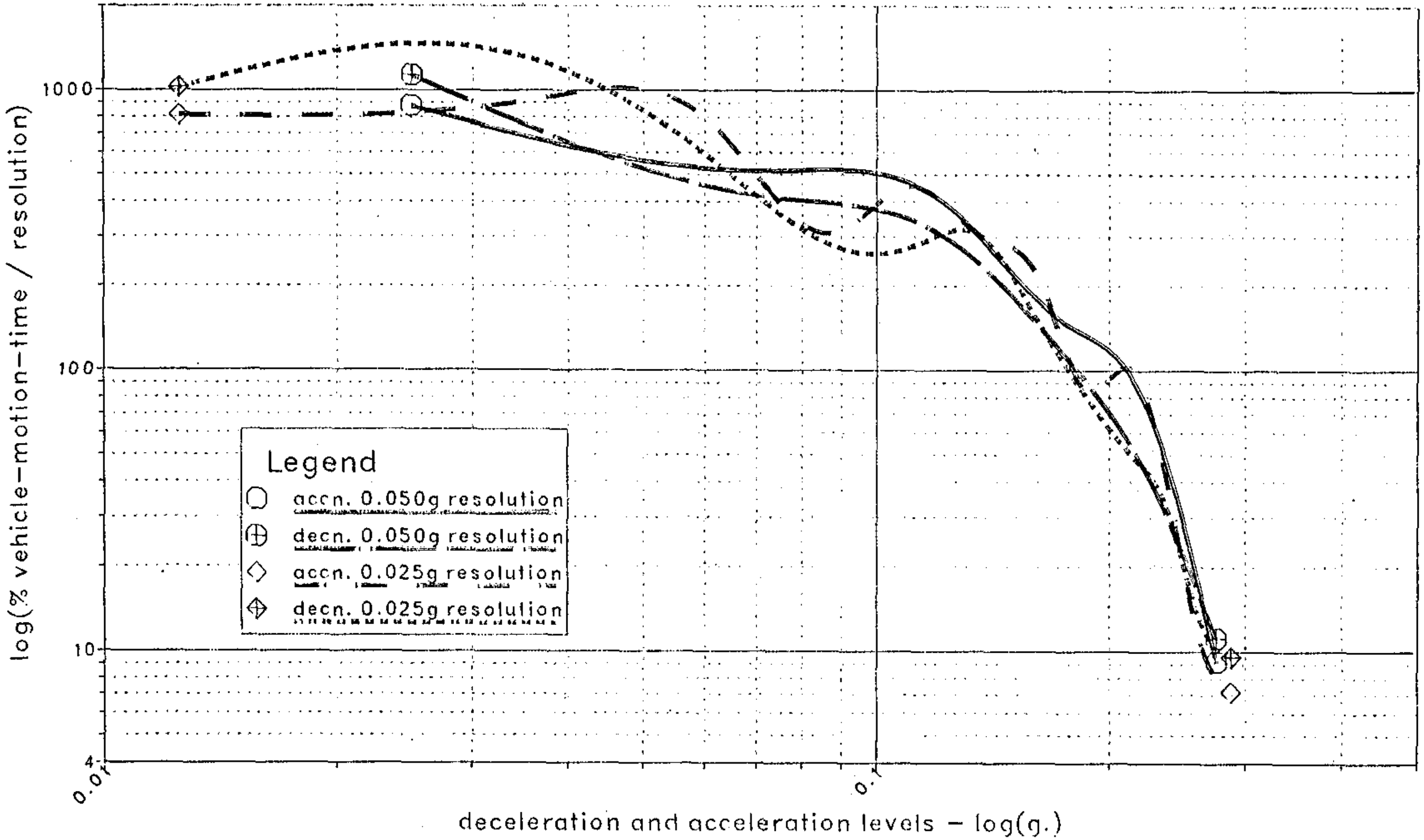


Figure No.46

VAUXHALL CAVALIER FUEL CONSUMPTION TESTS – SPRING 1985

Vehicle deceleration and acceleration characteristics

Linear regression of data for Driver No.1 – 1600 Petrol – Urban Cycle

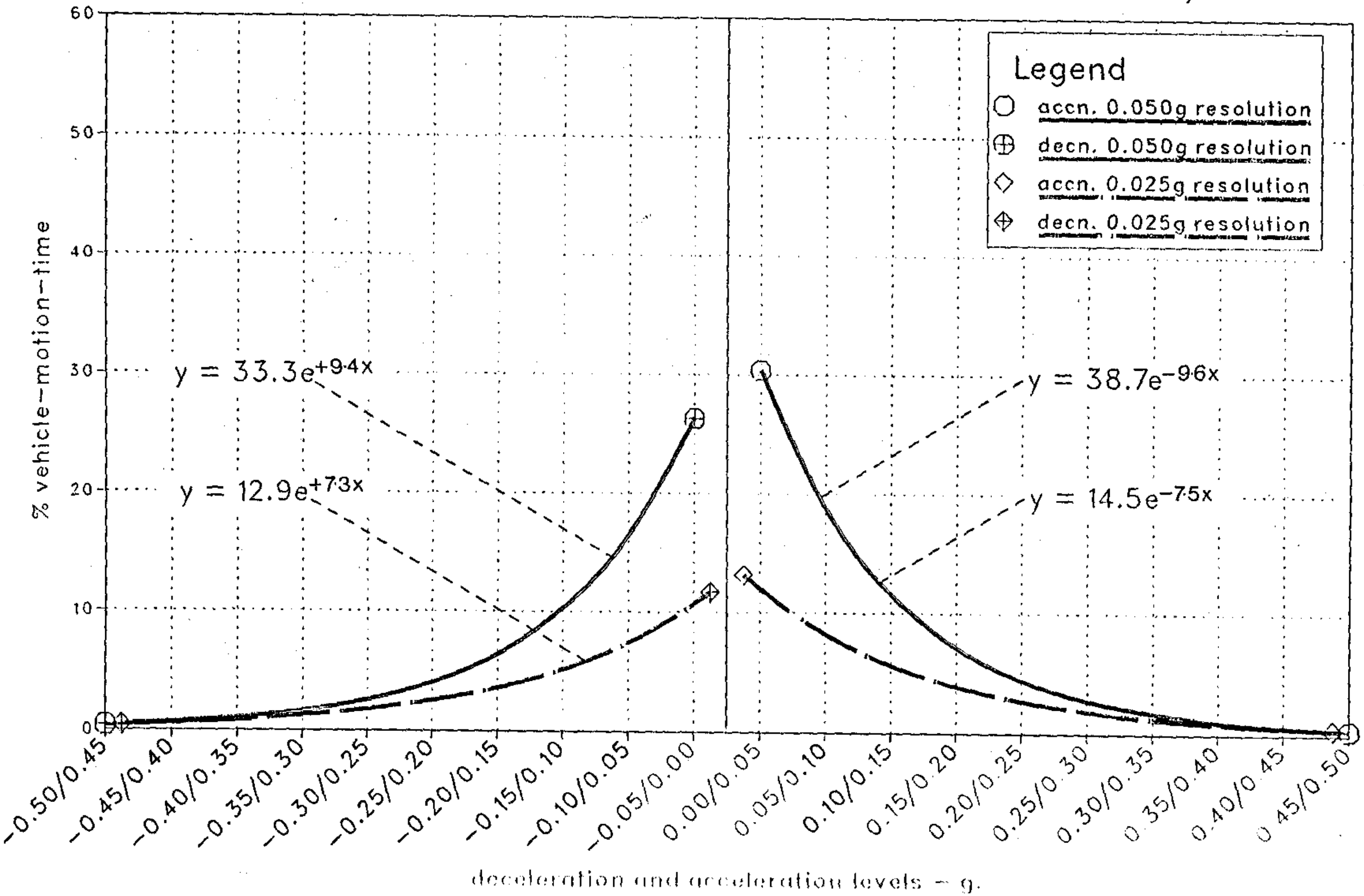
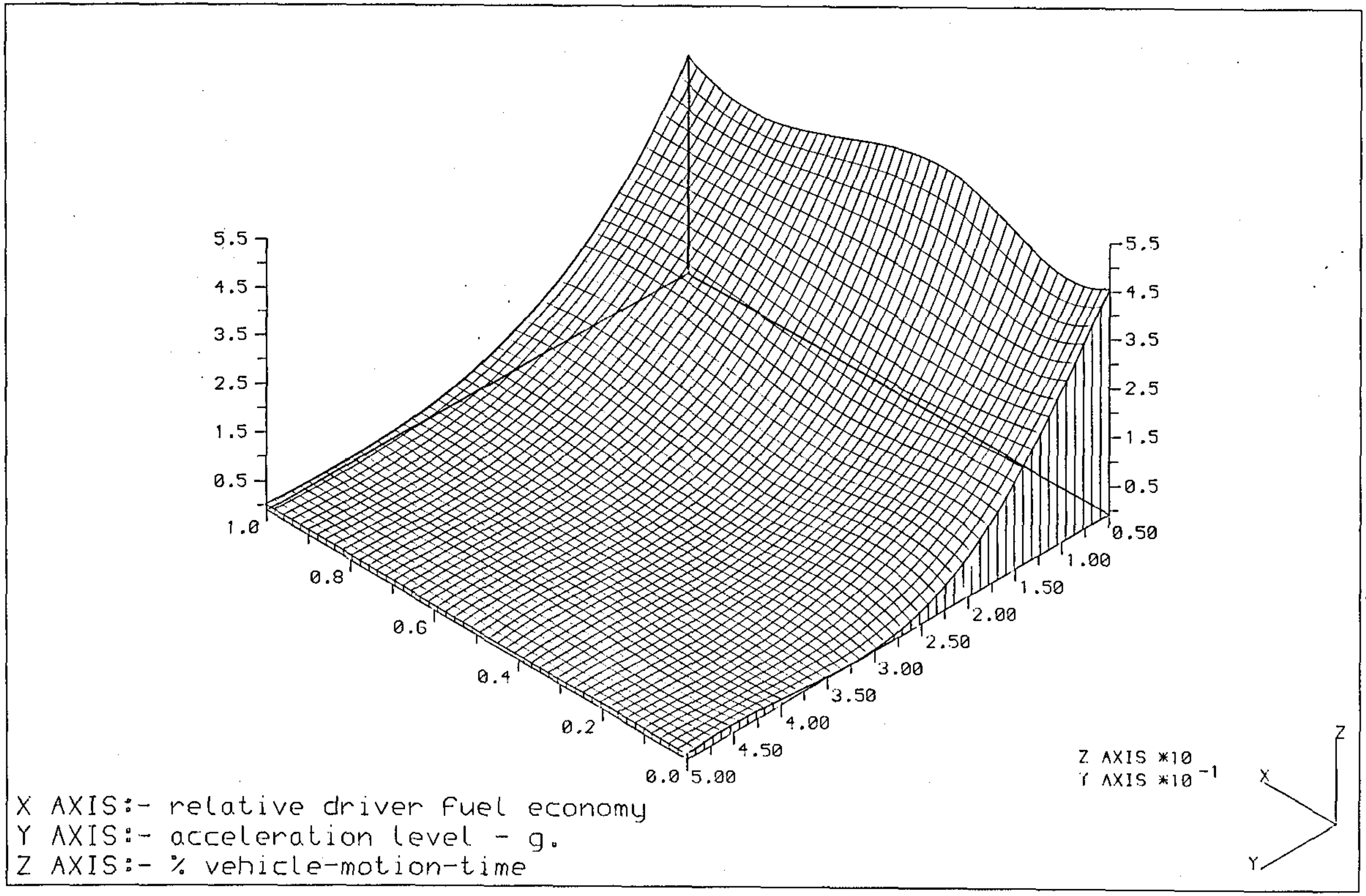
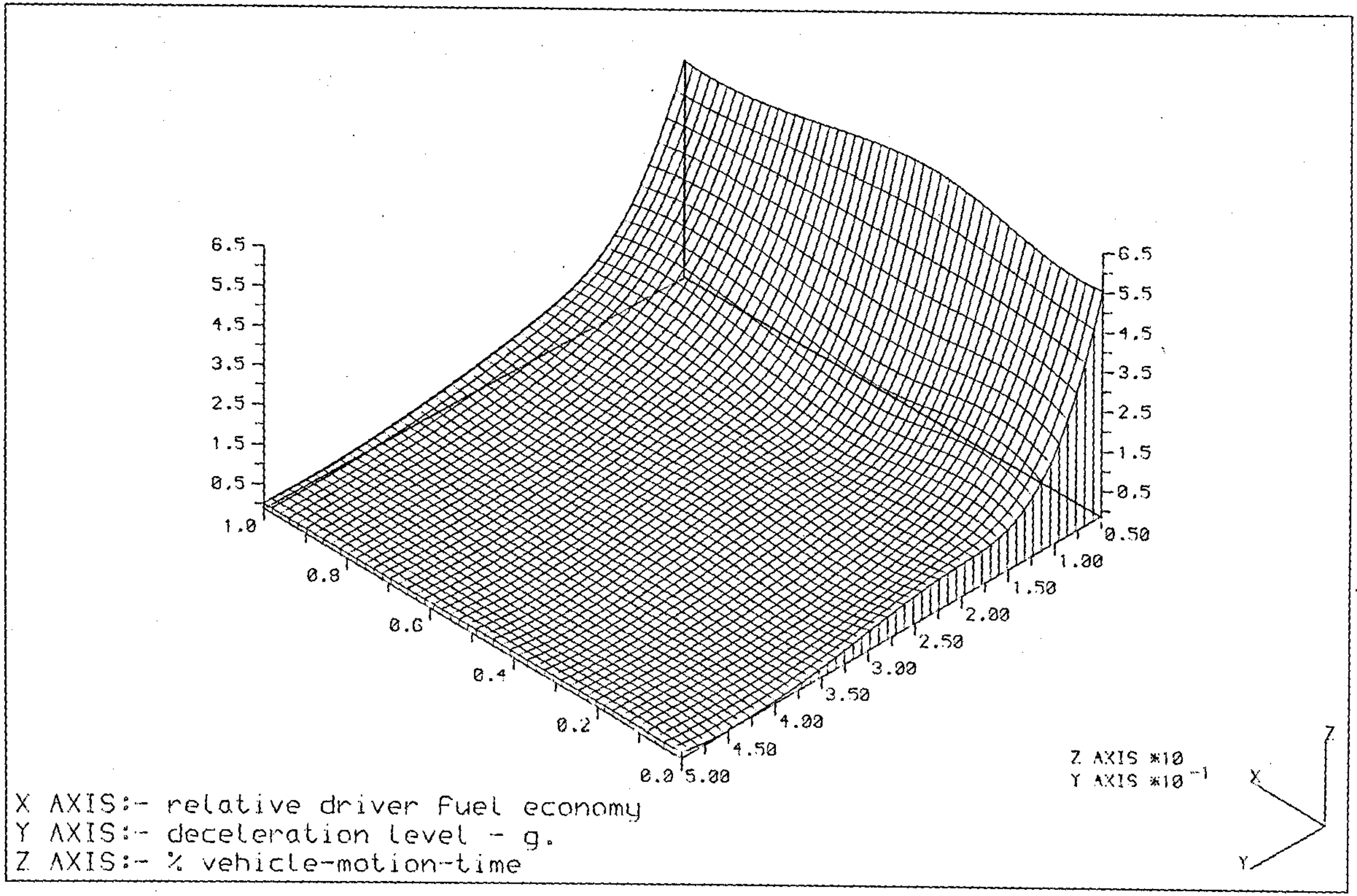


Figure No.47



acceleration histogram versus fuel economy for urban 1 route section

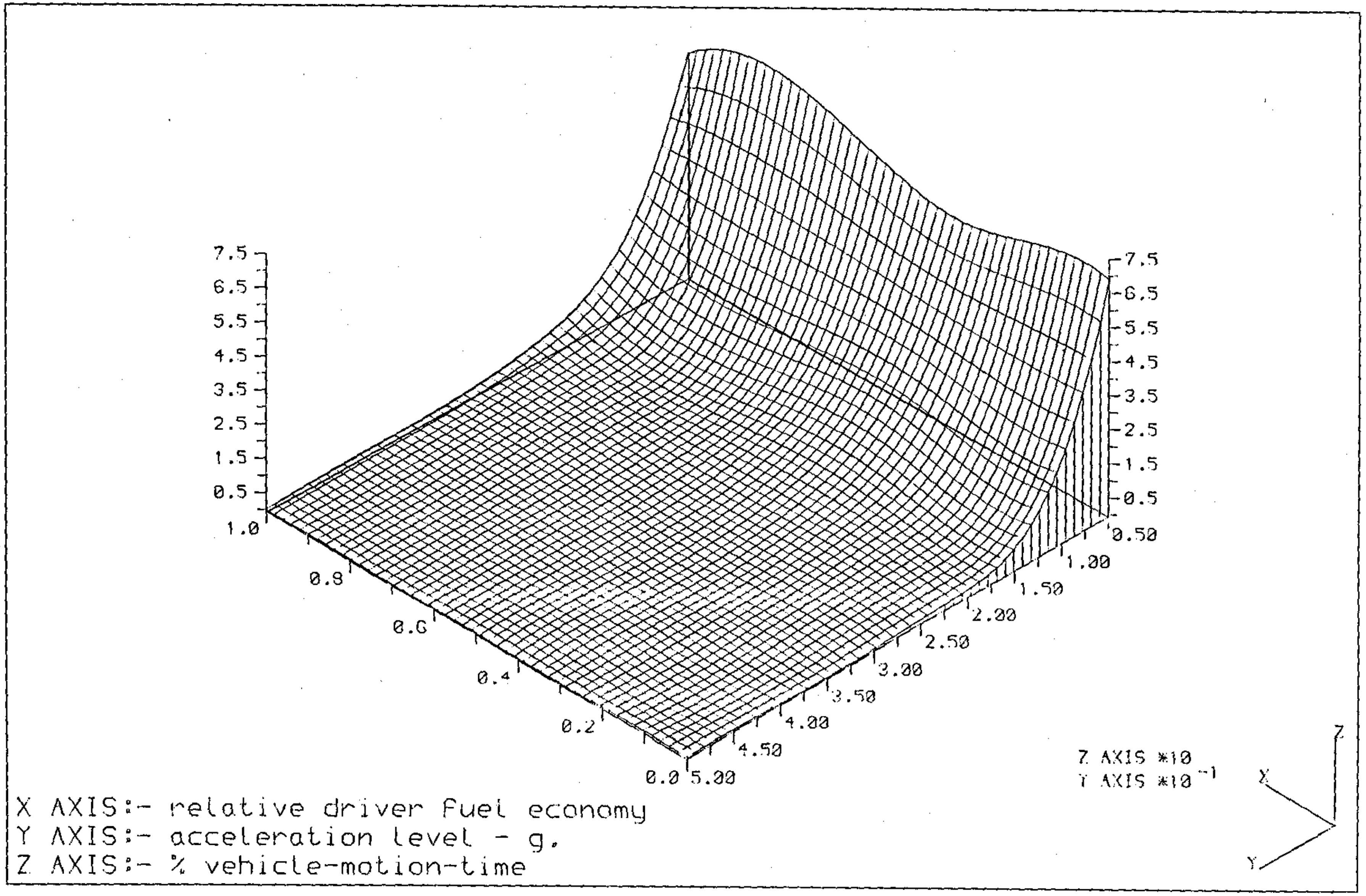
Figure No.48



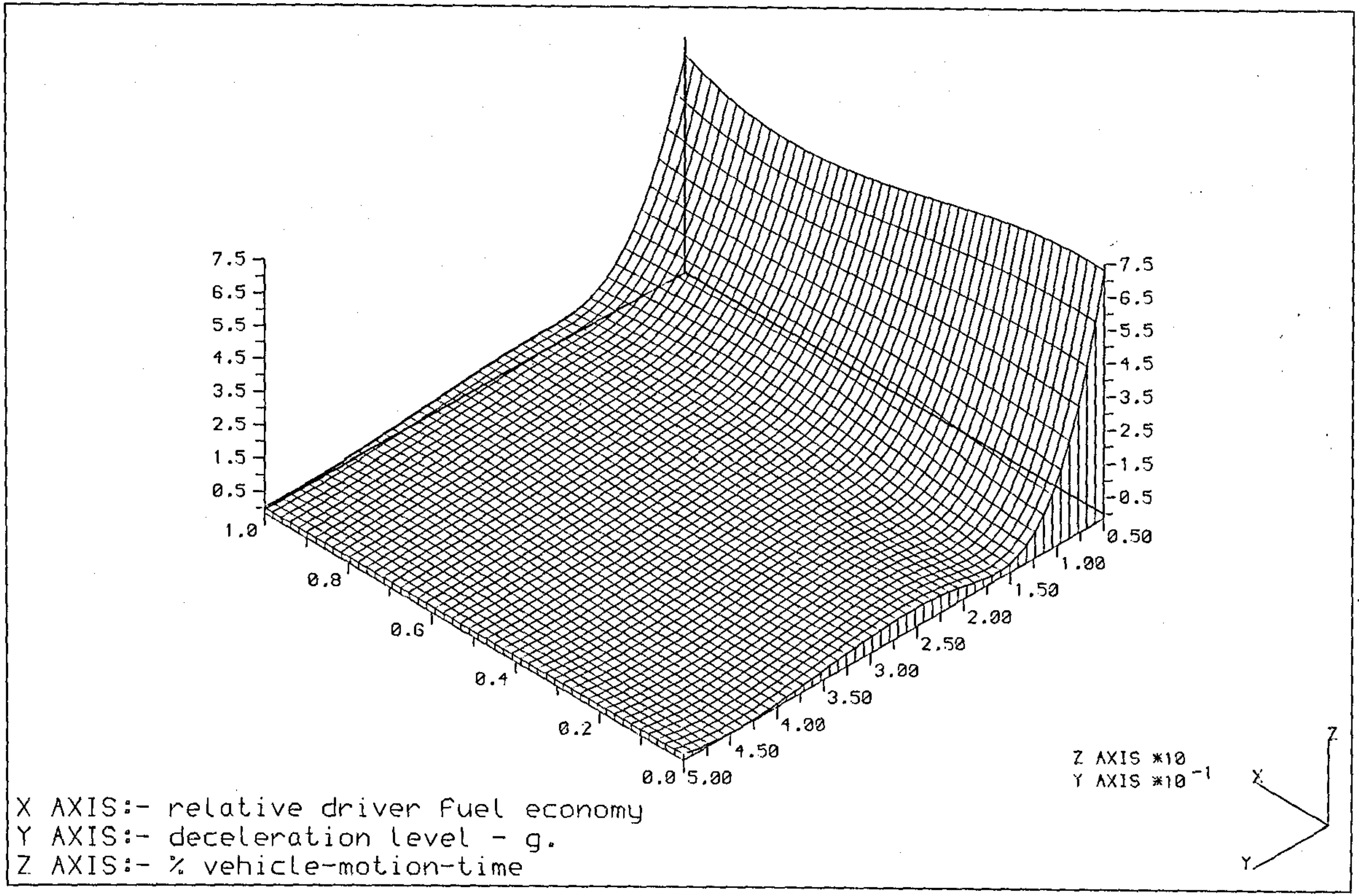
deceleration histogram versus fuel economy for urban 1 route section

Figure No.49

Figure No.50



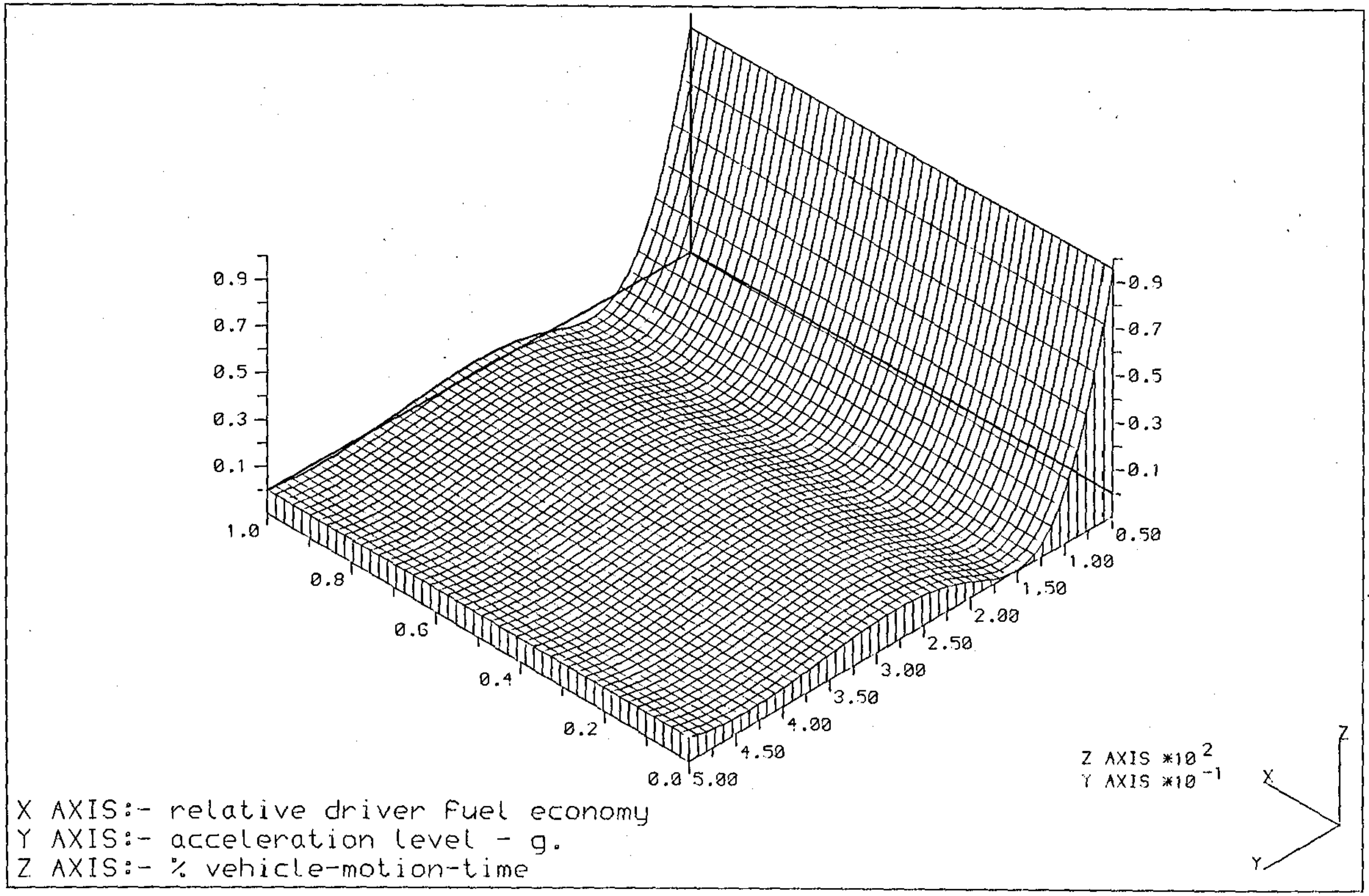
acceleration histogram versus fuel economy for suburban 2 route section



deceleration histogram versus fuel economy for suburban 2 route section

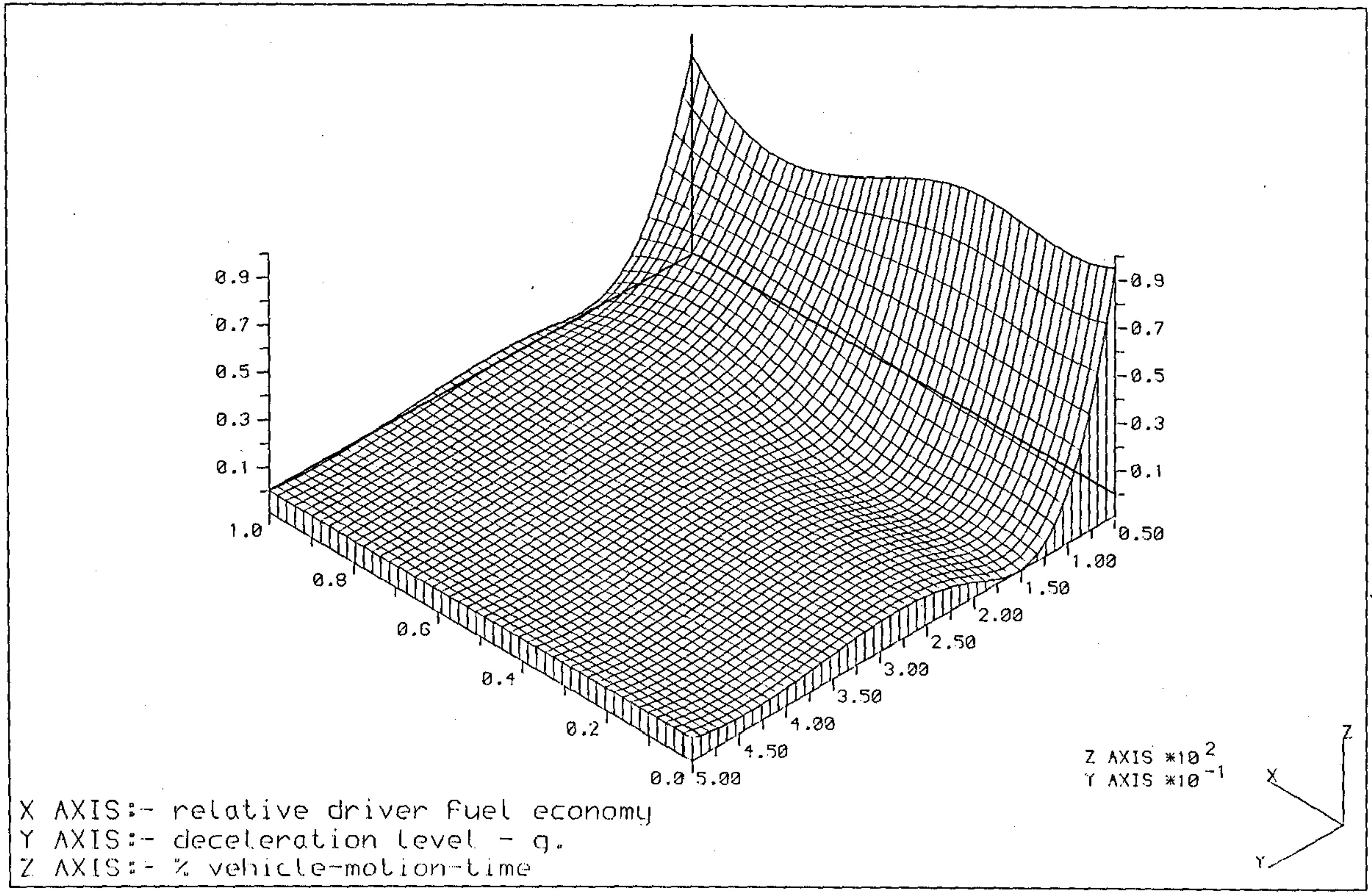
Figure No.51

Figure No.52



acceleration histogram versus fuel economy for motorway route section

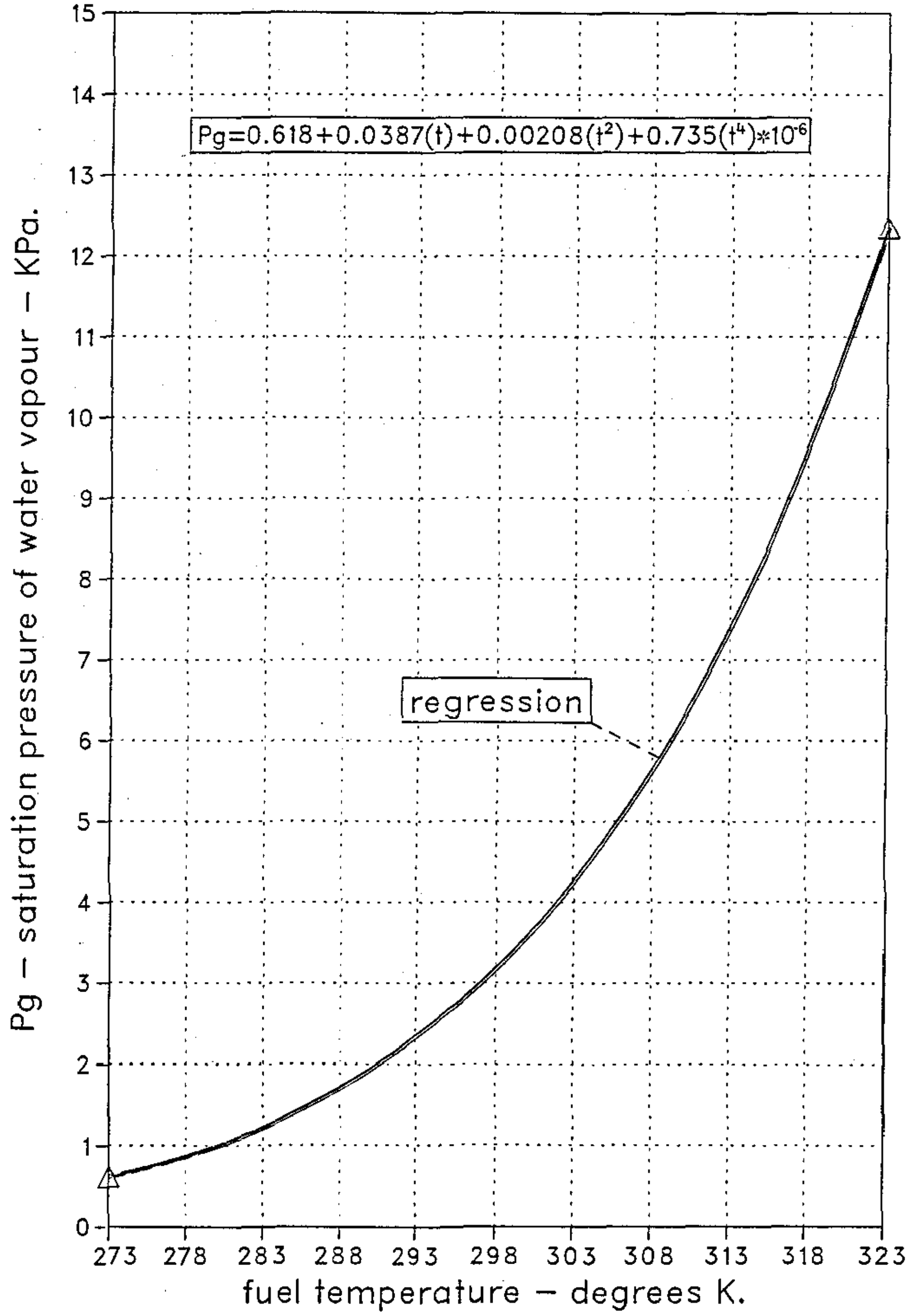
Figure No.53



deceleration histogram versus fuel economy for motorway route section

Figure No.54

SATURATION PRESSURE OF WATER VAPOUR
Relationship between ambient temperature and the saturation pressure of water vapour – Pg.



TABLES

Index to Tables.

Table No.1

Characteristics of the test vehicles.

MAKE / Model:	VAUXHALL / Cavalier		
VEHICLE CODE:	1	2	3
TYPE:	1·6GL (4-dr)	1·3GL (4-dr)	1·6LD (4-dr)
FUEL:	PETROL	PETROL	DIESEL
ENGINE:	4 in line	4 in line	4 in line
Capacity	1598 cc	1297 cc	1598 cc
Compression	9·2:1	9·2:1	23·0:1
Max. power	90 bhp @ 5800 rpm	75 bhp @ 5800 rpm	54 bhp @ 4600 rpm
Max. torque	93 lbft @ 3800 rpm	73·3 lbft @ 3800 rpm	71 lbft @ 2400 rpm
GEARBOX:	Manual	Manual	Manual
Ratio 1st.	3·545	3·646	3·545
2nd.	2·158	2·211	2·158
3rd.	1·370	1·429	1·370
4th.	0·971	0·969	0·971
Rev.	3·333	3·182	3·333
Final drive	3·740	4·180	3·740
TYRES:	Pressed steel 5J x 13in. (165 SR 13)		
Unladen weight*	991 Kg.	925 Kg.	1006 Kg.
Fuel tank capacity	60 litres	60 litres	61 litres
Battery	12 V 44 Ah	12 V 36 Ah	12 V 66 Ah
PERFORMANCE:			
Max. speed	164·6 Kph.	152·4 Kph.	141·8 Kph.
Accn. 0 - 80 Kph.	8·3 secs.	9·0 secs.	12·2 secs.
Accn. 0 - 100 Kph.	13·0 secs.	13·7 secs.	19·3 secs.
FUEL CONSUMPTION:**			
Urban	29·4 mpg.	28·8 mpg.	39·7 mpg.
56 mph.	46·3 mpg.	42·8 mpg.	54·3 mpg.
75 mph.	35·3 mpg.	32·1 mpg.	38·1 mpg.
NOISE:			
@ 30 mph.	65 dBA.	63 dBA.	65 dBA.
@ 50 mph.	69 dBA.	67 dBA.	70 dBA.
@ 70 mph.	75 dBA.	76 dBA.	76 dBA.

* with fuel in tank for approximately 50 miles.
**government figures.

Table No.2

Test driver characteristics.

DRIVER CODE NUMBER	1	2	3	4	5	6	7*
SEX (Male/Female)	M	M	M	M	F	F	M
AGE (Years)	37	70	49	27	36	25	45
Driving experience (Yrs.)	19	55	32	9	13	5	28
Approx. annual mileage	7500	8250	20000	35000	3000	2000	10000
Approx. split of driving	%	%	%	%	%	%	%
Business -	30	0	33	95	10	0	50
Domestic -	30	20	33	4	40	50	25
Pleasure -	40	80	33	1	50	50	25
OCCUPATION	Manual worker	Retired pensioner	Retired engineer	Service engineer	Housewife	Staff Manageress	Police service

* used as the "expert" driver (received occupational driver training and in possession of an Advanced Driving Certificate).

Table No.3

National Road Travel Statistics - 1984.

ROAD TRAFFIC - 1984 BY TYPE OF VEHICLE AND CLASS OF ROAD (figures presented for "cars and taxis" category)			
BILLION VEHICLE KILOMETRES			
ROAD CLASS	B.V.K.	ROAD CLASS	B.V.K.
Motorways	26·19	Non built-up roads**	
Built-up roads*		Trunk	31·92
Trunk	6·86	Principal	33·67
Principal	47·73	B roads	10·16
B roads	12·58	C roads	11·27
C roads	10·61	All trunk and classified	87·02
All trunk and classified	77·77	Unclassified	4·94
Unclassified	25·88	All non built-up roads	91·96
All built-up roads	103·64	All roads	221·79

* built-up roads are those with a speed limit of 40 m.p.h. or less.

** non built-up roads are those with a speed limit exceeding 40 m.p.h. (excluding motorways).

Table No.4

Distance of individual route sections of the Leicestershire Test Route.

EVENT MARKER NUMBERS	KILOMETRES	MILES
1 to 2	1·85	1·15
2 to 3	1·40	0·86
3 to 4	12·72	7·90
4 to 5	2·45	1·52
5 to 6	9·20	5·72
6 to 7	7·47	4·64
HALFWAY BREAK		
8 to 9	7·33	4·55
9 to 10	9·20	5·72
10 to 11	11·48	7·13
11 to 16 (omitting 14 to 15)	12·03	7·47
12 to 13 (optional)	0·20	0·13
16 to 17	7·26	4·51
17 to 18	4·15	2·58
18 to 19	11·55	7·17
DISTANCES FOR ADDITIONAL MOTORWAY SECTION		
11 to 14	29·31	18·21
14 to 15	1·57	0·97
15 to 16	15·73	9·77
16 to 17	7·88	4·89
DISTANCES FOR THE MAIN ROUTE SECTIONS		
Motorway J21 to J22	12·03	7·47
Urban 1 and 2	9·20	5·72
Suburban 1	16·00	9·91
Suburban 2	22·90	14·26
Urban 2 to Motorway	11·48	7·13
First mile	1·85	1·15

Table No.5

Example of output from "ROADTEST.FORTRAN".

```
*******************************************************************
VAUXHALL CAVALIER FUEL CONSUMPTION ROAD TEST
*******************************************************************
ANALYSIS FILE of L132021001                       1300 Petrol  (BLUE)
*******************************************************************
Commencing at mark No.01
and terminating at mark No.04
before the intermission, with a
duration of  26·133 minutes
from D059H08M27S52·9 minus 56·0 seconds
*******************************************************************
TOTAL DISTANCE         -      15·968 KM.              {  9·92 miles }
AVE.VEHICLE SPEED      -      36·661 KPH.             { 22·78 mph.  }
AVE.VEHICLE ACCN.      -       0·310 M/S/S.
AVE.VEHICLE DECN.      -      -0·422 M/S/S.
AVE.THROTTLE ANGLE     -       8·602 DEG.
AVE.THROTTLE SPEED     -       3·178 DEG/S.
AVE.THROTTLE ACCN.     -       6·170 DEG/S/S.
GEAR CHANGES           -       117·5
AVE.ENGINE REVS        -    1684·332 R.P.M.
TOTAL FUEL USED        -       1·321 LITRES           {  0·29 galls }
AVE.FUEL CONSP.        -       8·273 LIT./100KM.      { 34·14 mpg.  }
AVE.FUEL FLOW RATE     -       3·032 LIT./HR.         {  0·67 gal/hr}
AVE.FUEL FLOW CHECK    -       3·033 LIT./HR.         {  0·67 gal/hr}
AVE.FUEL TEMP.         -      12·902 DEG C.
AVE.OIL TEMP.          -      80·445 DEG C.
*******************************************************************
VEHICLE ACCN/DECCN CHARACTERISTICS
*******************************************************************
% of vehicle-motion-time at g level
g-level 0·025 0·050 0·075 0·100 0·125 0·150 0·175 0·200 0·225 0·250
accn  - 36·41 33·28 14·47  3·86  4·18  3·70  2·17  0·72  0·72  0·08
decn  - 36·60 38·06 11·18  3·83  4·52  2·60  1·38  0·92  0·54  0·15
g-level 0·275 0·300 0·325 0·350 0·375 0·400 0·425 0·450 0·475 0·500
accn  -  0·16  0·08  0·08  0·08  0·00  0·00  0·00  0·00  0·00  0·00
decn  -  0·08  0·08  0·08  0·00  0·00  0·00  0·00  0·00  0·00  0·00
*******************************************************************
VEHICLE STATE AT SECTION BOUNDARIES
*******************************************************************
Commencing at Event No.01
VEHICLE SPEED          -       0·081 KPH              {  0·05 mph.  }
THROTTLE ANGLE         -       7·663 DEG.
ENGINE REVS.           -    2130·248 RPM.
FUEL FLOW RATE         -       4·320 LIT./HR.         {  0·95 gal/hr}
FUEL TEMP.             -      12·400 DEG C.
OIL TEMP.              -      38·300 DEG C.
GEAR SELECTION         -      +NTRL
Terminating at Event No.04
VEHICLE SPEED          -      25·453 KPH.             { 15·82 mph.  }
THROTTLE ANGLE         -      32·356 DEG.
ENGINE REVS.           -    3564·793 RPM.
FUEL FLOW RATE         -       3·600 LIT./HR.         {  0·79 gal/hr}
FUEL TEMP.             -      14·000 DEG C.
OIL TEMP.              -      92·000 DEG C.
GEAR SELECTION         -      +NTRL
*******************************************************************
```

Table No.6

Test sequence numbers and dates for the Spring test programme 1985.

(two tests per driver in each vehicle)

DRIVER CODE No. SEX & AGE	NUMBER AND DATE OF EACH TEST 1600cc PETROL 1		1300cc PETROL 2		1600cc DIESEL 3	
1 Male 37 yrs.	1 28/2	23 21/3	8 7/3	29 28/3	15 14/3	36 17/4
2 Male 70 yrs.	16 15/3	37 4/4	2 1/3	24 22/3	9 8/3	30 28/3
3 Male 49 yrs.	3 4/3	31 1/4	17* 18/3 (22/4)	38 15/4	10 11/3	25 25/3
4 Male 27 yrs.	4* 5/3 (23/4)	18 18/3	11* 12/3 (30/4)	32 2/4	19 19/3	39 16/4
5 Female 36 yrs.	20 19/3	40 16/4	5* 5/3 (23/4)	26 26/3	12 12/3	33 2/4
6 Female 25 yrs.	13 13/3	34 3/4	21* 20/3 (24/4)	41 17/4	6 6/3	27 1/4

* repeated test drive required due to data corruption.
(date of test in parenthesis)

Table No.7

Test sequence numbers and dates for additional test programmes 1985.

ADDITIONAL TEST PROGRAMMES			
DRIVER CODE No. SEX & AGE	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
EXTRA MOTORWAY TEST DRIVES			
1 Male 37 yrs.	7 6/3	14* 13/3 (19/4)	22 20/3
LATE START TEST DRIVES			
1 Male 37 yrs.	28 27/3	35 3/4	42 18/4
HOT START TEST DRIVES			
3 Male 49 yrs.	43 25/4	44 26/4	45 29/4

* repeated test drive required due to data corruption.
(date of test in parenthesis)

Table No.8

Mean and Standard Error of test variables for each vehicle on the URBAN route section.

(from twelve test drives - two by each driver)

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	11·076 (0·192)	10·080 (0·146)	7·910 (0·120)
SPEED (Km./Hr.)	21·986 (0·601)	22·444 (0·370)	22·852 (0·721)
VACC (m./s./s.)	0·433 (0·014)	0·404 (0·012)	0·421 (0·014)
VDEC (m./s./s.)	-0·723 (0·013)	-0·698 (0·013)	-0·669 (0·014)
TPOS (degrees)	4·030 (0·221)	6·423 (0·240)	10·947 (0·366)
TVEL (degs./s.)	2·401 (0·140)	2·911 (0·270)	4·545 (0·230)
TACC (degs./s./s.)	4·847 (0·299)	6·842 (1·167)	9·078 (0·654)
GEAR (No./Km.)	13·835 (0·369)	21·768 (0·641)	13·499 (0·361)
REVS (r.p.m.)	1681·3 (31·1)	1611·9 (23·6)	1685·9 (31·8)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	279·7	279·9	279·9
PRESS (mBars.)	1008·9	1005·5	1014·1
HUMID (%)	82·5	82·1	78·5

Table No.9

Mean and Standard Error of test variables for each vehicle on the SUBURBAN route section.

(from twelve test drives - two by each driver)

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	7·487 (0·187)	6·933 (0·172)	5·748 (0·089)
SPEED (Km./Hr.)	46·619 (1·232)	46·414 (0·864)	47·006 (1·113)
VACC (m./s./s.)	0·427 (0·015)	0·363 (0·011)	0·375 (0·011)
VDEC (m./s./s.)	-0·549 (0·019)	-0·501 (0·013)	-0·500 (0·011)
TPOS (degrees)	8·570 (0·497)	10·465 (0·289)	17·932 (0·614)
TVEL (degs./s.)	2·925 (0·269)	2·925 (0·184)	4·658 (0·387)
TACC (degs./s./s.)	5·798 (0·588)	6·137 (0·370)	9·195 (1·004)
GEAR (No./Km.)	4·049 (0·205)	5·874 (0·227)	3·890 (0·178)
REVS (r.p.m.)	2198·7 (70·9)	2120·6 (46·3)	2159·6 (47·8)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	279·9	280·1	280·2
PRESS (mBars.)	1008·9	1005·5	1014·1
HUMID (%)	82·0	81·4	77·6

Table No.10

Mean and Standard Error of test variables for each vehicle on the MOTORWAY route section.

(from twelve test drives - two by each driver)

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	9·593 (0·538)	8·406 (0·380)	8·078 (0·345)
SPEED (Km./Hr.)	114·369 (3·925)	110·996 (3·178)	107·615 (3·197)
VACC (m./s./s.)	0·250 (0·017)	0·157 (0·005)	0·151 (0·006)
VDEC (m./s./s.)	-0·343 (0·022)	-0·240 (0·009)	-0·255 (0·013)
TPOS (degrees)	33·485 (3·297)	28·536 (1·841)	52·488 (3·798)
TVEL (degs./s.)	2·839 (0·391)	2·178 (0·107)	1·922 (0·212)
TACC (degs./s./s.)	6·333 (0·968)	5·144 (0·356)	3·797 (0·582)
GEAR (No./Km.)	0·038 (0·023)	0·000 (0·000)	0·024 (0·016)
REVS (r.p.m.)	4291·1 (146·3)	4161·0 (122·4)	4041·6 (121·6)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	281·1	281·4	281·9
PRESS (mBars.)	1008·9	1005·5	1014·1
HUMID (%)	78·4	75·3	70·7

Table No.11

Mean and Standard Error of test variables for each vehicle on the 50/40/10% route section.

(from twelve test drives - two by each driver)

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	9·492 (0·195)	8·653 (0·174)	7·063 (0·106)
SPEED (Km./Hr.)	30·977 (0·815)	31·410 (0·393)	31·858 (0·727)
VACC (m./s./s.)	0·412 (0·014)	0·363 (0·010)	0·376 (0·009)
VDEC (m./s./s.)	-0·615 (0·016)	-0·573 (0·012)	-0·560 (0·012)
TPOS (degrees)	8·792 (0·614)	10·251 (0·374)	17·895 (0·865)
TVEL (degs./s.)	2·654 (0·217)	2·843 (0·160)	4·328 (0·268)
TACC (degs./s./s.)	5·376 (0·477)	6·390 (0·585)	8·597 (0·765)
GEAR (No./Km.)	8·541 (0·244)	13·233 (0·384)	8·308 (0·285)
REVS (r.p.m.)	2149·2 (60·4)	2070·3 (42·5)	2110·9 (45·3)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	279·9	280·1	280·2
PRESS (mBars.)	1008·9	1005·5	1014·1
HUMID (%)	82·0	81·4	77·6

Table No.12

Mean and Standard Error of test variables for each driver on the URBAN route section.

(from six test drives - two in each vehicle)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	9·774 (0·494)	10·137 (0·430)	9·549 (0·413)	10·030 (0·381)	8·752 (0·347)	9·888 (0·526)
SPEED (Km./Hr.)	21·725 (0·804)	22·356 (0·756)	21·050 (0·453)	25·263 (0·933)	22·331 (0·541)	21·838 (0·867)
VACC (m./s./s.)	0·411 (0·017)	0·448 (0·016)	0·404 (0·011)	0·493 (0·018)	0·370 (0·010)	0·391 (0·018)
VDEC (m./s./s.)	–0·670 (0·019)	–0·720 (0·015)	–0·663 (0·014)	–0·780 (0·018)	–0·682 (0·012)	–0·665 (0·019)
TPOS (degrees)	7·017 (0·801)	7·266 (0·817)	6·576 (0·934)	8·882 (1·043)	6·248 (0·928)	6·812 (0·986)
TVEL (degs./s.)	3·572 (0·261)	3·398 (0·275)	3·222 (0·526)	4·297 (0·453)	2·353 (0·264)	2·872 (0·416)
TACC (degs./s./s.)	7·038 (0·486)	6·107 (0·583)	8·025 (2·313)	9·728 (1·140)	4·654 (0·345)	5·980 (0·844)
GEAR (No./Km.)	16·222 (0·843)	15·593 (1·138)	16·821 (1·352)	15·559 (1·292)	15·655 (1·573)	18·356 (1·510)
REVS (r.p.m.)	1530·900 (28·4)	1638·800 (18·9)	1589·400 (15·2)	1817·200 (29·3)	1562·400 (22·1)	1819·300 (32·4)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	278·8	278·5	280·5	280·1	279·2	282·1
PRESS (mBars.)	1010·0	1003·7	1007·9	1010·9	1011·6	1013·0
HUMID (%)	82·5	88·5	79·1	79·9	77·4	78·7

Table No.13

Mean and Standard Error of test variables for each driver on the SUBURBAN route section.

(from six test drives - two in each vehicle)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	6·871 (0·429)	6·639 (0·339)	6·164 (0·219)	7·489 (0·376)	6·269 (0·277)	6·903 (0·392)
SPEED (Km./Hr.)	46·100 (1·243)	45·349 (1·302)	44·857 (1·050)	49·012 (1·885)	45·603 (1·588)	49·156 (1·196)
VACC (m./s./s.)	0·416 (0·016)	0·390 (0·012)	0·344 (0·015)	0·418 (0·023)	0·344 (0·008)	0·418 (0·022)
VDEC (m./s./s.)	−0·496 (0·015)	−0·490 (0·006)	−0·449 (0·011)	−0·581 (0·014)	−0·523 (0·008)	−0·560 (0·024)
TPOS (degrees)	12·369 (1·781)	11·493 (1·623)	11·201 (1·893)	14·435 (2·113)	10·985 (1·856)	13·451 (1·875)
TVEL (degs./s.)	4·704 (0·509)	3·024 (0·262)	2·588 (0·335)	4·251 (0·453)	2·429 (0·248)	4·021 (0·568)
TACC (degs./s./s.)	9·086 (1·042)	4·851 (0·444)	5·431 (0·645)	9·596 (1·189)	4·809 (0·420)	8·487 (1·019)
GEAR (No./Km.)	4·568 (0·337)	4·501 (0·403)	4·414 (0·457)	4·591 (0·580)	4·426 (0·488)	5·129 (0·626)
REVS (r.p.m.)	2044·100 (33·8)	2074·600 (28·7)	2009·600 (25·9)	2366·800 (48·0)	3055·800 (33·1)	2406·600 (66·1)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	279·0	278·6	280·7	280·3	279·4	282·3
PRESS (mBars.)	1010·0	1003·7	1007·9	1010·9	1011·6	1013·0
HUMID (%)	82·0	88·2	78·3	79·0	76·6	77·9

Table No.14

Mean and Standard Error of test variables for each driver on the MOTORWAY route section.

(from six test drives - two in each vehicle)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	8·437 (0·369)	7·747 (0·336)	7·596 (0·308)	11·399 (0·639)	8·422 (0·288)	8·554 (0·431)
SPEED (Km./Hr.)	107·940 (2·782)	100·735 (2·801)	102·894 (1·579)	131·614 (3·014)	106·934 (2·441)	115·843 (2·038)
VACC (m./s./s.)	0·181 (0·022)	0·177 (0·020)	0·162 (0·017)	0·216 (0·037)	0·175 (0·008)	0·204 (0·032)
VDEC (m./s./s.)	-0·268 (0·019)	-0·258 (0·022)	-0·248 (0·021)	-0·332 (0·047)	-0·264 (0·010)	-0·305 (0·032)
TPOS (degrees)	35·748 (5·318)	30·543 (3·166)	31·231 (4·243)	57·704 (6·416)	35·259 (4·515)	38·532 (5·981)
TVEL (degs./s.)	2·778 (0·544)	1·827 (0·248)	1·775 (0·216)	3·321 (0·518)	2·014 (0·162)	2·163 (0·166)
TACC (degs./s./s.)	5·600 (1·302)	3·255 (0·526)	3·797 (0·590)	8·323 (1·243)	4·740 (0·465)	4·834 (0·441)
GEAR (No./Km.)	0·014 (0·014)	0·069 (0·045)	0·000 (0·000)	0·021 (0·021)	0·000 (0·000)	0·021 (0·021)
REVS (r.p.m.)	4048·000 (105·3)	3784·900 (103·7)	3854·500 (59·5)	4953·600 (107·1)	4005·800 (91·0)	4340·600 (77·2)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	280·1	279·6	282·3	282·1	280·9	284·1
PRESS (mBars.)	1010·0	1003·7	1007·9	1010·9	1011·6	1013·0
HUMID (%)	78·0	85·4	72·7	71·6	70·0	71·4

Table No.15

Mean and Standard Error of test variables for each driver on the 50/40/10% route section.

(from six test drives - two in each vehicle)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	8·479 (0·525)	8·500 (0·463)	8·000 (0·404)	9·151 (0·462)	7·726 (0·369)	8·561 (0·565)
SPEED (Km./Hr.)	30·614 (0·749)	31·045 (0·452)	29·703 (0·443)	34·751 (1·078)	31·093 (0·756)	31·286 (0·630)
VACC (m./s./s.)	0·390 (0·013)	0·397 (0·010)	0·356 (0·011)	0·435 (0·020)	0·340 (0·006)	0·383 (0·015)
VDEC (m./s./s.)	-0·560 (0·015)	-0·582 (0·010)	-0·536 (0·011)	-0·655 (0·017)	-0·576 (0·006)	-0·587 (0·026)
TPOS (degrees)	12·031 (1·746)	11·285 (1·490)	10·891 (1·820)	15·986 (2·127)	11·044 (1·842)	12·640 (1·950)
TVEL (degs./s.)	3·945 (0·338)	3·091 (0·254)	2·824 (0·320)	4·181 (0·474)	2·349 (0·290)	3·260 (0·496)
TACC (degs./s./s.)	7·714 (0·614)	5·320 (0·398)	6·565 (1·188)	9·535 (1·194)	4·724 (0·392)	6·868 (0·902)
GEAR (No./Km.)	9·939 (0·692)	9·604 (0·847)	10·176 (1·068)	9·617 (1·167)	9·598 (1·259)	11·231 (1·328)
REVS (r.p.m.)	1987·900 (36·0)	2027·700 (16·7)	1984·100 (20·5)	2350·700 (33·2)	2004·100 (23·0)	2306·400 (40·2)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	279·0	278·6	280·7	280·3	279·4	282·3
PRESS (mBars.)	1010·0	1003·7	1007·9	1010·9	1011·6	1013·0
HUMID (%)	82·0	88·2	78·3	79·0	76·6	77·9

Table No.16

Mean and Standard Error of test variables for the expert driver on each route section.

(from three test drives - one in each vehicle)

	TEST ROUTE SECTION			
	URBAN	SUBURBAN	MOTORWAY	50/40/10%
VARIABLE	MEAN & (Standard Error)			
FUEL (lit./100Km.)	8·810 (0·461)	6·025 (0·405)	6·574 (0·206)	7·473 (0·507)
SPEED (Km./Hr.)	20·988 (1·051)	46·070 (0·379)	87·165 (1·624)	29·683 (0·830)
VACC (m./s./s.)	0·380 (0·019)	0·334 (0·019)	0·133 (0·023)	0·337 (0·017)
VDEC (m./s./s.)	-0·599 (0·014)	-0·462 (0·027)	-0·211 (0·026)	-0·505 (0·022)
TPOS (degrees)	5·632 (1·191)	10·546 (2·482)	23·874 (4·891)	9·422 (2·384)
TVEL (degs./s.)	2·249 (0·356)	2·317 (0·278)	1·227 (0·240)	2·174 (0·402)
TACC (degs./s./s.)	4·418 (0·445)	4·392 (0·294)	2·264 (0·406)	4·192 (0·441)
GEAR (No./Km.)	20·094 (2·489)	4·675 (0·757)	0·000 (0·000)	11·917 (1·939)
REVS (r.p.m.)	1480·200 (37·3)	2010·500 (3·3)	3265·300 (60·3)	1870·800 (21·8)
	MEAN AMBIENT CONDITIONS			
TAMB (°K)	283·9	284·1	285·5	284·1
PRESS (mBars.)	1015·5	1015·5	1015·5	1015·5
HUMID (%)	71·3	71·0	68·8	71·0

Table No.17

Mean and Standard Error of test variables for each driver using the 1600cc petrol vehicle on the URBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	11·276 (0·447)	11·601 (0·298)	10·831 (0·344)	10·878 (0·245)	9·802 (0·403)	12·064 (0·252)
SPEED (Km./Hr.)	21·751 (1·801)	21·929 (1·173)	20·887 (0·905)	25·991 (1·413)	21·443 (0·992)	19·917 (0·937)
VACC (m./s./s.)	0·440 (0·036)	0·451 (0·024)	0·421 (0·022)	0·520 (0·025)	0·361 (0·019)	0·406 (0·026)
VDEC (m./s./s.)	-0·690 (0·034)	-0·706 (0·025)	-0·702 (0·016)	-0·820 (0·026)	-0·678 (0·024)	-0·744 (0·017)
TPOS (degrees)	4·099 (0·471)	4·465 (0·450)	3·417 (0·157)	5·692 (0·349)	2·887 (0·063)	3·621 (0·260)
TVEL (degs./s.)	2·861 (0·242)	2·711 (0·158)	2·030 (0·101)	3·315 (0·260)	1·617 (0·061)	1·869 (0·073)
TACC (degs./s./s.)	5·603 (0·633)	4·880 (0·190)	4·057 (0·376)	7·106 (0·722)	3·496 (0·098)	3·940 (0·181)
GEAR (No./Km.)	13·731 (0·621)	13·470 (0·958)	13·646 (0·487)	12·347 (0·402)	13·032 (0·499)	16·788 (0·641)
REVS (r.p.m.)	1583·900 (37·4)	1635·100 (26·7)	1614·400 (25·2)	1850·800 (34·9)	1523·700 (25·9)	1879·700 (58·9)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	278·8	276·4	280·0	284·3	278·0	280·9
PRESS (mBars.)	1014·8	991·5	1015·8	1004·5	1005·0	1021·8
HUMID (%)	86·8	98·3	81·0	79·4	79·0	70·8

Table No.18

Mean and Standard Error of test variables for each driver using the 1600cc petrol vehicle on the SUBURBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	7·842 (0·511)	7·498 (0·059)	6·551 (0·333)	8·132 (0·172)	6·966 (0·016)	7·932 (0·164)
SPEED (Km./Hr.)	45·608 (4·271)	43·014 (0·562)	47·320 (1·845)	51·619 (0·865)	42·115 (2·428)	50·036 (0·308)
VACC (m./s./s.)	0·453 (0·001)	0·405 (0·016)	0·376 (0·008)	0·480 (0·022)	0·361 (0·008)	0·488 (0·011)
VDEC (m./s./s.)	−0·535 (0·077)	−0·499 (0·011)	−0·466 (0·034)	−0·617 (0·031)	−0·543 (0·003)	−0·635 (0·021)
TPOS (degrees)	8·671 (0·710)	7·756 (0·044)	7·453 (0·277)	11·068 (0·093)	6·456 (0·873)	10·018 (0·437)
TVEL (degs./s.)	4·219 (0·291)	2·416 (0·012)	2·126 (0·020)	3·838 (0·039)	1·841 (0·159)	3·113 (0·178)
TACC (degs./s./s.)	7·807 (0·627)	3·825 (0·043)	4·245 (0·097)	8·415 (0·032)	3·771 (0·398)	6·721 (0·375)
GEAR (No./Km.)	4·192 (0·668)	4·582 (0·672)	3·238 (0·372)	3·611 (0·380)	4·453 (0·487)	4·218 (0·010)
REVS (r.p.m.)	2080·900 (38·0)	2028·800 (11·1)	2071·500 (16·1)	2455·800 (2·2)	1972·800 (44·7)	2582·700 (63·1)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	278·9	276·5	280·2	284·5	278·2	281·1
PRESS (mBars.)	1014·8	991·5	1015·8	1004·5	1005·0	1021·8
HUMID (%)	86·8	98·3	80·5	78·5	78·5	69·8

Table No.19

Mean and Standard Error of test variables for each driver using the 1600cc petrol vehicle on the MOTORWAY route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	9·184 (0·694)	8·182 (0·139)	8·296 (0·517)	13·289 (0·484)	8·998 (0·430)	9·611 (0·167)
SPEED (Km./Hr.)	110·014 (1·054)	100·538 (2·222)	106·633 (0·970)	140·241 (1·450)	108·709 (1·114)	120·078 (1·590)
VACC (m./s./s.)	0·243 (0·036)	0·231 (0·021)	0·207 (0·001)	0·321 (0·061)	0·198 (0·000)	0·300 (0·025)
VDEC (m./s./s.)	−0·322 (0·029)	−0·284 (0·023)	−0·310 (0·019)	−0·458 (0·061)	−0·278 (0·020)	−0·403 (0·015)
TPOS (degrees)	29·929 (2·626)	25·409 (0·199)	26·380 (1·732)	56·674 (3·952)	28·800 (1·797)	33·716 (0·860)
TVEL (degs./s.)	4·104 (1·143)	2·119 (0·615)	2·275 (0·269)	4·763 (0·319)	1·737 (0·470)	2·035 (0·125)
TACC (degs./s./s.)	8·535 (2·835)	3·786 (1·302)	4·885 (1·137)	11·613 (1·112)	4·250 (1·307)	4·932 (0·553)
GEAR (No./Km.)	0·041 (0·041)	0·125 (0·125)	0·000 (0·000)	0·000 (0·000)	0·000 (0·000)	0·062 (0·062)
REVS (r.p.m.)	4137·000 (43·0)	3781·900 (97·7)	3995·900 (36·3)	5255·400 (54·4)	4073·700 (41·8)	4502·700 (56·7)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	280·0	277·4	281·4	286·0	279·1	283·1
PRESS (mBars.)	1014·8	991·5	1015·8	1004·5	1005·0	1021·8
HUMID (%)	86·9	98·4	76·9	71·9	75·2	61·3

Table No.20

Mean and Standard Error of test variables for each driver using the 1600cc petrol vehicle on the 50/40/10% route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	9·693 (0·273)	9·618 (0·092)	8·866 (0·412)	10·021 (0·319)	8·588 (0·386)	10·165 (0·040)
SPEED (Km./Hr.)	30·593 (1·665)	30·204 (0·523)	29·998 (1·671)	36·071 (2·094)	29·531 (1·114)	29·464 (0·557)
VACC (m./s./s.)	0·425 (0·019)	0·410 (0·022)	0·382 (0·011)	0·485 (0·000)	0·344 (0·011)	0·428 (0·001)
VDEC (m./s./s.)	-0·591 (0·009)	-0·580 (0·028)	-0·568 (0·010)	-0·702 (0·005)	-0·584 (0·012)	-0·666 (0·024)
TPOS (degrees)	8·511 (0·679)	7·876 (0·121)	7·328 (0·188)	12·940 (0·210)	6·905 (0·483)	9·189 (0·288)
TVEL (degs./s.)	3·528 (0·048)	2·534 (0·008)	2·093 (0·095)	3·668 (0·161)	1·719 (0·063)	2·383 (0·026)
TACC (degs./s./s.)	6·778 (0·058)	4·349 (0·033)	4·215 (0·293)	8·081 (0·484)	3·682 (0·249)	5·152 (0·074)
GEAR (No./Km.)	8·547 (0·188)	8·581 (0·075)	8·118 (0·129)	7·618 (0·437)	8·298 (0·044)	10·087 (0·445)
REVS (r.p.m.)	2038·000 (26·8)	2007·200 (7·0)	2035·400 (28·6)	2433·200 (19·1)	1958·400 (8·0)	2423·200 (35·5)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	278·9	276·5	280·2	284·5	278·2	281·1
PRESS (mBars.)	1014·8	991·5	1015·8	1004·5	1005·0	1021·8
HUMID (%)	86·8	98·3	80·5	78·5	78·5	69·8

Table No.21

Mean and Standard Error of test variables for each driver using the 1300cc petrol vehicle on the URBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN AND (Standard Error)					
FUEL (lit./100Km.)	10·394 (0·211)	10·495 (0·178)	10·079 (0·116)	10·797 (0·329)	9·056 (0·297)	9·660 (0·139)
SPEED (Km./Hr.)	22·108 (1·120)	22·773 (1·087)	21·135 (0·859)	23·928 (0·785)	22·100 (0·735)	22·618 (0·723)
VACC (m./s./s.)	0·400 (0·024)	0·443 (0·022)	0·384 (0·018)	0·477 (0·028)	0·354 (0·015)	0·365 (0·018)
VDEC (m./s./s.)	-0·685 (0·045)	-0·743 (0·014)	-0·661 (0·024)	-0·765 (0·026)	-0·686 (0·025)	-0·648 (0·011)
TPOS (degrees)	6·977 (0·844)	6·878 (0·354)	5·703 (0·617)	7·573 (0·478)	5·576 (0·159)	5·832 (0·168)
TVEL (degs./s.)	3·229 (0·188)	2·908 (0·090)	3·703 (1·518)	3·525 (0·229)	1·881 (0·106)	2·221 (0·156)
TACC (degs./s./s.)	6·675 (0·569)	5·160 (0·299)	11·855 (0·696)	8·082 (0·684)	4·346 (0·278)	4·934 (0·382)
GEAR (No./Km.)	19·109 (1·096)	20·176 (1·671)	22·548 (1·793)	21·483 (0·430)	22·502 (1·650)	24·790 (1·468)
REVS (r.p.m.)	1507·900 (61·3)	1611·100 (28·9)	1554·400 (23·8)	1733·900 (32·3)	1517·900 (26·7)	1745·600 (13·2)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	276·8	280·2	283·1	276·6	279·3	283·3
PRESS (mBars.)	1000·3	1001·5	994·0	1014·5	1013·8	1009·3
HUMID (%)	85·7	82·6	81·3	83·4	77·1	82·8

Table No.22

Mean and Standard Error of test variables for each driver using the 1300cc petrol vehicle on the SUBURBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	7·121 (0·062)	6·754 (0·173)	6·398 (0·087)	8·012 (0·131)	6·338 (0·198)	6·975 (0·033)
SPEED (Km./Hr.)	45·058 (0·691)	47·633 (1·451)	43·672 (0·652)	43·783 (2·649)	48·898 (1·451)	49·444 (1·995)
VACC (m./s./s.)	0·371 (0·020)	0·397 (0·002)	0·296 (0·004)	0·382 (0·013)	0·345 (0·010)	0·385 (0·006)
VDEC (m./s./s.)	−0·466 (0·025)	−0·498 (0·001)	−0·438 (0·017)	−0·565 (0·005)	−0·525 (0·003)	−0·515 (0·012)
TPOS (degrees)	10·609 (0·715)	10·423 (0·304)	9·041 (0·107)	11·168 (0·782)	10·156 (0·147)	11·394 (0·881)
TVEL (degs./s.)	3·640 (0·186)	3·049 (0·080)	2·001 (0·006)	3·399 (0·399)	2·321 (0·042)	3·141 (0·088)
TACC (degs./s./s.)	7·181 (0·603)	5·389 (0·194)	4·623 (0·217)	7·384 (1·029)	5·173 (0·045)	7·075 (0·471)
GEAR (No./Km.)	5·446 (0·111)	5·410 (0·215)	5·593 (0·154)	6·304 (0·505)	5·472 (0·960)	7·021 (0·051)
REVS (r.p.m.)	1960·700 (69·9)	2119·400 (27·9)	1945·900 (19·7)	2247·700 (10·6)	2092·900 (33·3)	2357·100 (72·0)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	276·9	280·4	283·2	276·9	279·5	283·5
PRESS (mBars.)	1000·3	1001·5	994·0	1014·5	1013·8	1009·3
HUMID (%)	85·0	81·8	80·8	82·5	76·0	82·3

Table No.23

Mean and Standard Error of test variables for each driver using the 1300cc petrol vehicle on the MOTORWAY route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	7·777 (0·664)	7·985 (0·711)	7·246 (0·236)	10·891 (0·006)	8·451 (0·169)	8·085 (0·532)
SPEED (Km./Hr.)	104·123 (9·557)	107·818 (0·753)	100·455 (3·849)	130·582 (0·659)	110·753 (2·060)	112·244 (1·298)
VACC (m./s./s.)	0·151 (0·002)	0·163 (0·010)	0·151 (0·025)	0·160 (0·021)	0·166 (0·011)	0·149 (0·016)
VDEC (m./s./s.)	−0·231 (0·015)	−0·245 (0·001)	−0·220 (0·013)	−0·252 (0·051)	−0·246 (0·024)	−0·246 (0·028)
TPOS (degrees)	25·451 (3·934)	26·336 (2·015)	23·127 (0·156)	40·955 (0·794)	28·510 (0·039)	26·837 (1·637)
TVEL (degs./s.)	2·407 (0·292)	2·012 (0·034)	1·782 (0·162)	2·455 (0·381)	2·309 (0·036)	2·103 (0·397)
TACC (degs./s./s.)	5·397 (0·604)	3·888 (0·024)	4·212 (0·330)	6·792 (1·028)	5·711 (0·212)	4·863 (1·085)
GEAR (No./Km.)	0·000 (0·000)	0·000 (0·000)	0·000 (0·000)	0·000 (0·000)	0·000 (0·000)	0·000 (0·000)
REVS (r.p.m.)	3897·900 (357·8)	4036·200 (28·2)	3760·600 (144·1)	4923·300 (59·4)	4146·100 (77·1)	4201·900 (48·6)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	278·0	281·5	284·3	279·2	281·1	284·8
PRESS (mBars.)	1000·3	1001·5	994·0	1014·5	1013·8	1009·3
HUMID (%)	79·7	74·9	76·6	72·5	67·3	78·1

Table No.24

Mean and Standard Error of test variables for each driver using the 1300cc petrol vehicle on the 50/40/10% route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	8·823 (0·220)	8·748 (0·139)	8·322 (0·012)	9·692 (0·238)	7·907 (0·107)	8·428 (0·137)
SPEED (Km./Hr.)	30·800 (1·484)	31·932 (0·720)	29·572 (0·112)	32·458 (1·002)	31·535 (0·394)	32·165 (0·773)
VACC (m./s./s.)	0·363 (0·016)	0·396 (0·016)	0·326 (0·001)	0·407 (0·025)	0·332 (0·002)	0·352 (0·001)
VDEC (m./s./s.)	−0·552 (0·040)	−0·595 (0·005)	−0·528 (0·010)	−0·633 (0·015)	−0·577 (0·016)	−0·555 (0·010)
TPOS (degrees)	10·277 (1·303)	10·242 (0·271)	8·781 (0·374)	12·349 (0·609)	9·701 (0·082)	10·157 (0·221)
TVEL (degs./s.)	3·311 (0·112)	2·875 (0·019)	2·830 (0·677)	3·367 (0·330)	2·100 (0·011)	2·577 (0·030)
TACC (degs./s./s.)	6·750 (0·491)	5·124 (0·020)	8·198 (3·500)	7·674 (0·754)	4·813 (0·062)	5·783 (0·075)
GEAR (No./Km.)	11·733 (0·818)	12·253 (0·212)	13·511 (0·279)	13·262 (0·432)	13·439 (0·686)	15·203 (1·043)
REVS (r.p.m.)	1928·000 (108·6)	2057·100 (1·31)	1931·700 (3·9)	2258·400 (15·4)	2010·700 (18·9)	2235·900 (31·1)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	277·0	280·4	283·2	276·9	279·5	283·5
PRESS (mBars.)	1000·3	1001·5	994·0	1014·5	1013·8	1009·3
HUMID (%)	85·0	81·8	80·8	82·5	76·0	82·3

Table No.25

Mean and Standard Error of test variables for each driver using the 1600cc diesel vehicle on the URBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	7·653 (0·237)	8·314 (0·217)	7·738 (0·113)	8·414 (0·350)	7·397 (0·249)	7·941 (0·315)
SPEED (Km./Hr.)	21·317 (1·586)	22·367 (1·902)	21·129 (0·828)	25·870 (2·461)	23·449 (0·998)	22·978 (2·238)
VACC (m./s./s.)	0·394 (0·028)	0·450 (0·040)	0·407 (0·016)	0·481 (0·042)	0·395 (0·015)	0·401 (0·048)
VDEC (m./s./s.)	−0·636 (0·006)	−0·713 (0·038)	−0·626 (0·018)	−0·755 (0·035)	−0·681 (0·015)	−0·603 (0·005)
TPOS (degrees)	9·975 (0·610)	10·454 (0·979)	10·607 (0·430)	13·382 (0·950)	10·282 (0·336)	10·985 (1·035)
TVEL (degs./s.)	4·627 (0·276)	4·574 (0·313)	3·933 (0·098)	6·053 (0·741)	3·560 (0·103)	4·526 (0·697)
TACC (degs./s./s.)	8·837 (0·260)	8·283 (1·109)	8·164 (0·331)	13·997 (2·013)	6·119 (0·161)	9·068 (1·650)
GEAR (No./Km.)	15·825 (1·151)	13·133 (0·138)	14·270 (0·442)	12·847 (0·657)	11·430 (0·625)	13·491 (0·148)
REVS (r.p.m.)	1500·800 (48·1)	1669·800 (42·9)	1599·400 (26·6)	1867·000 (61·0)	1645·600 (23·1)	1832·000 (69·5)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	280·9	278·8	278·4	279·3	280·3	282·0
PRESS (mBars.)	1015·0	1018·0	1014·0	1013·8	1016·0	1008·0
HUMID (%)	75·1	84·7	74·9	77·1	76·3	82·6

Table No.26

Mean and Standard Error of test variables for each driver using the 1600cc diesel vehicle on the SUBURBAN route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	5·650 (0·053)	5·667 (0·011)	5·542 (0·102)	6·321 (0·157)	5·503 (0·178)	5·803 (0·015)
SPEED (Km./Hr.)	47·635 (0·887)	45·401 (3·513)	43·578 (1·901)	51·633 (2·120)	45·796 (2·605)	47·989 (3·895)
VACC (m./s./s.)	0·425 (0·101)	0·367 (0·033)	0·359 (0·004)	0·393 (0·037)	0·326 (0·012)	0·382 (0·003)
VDEC (m./s./s.)	−0·488 (0·006)	−0·474 (0·002)	−0·445 (0·010)	−0·560 (0·009)	−0·501 (0·001)	−0·532 (0·007)
TPOS (degrees)	17·827 (0·038)	16·302 (1·074)	17·109 (0·211)	21·070 (0·552)	16·343 (1·002)	18·942 (2·371)
TVEL (degs./s.)	6·252 (0·040)	3·606 (0·557)	3·639 (0·150)	5·517 (0·642)	3·124 (0·234)	5·808 (0·015)
TACC (degs./s./s.)	12·270 (0·347)	5·338 (1·155)	7·425 (0·381)	12·988 (1·533)	5·482 (0·908)	11·664 (0·066)
GEAR (No./Km.)	4·066 (0·286)	3·510 (0·350)	4·410 (0·451)	3·856 (0·467)	3·354 (0·403)	4·147 (0·712)
REVS (r.p.m.)	2090·600 (18·9)	2075·700 (85·6)	2012·200 (38·8)	2397·000 (106·9)	2101·800 (54·1)	2280·100 (83·2)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	281·1	278·9	278·7	279·5	280·5	282·4
PRESS (mBars.)	1015·0	1018·0	1014·0	1013·8	1016·0	1008·0
HUMID (%)	74·3	84·5	73·8	76·0	75·3	81·8

Table No.27

Mean and Standard Error of test variables for each driver using the 1600cc diesel vehicle on the MOTORWAY route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	8·350 (0·340)	7·074 (0·686)	7·245 (0·606)	10·016 (0·377)	7·818 (0·575)	7·966 (0·892)
SPEED (Km./Hr.)	109·683 (1·312)	93·849 (3·811)	101·593 (0·055)	124·000 (0·771)	101·339 (5·901)	115·205 (5·178)
VACC (m./s./s.)	0·147 (0·012)	0·137 (0·025)	0·127 (0·017)	0·167 (0·007)	0·162 (0·007)	0·162 (0·012)
VDEC (m./s./s.)	−0·249 (0·003)	−0·246 (0·074)	−0·214 (0·015)	−0·287 (0·055)	−0·269 (0·001)	−0·265 (0·009)
TPOS (degrees)	51·863 (1·522)	39·883 (3·869)	44·186 (3·154)	75·484 (1·864)	48·468 (6·392)	55·042 (10·031)
TVEL (degs./s.)	1·822 (0·483)	1·349 (0·439)	1·266 (0·303)	2·747 (0·783)	1·997 (0·069)	2·352 (0·429)
TACC (degs./s./s.)	2·867 (0·940)	2·091 (0·645)	2·294 (0·454)	6·565 (2·151)	4·259 (0·288)	4·708 (1·185)
GEAR (No./Km.)	0·000 (0·000)	0·083 (0·083)	0·000 (0·000)	0·062 (0·062)	0·000 (0·000)	0·000 (0·000)
REVS (r.p.m.)	4109·300 (48·3)	3536·600 (162·5)	3807·100 (2·1)	4682·300 (6·0)	3797·500 (221·1)	4317·200 (194·1)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	282·4	280·0	281·1	281·1	282·5	284·5
PRESS (mBars.)	1015·0	1018·0	1014·0	1013·8	1016·0	1008·0
HUMID (%)	67·4	82·9	64·6	67·3	67·4	75·0

Table No.28

Mean and Standard Error of test variables for each driver using the 1600cc diesel vehicle on the 50/40/10% route section.

(from two test drives)

	TEST DRIVER SEX, AGE AND CODE No.					
	MALE	MALE	MALE	MALE	FEMALE	FEMALE
	37 yrs.	70 yrs.	49 yrs.	27 yrs.	36 yrs.	25 yrs.
	1	2	3	4	5	6
VARIABLE	MEAN & (Standard Error)					
FUEL (lit./100Km.)	6·923 (0·035)	7·133 (0·116)	6·813 (0·127)	7·739 (0·023)	6·683 (0·121)	7·090 (0·093)
SPEED (Km./Hr.)	30·448 (1·836)	30·998 (0·880)	29·538 (0·077)	35·725 (2·021)	32·213 (1·812)	32·229 (0·259)
VACC (m./s./s.)	0·382 (0·007)	0·385 (0·021)	0·360 (0·006)	0·414 (0·038)	0·344 (0·017)	0·370 (0·005)
VDEC (m./s./s.)	−0·538 (0·002)	−0·571 (0·016)	−0·512 (0·007)	−0·630 (0·031)	−0·568 (0·007)	−0·541 (0·001)
TPOS (degrees)	17·304 (0·535)	15·736 (0·825)	16·565 (0·377)	22·668 (0·549)	16·525 (1·305)	18·574 (1·903)
TVEL (degs./s.)	4·996 (0·125)	3·864 (0·105)	3·549 (0·109)	5·508 (0·742)	3·230 (0·138)	4·821 (0·118)
TACC (degs./s./s.)	9·613 (0·083)	6·486 (0·176)	7·282 (0·366)	12·851 (2·002)	5·678 (0·483)	9·670 (0·459)
GEAR (No./Km.)	9·538 (1·072)	7·979 (0·092)	8·899 (0·131)	7·972 (0·236)	7·056 (0·621)	8·404 (0·292)
REVS (r.p.m.)	1997·600 (26·4)	2018·900 (52·6)	1985·300 (8·45)	2360·600 (22·8)	2043·300 (61·7)	2260·100 (34·5)
	MEAN AMBIENT CONDITIONS					
TAMB (°K)	281·1	278·9	278·7	279·5	280·5	282·4
PRESS (mBars.)	1015·0	1018·0	1014·0	1013·8	1016·0	1008·0
HUMID (%)	74·3	84·5	73·8	76·0	72·3	81·8

Table No.29

Means of the test variables for each vehicle with the expert driver on the URBAN route section.

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE		MEAN	
FUEL (lit./100Km.)	9·577	9·437	7·416
SPEED (Km./Hr.)	21·975	19·227	21·761
VACC (m./s./s.)	0·390	0·341	0·409
VDEC (m./s./s.)	-0·627	-0·560	-0·609
TPOS (degrees)	2·893	4·877	9·125
TVEL (degs./s.)	1·764	1·656	3·326
TACC (degs./s./s.)	3·807	3·752	5·694
GEAR (No./Km.)	15·529	26·458	18·296
REVS (r.p.m.)	1502·1	1386·2	1552·4
		MEAN AMBIENT CONDITIONS	
TAMB (°K)	287·1	286·6	278·3
PRESS (mBars.)	1022·5	1020·5	1003·5
HUMID (%)	59·9	59·9	94·1

Table No.30

Means of the test variables for each vehicle with the expert driver on the SUBURBAN route section.

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE		MEAN	
FUEL (lit./100Km.)	6·745	5·986	5·343
SPEED (Km./Hr.)	45·511	46·793	45·906
VACC (m./s./s.)	0·372	0·312	0·318
VDEC (m./s./s.)	-0·515	-0·434	-0·437
TPOS (degrees)	7·094	9·182	15·362
TVEL (degs./s.)	1·969	2·117	2·866
TACC (degs./s./s.)	3·813	4·597	4·766
GEAR (No./Km.)	3·844	6·186	3·995
REVS (r.p.m.)	2015·7	2004·5	2011·4
		MEAN AMBIENT CONDITIONS	
TAMB (°K)	287·2	286·7	278·4
PRESS (mBars.)	1022·5	1020·5	1003·5
HUMID (%)	59·5	59·5	94·0

Table No.31

Means of the test variables for each vehicle
with the expert driver on the MOTORWAY route section.

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE		MEAN	
FUEL (lit./100Km.)	6·975	6·292	6·454
SPEED (Km./Hr.)	88·757	88·822	83·917
VACC (m./s./s.)	0·177	0·101	0·120
VDEC (m./s./s.)	-0·262	-0·178	-0·192
TPOS (degrees)	19·035	18·931	33·657
TVEL (degs./s.)	0·889	1·101	1·692
TACC (degs./s./s.)	1·557	2·269	2·965
GEAR (No./Km.)	0·000	0·000	0·000
REVS (r.p.m.)	3326·0	3325·1	3144·7
		MEAN AMBIENT CONDITIONS	
TAMB (°K)	288·5	288·0	279·9
PRESS (mBars.)	1022·5	1020·5	1003·5
HUMID (%)	56·5	56·5	93·3

Table No.32

Means of the test variables for each vehicle with the expert driver on the 50/40/10% route section.

	VEHICLE TYPE, CAPACITY AND CODE NUMBER		
	PETROL 1600cc 1	PETROL 1300cc 2	DIESEL 1600cc 3
VARIABLE		MEAN	
FUEL (lit./100Km.)	8·184	7·742	6·492
SPEED (Km./Hr.)	30·610	28·028	30·412
VACC (m./s./s.)	0·362	0·305	0·344
VDEC (m./s./s.)	-0·546	-0·471	-0·498
TPOS (degrees)	6·188	8·005	14·075
TVEL (degs./s.)	1·759	1·785	2·979
TACC (degs./s./s.)	3·584	3·942	5·050
GEAR (No./Km.)	9·302	15·704	10·746
REVS (r.p.m.)	1889·9	1827·4	1895·2
		MEAN AMBIENT CONDITIONS	
TAMB (°K)	287·2	286·7	278·4
PRESS (mBars.)	1022·5	1020·5	1003·5
HUMID (%)	59·5	59·5	94·0

Table No.33

Mean fuel consumption and vehicle speed for the "extra motorway" and "normal" test drives.

(all vehicles - Driver No.1)

	VEHICLE & VARIABLES MEASURED					
	1600cc PETROL		1300cc PETROL		1600cc DIESEL	
	FUEL	SPEED	FUEL	SPEED	FUEL	SPEED
	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.
ROUTE SECTION	MEAN FOR "EXTRA M1" & ("NORMAL") TESTS					
URBAN 2 to MOTORWAY	9·828 (9·132)	34·615 (33·511)	9·030 (8·881)	35·423 (32·372)	7·264 (6·948)	31·501 (32·528)
MOTORWAY	8·325 (9·184)	109·935 (110·014)	8·018 (7·777)	110·402 (104·123)	8·545 (8·350)	118·857 (109·683)
SUBURBAN 2	6·789 (7·506)	52·257 (48·990)	6·672 (6·456)	52·128 (51·462)	5·482 (5·337)	56·700 (53·486)
50/40/10%	9·229 (9·693)	30·940 (30·593)	8·769 (8·823)	30·761 (30·800)	7·298 (6·923)	31·421 (30·448)
	* MEAN AMBIENT CONDITIONS					
TAMB (°K)	286·7	(278·9)	278·3	(270·0)	272·9	(281·0)
PRESS (mBars.)	1013·5	(1014·8)	1022·0	(1000·3)	994·0	(1015·0)
HUMID (%)	58·5	(86·8)	85·0	(85·0)	81·5	(74·3)

* mean ambient conditions for complete test, those for the "normal" test are shown in parentheses.

Table No.34

Mean fuel consumption and vehicle speed for the "late" and "normal" test drives.

(all vehicles - Driver No.1)

	VEHICLE & VARIABLES MEASURED					
	1600cc PETROL		1300cc PETROL		1600cc DIESEL	
	FUEL	SPEED	FUEL	SPEED	FUEL	SPEED
	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.
ROUTE SECTION	MEAN FOR "LATE" & ("NORMAL") TESTS					
MOTORWAY	7·493 (9·184)	103·963 (110·014)	8·756 (7·777)	103·258 (104·123)	6·746 (8·350)	106·673 (109·683)
URBAN	9·567 (11·276)	23·685 (21·751)	9·228 (10·394)	24·539 (22·108)	7·483 (7·653)	21·344 (21·317)
SUBURBAN	6·874 (7·842)	52·466 (45·608)	6·964 (7·121)	47·026 (45·056)	5·303 (5·650)	50·525 (47·635)
50/40/10%	8·288 (9·693)	33·674 (30·593)	8·275 (8·823)	33·500 (30·800)	6·539 (6·923)	30·979 (30·448)
	* MEAN AMBIENT CONDITIONS					
TAMB (°K)	287·1	(278·9)	278·8	(270·0)	285·4	(281·0)
PRESS (mBars.)	1001·5	(1014·8)	1005·5	(1000·3)	1021·5	(1015·0)
HUMID (%)	76·5	(86·8)	75·0	(85·0)	69·5	(74·3)

* mean ambient conditions for complete test, those for the "normal" test are shown in parentheses.

Table No.35

Mean fuel consumption and vehicle speed for the "hot start" and "normal" test drives.

(all vehicles - Driver No.3)

	VEHICLE & VARIABLES MEASURED					
	1600cc PETROL		1300cc PETROL		1600cc DIESEL	
	FUEL	SPEED	FUEL	SPEED	FUEL	SPEED
	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.	lit./100Km.	Km./Hr.
ROUTE SECTION	MEAN FOR "HOT START" & "NORMAL" TESTS					
FIRST MILE	8·199 (9·797)	26·093 (26·283)	8·865 (11·487)	18·508 (23·356)	7·250 (8·075)	22·854 (23·763)
SUBURBAN 1	7·053 (7·129)	38·333 (40·513)	6·603 (6·982)	36·719 (39·353)	6·410 (6·097)	27·018 (36·844)
URBAN 1	10·516 (11·145)	21·763 (20·073)	9·325 (10·099)	19·519 (19·691)	7·532 (7·928)	21·860 (19·722)
50/40/10%	8·649 (8·866)	30·379 (29·998)	8·125 (8·322)	28·517 (29·572)	6·845 (6·813)	28·448 (29·538)
	* MEAN AMBIENT CONDITIONS					
TAMB (°K)	279·2	(280·2)	277·8	(283·2)	278·0	(278·7)
PRESS (mBars.)	1012·5	(1015·8)	1015·5	(994·0)	1005·5	(1014·0)
HUMID (%)	69·0	(80·5)	83·5	(80·8)	91·5	(73·8)

* mean ambient conditions for complete test, those for the "normal" test are shown in parentheses.

Table No.36

Mean and Standard Error of test variables for the URBAN route section of the Spring and Summer test programmes.

(1600cc petrol and diesel cars with Driver No.3)

	TEST PROGRAMME & VEHICLE TYPE & CODE No.			
	SUMMER	SUMMER	SPRING	SPRING
	PETROL (1)	DIESEL (3)	PETROL (1)	DIESEL (3)
VARIABLE	MEAN & (Standard Error)			
FUEL (lit./100Km.)	9·772 (0·162)	7·315 (0·154)	10·831 (0·344)	7·910 (0·120)
SPEED (Km./Hr.)	22·158 (0·496)	21·525 (0·639)	20·887 (0·905)	22·852 (0·721)
VACC (m./s./s.)	0·420 (0·009)	0·376 (0·014)	0·421 (0·022)	0·421 (0·014)
VDEC (m./s./s.)	−0·632 (0·006)	−0·616 (0·010)	−0·702 (0·016)	−0·669 (0·014)
TPOS (degrees)	3·456 (0·141)	10·465 (0·299)	3·417 (0·157)	10·947 (0·366)
TVEL (degs./s.)	2·183 (0·102)	3·476 (0·140)	2·030 (0·101)	4·545 (0·230)
TACC (degs./s./s.)	4·400 (0·220)	6·738 (0·310)	4·057 (0·376)	9·078 (0·654)
GEAR (No./Km.)	14·619 (0·414)	13·928 (0·352)	13·646 (0·487)	13·499 (0·361)
REVS (r.p.m.)	1549·300 (14·8)	1519·600 (15·0)	1614·400 (25·2)	1685·900 (31·8)
	MEAN AMBIENT CONDITIONS			
TAMB (°K)	288·1	288·9	280·0	279·9
PRESS (mBars.)	1013·8	1008·3	1015·8	1014·1
HUMID (%)	81·5	83·8	81·0	78·5

Table No.37

Mean and Standard Error of test variables for the SUBURBAN route section of the Spring and Summer test programmes.

(1600cc petrol and diesel cars with Driver No.3)

	TEST PROGRAMME & VEHICLE TYPE & CODE No.			
	SUMMER	SUMMER	SPRING	SPRING
	PETROL (1)	DIESEL (3)	PETROL (1)	DIESEL (3)
VARIABLE	MEAN & (Standard Error)			
FUEL (lit./100Km.)	6·348 (0·081)	5·080 (0·023)	6·551 (0·333)	5·748 (0·089)
SPEED (Km./Hr.)	43·978 (0·979)	45·433 (1·553)	47·320 (1·845)	47·006 (1·113)
VACC (m./s./s.)	0·346 (0·009)	0·304 (0·006)	0·376 (0·008)	0·375 (0·011)
VDEC (m./s./s.)	−0·454 (0·009)	−0·439 (0·016)	−0·466 (0·034)	−0·500 (0·011)
TPOS (degrees)	5·666 (0·797)	16·123 (0·459)	7·453 (0·277)	17·932 (0·614)
TVEL (degs./s.)	2·450 (0·360)	2·533 (0·077)	2·126 (0·020)	4·658 (0·387)
TACC (degs./s./s.)	5·423 (1·046)	4·729 (0·207)	4·245 (0·097)	9·195 (1·004)
GEAR (No./Km.)	4·240 (0·215)	3·675 (0·278)	3·238 (0·372)	3·890 (0·178)
REVS (r.p.m.)	1958·300 (18·5)	1994·800 (30·8)	2071·500 (16·1)	2159·600 (45·8)
	MEAN AMBIENT CONDITIONS			
TAMB (°K)	288·4	289·1	280·2	280·2
PRESS (mBars.)	1013·8	1008·3	1015·8	1014·1
HUMID (%)	80·9	83·1	80·5	77·6

Table No.38

Mean and Standard Error of test variables for the MOTORWAY route section of the Spring and Summer test programmes.

(1600cc petrol and diesel cars with Driver No.3)

	TEST PROGRAMME & VEHICLE TYPE & CODE No.			
	SUMMER	SUMMER	SPRING	SPRING
	PETROL (1)	DIESEL (3)	PETROL (1)	DIESEL (3)
VARIABLE	MEAN & (Standard Error)			
FUEL (lit./100Km.)	7·520 (0·125)	7·463 (0·234)	8·296 (0·517)	8·073 (0·345)
SPEED (Km./Hr.)	104·013 (1·390)	105·673 (1·015)	106·633 (0·970)	107·615 (3·197)
VACC (m./s./s.)	0·224 (0·004)	0·131 (0·007)	0·207 (0·001)	0·151 (0·006)
VDEC (m./s./s.)	-0·293 (0·012)	-0·228 (0·014)	-0·310 (0·019)	-0·255 (0·013)
TPOS (degrees)	24·398 (0·444)	46·131 (1·415)	26·380 (1·732)	52·488 (3·798)
TVEL (degs./s.)	1·909 (0·322)	1·303 (0·236)	2·275 (0·269)	1·922 (0·212)
TACC (degs./s./s.)	3·819 (0·594)	2·477 (0·391)	4·885 (1·137)	3·797 (0·582)
GEAR (No./Km.)	0·000 (0·000)	0·021 (0·021)	0·000 (0·000)	0·024 (0·016)
REVS (r.p.m.)	3897·500 (52·1)	3965·500 (36·1)	3995·900 (36·3)	4041·600 (121·6)
	MEAN AMBIENT CONDITIONS			
TAMB (°K)	290·1	290·0	281·4	281·9
PRESS (mBars.)	1013·8	1008·2	1015·8	1014·1
HUMID (%)	75·8	77·7	76·9	70·7

Table No.39

Mean and Standard Error of test variables for the 50/40/10% route section of the Spring and Summer test programmes.

(1600cc petrol and diesel cars with Driver No.3)

	TEST PROGRAMME & VEHICLE TYPE & CODE No.			
	SUMMER	SUMMER	SPRING	SPRING
	PETROL (1)	DIESEL (3)	PETROL (1)	DIESEL (3)
VARIABLE	MEAN & (Standard Error)			
FUEL (lit./100Km.)	8·177 (0·062)	6·438 (0·085)	8·866 (0·412)	7·063 (0·106)
SPEED (Km./Hr.)	30·646 (0·283)	30·296 (0·587)	29·998 (1·671)	31·858 (0·727)
VACC (m./s./s.)	0·370 (0·006)	0·323 (0·004)	0·382 (0·011)	0·376 (0·009)
VDEC (m./s./s.)	-0·527 (0·004)	-0·506 (0·009)	-0·568 (0·010)	-0·560 (0·012)
TPOS (degrees)	6·434 (0·215)	16·294 (0·165)	7·328 (0·188)	17·895 (0·765)
TVEL (degs./s.)	2·262 (0·182)	2·881 (0·058)	2·093 (0·095)	4·328 (0·268)
TACC (degs./s./s.)	4·751 (0·469)	5·508 (0·174)	4·215 (0·293)	8·597 (0·775)
GEAR (No./Km.)	9·006 (0·118)	8·436 (0·211)	8·118 (0·129)	8·308 (0·285)
REVS (r.p.m.)	1947·800 (4·1)	1954·300 (13·5)	2035·400 (28·6)	2110·900 (45·3)
	MEAN AMBIENT CONDITIONS			
TAMB (°K)	288·4	289·1	280·2	280·2
PRESS (mBars.)	1013·8	1008·3	1015·8	1014·1
HUMID (%)	80·9	83·1	80·5	77·6

Table No.40

Mean and Standard Error of test variables for
the Austin-Rover Montego vehicles
on the URBAN route section.

(expert and No.6 drivers)

	DRIVER AND VEHICLE IDENTIFICATION		
	DRIVER No.6	DRIVER No.6	EXPERT
	PETROL (WHITE)	PETROL (IVORY)	PETROL (WHITE)
	1	2	2
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	10·976 (0·200)	12·109 (0·338)	10·937 (0·320)
SPEED (Km./Hr.)	24·420 (0·598)	25·646 (1·129)	24·025 (0·857)
VACC (m./s./s.)	0·308 (0·009)	0·315 (0·015)	0·307 (0·003)
VDEC (m./s./s.)	−0·761 (0·003)	−0·768 (0·009)	−0·752 (0·000)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	290·0	287·9	294·6
PRESS (mBars.)	1015·5	999·8	1010·5
HUMID (%)	77·7	85·5	66·8

Table No.41

Mean and Standard Error of test variables for the Austin-Rover Montego vehicles on the SUBURBAN route section.

(expert and No.6 drivers)

	DRIVER AND VEHICLE IDENTIFICATION		
	DRIVER No.6	DRIVER No.6	EXPERT
	PETROL (WHITE)	PETROL (IVORY)	PETROL (WHITE)
	1	2	2
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	7·624 (0·088)	7·712 (0·103)	6·119 (-)
SPEED (Km./Hr.)	50·406 (1·057)	52·121 (0·449)	45·617 (-)
VACC (m./s./s.)	0·379 (0·007)	0·391 (0·008)	0·367 (-)
VDEC (m./s./s.)	-0·749 (0·004)	-0·749 (0·001)	-0·727 (-)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	290·2	288·1	294·8
PRESS (mBars.)	1015·5	999·8	1010·5
HUMID (%)	77·0	85·3	66·0

Table No.42

Mean and Standard Error of test variables for
the Austin-Rover Montego vehicles
on the MOTORWAY route section.

(expert and No.6 drivers)

	DRIVER AND VEHICLE IDENTIFICATION		
	DRIVER No.6	DRIVER No.6	EXPERT
	PETROL (WHITE)	PETROL (IVORY)	PETROL (WHITE)
	1	2	2
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	10·060 (0·175)	9·678 (0·264)	6·344 (-)
SPEED (Km./Hr.)	133·645 (0·635)	130·636 (3·649)	99·807 (-)
VACC (m./s./s.)	0·350 (0·000)	0·337 (0·027)	0·387 (-)
VDEC (m./s./s.)	-0·721 (0·000)	-0·714 (0·002)	-0·713 (-)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	291·4	288·7	296·8
PRESS (mBars.)	1015·5	999·8	1010·5
HUMID (%)	71·7	83·4	60·0

Table No.43

Mean and Standard Error of test variables for the Austin-Rover Montego vehicles on the 50/40/10% route section.

(expert and No.6 drivers)

	DRIVER AND VEHICLE IDENTIFICATION		
	DRIVER No.6	DRIVER No.6	EXPERT
	PETROL (WHITE)	PETROL (IVORY)	PETROL (WHITE)
	1	2	2
VARIABLE	MEAN & (Standard Error)		
FUEL (lit./100Km.)	9·544 (0·050)	10·107 (0·201)	8·549 (-)
SPEED (Km./Hr.)	34·286 (0·160)	35·789 (1·120)	32·699 (-)
VACC (m./s./s.)	0·340 (0·004)	0·348 (0·011)	0·339 (-)
VDEC (m./s./s.)	-0·752 (0·003)	-0·755 (0·001)	-0·738 (-)
	MEAN AMBIENT CONDITIONS		
TAMB (°K)	290·2	288·1	294·8
PRESS (mBars.)	1015·5	999·8	1010·5
HUMID (%)	77·0	85·3	66·0

Table No.44

Regression of mean fuel consumption with mean speed for each vehicle.

(mean values for all route sections)

REGRESSION EQUATION (1) - FUEL = A + $B/_S$ + CS^2				
VEHICLE TYPE	COEFFICIENTS			Variance explained
	A	B	C	%
1600cc PETROL	3·0524	170·010	0·000392	80·20
(Standard Error)	-	(9·399)	(0·000030)	(0·813)
F-value	-	327·149	185·373	164·128
1300cc PETROL	2·9094	157·335	0·000332	76·40
(Standard Error)	-	(9·762)	(0·000030)	(0·755)
F-value	-	259·784	119·694	130·972
1600cc DIESEL	2·7188	111·235	0·000369	78·10
(Standard Error)	-	(6·967)	(0·000020)	(0·565)
F-value	-	254·918	242·094	144·160

REGRESSION EQUATION (2) - A + $B/_S$ + CS + DS^2					
VEHICLE TYPE	COEFFICIENTS				Variance explained
	A	B	C	D	%
1600cc PETROL	10·0073	77·240	-0·1412	0·00114	83·30
(Standard Error)	-	(25·775)	(0·0369)	(0·00020)	(0·752)
F-value	-	8·98	14·619	33·403	132·688
1300cc PETROL	13·7729	9·863	-0·2216	0·00153	82·00
(Standard Error)	-	(30·630)	(0·0442)	(0·00024)	(0·662)
F-value	-	0·104	25·148	40·433	121·728
1600cc DIESEL	9·3870	23·928	-0·1403	0·00116	82·20
(Standard Error)	-	(21·115)	(0·0324)	(0·00018)	(0·512)
F-value	-	1·284	18·773	39·964	123·452

Table No.45

Linear regression of mean fuel consumption with mean speed for each vehicle.

(all route sections)

REGRESSION EQUATION - FUEL = A + B/V			
ROUTE SECTIONS & VEHICLE TYPE	COEFFICIENTS		Variance explained
	A	B	%
URBAN & SUBURBAN:			
1600cc PETROL	4·552	139·072	84·26
(Standard Error)	-	(7·893)	(0·775)
F-value	-	310·489	310·489
1300cc PETROL	4·147	131·441	82·43
(Standard Error)	-	(7·969)	(0·717)
F-value	-	272·054	272·054
1600cc DIESEL	3·985	85·844	83·03
(Standard Error)	-	(5·096)	(0·483)
F-value	-	283·736	283·736
MOTORWAY:			
1600cc PETROL	25·647	-1814·603	86·01
(Standard Error)	-	(230·526)	(0·728)
F-value	-	61·962	61·962
1300cc PETROL	20·131	-1290·090	74·00
(Standard Error)	-	(241·792)	(0·703)
F-value	-	28·468	28·468
1600cc DIESEL	17·778	-1033·825	69·72
(Standard Error)	-	(241·792)	(0·689)
F-value	-	23·024	23·024

Table No.46

Driver annual fuel saving with the diesel vehicle
compared to the 1300cc petrol car.

(figures in parentheses for petrol car comparison)
1984 prices.

DRIVER CODE No.	1	2	3	4	5	6	7
SEX (M/F)	M	M	M	M	F	F	M
AGE (yrs.)	37	70	49	27	36	25	45
* VEHICLE DIFFERENTIAL FUEL SAVING (lit./100Km.)							
URBAN	2·741 (0·882)	2·181 (1·106)	2·341 (0·752)	2·383 (0·081)	1·659 (0·746)	1·719 (2·404)	2·021 (0·140)
SUBURBAN	1·471 (0·721)	1·087 (0·744)	0·856 (0·153)	1·691 (0·120)	0·835 (0·628)	1·172 (0·957)	0·643 (0·759)
MOTORWAY	-0·573 (1·407)	0·991 (0·197)	0·001 (1·050)	0·875 (2·398)	0·633 (0·547)	0·119 (1·526)	-0·162 (0·683)
50/40/10% road mix annually	1·900 (0·870)	1·615 (0·870)	1·509 (0·544)	1·953 (0·329)	1·224 (0·681)	1·338 (1·737)	1·250 (0·442)
ANNUAL MILEAGE	7500	8250	20000	35000	3000	2000	10000
Annual fuel saving (lit.)	229·3 (105·0)	214·4 (115·5)	485·7 (175·1)	1100·1 (185·3)	59·1 (32·9)	43·1 (55·9)	201·2 (71·1)
** Monetary saving (£)	117·40 (42·39)	114·69 (46·63)	261·21 (70·69)	573·56 (74·81)	33·44 (13·28)	24·16 (22·57)	112·24 (28·70)

* Figures in parentheses denote the corresponding values for the 1300cc and 1600cc petrol car comparison.

** 1984 fuel prices used to correlate with the vehicle data given on Table No.47.
(petrol @ 40·37 pence/lit. & diesel @ 37·40 pence/lit.)

Table No.47

Vehicle standing and running costs.
(1984 figures)

VAUXHALL CAVALIER TEST VEHICLES			
Capacity (cc.)	1600	1300	1600
Fuel	Petrol	Petrol	Diesel
* STANDING CHARGES PER ANNUM (£)			
Car licence	90·00	90·00	90·00
Insurance	412·00	343·00	343·00
Depreciation	797·03	676·78	879·84
** Interest on capital	306·55	260·30	338·40
Parking	156·00	156·00	156·00
TOTAL	1761·58	1526·08	1807·24
* RUNNING COSTS PER KM (pence)			
*** Fuel	3·832	3·493	2·642
Oil	0·216	0·203	0·277
Tyres	0·438	0·356	0·397
Servicing	0·368	0·408	0·382
Repairs	2·943	2·518	2·731
TOTAL	7·797	6·978	6·429
TOTAL COSTS PER KM (pence)			
Based on annual travel of 15,000 Km.	19·54	17·15	18·48

* Estimated costs in 1984 from references [28][29] and [30].

** New car value invested at 6·25% per annum (1984).

*** Estimated from average (50/40/10%) fuel consumption figures from main test programme (Figure No.10).

Table No.48

Vehicle running cost comparisons for each driver (1984 figures).

VEHICLE FUEL ECONOMY COMPARISON							
Driver code:	1	2	3	4	5	6	7
Annual Kms.:	12070	13280	32190	56330	4830	3210	16090
* DIFFERENCE IN VEHICLE STANDING CHARGES (£ per annum)							
Diesel vs. 1300 Petrol	-281·16	-281·16	-281·16	-281·16	-281·16	-281·16	-281·16
1300 vs. 1600 Petrol	235·50	235·50	235·50	235·50	235·50	235·50	235·50
** VEHICLE RUNNING COSTS FOR EACH DRIVER (£ per annum)							
1600 Petrol	478·58	526·55	1276·33	2233·49	191·51	127·28	637·97
1300 Petrol	420·64	462·81	1121·82	1963·10	168·32	111·87	560·74
1600 Diesel	457·09	502·91	1219·04	2133·22	182·91	121·56	609·33
*** DIFFERENCE IN TOTAL VEHICLE COSTS FOR EACH DRIVER (£ per annum)							
Diesel vs. 1300 Petrol	-200·21	-206·58	-117·16	122·29	-262·31	-266·69	-217·52
1300 vs. 1600 Petrol	335·83	345·87	460·70	580·69	271·96	273·48	341·43

* i.e., diesel car standing charge is £281·16 higher per annum and 1600cc petrol car standing charge is £235·50 higher per annum, than the 1300cc petrol car.

** these figures do not include fuel costs.

*** these figures present the difference in total costs (per annum) having accounted for a driver's fuel saving (Table No.46) for the respective vehicles. Positive figures indicate savings made by the diesel over the 1300cc petrol car, and the 1300cc petrol over the 1600cc petrol vehicle.

Table No.49

National energy consumption and comparison
for each test vehicle (1980 to 1984).

NATIONAL VEHICLE FUEL SAVINGS					
YEAR:	1980	1981	1982	1983	1984
* ROAD TRAFFIC BY ROAD CLASS (B.V.K.)					
URBAN:	101·10	103·80	107·20	103·90	103·60
SUBURBAN:	75·75	76·81	79·82	86·18	91·96
MOTORWAY:	20·45	20·78	21·74	23·11	26·19
** NATIONAL FUEL CONSUMPTION (billion litres)					
1600cc Petrol:	18·831	19·209	19·935	20·177	20·872
1300cc Petrol:	17·162	17·535	18·167	18·391	19·020
1600cc Diesel:	14·003	14·304	14·824	15·039	15·596
NATIONAL FUEL SAVING (billion litres)					
Diesel vs. 1300 Petrol	3·159	3·231	3·343	3·352	3·424
1300 vs. 1600 Petrol	1·669	1·674	1·768	1·786	1·852
*** NATIONAL MOTORIST SAVING (billion litres)					
Diesel vs. 1300 Petrol	72·86	107·28	132·03	147·62	184·55
1300 vs. 1600 Petrol	46·63	53·95	63·79	68·96	74·77

* Billion-vehicle-kilometres from reference [1].

** Based on average fuel consumption for each vehicle/road class with all test drivers (Figure No.46).

*** Using 1980 to 1984 prices for petrol and derv, from reference [1], showing annual monetary saving of the diesel over the 1300cc petrol and the 1300cc petrol over the 1600cc petrol vehicle.

Table No.50

Correlation Coefficients for the 1600cc diesel car on the URBAN route section.

VARIABLE	FUEL	SPEED	VACC	VDEC	TPOS
FUEL	1·00000	-0·74689	-0·04822	0·04694	-0·40300
SPEED	-0·74689	1·00000	0·57115	-0·33375	0·87955
VACC	-0·04822	0·57115	1·00000	-0·45851	0·73885
VDEC	0·04694	-0·33375	-0·45851	1·00000	-0·40561
TPOS	-0·40300	0·87955	0·73885	-0·40561	1·00000
TVEL	0·13622	0·43575	0·75496	-0·43581	0·68800
TACC	0·07690	0·39397	0·57567	-0·48773	0·53341
GEAR	0·08919	-0·36287	-0·07140	-0·09153	-0·46005
REVS	0·34281	0·32748	0·66734	-0·41181	0·61746
FLOW	-0·06468	0·70869	0·80885	-0·50125	0·89695
TFUEL	-0·46059	0·07931	-0·47054	0·20849	-0·13302
TOIL	-0·51355	0·22215	-0·27341	0·00624	0·04024
TAMB	-0·47859	0·15012	-0·36307	0·22885	-0·05394
PRESS	0·13160	0·10840	-0·03641	-0·24121	0·27048
HUMID	0·11854	-0·53408	-0·49310	0·27387	-0·63964

VARIABLE	TVEL	TACC	GEAR	REVS	FLOW
FUEL	0·13622	0·07690	0·08919	0·34281	-0·06468
SPEED	0·43575	0·39397	-0·36287	0·32748	0·70869
VACC	0·75496	0·57567	-0·07140	0·66734	0·80885
VDEC	-0·43581	-0·48773	-0·09153	-0·41181	-0·50125
TPOS	0·68800	0·53341	-0·46005	0·61746	0·89695
TVEL	1·00000	0·88615	-0·03070	0·75390	0·77452
TACC	0·88615	1·00000	0·16172	0·69789	0·63386
GEAR	-0·03070	0·16172	1·00000	-0·36881	-0·45401
REVS	0·75390	0·69789	-0·36881	1·00000	0·84086
FLOW	0·77452	0·63386	-0·45401	0·84086	1·00000
TFUEL	-0·65620	-0·71459	-0·26289	-0·63136	-0·32341
TOIL	-0·43719	-0·48238	-0·11595	-0·47042	-0·15926
TAMB	-0·64192	-0·72936	-0·33148	-0·56891	-0·23568
PRESS	0·39241	0·47204	0·09451	0·29665	0·30513
HUMID	-0·51339	-0·56306	0·32865	-0·72512	-0·65061

VARIABLE	TFUEL	TOIL	TAMB	PRESS	HUMID
FUEL	-0·46059	-0·51355	-0·47859	0·13160	0·11854
SPEED	0·07931	0·22215	0·15012	0·10840	-0·53408
VACC	-0·47054	-0·27341	-0·36307	-0·03641	-0·49310
VDEC	0·20849	0·00624	0·22855	-0·24121	0·27387
TPOS	-0·13302	0·04024	-0·05394	0·27048	-0·63964
TVEL	-0·65620	-0·43719	-0·64192	0·39241	-0·51339
TACC	-0·71459	-0·48239	-0·72936	0·47204	-0·56306
GEAR	-0·26289	-0·11595	-0·33148	0·09451	0·32865
REVS	-0·63136	-0·47042	-0·56891	0·29665	-0·72512
FLOW	-0·32341	-0·15926	-0·23568	0·30513	-0·65061
TFUEL	1·00000	0·90252	0·98104	-0·24505	0·59456
TOIL	0·90252	1·00000	0·86116	-0·11748	0·50786
TAMB	0·98104	0·86116	1·00000	-0·29491	0·51404
PRESS	-0·24505	-0·11748	-0·29491	1·00000	-0·33863
HUMID	0·59456	0·50786	0·51404	-0·33863	1·00000

<u>Table No.51</u>

Factor Analysis Matrix and Eigenvalues for the
1600cc diesel car on the URBAN route section.

VARIABLE	MEAN	STANDARD DEV.	CASES
FUEL	7·4559	0·4216	12
SPEED	21·3935	1·6918	12
VACC	0·3867	0·0383	12
VDEC	-0·6192	0·0298	12
TPOS	10·5122	0·8141	12
TVEL	3·6284	0·4004	12
TACC	7·2138	1·0498	12
GEAR	14·0418	0·9343	12
REVS	1546·1833	58·8079	12
FLOW	1·5989	0·0836	12
TFUEL	294·2687	4·9486	12
TOIL	365·6962	1·8329	12
TAMB	285·4083	5·5252	12
PRESS	1010·1667	14·3675	12
HUMID	80·8500	6·9164	12

FACTOR	EIGENVALUE	% OF VARIANCE	CUM.%
1	6·92547	46·2	46·2
2	3·57636	23·8	70·0
3	1·38408	9·2	79·2
4	1·05319	7·0	86·3
5	0·95958	6·4	92·7
6	0·55790	3·7	96·4
7	0·26028	1·7	98·1
8	0·16752	1·1	99·2
9	0·08205	0·5	99·8
10	0·02731	0·2	100·0
11	0·00625	0·0	100·0
12	0·00000	0·0	100·0
13	0·00000	0·0	100·0
14	0·00000	0·0	100·0
15	0·00000	0·0	100·0

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FUEL	0·09513	-0·77023	-0·34439	0·25671	0·44785
SPEED	0·52212	0·79249	0·13721	-0·13846	-0·22642
VACC	0·78999	0·21244	0·02697	-0·40947	0·27955
VDEC	-0·51694	-0·15549	-0·44262	-0·08560	-0·44930
TPOS	0·74623	0·63403	-0·02478	0·02137	-0·02914
TVEL	0·91062	-0·04074	0·13417	0·00146	0·12322
TACC	0·87226	-0·15798	0·31605	0·04719	-0·05461
GEAR	-0·14943	-0·52942	0·77133	-0·21203	-0·01532
REVS	0·88845	-0·04179	-0·32107	0·12865	0·18852
FLOW	0·86372	0·40668	-0·14102	0·08693	0·19160
TFUEL	-0·72764	0·64459	0·01380	0·17184	0·14360
TOIL	-0·53378	0·69779	0·24586	0·18737	0·23117
TAMB	-0·67319	0·69924	-0·07711	0·09959	0·13626
PRESS	0·39754	-0·10029	0·30868	0·80385	-0·22618
HUMID	-0·78885	-0·09115	0·22742	-0·02551	0·43869

Table No.52

Correlation Coefficients for the 1600cc diesel car on the SUBURBAN route section.

VARIABLE	CORRELATION COEFFICIENTS				
	FUEL	SPEED	VACC	VDEC	TPOS
FUEL	1·00000	-0·45210	0·96757	-0·26736	0·50204
SPEED	-0·45210	1·00000	-0·40915	-0·39345	0·54310
VACC	0·96757	-0·40915	1·00000	-0·31907	0·50179
VDEC	-0·26736	-0·39345	-0·31907	1·00000	-0·60756
TPOS	0·50204	0·54310	0·50179	-0·60756	1·00000
TVEL	0·98707	-0·49573	0·98454	-0·19994	0·44385
TACC	0·98826	-0·39051	0·99067	-0·32576	0·54495
GEAR	0·74800	-0·84643	0·75277	-0·11502	-0·13146
REVS	0·02112	0·86850	0·05495	-0·46007	0·86283
FLOW	0·22696	0·76538	0·25733	-0·63227	0·95251
TFUEL	-0·91083	0·24915	-0·88978	0·11487	-0·62237
TOIL	-0·89751	0·55171	-0·91784	-0·05749	-0·30577
TAMB	-0·90599	0·25470	-0·86188	0·11077	-0·61633
PRESS	0·41608	-0·27053	0·21940	-0·33567	0·15072
HUMID	-0·85909	0·53956	-0·74384	-0·19053	-0·30782
	TVEL	TACC	GEAR	REVS	FLOW
FUEL	0·98707	0·98826	0·74800	0·02112	0·22696
SPEED	-0·49573	-0·39051	-0·84643	0·86850	0·76538
VACC	0·98454	0·99067	0·75277	0·05495	0·25733
VDEC	-0·19994	-0·32576	-0·11502	-0·46007	-0·63227
TPOS	0·44385	0·54495	-0·13146	0·86283	0·95251
TVEL	1·00000	0·99016	0·77194	-0·02521	0·17168
TACC	0·99016	1·00000	0·72706	0·07980	0·28793
GEAR	0·77194	0·72706	1·00000	-0·58278	-0·37644
REVS	-0·02521	0·07980	-0·58278	1·00000	0·96411
FLOW	0·17168	0·28793	-0·37644	0·96411	1·00000
TFUEL	-0·92142	-0·92166	-0·48434	-0·23031	-0·37673
TOIL	-0·93811	-0·89648	-0·72098	0·07909	-0·05165
TAMB	-0·90612	-0·90681	-0·47341	-0·21322	-0·36368
PRESS	0·29579	0·32198	0·37223	-0·18472	-0·01494
HUMID	-0·84191	-0·79476	-0·57742	0·09932	-0·01812
	TFUEL	TOIL	TAMB	PRESS	HUMID
FUEL	-0·91083	-0·89751	-0·90599	0·41608	-0·85909
SPEED	0·24915	0·55171	0·25470	-0·27053	0·53956
VACC	-0·88978	-0·91784	-0·86188	0·21940	-0·74384
VDEC	0·11487	-0·05749	0·11077	-0·33567	-0·19053
TPOS	-0·62237	-0·30577	-0·61633	0·15072	-0·30782
TVEL	-0·92142	-0·93811	-0·90612	0·29579	-0·84191
TACC	-0·92166	-0·89648	-0·90681	0·32198	-0·79476
GEAR	-0·48434	-0·72098	-0·47341	0·37223	-0·57742
REVS	-0·23031	0·07909	-0·21322	-0·18472	0·09932
FLOW	-0·37673	-0·05165	-0·36368	-0·01494	-0·01812
TFUEL	1·00000	0·86215	0·99451	-0·21795	0·86077
TOIL	0·86215	1·00000	0·82575	-0·04342	0·83918
TAMB	0·99451	0·82575	1·00000	-0·30137	0·88015
PRESS	-0·21795	-0·04342	-0·30137	1·00000	-0·42202
HUMID	0·86077	0·83918	0·88015	-0·42202	1·00000

Table No.53

Factor Analysis Matrix and Eigenvalues for the 1600cc diesel car on the SUBURBAN route section.

VARIABLE	MEAN	STANDARD DEV.	CASES
FUEL	5·2338	0·2499	6
SPEED	44·8143	2·8545	6
VACC	0·3227	0·0297	6
VDEC	−0·4407	0·0254	6
TPOS	16·4513	0·8847	6
TVEL	2·9015	0·5909	6
TACC	5·6278	1·4487	6
GEAR	3·9197	0·6406	6
REVS	2000·5833	54·3401	6
FLOW	2·3440	0·1350	6
TFUEL	290·5720	4·9644	6
TOIL	356·6033	1·6316	6
TAMB	285·5833	5·5901	6
PRESS	1010·1667	15·0687	6
HUMID	80·0000	5·5588	6

FACTOR	EIGENVALUE	% OF VARIANCE	CUM.%
1	8·46816	56·5	56·5
2	4·25278	28·4	84·8
3	1·34851	9·0	93·8
4	0·83457	5·6	99·4
5	0·09599	0·6	100·0
6	0·00000	0·0	100·0
7	0·00000	0·0	100·0
8	0·00000	0·0	100·0
9	0·00000	0·0	100·0
10	0·00000	0·0	100·0
11	0·00000	0·0	100·0
12	0·00000	0·0	100·0
13	0·00000	0·0	100·0
14	0·00000	0·0	100·0
15	0·00000	0·0	100·0

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FUEL	0·99500	−0·00490	0·08459	0·00466	0·05275
SPEED	−0·44417	0·89371	−0·05468	−0·02483	−0·01970
VACC	0·97011	0·03202	0·01800	0·23986	−0·00314
VDEC	−0·21250	−0·59715	−0·69488	−0·33850	0·02860
TPOS	0·50585	0·85896	0·01672	−0·06937	0·03489
TVEL	0·99337	−0·05952	−0·01227	0·09560	−0·01953
TACC	0·98951	0·06094	0·05656	0·11546	−0·02502
GEAR	0·72112	−0·56238	0·29540	0·27513	0·02771
REVS	0·03623	0·98025	−0·17113	−0·03434	0·08558
FLOW	0·23087	0·97225	0·00056	0·00972	0·03653
TFUEL	−0·94308	−0·17016	0·22029	0·11272	0·14286
TOIL	−0·91771	0·17140	0·28900	−0·16130	−0·13745
TAMB	−0·93581	−0·16023	0·17283	0·20222	0·16678
PRESS	0·35638	−0·09581	0·73460	−0·56863	0·02886
HUMID	−0·87397	0·18904	0·18290	0·39319	−0·11128

Table No.54

Correlation Coefficients for the 1600cc diesel car on the MOTORWAY route section.

VARIABLE	CORRELATION COEFFICIENTS				
	FUEL	SPEED	VACC	VDEC	TPOS
FUEL	1·00000	0·47125	−0·66807	0·52514	0·98723
SPEED	0·47125	1·00000	−0·26810	−0·00506	0·54642
VACC	−0·66807	−0·26810	1·00000	−0·69500	−0·55911
VDEC	0·52514	−0·00506	−0·69500	1·00000	0·42972
TPOS	0·98723	0·54642	−0·55911	0·42972	1·00000
TVEL	−0·17409	0·14883	0·57604	−0·71506	−0·07687
TACC	−0·11063	0·24210	0·53952	−0·71945	−0·00638
GEAR	−0·37956	−0·32913	0·45300	−0·21813	−0·34089
REVS	0·44877	0·99620	−0·23332	−0·02542	0·52953
FLOW	0·95572	0·70926	−0·60919	0·41643	0·97278
TFUEL	0·25581	0·80652	0·12581	−0·25257	0·37607
TOIL	−0·01997	0·78817	0·11911	−0·24167	0·07949
TAMB	0·34186	0·87347	0·07922	−0·19823	0·46288
PRESS	0·58270	−0·16285	−0·79815	0·55360	0·47022
HUMID	0·21375	0·91893	−0·15509	−0·15996	0·29095
	TVEL	TACC	GEAR	REVS	FLOW
FUEL	−0·17409	−0·11063	−0·37956	0·44877	0·95572
SPEED	0·14883	0·24210	−0·32913	0·99620	0·70926
VACC	0·57604	0·53952	0·45300	−0·23332	−0·60919
VDEC	−0·71506	−0·71945	−0·21813	−0·02542	0·41643
TPOS	−0·07687	−0·00638	−0·34089	0·52953	0·97278
TVEL	1·00000	0·99423	−0·36324	0·11945	−0·08077
TACC	0·99423	1·00000	−0·36464	0·21506	0·00064
GEAR	−0·36324	−0·36464	1·00000	−0·24566	−0·40950
REVS	0·11945	0·21506	−0·24566	1·00000	0·69034
FLOW	−0·08077	0·00064	−0·40950	0·69034	1·00000
TFUEL	0·09717	0·18995	0·26082	0·85203	0·47746
TOIL	0·00183	0·08070	0·23518	0·83077	0·24740
TAMB	0·16576	0·25956	0·11080	0·90693	0·56952
PRESS	−0·66682	−0·64827	−0·00542	−0·16777	0·39879
HUMID	0·01044	0·10405	−0·02045	0·94141	0·47343
	TFUEL	TOIL	TAMB	PRESS	HUMID
FUEL	0·25581	−0·01997	0·34186	0·58270	0·21375
SPEED	0·80652	0·78817	0·87347	−0·16285	0·91893
VACC	0·12581	0·11911	0·07922	−0·79815	−0·15509
VDEC	−0·25257	−0·24167	−0·19823	0·55360	−0·15996
TPOS	0·37607	0·07949	0·46288	0·47022	0·29095
TVEL	0·09717	0·00183	0·16576	−0·66682	0·01044
TACC	0·18995	0·08070	0·25956	−0·64827	0·10405
GEAR	0·26082	0·23518	0·11080	−0·00542	−0·02045
REVS	0·85203	0·83077	0·90693	−0·16777	0·94141
FLOW	0·47746	0·24740	0·56952	0·39879	0·47343
TFUEL	1·00000	0·91111	0·98564	−0·25529	0·88085
TOIL	0·91111	1·00000	0·88429	−0·37895	0·93965
TAMB	0·98564	0·88429	1·00000	−0·27964	0·88402
PRESS	−0·25529	−0·37895	−0·27964	1·00000	−0·18347
HUMID	0·88085	0·93965	0·88402	−0·18347	1·00000

Table No.55

Factor Analysis Matrix and Eigenvalues for the 1600cc diesel car on the MOTORWAY route section.

VARIABLE	MEAN	STANDARD DEV.	CASES
FUEL	7·3903	0·5399	6
SPEED	104·3130	2·7149	6
VACC	0·1295	0·0157	6
VDEC	-0·2237	0·0255	6
TPOS	45·4825	3·1293	6
TVEL	1·2907	0·4136	6
TACC	2·4157	0·6767	6
GEAR	0·0138	0·0339	6
REVS	3912·7000	99·1124	6
FLOW	7·7493	0·6991	6
TFUEL	292·3372	4·8757	6
TOIL	375·9172	1·1558	6
TAMB	287·0167	4·7897	6
PRESS	1010·1667	15·0687	6
HUMID	73·3167	7·5861	6

FACTOR	EIGENVALUE	% OF VARIANCE	CUM.%
1	6·47924	43·2	43·2
2	4·75906	31·7	74·9
3	2·34661	15·6	90·6
4	0·93208	6·2	96·8
5	0·48300	3·2	100·0
6	0·00000	0·0	100·0
7	0·00000	0·0	100·0
8	0·00000	0·0	100·0
9	0·00000	0·0	100·0
10	0·00000	0·0	100·0
11	0·00000	0·0	100·0
12	0·00000	0·0	100·0
13	0·00000	0·0	100·0
14	0·00000	0·0	100·0
15	0·00000	0·0	100·0

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FUEL	0·60131	-0·66681	0·32529	0·29317	0·04518
SPEED	0·96901	0·09863	0·05743	-0·21903	-0·00293
VACC	-0·29260	0·86817	-0·04407	0·30548	0·25572
VDEC	0·04707	-0·85792	-0·12111	-0·19282	0·45816
TPOS	0·67965	-0·54596	0·33093	0·35196	0·08138
TVEL	0·06100	0·69827	0·70662	0·09054	-0·03458
TACC	0·16220	0·69233	0·69218	0·10633	-0·06282
GEAR	-0·19780	0·23297	-0·79481	0·52420	-0·00902
REVS	0·97652	0·12283	-0·01423	-0·17639	-0·00379
FLOW	0·80394	-0·49175	0·28293	0·17059	0·05209
TFUEL	0·86364	0·34234	-0·30214	0·21337	0·01097
TOIL	0·76281	0·42444	-0·46288	-0·15397	0·00178
TAMB	0·91740	0·31038	-0·16863	0·16528	0·07926
PRESS	-0·02653	-0·88851	-0·10875	0·20282	-0·39609
HUMID	0·88870	0·23596	-0·27417	-0·22712	-0·16665

Table No.56

Analysis of Variance of all vehicles on the URBAN route section and for all route sections.

ANALYSIS OF VARIANCE FOR ALL ROUTE SECTIONS					
SOURCE OF VARIATION	SUM OF SQUARES	DEG. OF FRD.	MEAN SQUARE	F	SIGNIF. OF F
COVARIATES	53·359	5	10·672	23·636	0·000
VACC	40·973	1	40·973	90·749	0·000
VDEC	10·623	1	10·623	23·529	0·000
TPOS	8·456	1	8·456	18·729	0·000
TVEL	3·941	1	3·941	8·728	0·003
TACC	3·748	1	3·748	8·301	0·004
MAIN EFFECTS	653·078	16	40·817	90·404	0·000
VEHICLE	62·720	2	31·360	69·458	0·000
ROUTE	389·492	9	43·277	95·852	0·000
DRIVER	28·732	5	5·746	12·727	0·000
2-WAY INTERACTIONS	98·278	73	1·346	2·982	0·000
VEHICLE - ROUTE	37·734	18	2·096	4·643	0·000
VEHICLE - DRIVER	25·401	10	2·540	5·626	0·000
ROUTE - DRIVER	28·811	45	0·640	1·418	0·050
EXPLAINED VARIANCE	1297·556	94	13·804	30·573	0·000
RESIDUAL VARIANCE	119·647	265	0·451		
TOTAL VARIANCE	1417·203	359	3·948		

ANALYSIS OF VARIANCE FOR URBAN ROUTE SECTION					
SOURCE OF VARIATION	SUM OF SQUARES	DEG. OF FRD.	MEAN SQUARE	F	SIGNIF. OF F
COVARIATES	8·035	5	1·607	9·002	0·000
VACC	2·269	1	2·269	12·712	0·001
VDEC	2·446	1	2·446	13·703	0·001
TPOS	0·230	1	0·230	1·288	0·262
TVEL	0·170	1	0·170	0·954	0·334
TACC	0·214	1	0·214	1·200	0·279
MAIN EFFECTS	23·065	7	3·295	18·458	0·000
VEHICLE	1·868	2	0·934	5·231	0·009
DRIVER	15·952	5	3·190	17·871	0·000
2-WAY INTERACTIONS	7·926	10	0·793	4·440	0·000
VEHICLE - DRIVER	7·926	10	0·793	4·440	0·000
EXPLAINED VARIANCE	157·040	22	7·138	39·986	0·000
RESIDUAL VARIANCE	8·747	49	0·179		
TOTAL VARIANCE	165·787	71	2·335		

Table No.57

Analysis of Variance of all vehicles on the SUBURBAN and MOTORWAY route sections.

ANALYSIS OF VARIANCE FOR SUBURBAN ROUTE SECTION					
SOURCE OF VARIATION	SUM OF SQUARES	DEG. OF FRD.	MEAN SQUARE	F	SIGNIF. OF F
COVARIATES	0·842	5	0·168	6·096	0·004
VACC	0·163	1	0·163	5·900	0·030
VDEC	0·673	1	0·673	24·387	0·000
TPOS	0·128	1	0·128	4·620	0·051
TVEL	0·162	1	0·162	5·868	0·031
TACC	0·069	1	0·069	2·513	0·137
MAIN EFFECTS	2·763	7	0·395	14·295	0·000
VEHICLE	0·376	2	0·188	6·816	0·009
DRIVER	1·414	5	0·283	10·245	0·000
2-WAY INTERACTIONS	1·296	10	0·130	4·695	0·006
VEHICLE - DRIVER	1·296	10	0·130	4·695	0·006
EXPLAINED VARIANCE	28·205	22	1·282	46·436	0·000
RESIDUAL VARIANCE	0·359	13	0·028		
TOTAL VARIANCE	28·564	35	0·816		

ANALYSIS OF VARIANCE FOR MOTORWAY ROUTE SECTION					
SOURCE OF VARIATION	SUM OF SQUARES	DEG. OF FRD.	MEAN SQUARE	F	SIGNIF. OF F
COVARIATES	7·829	5	1·566	12·148	0·000
VACC	0·005	1	0·005	0·040	0·845
VDEC	0·008	1	0·008	0·060	0·810
TPOS	6·376	1	6·376	49·470	0·000
TVEL	0·019	1	0·019	0·145	0·710
TACC	0·002	1	0·002	0·013	0·911
MAIN EFFECTS	10·570	7	1·510	11·715	0·000
VEHICLE	6·189	2	3·094	24·009	0·000
DRIVER	0·472	5	0·094	0·732	0·612
2-WAY INTERACTIONS	5·054	10	0·505	3·921	0·012
VEHICLE - DRIVER	5·054	10	0·505	3·921	0·012
EXPLAINED VARIANCE	86·416	22	3·928	30·476	0·000
RESIDUAL VARIANCE	1·676	13	0·129		
TOTAL VARIANCE	88·091	35	2·517		

Table No.58

Regression analysis for the prediction of
car fuel consumption on MOTORWAY and URBAN routes.

(model for all vehicles)

REGRESSION MODEL OF FUEL CONSUMPTION						
STEP NUMBER	TERM ENTERED	VALUE	STANDARD ERROR	** F VALUE	R SQUARE %	R SQUARE CHANGE %
MOTORWAY	a	1·1404		Regression F-value	-	29·837
1	b	0·1916	0·262	(0·535)	8·44	8·44
2	c	2·8515	3·563	(0·640)	18·17	9·72
3	d	0·2400	0·419	(0·329)	25·78	7·61
* 4	e	0·0000	-	-	25·78	0·00
5	f	1·0393	0·098	111·881	85·32	59·55
6	g	0·2733	0·848	(0·104)	85·35	0·03
7	h	2·600	1·023	6·658	88·01	2·66
8	j	-0·0595	0·093	(0·411)	88·18	0·17
URBAN	a	7·4576		Regression F-value	-	139·180
1	b	-1·8001	0·098	340·924	71·92	71·92
2	c	-0·6960	0·059	138·235	84·23	12·32
3	d	0·4316	0·194	4·973	86·40	2·17
* 4	e	0·0000	-	-	86·40	0·00
5	f	0·5018	0·067	55·966	90·96	0·11
6	g	-0·1917	0·408	(0·221)	90·96	0·11
7	h	0·9333	0·378	6·090	92·36	1·40
8	j	-0·2016	0·052	15·308	93·84	1·47

* Engine displacement parameter had no statistical tolerance or significance and was hence omitted from the regression model.

** F-values in parentheses are below the 5% level of significance.

Table No.59

Regression analysis for the prediction of
car fuel consumption on SUBURBAN and 50/40/10% routes.

(model for all vehicles)

REGRESSION MODEL FOR FUEL CONSUMPTION

STEP NUMBER	TERM ENTERED	VALUE	STANDARD ERROR	** F VALUE	R SQUARE %	R SQUARE CHANGE %
SUBURBAN	a	6·1671		Regression F-value	–	48·598
1	b	-1·2357	0·141	77·295	63·57	63·57
2	c	-0·4997	0·133	14·196	79·45	15·88
3	d	0·1772	0·269	(0·434)	81·86	2·41
* 4	e	0·0000	-	-	81·86	0·00
5	f	0·6467	0·109	35·534	88·58	6·71
6	g	-0·0034	0·560	(0·0)	88·64	0·05
7	h	1·2385	0·530	5·469	90·60	1·96
8	j	-0·2157	0·084	6·612	92·40	1·80
50/40/10%	a	6·3967		Regression F-value	–	76·170
1	b	-1·3865	0·125	122·535	72·23	72·23
2	c	-0·5012	0·108	21·377	79·61	7·37
3	d	0·3140	0·235	(1·782)	83·46	3·85
* 4	e	0·0000	-	-	83·46	0·00
5	f	0·7007	0·095	54·179	92·36	8·89
6	g	0·0860	0·495	(0·030)	92·36	0·00
7	h	0·8859	0·470	3·549	93·36	1·00
8	j	-0·2070	0·068	9·291	95·01	1·65

* Engine displacement parameter had no statistical tolerance or significance and was hence omitted from the regression model.

** F-values in parentheses are below the 5% level of significance.

Table No.60

Correlation Coefficients for the 1600cc diesel car on the URBAN route section with the inclusion of a "traffic flow" parameter.

VARIABLE	CORRELATION COEFFICIENTS				
	FUEL	SPEED	VACC	VDEC	TPOS
FUEL	1·00000	−0·49054	−0·26377	−0·12595	−0·23459
SPEED	−0·49054	1·00000	0·87380	−0·60297	0·91713
VACC	−0·26377	0·87380	1·00000	−0·69183	0·88736
VDEC	−0·12595	−0·60297	−0·69183	1·00000	−0·63772
TPOS	−0·23459	0·91713	0·88736	−0·63772	1·00000
TVEL	−0·06929	0·75233	0·78958	−0·51801	0·83319
TACC	0·05075	0·63778	0·67103	−0·46013	0·77932
GEAR	0·26274	−0·56270	−0·32751	0·36834	−0·40798
REVS	−0·01415	0·76235	0·64301	−0·42821	0·79940
FLOW	−0·01031	0·87386	0·86663	−0·78003	0·92683
TFUEL	0·05099	−0·29214	−0·31223	0·36960	−0·25073
TOIL	0·29814	0·05189	0·04023	0·05908	0·17337
TAMB	−0·19547	−0·04772	−0·08902	0·27833	−0·08738
TRAF	0·63781	−0·61843	−0·58742	0·19142	−0·49464
PRESS	0·11220	−0·14179	−0·20396	−0·09111	−0·12355
HUMID	0·56965	−0·33652	−0·23963	0·06337	−0·29276

	TVEL	TACC	GEAR	REVS	FLOW
FUEL	−0·06929	0·05075	0·26274	−0·01415	−0·01031
SPEED	0·75233	0·63778	−0·56270	0·76235	0·87386
VACC	0·78958	0·67103	−0·32751	0·64301	0·86663
VDEC	−0·51801	−0·46013	0·36834	−0·42821	−0·78003
TPOS	0·83319	0·77932	−0·40798	0·79940	0·92683
TVEL	1·00000	0·95743	−0·13815	0·66799	0·82145
TACC	0·95743	1·00000	−0·07956	0·65208	0·75871
GEAR	−0·13815	−0·07956	1·00000	−0·53630	−0·48772
REVS	0·66799	0·65208	−0·53630	1·00000	0·85537
FLOW	0·82145	0·75871	−0·48772	0·85537	1·00000
TFUEL	−0·24468	−0·19169	0·30498	−0·11857	−0·30055
TOIL	0·08159	0·13363	−0·06652	0·50394	0·21885
TAMB	−0·13122	−0·14821	0·17370	−0·00151	−0·15258
TRAF	−0·39777	−0·23470	0·25851	−0·27995	−0·36166
PRESS	−0·02923	0·00778	0·18743	−0·14290	−0·11817
HUMID	−0·13780	−0·12539	−0·01824	0·05421	−0·08093

	TFUEL	TOIL	TAMB	TRAF	PRESS	HUMID
FUEL	0·05099	0·29814	−0·19547	0·63781	0·11220	0·56965
SPEED	−0·29214	0·05189	−0·04772	−0·61843	−0·14179	−0·33652
VACC	−0·31223	0·04023	−0·08902	−0·58742	−0·20396	−0·23963
VDEC	0·36960	0·05908	0·27833	0·19142	−0·09111	0·06337
TPOS	−0·25073	0·17337	−0·08738	−0·49464	−0·12355	−0·29276
TVEL	−0·24468	0·08159	−0·13122	−0·39777	−0·02923	−0·13780
TACC	−0·19169	0·13363	−0·14821	−0·23470	0·00778	−0·12539
GEAR	0·30498	−0·06652	0·17370	0·25851	0·18743	−0·01824
REVS	−0·11857	0·50394	−0·00151	−0·27995	−0·14290	0·05421
FLOW	−0·30055	0·21885	−0·15258	−0·36166	−0·11817	−0·08093
TFUEL	1·00000	0·69986	0·93171	−0·09997	−0·03292	−0·17691
TOIL	0·69986	1·00000	0·63883	−0·12735	−0·06947	0·07728
TAMB	0·93171	0·63883	1·00000	−0·33287	−0·17270	−0·28710
TRAF	−0·09997	−0·12735	−0·33287	1·00000	0·09194	0·57853
PRESS	−0·03292	−0·06947	−0·17270	0·09194	1·00000	0·02472
HUMID	−0·17691	0·07728	−0·28710	0·57853	0·02472	1·00000

Table No.61

Factor Analysis Matrix and Eigenvalues for the 1600cc diesel car on the URBAN route section with the inclusion of a "traffic flow" parameter.

VARIABLE	MEAN	STANDARD DEV.	CASES
FUEL	7·9096	0·5864	24
SPEED	22·8517	3·5306	24
VACC	0·4212	0·0687	24
VDEC	−0·6688	0·0684	24
TPOS	10·9474	1·7929	24
TVEL	4·5455	1·1276	24
TACC	9·0780	3·2057	24
GEAR	13·4992	1·7687	24
REVS	1685·8750	155·9364	24
FLOW	1·7996	0·2440	24
TFUEL	288·7996	3·8586	24
TOIL	364·5517	2·6157	24
TAMB	279·9333	4·0901	24
TRAF	1131·6667	116·3618	24
PRESS	1014·1250	13·6432	24
HUMID	78·4500	6·9993	24

FACTOR	EIGENVALUE	% OF VARIANCE	CUM.%
1	6·94047	43·4	43·4
2	2·85064	17·8	61·2
3	2·19117	13·7	74·9
4	1·33116	8·3	83·2
5	0·92605	5·8	89·0
6	0·66390	4·1	93·1
7	0·41803	2·6	95·8
8	0·28366	1·8	97·5
9	0·22396	1·4	98·9
10	0·06541	0·4	99·3
11	0·04432	0·3	99·6
12	0·03631	0·2	99·8
13	0·01625	0·1	99·9
14	0·00576	0·0	100·0
15	0·00190	0·0	100·0
16	0·00101	0·0	100·0

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FUEL	−0·24888	−0·36098	0·81410	0·10980	0·02789
SPEED	0·95384	0·09603	−0·19487	−0·10131	−0·06063
VACC	0·92346	0·01541	−0·08181	0·05722	0·11592
VDEC	−0·69712	0·30421	−0·09687	−0·05859	0·26362
TPOS	0·96621	0·05254	0·03241	0·05326	0·02463
TVEL	0·86528	−0·04973	0·14966	0·34589	0·19914
TACC	0·78583	−0·07472	0·26298	0·39859	0·21194
GEAR	−0·49321	0·08482	0·11819	0·72935	0·33352
REVS	0·81252	0·09217	0·38750	−0·25288	−0·06701
FLOW	0·95836	−0·08340	0·22172	−0·04972	−0·03949
TFUEL	−0·32159	0·85607	0·33327	0·10387	−0·05742
TOIL	0·12085	0·63719	0·69564	−0·14589	−0·15555
TAMB	−0·12939	0·94285	0·15432	0·00667	−0·00190
TRAF	−0·54336	−0·53071	0·45513	−0·04710	0·10407
PRESS	−0·13128	−0·20213	0·04118	0·54071	−0·77234
HUMID	−0·24705	−0·48429	0·58382	−0·30938	0·03690