Usage Patterns of Urban Cars: Their Effect on Fuel Consumption and Emissions

Occasional Paper

This report examines the hypothesis that there are no significant differences in the urban usage characteristics of various sized passenger vehicles, and discusses some implications of these results. The purpose of this study, carried out in the Melbourne metropolitan area, was to ascertain whether there were any significant differences in the characteristics which describe the usage pattern of various types of passenger (and other) vehicles, in the context of the measurement of urban emissions and fuel consumption. Such differences would determine whether or not passenger vehicles could be considered to be homogeneous for the purpose of these measurements. This analysis will assist in the assessment of the impact of the Australian urban vehicle fleet enery consumption and emissions production.

Subject
Series
Date
A to Z
Search
Results
Print
Exit
GO BACK

BUREAU OF TRANSPORT ECONOMICS

USAGE PATTERNS OF URBAN CARS - THEIR EFFECT ON FUEL CONSUMPTION AND EMISSIONS

L. C. Lawlor

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1978

Printed by Canberra Reprographic Printers, 119 Wollongong Street, Fyshwick, Canberra, A.C.T. 2609

FOREWORD

Given its increasing reliance on imported crude oil, Australia's consumption of energy for transport purposes is a matter of national concern. There is also concern that the increasing levels of air pollution be efficiently controlled.

This report examines the hypothesis that there are no significant differences in the urban usage characteristics of various sized passenger vehicles, and discusses some implications of these results. This analysis will assist in the assessment of the impact of the Australian urban vehicle fleet on energy consumption and emissions production.

The report was prepared by Mr L. Lawlor of the Transport Engineering Branch, using information supplied by the Civil Engineering Department, University of Melbourne. This information was published in Bureau Occasional Paper No 12 entitled "Urban Passenger Travel; the Role of the Electric Car".

The Bureau assumes responsibility for the analysis presented in this report. However, the Bureau has had no control over the collection of the data on which the report is based.

(R.H. HEACOCK)
Acting Assistant Director
Transport Engineering

Bureau of Transport Economics
Canberra
September 1978

CONTENTS

TABLES

Page

FIGURES

SUMMARY

The purpose of this study, carried out in the Melbourne metropolitan area, was to ascertain whether there were any significant differences in the characteristics which describe the usage pattern of various types of passenger (and other) vehicles, in the context of the measurement of urban emissions and fuel consumption. Such differences would determine whether or not passenger vehicles could be considered to be homogeneous for the purpose of these measurements.

It was also intended to assess some of the implications of these findings in terms of current approaches to emissions and fuel consumption measurement.

The study investigated trip length, trip frequency and distance travelled by various categories of vehicles, as well as a number of other characteristics of motor vehicle usage.

Emissions and fuel consumption rates of motor vehicles are known to be strongly dependent on the frequency of trips they undertake, while fuel consumption is also a function of the average length of trips. These effects are caused by the different engine operating conditions which apply when an engine is cold compared to when it is fully warmed up.

In addition, information about the annual urban distance travelled by vehicles combined with corresponding unit energy consumption rates would assist in the estimation of annual urban transport energy consumption by motor vehicles.

Vehicle size was used as a surrogate for passenger vehicle mass and two size categories were used - small and large. Passenger vehicles in the small category had 4 seats or less; those in the large category had 5 or 6 seats.

It was found that in the sample urban area there was no significant difference at the 5 per cent level in the urban usage of passenger sedans and station wagons on the basis of vehicle size with respect to trip length and trip frequency. The only area of significant difference was in vehicle occupancy. Small sedans had an average of 12 per cent less occupants per trip than larger sedans and station wagons taken as a group.

Other differences were found, however, when both urban and non-urban usage were considered. These differences concerned the annual distance travelled and the proportion of non-metropolitan travel, for which small sedans showed significantly lower figures than did other (larger) sedans and all station wagons taken as a group. Estimated weekday and annual urban travel was similar for small sedans and other passenger vehicles, while there was a significant difference between the estimated total annual distances travelled by these groups of vehicles. These findings indicate that while the urban usage patterns of sedans and station wagons were generally independent of the size (mass) of the vehicles, larger sedans and all station wagons were used more for non-metropolitan travel.

Thus as far as urban usage is concerned, passenger vehicles may be said to have similar distributions of trip length, trip frequency and annual distance travelled. They may therefore be considered as a homogeneous group for the purposes of measuring emissions and fuel consumption rates as well as national fuel consumption.

These findings indicate that modifications could be made to the current emissions test procedure (ADR 27A) to enable it to more accurately reflect the usage pattern of Australian passenger vehicles in urban areas. Since the Australian standard for fuel consumption measurement - AS 2077 - incorporates the ADR 27A driving cycle, this standard may also be improved through modification. These modifications concern the following matters:

- emissions and fuel consumption measurements for all passenger vehicles over the appropriate driving cycle should be weighted in a similar way to reflect the relative proportions of cold/hot starts in urban areas;

- fuel consumption measurements for all passenger vehicles obtained from driving cycle tests should be adjusted in a similar way to allow for the difference between the driving cycle duration (in distance terms) and average urban trip length.

Motor vehicles other than sedans and station wagons showed a quite different usage pattern from passenger vehicles. This indicates that with significantly different trip lengths and annual urban distance travelled, these vehicles require separate consideration from passenger vehicles in the measurement of emissions and fuel consumption.

The increase in age of sedans and wagons was accompanied by a marked reduction in their usage. This reduction in usage was noted for all characteristics considered, and was statistically significant at the 5 per cent level in each case. The increased usage of "younger" vehicles is indicated by the fact that vehicles less than 6 years accounted for nearly 60 per cent of total annual passenger vehicle-km. Thus in the sixth year after implementing a regulation such as Australian Design Rule 27A (for vehicle emissions), over one half of urban passenger vehicle-km would be travelled by vehicles built to ADR 27A.

As stated above, the results obtained relate specifically to the Melbourne metropolitan area. Investigation of usage patterns in other cities should be undertaken to ascertain whether these conclusions apply to Australia as a whole.

CHAPTER 1 - INTRODUCTION

The factors which can affect motor vehicle emissions and fuel consumption may be divided into the general categories of vehicle design and vehicle operation. While vehicle design is fixed for a vehicle fleet, vehicle operation is highly dependent on the way in which vehicles are used on the roads, i.e., on their usage patterns(1).

Among the factors which affect emissions and fuel consumption from an operating point of view, the following are of considerable significance:

- trip length and trip frequency
- road network shape
- traffic conditions by time of day.

Trip length is important because engine efficiency is highly dependent on engine temperature. Daily trip frequency is also important because this determines the relative proportions of cold/hot starts which in turn affect the emissions and fuel consumption rates. Typically, the first trip of a day would be a cold start, while other trips during the day would commence at higher engine temperatures.

The shape of the road network, together with the proportion of each type of road (freeway etc.) will cause typical driving parameters (average speed, average acceleration, proportion of idle time) to vary from region to region. Variation of traffic conditions by time of day will cause corresponding changes to driving parameters as driving conditions vary between saturated and free-flow.

---

(1) Vehicle usage patterns are defined in Chapter 4 in terms of daily and annual travel characteristics, area of travel and vehicle occupancy.

While all these factors affect emissions and fuel consumption directly, this report is concerned with determining whether there are significant differences among categories of passenger vehicles in terms of their usage patterns, with emphasis on trip length and trip frequency.

The report assesses the effects of any significant differences in usage patterns on the measurement of emissions of pollutants and fuel consumption rates. The reasons for undertaking such an analysis are outlined below.

EMISSIONS AS A FUNCTION OF VEHICLE OPERATING CONDITIONS

Transport and Recirculation of Photochemical Smog

A paper presented at the 1978 Brisbane Clean Air Conference (1) examined the movement of photochemical smog within and across the boundaries of the Sydney (air) Basin. The study investigated the reasons for the much higher levels of ozone at Campbelltown (43 km inland) compared to coastal areas, and the persistence of ozone at Coogee (on the coast) for several hours after the onset of a seabreeze.

The inland ozone levels were found to be caused by three factors:

- transport of oxidants and their precursors from the city and coastal source regions into the southwest of the region by the afternoon seabreeze;
- transport of oxidants and their precursors from an inland source area (most likely the Silverwater area) by north-northwesterly gradient winds;

(1) Hyde, R., Hawke G.S. and Heggie A.C., The transport and recirculation of photochemical smog across the Sydney Basin, Parts I and II, International Clean Air Conference, "Clean Air - the Continuing Challenge", ed. White, Hetherington and Thiele, Ann Arbor Science Publications Inc., USA, 1978.

- recirculation of oxidants and their precursors into the Sydney Basin by nocturnal drainage flows.

The coastal ozone levels were found to be due to the following mechanisms:

- horizontal transport and recirculation of air advected off-shore by westerly drainage flow and then back inland within the seabreeze;

- vertical recirculation of air within a shallow, slow-moving seabreeze.

The paper indicates that Sydney is subject to the same problem of long distance transport and recirculation of pollution as has been found to exist in many parts of the US[(1)(2)(3)(4)].

In the absence of knowledge of the long distance transport and recirculation of emissions and smog in relation to airsheds, it had previously been considered sufficient to measure vehicle emissions during the early daylight hours. However with the increasing recognition of the transport and recirculation problem in the US, measures have been taken there to account for emissions over the 24 hours of a day. This is at present achieved in US regulations by means of a weighting of emissions of cold/hot starts as discussed below.

---

(1) Rubins R.A., Bruchman L. and Magyer J., Ozone Transport, J. Air Poll. Assoc., 1976, 26.

(2) Ludwig F.L., Johnson W.B., Ruff R.E. and Singh H.B., Important factors affecting rural ozone concentration, Proc. Inter. Conf. on photochemical oxidant pollution and its Control, 1976, US EPA, Raleigh, North Carolina, September 1976.

(3) Cleveland W.S., Kleiner B., McRae J.E., Warner J.L. and Pasceri R.E., Geographical properties of ozone concentrations in the northwestern US, J. Air Poll. Control Assoc., 1977, 27.

(4) Alkezweeny A.J. and Drewes D.R., Airborne measurements of pollutants over urban and rural sites, J. Appl. Meteor., 1977, 16.

Vehicle Emissions and Engine Temperature

Motor vehicle emissions are strongly influenced by the engine temperature at the start of a trip. The effect of initial engine temperature on overall emissions may be examined in the context of "soak" time.(1) Soak time can be considered as a function of trip frequency, since high trip frequencies would generally correspond to short soak times. A recent report for the US Environmental Protection Authority(2) indicates an almost linear relationship between normalized emissions(3) and the logarithm of soak time, as shown in Figure 1, and is summarised below:

> HC and NO_x emission rates during the Urban Dynamometer Driving Schedule (UDDS)(4) increased almost linearly with the logarithm of soak period length (ie as engine temperature decayed). HC emission rates following a 10 minute soak period were typically 40 percent of values following a 16 hour soak period, but were not normally higher following a 36 hour soak than a 16 hour soak period.
>
> Following a 10 minute soak, NO_x was approximately 90 per cent of 16 hour soak values but was slightly higher following a 36 hour soak than a 16 hour soak period.
>
> CO emission rates during the UDDS were stable following soak periods of 10 minutes to 1 hour in length, but the level ranged from 10 to 70 percent of the 16 hour soak value depending on the type of exhaust after-treatment. Following 2 hour and longer soak periods, CO increased approximately linearly with the logarithm of soak time.

---

(1) Soak time is defined as the time for which a vehicle engine is switched off between trips. It may be considered a composite proxy for the decay in the temperature of the various heat sources within an engine, viz., engine oil, cooling water, engine block, etc..

(2) Srubar R.L., Springer K.J. and Reineman M.E., Soak Time Effects on Car Emissions and Fuel Economy, SAE paper 780083, February 27, 1978.

(3) Normalized emissions = $\frac{\text{Emission rate after given soak time}}{\text{Emission rate after 16 hour soak}} \times 100\%$

(4) UDDS: The Urban Dynamometer Driving Schedule is equivalent to the ADR 27A driving cycle.

It should be noted that all vehicles in the EPA test were fitted with exhaust after-treatments which are not typical of Australian vehicles. The test results may therefore differ to some degree from similar vehicles equipped to ADR 27A requirements. It is clear, however, that variations in trip frequency will cause considerable relative variation in the output of emissions from motor vehicles.

The dependence of motor vehicle emissions on soak time, and thus trip frequency, is not taken into account in the Australian Design Rule applicable to emission control (ADR 27A)(1). This rule is based on the US Federal Test Procedure (FTP) for motor vehicles, brought into force in the US in 1972. The test procedure incorporates a driving cycle(2) which is 12.1 km in length(3) and starts with the engine cold (after a 12 hour soak). If the mean Australian urban trip length is close to 12 km, this test would reflect actual Australian urban conditions, at least for cold-start trips, assuming of course that the driving cycle itself is appropriate.

The fact that emissions will vary with engine soak time has however been taken into account in the test procedures prescribed in the US 1975 FTP. The average daily trip frequency was assumed to be 4.7, comprising 1 cold start with the remainder being hot

---

(1) Commonwealth Department of Transport, Australian Design Rules for Motor Vehicle Safety, Melbourne, July 1976.
(2) A driving cycle is defined as a prescribed velocity-time relationship intended to represent typical driving conditions.
(3) Direct conversion from 7.5 mi specified in the FTP.

starts. This split-up is taken into account by means of weights of 0.43, 1.00 and 0.57 applied to emissions obtained from "cold", "stabilized" and "hot" sections of the driving cycle(1)(2).

FUEL CONSUMPTION AS A FUNCTION OF VEHICLE OPERATING CONDITIONS

Fuel Consumption and Engine Temperature

Motor vehicle fuel consumption has a negative correlation with both the engine temperature at the start of a trip, and the increase in engine temperature during a trip.

The relationship between engine temperature at the start of a trip and fuel consumption is shown in Figure 1 in terms of soak time. Fuel consumption over the UDDS procedure increased almost linearly with the logarithm of soak time. Fuel consumption following a 10 minute soak was approximately 85 per cent of 16 hour soak values, but was slightly higher following a 36 hour soak than a 16 hour soak period.

The relationship between fuel consumption and trip length is shown in Figure 2. This shows the relative cold-hot weighted fuel economy for typical US vehicles(3).

---

(1) The weights of 0.43 and 0.57 are derived as follows:
$0.43 = 2(1/4.7)$
$0.57 = 1.00-0.43$
Total weight = 0.43 + 0.57 + 1.00 = 2.00

(2) In the 1975 FTP, the 1372 seconds of the US 1972 FTP are divided into two segments as follows:
- 505s cold transient phase, C_t; (from cold start)
- 867s cold stabilized phase, C_s;

This is followed, after a 10 minute soak at ambient conditions, by a repeat of the first 505s, termed the hot transient phase H_t. The mass of emissions from each phase are summed as follows, to give total emissions in gm/km:
$$\text{Emissions (gm/km)} = (0.43\ C_t + 1.00\ C_s + 0.57\ H_t)/12.1$$
where 12.1 km = length of driving cycle distance.

(3) Austin T.C., and Hellman K.H., Passenger Car Fuel Economy as Influenced by Trip Length, SAE Paper 750004.

A wide range of data on fuel consumption as a function of trip length were utilized in the development of Figure 2. Cold start data were obtained from test runs on General Motors CBD and SAE urban driving cycles. Hot start data were obtained from consideration of seven driving cycles developed by GM and SAE which related to city, suburban, highway and interstate driving patterns.

Cold and hot start data have been weighted 0.43/0.57 on the basis of the US regulations discussed above for emissions. As discussed later in this report, these weights may not be relevant in the Australian context. However, it is quite clear that a relationship of the type depicted in Figure 2 will apply to Australian urban driving, whatever weights may be appropriate.

Figure 2 indicates that thermal equilibrium and thus the minimum fuel consumption rate is not reached until a typical vehicle has travelled a distance of about 60 km. It can be seen that motor vehicle fuel consumption is highly dependent on trip length and trip frequency (the latter being a function of soak time).

Australian Standard for Fuel Consumption Measurement

The Australian Standard for fuel consumption measurement, AS-2077 (1), is based on early US EPA procedures which involve the use of the UDDS (urban) cycle (equivalent to ADR 27A) and the EPA highway cycle. These cycles taken together are considered representative of typical US driving conditions. The standard states that it is primarily intended to provide values for the purpose of comparing the petrol consumption of different cars.

A recent study commissioned by the US Department of Energy (2) investigates the growing concern in that country that fuel

(1) Method of Test for Petrol Consumption of Passenger Cars and their Derivatives, AS 2077-1977, Standards Association of Australia, Sydney, 1977.

(2) McNutt B., Pirkey D., Dulla R. and Miller C., A Comparison of Fuel Economy Results from EPA Tests and Actual in-use Experience, 1974-1977 Model Year Cars, SAE Paper 780037.

consumption data derived from EPA tests do not reflect typical on-road fuel consumption. The study confirms that there are serious discrepancies between EPA test data and on-road measurements. It states that vehicle weight may be a better parameter for ranking the in-use fuel consumption of vehicles than EPA test values.

Although the problem has not been resolved, it is clear that care should be taken in utilizing AS-2077 for fuel consumption measurements in Australia.

Application of Fuel Consumption Data

There are two aspects concerning fuel consumption measurement which relate to vehicle usage patterns.

The first is the measurement of mean fuel consumption rates for categories of passenger motor vehicles in urban areas. The only available data on a national basis estimate that the average petrol consumption rate for Australian urban and non-urban areas combined was 12.3 l/100 km in 1971[(1)]. This figure was averaged across all vehicle categories.

Accurate fuel consumption rates disaggregated by vehicle category would be of considerable value in implementing a policy of fuel consumption labelling of motor vehicles. This policy implies that vehicles would be labelled with the appropriate fuel consumption figure for "typical" city, suburban or non-urban trips.

The second aspect concerns the estimation of aggregate annual urban fuel consumption, which would be assisted by information on the annual urban distance travelled by motor vehicles. This would lead to a more effective assessment of proposed vehicle design and energy use policies.

---

(1) Australian Bureau of Statistics, Survey of Motor Vehicle Usage, September 1971, Ref. 14.4.

In 1971, sedans and station wagons performed an estimated 72 per cent of the passenger transport task, and accounted for the consumption of about 54 per cent of oil based transportation energy used for both passenger and freight purposes. Approximately 70 per cent of the national energy consumption of sedans and station wagons in 1971 is estimated to have occurred in capital city or provincial urban areas[1]. Thus about 40 per cent of oil based transportation energy was accounted for by passenger vehicles in urban areas in 1971. The proportion is likely to have risen since then.

These estimates are based on applying the average petrol consumption rate of 12.3 l/100 km to the estimated annual distance travelled by passenger vehicles in urban areas. Estimates of aggregate urban transport energy consumption would be greatly improved not only with data on the energy consumption rates of various categories of vehicles, but also with more accurate data on the average annual urban distance travelled by each category of vehicle.

---

(1) Bureau of Transport Economics, Occasional Paper No 4, Transport and Energy in Australia, Part 2, Consumption by Categories, Canberra 1975.

CHAPTER 2 - HYPOTHESES INVESTIGATED

VEHICLE CLASS ANALYSIS

The basic premise of this investigation was that passenger vehicle usage (expressed principally in terms of trip length and trip frequency) is a function of vehicle size[1]. Larger passenger vehicles have more seating and luggage carrying capacity than smaller vehicles and can be used more frequently for trips involving a larger number of occupants and/or greater load carrying requirement.

Vehicle comfort is not considered an important usage measure on which to base the investigation since in many cases, smaller passenger vehicles are as comfortable, if not more so, than larger vehicles, while in other cases the opposite applies.

Comfort may be an important measure in the usage of an increasing number of motor vehicles which could be termed recreational vehicles. These vehicles may possibly be driven in a manner different from passenger vehicles. Such vehicles have been included in the "other" vehicle class which includes all vehicles apart from passenger vehicles. Vehicle comfort has therefore been ignored as a factor affecting vehicle usage. It is felt that the error implicit in this assumption would be small.

While vehicle energy consumption is related to vehicle mass, a number of makes of passenger vehicles are produced with a range of engines from 4 to 8 cylinders. It has been assumed that variations in engine capacity in a vehicle of given size would not significantly affect its urban usage pattern. Variations in

---

(1) Vehicle size takes into account the dimensions of vehicles. The prime concern was to differentiate between 4 seat vehicles on one hand, and 5 and 6 seat vehicles on the other. The complete definition of small vehicles is at Appendix A.

vehicle mass as a function of variations in engine size have been considered to be of minor importance and have been ignored. Thus the fact that a vehicle may be built with different sized engines has been assumed not to affect the validity of using vehicle size as a proxy for vehicle mass.

Of course, the numbers of vehicles of a given size with each size of engine would need to be taken into account in measuring the energy consumption rate of each vehicle type.

Since the categorization of small/large mass vehicles would generally correspond with the categorization of small/large size vehicles, it is considered quite reasonable to utilize vehicle size as a proxy for vehicle mass, in order to link vehicle usage with energy consumption rates. However, since non-passenger vehicles were included in the analysis, it is preferable to use the terms "vehicle class" or "vehicle category" as the basis of the analysis rather than "vehicle size".

Energy consumption is also a function of aerodynamic drag and rolling resistance. Aerodynamic drag is related to vehicle dimensions and thus vehicle size. Rolling resistance is dependent to some extent on the type of tyres used, radial or crossply, but is of fairly small relative magnitude. For this reason, rolling resistance has been ignored in this study.

Although trip length and trip frequency are the usage characteristics which determine the extent to which vehicle categories differ significantly in usage or operation, a number of other usage characteristics have been included in the analysis in order to more fully describe vehicle usage patterns. These other characteristics are not critical to the analysis, but provide a useful background for it.

Two sets of hypothesis testing were carried out. The first set of tests concerned the analysis of usage patterns by vehicle category, while the second concerned vehicle age analysis.

The various classes of passenger vehicles sampled were grouped in pairs for the purpose of vehicle category analysis. The principal comparison was made between small and large passenger vehicles to determine their homogeneity in terms of usage patterns. Passenger vehicles were also compared with other vehicles to obtain a general indication of the extent of differences between these categories. Lack of adequate data prevented a detailed analysis of the "other" vehicle category.

The null hypothesis tested was that for each usage characteristic compared, vehicles in each category pair were drawn from the same population. Stated another way, the null hypothesis was that the difference between the means of values of each usage characteristic for each sample of vehicles was zero.

The alternative hypothesis tested was that vehicles in each category pair were drawn from different populations. Again, stated another way, the alternative hypothesis was that differences between the means of values of each usage characteristic for each sample of vehicles was significantly different from zero.

The statistical procedure used in this study measured the probability of obtaining by chance a difference between two sample means as large or greater than that observed. For probability values greater than a specified value, it was assumed that the differences observed were caused by chance, while for probability values less than the specified value, a meaningful difference was considered likely between the samples. This process is explained below.

While statistical analysis provides a rationale for rejecting a hypothesis, it does not provide a formal basis for accepting the hypothesis as proven. The best that can be said is that a hypothesis, given that it has not been rejected, is <u>acceptable</u>, as distinct from being <u>accepted</u>. One should really be concerned with the strength of the relationship between means of characteristics of the sample groups of vehicles. Probabilities of differences of means of the order of say 10 per cent or greater indicate the likelihood of strong similarity between two samples. On the other hand probabilities of the order of say 1 per cent indicate that a meaningful difference is much more likely to be present.

For these reasons, probabilities of differences of means of greater than 5 per cent are taken to indicate the likely similarity of sample groups. Conversely, probabilities of differences of means of less than 5 per cent are taken to indicate the likelihood of significant differences between samples. The selection of 5 per cent as the confidence limit for rejecting the null hypothesis implies that the magnitude (α) of Type I errors that would be accepted was also 5 per cent. This means that if the null hypothesis was actually true, and given that a difference between the two categories was found for a particular characteristic, there would be a 5 per cent maximum probability of rejecting the null hypothesis and a 95 per cent maximum probability of declaring the null hypothesis acceptable.

Since appropriate data was not available with respect to the total urban vehicle population, it was not possible to determine the corresponding Type II errors or the power of the statistical tests. Type II errors refer to the probability of accepting the null hypothesis given that it is actually false. The magnitude of type II errors is usually designated "β". The power of a test, which refers to the probability of rejecting a hypothesis when it is false, is calculated as $(1-\beta)$.

If the null hypothesis for a vehicle category pair with respect to trip length and trip frequency was acceptable, it would imply that the vehicles were likely to be homogeneous from the point of view of emissions and energy usage analysis. If trip length was found to be similar for each vehicle category, it would indicate that the same corrections could be made to fuel consumption measurements for each such category. Similarity in trip frequency would indicate that the proportion of cold/hot starts was the same for each category of vehicle, and that the same weights for cold/hot starts could be utilized in the measurement of emissions and fuel consumption. If the null hypothesis was also acceptable for annual distance travelled, then in terms of the total fuel consumption of the vehicle fleet, the proportion of fuel consumed by a class of vehicles would be a function of the proportion of vehicles in the vehicle category and the corresponding fuel consumption rate[(1)]. Conversely, rejection of the null hypothesis would indicate that no such relationship would apply.

VEHICLE AGE ANALYSIS

All passenger vehicles were grouped together for the purposes of vehicle age analysis. Other vehicles were not analysed with respect to vehicle age. The effect of vehicle age on urban vehicle usage was examined by testing the null hypothesis that, for each vehicle usage characteristic, passenger vehicles of each age category were drawn from the same population. The alternative hypothesis was that vehicles in each age category were drawn from different populations.

If the null hypothesis was acceptable, then vehicles in each age group of the fleet could be assumed to make a contribution to annual urban travel proportional to the size of the group. Conversely, rejection of the null hypothesis would indicate that younger vehicles made either a greater or less than average contribution to annual travel. If the means of each characteristic were calculated for each age group it would be possible to determine the relative contributions of vehicles of different ages.

---

(1) If VKT is the same for all vehicle categories, the proportion of total annual fuel consumption attributable to a category of vehicles "i" is given by:

$$\frac{R_i N_i}{\sum_{i=1}^{N} R_i N_i}$$

where Ri = fuel consumption rate of vehicle category "i".
Ni = number of vehicles in category "i".
N = number of vehicle categories in vehicle population.

CHAPTER 3 - DESCRIPTION OF DATA

The data analysed in this paper were obtained from a study published as the Bureau Occasional Paper No 12 entitled "Urban Passenger Travel; the Role of the Electric Car". In that study, 679 households in 10 Local Government Areas (LGAs) in suburban Melbourne provided information on the usage of motor vehicles (excluding motor cycles) normally garaged at the households. The 10 LGAs surveyed were not selected at random, but were carefully chosen in order to ensure that the survey was fully representative of the Melbourne metropolitan area. Thus the findings of the survey and of this report refer specifically to the Melbourne urban area.

The vehicle sample was adjusted to correct for under or over sampling in the LGAs, and then normalized to give the vehicle population appropriate to a group of 100 000 households within the Melbourne Metropolitan Area. Both the sample vehicle population and the normalized vehicle population were analysed for the purposes of Occasional Paper No 12. That report contains full details of the data collected and methods of analysis used. Table 1 of this Paper contains details of the original sample population of 873 motor vehicles, and the normalized vehicle population corresponding to 100 000 households.

It was originally intended to group small(1) sedans and station wagons together and to compare these small passenger vehicles with other (larger) sedans and station wagons. Since small station wagons amounted to only 1.6 per cent of the sample vehicle population, it was decided to group small station wagons with other station wagons to form a single class of station wagons. This left two classes of sedans, small and other, and a single class of station wagons as the major categories of passenger vehicles for hypothesis testing. A further class was included in the testing, that of "other vehicles" (vehicles other than passenger vehicles).

---

(1) The definition of "small" vehicles is discussed at Appendix A.

The data which have been analysed were collected as 2 subsets, one relating to vehicle characteristics and estimated vehicle usage over the previous 12 months, and the other relating to trips made by the vehicles on the weekday before the survey interviewers called. Data on vehicle usage characteristics are subjective in nature since relevant data were estimated by respondents. Data on trip characteristics may be considered objective in nature since they relate to actual trips made by the vehicles. Vehicle age is, of course, an objective item of information.

While vehicle and trip characteristics have been analysed in terms of all classes of vehicles, separate analyses were carried out on sedans and station wagons as a group, where possible.

CHAPTER 4 - ANALYSIS METHOD

ANALYSIS OF DATA

Characteristics of vehicle usage patterns which formed the basis of the analysis are as follows:

- Trip length
- Number of trips per day
- Distance travelled on a typical weekday
- Distance travelled in a year
- Days per week idle
- Proportion of travel outside the metropolitan area
- Number of occupants per vehicle

Two main measures were used to detect differences in vehicle usage patterns: class and age. Firstly, six classes of vehicles (excluding motor cycles) were analysed in four pairs as follows:

- Small sedans vs other sedans[1]
- Small sedans vs. other sedans and (all) station wagons taken together
- Other sedans vs. station wagons
- All sedans and station wagons vs. other vehicles

Secondly, the vehicle age categories were:

- Current year (1975) vehicles
- Vehicles 1-5 years old (1970-74)
- Vehicles 6-10 years old (1965-69)
- Vehicles 11-15 years old (1960-64)
- Vehicles greater than 15 years old (pre-1960)

---

(1) "Other sedans" were defined as all sedans not being small sedans.

Drivers' usual occupation and trip destination purpose were also investigated to study their relationship with a number of vehicle usage characteristics.

The analysis of variance method was used to analyse the data and determine whether significant differences could be determined between various vehicle category pairs with respect to each usage characteristic. One-way analysis was used in all cases. The analysis of variance method is discussed at Appendix B.

Two major sets of analyses were carried out:

(i) Data on vehicle class were analysed by comparing the 6 vehicle categories arranged in four pairs. These pairs were tested for significant differences between each of the 7 vehicle usage characteristics. This pairwise testing enabled a total 28 (= 4x7) tests for significance to be made.

(ii) Vehicle age information was analysed by testing, for each of 5 vehicle usage characteristics, whether there were any significant differences among the 5 vehicle age groups, taking all passenger vehicles together. Thus only 5 tests for significance were carried out on vehicle age data.

PRESENTATION OF DATA

Figures 1 and 2 present emission and fuel consumption data and have been referred to in Chapter 1. Table 1 describes the sample of vehicles while the results of the analyses are presented in Tables 2 through 17 and Figures 3 through 19. The data which have been analysed have been divided into two sets. The first set comprises the statistical analysis of vehicle usage characteristics from the sample population, as follows:

- Vehicle ownership - Table 2
- Vehicle class analysis - Tables 3 through 7
- Vehicle age analysis - Tables 8 through 10
- Analysis of other usage pattern measures - Tables 11 through 13

The second set of results comprises an analysis of the proportions of vehicles corresponding to various values of the usage characteristics. This analysis is based on the normalized vehicle population data, and is contained in Tables 14 through 17 and Figures 3 through 19.

The data presented in Figures 3 through 19 have been analysed on the basis of totals of reported vehicles and/or trips being equal to 100 per cent. There was a small deficiency in the survey data in that some data were not supplied by respondents concerning certain vehicles and trips. The data deficiency was of the order of 2 per cent of vehicles for data plotted in Figure 3 and Figures 6 through 13. For trip frequency (Figures 4 and 5) the data deficiency was 5 percent of vehicles. There was a resultant variation in the proportions of vehicles in some of the categories shown in Figures 3, 4, 6, 8, 10 and 12 as compared to the data of Table 1 (normalized population proportions).

Data were not collected on trips made by business vehicles during working hours. This fact is noted in Figures 3, 4, 6, 8, 10, 12, 14 and 15. Some segments of vertical columns in the Figures have no numerical values appended, due to their small size. These are of the order of 1 per cent in value.

CHAPTER 5 - RESULTS OF ANALYSIS

RESULTS OF VEHICLE OWNERSHIP ANALYSIS

Table 2 indicates that over 90 per cent of vehicles in each vehicle class of the sample population were privately owned.

RESULTS OF VEHICLE CLASS ANALYSIS

Table 3 contains the results of pairwise analysis of variance testing, and shows that the ranking of vehicle category pairs in order of increasing numbers of statistically significant differences in usage characteristics was as follows:

. other sedans	vs.	station wagons	(0)
. small sedans	vs.	other sedans	(2)
. small sedans	vs.	other sedans and station wagons	(3)
. all sedans and wagons	vs.	other vehicles	(4)

The figures in brackets indicate the number of usage characteristics for which significant differences were found, out of a possible total of 7 characteristics. The level of significance used was 5 per cent.

It was found that trip length and trip frequency were not significantly different when the categories of passenger vehicles were compared.

Vehicle occupancy was significantly different for 3 of the 4 vehicle category pairs, and accounted for the only significant difference in urban use of small sedans compared to other passenger vehicles. The annual (urban and non-urban) distance travelled and the proportion of non-metropolitan travel accounted for the next highest degree of difference between the categories.

When small sedans were compared with "other sedans" for total annual distance travelled, the probability of accepting the null hypothesis was 0.060, just outside the critical region of 0.050. When station wagons were combined with "other sedans", the probability of accepting the null hypothesis fell to 0.028 (critical).

Vehicles other than sedans and station wagons were significantly different from sedans and station wagons as a group in terms of weekday trip length and occupancy, as well as in weekday and total annual distance travelled.

The means and standard deviations of the vehicle usage characteristics (Table 4) were generally similar for all vehicle categories except "other vehicles". Table 5 contains the ratios of means of the usage characteristics shown in Table 4, for each vehicle category pair of interest. It can be seen that significant differences generally occurred between vehicle category pairs when the ratios of means differed from unity by at least 10 per cent.

Table 6 shows the fairly close agreement between passenger sedans and station wagons, in terms of the ratios of means of estimated and calculated daily travel, and estimated annual and weekday travel. The general agreement in these ratios provides a degree of confidence in using the estimates of vehicle usage supplied by the survey respondents.

The large difference in the ratio for estimated and calculated weekday travel shown by the other vehicle class when compared to the figure for all vehicles would be due to the fact that business trips during working hours were excluded from the survey.

Table 7 shows the close similarity of the estimated annual urban distance travelled by the various classes of passenger vehicles. Small sedans differed the most from the mean of the estimated total distance travelled for all passenger vehicles. However, when only urban travel was considered, this difference was reduced, but was still greatest for small sedans. This indicates that the larger vehicles were used more for non-urban travel than were smaller vehicles.

RESULTS OF VEHICLE AGE ANALYSIS

Table 8 sets out an analysis of the vehicles in the sample by age, with one half of the vehicles being less than six years old.

Tables 9 and 10 show the very strong relationship between the age of sedans and station wagons and their usage pattern. In almost every age group the means of each vehicle usage characteristic indicate a decline in vehicle usage with increasing age. In the few cases where the opposite applied, the general trend was not greatly affected. The ratios of means at the bottom of Table 9 show the relative increase in usage on the part of later (younger) as compared to earlier (older) vehicles.

Analysis of variance testing was applied to each usage characteristic of Table 9, taking all 5 vehicle age groups into account. This analysis was applied to passenger vehicles only. The null hypothesis tested was that for each characteristic, vehicles in the various age categories were drawn from the same population. The alternative hypothesis used was that vehicles in each age category were drawn from different populations. It was found that there was a significant difference at the 5 per cent level between the 5 vehicle age groups for each vehicle usage characteristic of Table 9. The probability of accepting the null hypothesis in each case was less than 0.010 (critical).

Table 10 shows the relationship between the age of sedans and station wagons and the estimated weekday and annual distances travelled. For both distance categories, vehicles less than 6 years old accounted for 58 per cent of total vehicle-km, while vehicles less than 11 years old accounted for about 86 per cent of total vehicle-km.

ANALYSIS OF OTHER USAGE PATTERN MEASURES

Tables 11 through 13 analyse trip length and vehicle occupancy in terms of drivers' occupation and trip purpose. Table 11 shows that professional and administrative drivers travelled on the longest trips, while the not-employed category(1) made the shortest trips. The not-employed category, however, had the highest level of vehicle occupany, while craftsmen and transport workers had the lowest.

The analysis of trip length and vehicle occupancy by trip purpose (Table 12) shows that the employer-business and work trip purposes were the longest trips on average, while shopping and serve-passenger(2) trips were the shortest. Vehicle occupancy was quite variable among trip purposes (more so than with occupation - Table 11), with serve-passenger trips having the highest occupancy and work and employer-business trips the lowest occupancies.

Home and work trip destination purposes (Table 13) made the largest contribution to the estimated weekday passenger task on the part of sedans and station wagons (44 and 22 per cent respectively). Together with serve-passenger destination purposes (10 per cent), they accounted for three-quarters of the estimated daily occupant-km in the urban area.

ANALYSIS OF NORMALIZED VEHICLE POPULATION DATA

The normalized vehicle population was used to develop the data presented in Figures 3 through 19. Tables 14 and 15 list the characteristics used in vehicle class, vehicle age and other analyses. Tables 16 and 17 summarize data from those figures which compared categories of vehicles (Figures 4, 6, 8, 10, 12, 14

---

(1) The not-employed category included housewives, students and retired/invalid persons. Unemployed people were included in the "other" category.

(2) A serve-passenger trip was defined as a trip whose purpose was to convey or pick up one or more passengers.

and 15). Comparing the characteristics of small sedans and other sedans, the major differences were in the annual distance travelled (at the 80 and 90 per cent cumulative levels of vehicles), and the proportion of non-metropolitan travel (at the 80 per cent cumulative level). Vehicle occupancy differed at the 90 per cent cumulative level. All sedans and station wagons as a group differed from small sedans with respect to trips per day and annual distance travelled (80 per cent cumulative level of vehicles) and vehicle occupancy (90 per cent cumulative level).

CHAPTER 6 - CONCLUSIONS

In the Melbourne region, the urban usage of small sedans, in terms of trip length, trip frequency and weekday distance travelled, was not significantly different at the 5 per cent level from other groupings of passenger vehicles. Significant differences between these vehicle categories were, however, found with respect to the annual distance travelled, the proportions of non-metropolitan travel and urban vehicle occupancy.

The first two of these latter characteristics relate to combined urban and non-urban usage. Thus as far as urban usage was concerned, small sedans differed from other passenger vehicles only in terms of occupancy. Small sedans had 1.37 occupants per trip on the average, while the mean for larger sedans and station wagons (taken together) was 1.53 occupants per trip, a difference of 12 per cent.

Mean weekday and annual urban distances travelled have been shown to be similar for each category of passenger vehicles. Thus the larger passenger vehicles, which travelled greater annual distances, must have been used more for non-metropolitan travel.

The fact that mean trip length and trip frequency were not significantly different between categories of passenger vehicles indicates that the hypothesis that all passenger sedans and station wagons may be treated homogeneously in the context of the measurement of emissions and fuel consumption is an acceptable one. Further investigation would be needed before this could be stated with certainty. The relationship between emission rates and trip frequency for all categories of passenger vehicles should therefore be taken into account in a similar way in the formulation of Australian standards for vehicle emission control. A weighting process for cold/hot starts along the lines of the US 1975 FTP may be appropriate.

Motor vehicle fuel consumption is seen to be strongly dependent on both trip length and soak time - which is a function of trip frequency. It is clear that these effects should be taken into account in a uniform manner for all passenger vehicles in the development of test procedures for fuel consumption measurement. Thus the length of the driving cycle used for fuel consumption measurement should be adjusted or weighted to take mean trip length into account. Further, a weighting procedure for cold/hot starts, as mentioned for emissions, should be utilized to enable fuel consumption data to reflect realistic vehicle operating conditions.

The mean trip length and trip frequency from the sample data (10.9 km, 3.1 trips per day) differ from corresponding US data embodied in the US 1975 Federal Test Procedure for passenger vehicles. (The corresponding US data are 12.1 km and 4.7 trips per day). It is therefore likely that the US weighting factors for cold/hot starts (based on 4.7 trips per day) will not apply in the Australian urban context. Further, an assessment of relevant US procedures would be required before they could be accepted as appropriate for Australian conditions.

Although the overall annual distance travelled was found to be significantly different among the passenger vehicle categories, the mean annual urban distance travelled was found to be much the same for these vehicles. In the absence of a significance test for annual urban distance travelled, it has been assumed that the same annual urban distance may be applied to all passenger vehicles, thus simplifying the estimation of the annual urban fuel consumption by passenger vehicles. The latter becomes a function of fuel consumption rates of the various vehicle categories and the numbers of vehicles within each category.

No investigation of urban weekend travel was carried out in this study. Since weekend occupancy of large passenger vehicles could differ from small sedans more than for weekday travel, it is not possible to comment on the difference in the total urban passenger task as a function of vehicle size.

The remaining category of vehicles, "other vehicles" (utilities, trucks, etc.), was significantly different in usage pattern from passenger vehicles with respect to a number of usage characteristics including trip length and annual urban distance travelled. It has been stated that trips undertaken during business hours by these vehicles were not measured by the survey. If these trips were included in the analysis, the degree of difference in usage patterns between these vehicles and passenger vehicles would probably increase.

Trucks garaged at commercial and government premises were not covered by the survey. The usage of these vehicles would need to be taken into account in determining the overall usage patterns of the "other vehicle" category.

The significant difference in average trip length between passenger vehicles and other vehicles indicates that different adjustments will need to be made to fuel consumption data obtained for these vehicle categories.

Since the "other vehicle" category was not subjected to disaggregated analysis, it is not possible to determine whether or not the same weighting for cold/hot starts could be used for vehicles within this category. However, it seems clear that any such weighting would differ from that applicable to passenger vehicles, given the almost critical difference between mean trip frequency for these categories of vehicles. The probability of accepting the null hypothesis in this instance was 5.3 per cent, while the critical level was 5 per cent.

Vehicle age is seen to have been an important determinant of passenger vehicle usage. There was a significant statistical relationship between each usage characteristic examined and the age of the vehicles.

The variation of the energy consumption rate of motor vehicles with age was not studied in this report. However, the variation of vehicle usage with age of vehicle does have implications for the effectiveness of policy measures to affect vehicle emissions or fuel consumption. Passenger vehicles less than 6 years old contributed nearly 60 per cent of estimated annual vehicle-km in urban areas. Thus, using Australian Design Rule 27A (implemented in July 1976) as an example, by the end of 1981 over one half of total urban passenger vehicle-km achieved in that year would be accounted for by vehicles built to the emission control standards of ADR 27A, assuming the vehicle fleet size remains constant during the period.

The urban passenger task analysed by trip destination purpose shows the dominance of home trips, as would be expected from the fact that nearly all vehicles sampled would have been garaged at home overnight, being privately owned. Work and serve-passenger trip purposes accounted for one-third of average daily occupant-km in the sample. When home was included as a trip destination purpose, these three purposes accounted for three-quarters of total daily occupant-km.

CHAPTER 7 - RECOMMENDATIONS

It was indicated in Chapter 6 that the mean trip length should be taken into consideration in the measurement of fuel consumption rates. It was stated that the weighting factors for cold/hot starts for Australian passenger vehicles in the Melbourne metropolitan area (based on trip frequency) are likely to differ from those prescribed in the US Federal Test Procedure for 1975. The mean annual distance travelled was relevant in the context of national urban fuel consumption estimates.

It is recommended therefore that studies be undertaken with the objective of determining the distributions of trip length, trip frequency and annual distance travelled for passenger vehicles in other Australian urban areas. Since there may be differences among Australian cities with respect to these vehicle usage characteristics, it will be necessary to carry out investigations in sufficient depth to be confident of determining the nature and extent of these differences with appropriate precision.

It is desirable to investigate all aspects of the approaches utilized by overseas regulatory bodies, such as the US EPA, in the design of weighting procedures for cold/hot starts for passenger vehicles to determine their suitability for emissions and fuel consumption measurement in Australian urban areas.

It will also be desirable to investigate the design of test procedures for fuel consumption measurement to ensure that the effect of mean trip length on fuel consumption is taken into account.

APPENDIX A

DEFINITION OF SMALL VEHICLES

In this study, vehicle size has been utilized as a proxy for vehicle mass. The dividing line between small and large passenger vehicles was determined, on the basis of passenger carrying capacity, at the 4 seat level. Thus small passenger vehicles were defined as those having up to 4 seats, while other passenger vehicles had mainly 5 or 6 seats.

Length and width criteria were used to ensure that size limits were applied jointly with the seating capacity criterion. The width criterion was particularly necessary to distinguish between 4 and 5 seat vehicles. Since the dimensional criteria were of necessity somewhat arbitrary, and given the variation in size among 4 seat vehicles, there was inevitably some "overflow" of small vehicles into the "other" category. The effect of such overflow would be to slightly reduce the proportion of 4 seat vehicles actually in the small vehicle category. This would lead in turn to a slightly increased emphasis on any differences in usage pattern between the vehicles size categories.

Vehicle wheelbase was not considered an appropriate determinant of seating capacity since it bears no direct relationship to vehicle width, which primarily determines seating capacity.

In this Paper, passenger vehicles have been divided into the categories of sedans and station wagons. Sedans have been further subdivided into size categories - small and other - for the purposes of hypothesis testing. Small sedans were defined, for the purpose of this Paper, as being 4 seat vehicles less than 1 600 mm wide and less than 4 200 mm long. It was mentioned in Chapter 2 that the proportion of station wagons which would qualify for the "small" category was negligible. Thus the proportion of small sedans and station wagons in the passenger vehicle population would be virtually equal to the proportion of small sedans in the same population.

The following analysis shows that the size category limits for small vehicles used in this Paper are more restrictive than the limits implicit in the categorization of small passenger vehicles used by the IAC in its published papers. As stated above, the effect of such restriction would be to emphasize the presence of any difference between vehicle size categories in terms of usage pattern.

Table A.1 lists the major suppliers and models of passenger sedans and station wagons within the two categories (small light and large light) which together make up the IAC small passenger vehicle classification. The vehicle models listed in Table A.1 accounted for 62 and 74 per cent of the small light and large light categories respectively, and for 32 per cent of total passenger vehicle registrations for 1973.

When the definition of small cars used in this Paper is applied to the data of Table A.1, it is found that the proportion of total 1973 registrations which it would cover was only 14 per cent, a reduction of over one half when compared to the IAC definition. (Equal proportions of each model type were assumed for grouped registration data, such as Mazda 1300/808).

Thus the definition of small passenger vehicles (which applies to sedans only) used in this Paper is rather more restrictive than the IAC definition of such vehicles when applied to 1973 registration data. It has been assumed that when the entire 1975 motor vehicle fleet is taken into account, the Bureau definition would also be more restrictive than the abovementioned IAC definition.

TABLE A.1 - CATEGORIES OF SMALL PASSENGER MOTOR VEHICLES USED BY INDUSTRIES ASSISTANCE COMMISSION

Category[1]/ Company	Model	Dimensions Length (m)	Dimensions Width (m)		Registrations (1973)[1] (number)
Small Light					
Mazda	1300	3.785	1.473	)	11 166
	*808	3.962	1.600	)	
	RX2	4.140	1.575	)	
	*RX3	4.063	1.600	)	6 655
	*RX4	4.325	1.670	)	
Nissan	Datsun 1200	3.835	1.499		16 412
Toyota	Corolla	3.955	1.505		15 214
GMH	*Torana - 4 Cylinder	4.120	1.600		11 355
SUB TOTAL					60 802
Large Light					
GMH	*Torana - 6 Cylinder	4.386	1.600		24 587
Ford	*Capri	4.262	1.645	)	22 733
	*Cortina	4.292	1.701	)	
Nissan	Datsun 1600	4.166	1.575	)	20 176
	*Datsun 180B	4.216	1.600	)	
Toyota	*Celica	4.165	1.600		4 786
	Corona	4.195	1.570		13 253
SUB TOTAL					85 535
TOTAL					146 337

(1) Includes sedans and station wagons.

Source: Dimensional data: NRMA Sydney
: Registration data: Industries Assistance Commission, Passenger Motor Vehicle, etc., July 1974.

NOTE: * denotes vehicle models excluded from Bureau classification of small vehicles on account of excessive size (length and/or width)
: Total registrations of sedans and station wagons for 1973 were 459 925

APPENDIX B
DISCUSSION OF STATISTICAL ANALYSIS METHODOLOGY

ANALYSIS OF VARIANCE METHOD

The basis of one way analysis of variance is the decomposition of variation or sums of squares corrected for the mean (SS). Let us consider a dependent, or criterion, variable Y and a categorical independent variable, or factor, A. The total sum of squares in Y, SS_y, can be decomposed into two independent components:

$$SS_y = SS_{between} + SS_{within} \qquad (1)$$

where $SS_y = \sum_j \sum_i (Y_{ji} - \bar{Y})^2$ in which $\bar{Y}$ is the mean of Y over the whole sample (known as the grand mean), and the summations are over all individual cases i in each category j of the factor A

$SS_{between} = \sum_j N_j(\bar{Y}_{j.} - \bar{Y})^2$ in which $\bar{Y}_{j.}$ is the mean of Y in the category j, and N_j is the number of cases in category j

$$SS_{within} = \sum_j \sum_i (Y_{ji} - \bar{Y}_{j.})^2$$

$SS_{between}$ is the portion of the sum of squares in Y due to factor A, that is, due to the variation in the $\bar{Y}_{j.}$ means of the categories of the factor A. Thus $SS_{between}$ is often denoted as SS_A. SS_{within} is the portion of the sum of squares in Y due to the variation within each of the categories of A. SS_{within} is variation which is not accounted for by A, and is thus often written as SS_{error}. Thus (1) may be written as

$$SS_y = SS_A + SS_{error} \qquad (2)$$

Intuitively, the relative magnitude of SS_A will become greater as the differences among the means of Y in various categories of A ($\bar{Y}_{j.}$) increase and as the variations in Y within the categories of A decrease.

In analysis of variance, the effects of A are often expressed, therefore, by the sum of the squared differences of the factor A category means of Y from the grand (overall) mean of Y.

Suppose that 300 students are randomly assigned to one of three different classes, each of which employs a different teaching method. Suppose also that after a certain period the students are tested on a common set of questions. The test score (Y) is then the criterion variable and the teaching method (A) is the experimental factor. If the overall average (the grand mean) is 50 and the three groups had respective means of 40, 48, and 61, the effects of the three methods a_1, a_2, and a_3 would be - 10, -2, and + 11 respectively.

Whether such differences are to be considered substantial or trivial depends, of course, on the degree of overall variability in the whole group (300 students) and, in particular, on the variability within each category of A.

It is possible, if we examine only samples, that the observed means may differ slightly from one another even if there is no difference among the group (category) means in the population from which the sample was drawn. The smaller the sample and the greater the overall variation in Y, the greater the variations between groups due to sampling fluctuation. Therefore, it is prudent to test the null hypothesis that, in the population $a_1 = a_2 = a_3 = 0$. The F test, commonly used to test such a null hypothesis, is based on the following sampling theorem.

If there is no difference between groups in the population, that is $a_1 = a_2 = a_3 = 0$, both SS_A and SS_{within} (observed from sample) come from the same source of variation- "errors." If samples were drawn randomly, the estimate of population variance based on the between category variations, $SS_A/(k - 1)$ = mean square due to A = MS_A, and the estimate of population variance based on the within category variations, $SS_{error}/(N - k) = MS_{error}$, are independent estimates of the same quantity-the population variance of Y. Therefore, the F ratio between these two estimates

$$F = \frac{SS_A/(k - 1)}{SS_{error}/(N - k)} = \frac{MS_A}{MS_{error}}$$

follows the F distribution with degrees of freedom given by both (k - 1), the number of categories in A, and (N - k), where N is the total number of observations.

Basic output from a one-way analysis of variance usually provides the user with the following three types of information: (1) decomposition of sum of squares to be used as a descriptive indicator of overall relationship between Y and A, (2) F ratio and accompanying statistics, to be used for testing statistical significance, and (3) estimates of effects of differences among the category means, to be used in interpreting the "pattern" of the A effect.

Source: Nie, N.H., et al, Statistical Package for the Social Sciences, McGraw Hill Inc, New York, 1975.

TABLE 1 - SAMPLE VEHICLE POPULATION AND NORMALIZED VEHICLE POPULATION

Vehicle Class	Vehicle Population: Sample (number)		Sample (per cent)	Normalized (number)		Normalized (per cent)
A. Small Sedans	127	127	(14.5)	18 320	18 320	(14.4)
B. Other Sedans						
Medium Sedans	183			26 656		
Large Sedans	327			47 726		
Luxury Sedans	4			553		
Speciality Sedans	1	515	(59.0)	170	75 105	(59.3)
C. Station Wagons						
Small Wagons	14			2 057		
Medium Wagons	13			1 912		
Large Wagons	116	143	(16.4)	16 691	20 660	(16.3)
D. Other Vehicles						
Utilities	23			3 032		
Panel Vans	27			3 950		
Campervans	13			1 839		
Trucks	22			3 365		
Other	3	88	(10.1)	466	12 652	(10.0)
		873	(100.0)		126 737	(100.0)
Vehicles excluded from sample:						
Motor cycles	13					
Not specified	4	17	(1.9)			

NOTE: Number of households in sample : 679
Number of households in normalized population : 100 000

TABLE 2 - OWNERSHIP OF MOTOR VEHICLES (SAMPLE DATA)

(per cent)

Vehicle Class	Ownership		
	Private	Company, Government and other	Total
Small sedans	13.9	0.6	14.5
Other sedans	54.6	4.4	59.0
Station wagons	14.9	1.5	16.4
Other vehicles[1]	8.3	1.8	10.1
TOTAL	91.7	8.3	100.0

(1) Excluding motor cycles.

TABLE 3 - STATISTICAL SIGNIFICANCE OF PAIRWISE TESTING OF VEHICLE USAGE CHARACTERISTICS (SAMPLE DATA)

Characteristics	Vehicle Classes			
	Small Sedans vs Other Sedans & Station Wagons	Small Sedans vs Other Sedans Only	Other Sedans vs Station Wagons Only	All Sedans & Station Wagons vs Other Vehicles
Trips per Day[1]	0.559[2]	0.761	0.202	0.053
Distance per Trip[1]	0.124	0.173	0.259	0.000*
Distance on Typical Weekday	0.204	0.200	0.759	0.000*
Distance per Year[3]	0.028*	0.060	0.335	0.000*
Days Idle per Week	0.831	0.826	0.966	0.643
Non Metropolitan Travel Proportion	0.000*	0.000*	0.993	0.363
Occupants per Vehicle[1]	0.001*	0.001*	0.812	0.000*

(1) Data measured from trip records; all other data estimated by respondents.
(2) Entries represent probabilities of accepting the null hypothesis.
(3) Includes urban and non-urban travel.

NOTE: * denotes significant differences between vehicle samples. In these cases the null hypothesis was rejected in favour of the alternative hypothesis.

: Level of significance used was 5 per cent (0.050)

: The null hypothesis tested was that for each characteristic compared, vehicles in each category pair were drawn from the same population. The alternative hypothesis used was that vehicles in each category pair were drawn from different populations.

TABLE 4 - MEANS AND STANDARD DEVIATIONS OF VEHICLE USAGE CHARACTERISTICS X VEHICLE CLASS (SAMPLE DATA)

Vehicle Class	Vehicle Usage Characteristics						
	Trips per Day(1) (number)	Distance per Trip(1) (km)	Distance per Typical Weekday (km)	Distance per Year(2) ('000 km)	Days Idle per Week (number)	Non Metro Travel Proportion (per cent)	Occupants per Vehicle(1) (number)
A. Small Sedans	2.99/2.09	9.70/9.07	31.91/28.04	13.86/7.00	1.29/1.57	12.28/16.78	1.37/0.68
B. Other Sedans	3.06/2.35	10.88/15.98	36.42/36.96	15.88/11.44	1.33/1.75	19.81/22.51	1.53/0.89
C. Station Wagons	3.35/2.47	11.87/18.34	35.38/31.31	16.89/9.04	1.32/1.81	19.79/21.54	1.55/0.91
D. Other Sedans & Station Wagons (B+C)	3.13/2.37	11.16/17.65	36.20/35.79	16.10/10.97	1.33/1.76	19.81/22.29	1.53/0.89
E. All Sedans & Station Wagons (A+B+C)	3.10/2.33	10.89/15.64	35.51/34.68	15.74/10.46	1.32/1.73	18.59/21.66	1.51/0.87
F. Other Vehicles	2.58/2.71	17.16/54.37	64.42/80.79	25.21/19.98	1.41/1.78	20.84/27.32	1.29/0.53
G. All Vehicles	3.05/2.37	11.43/21.90	38.46/42.62	16.69/12.10	1.33/1.74	18.82/22.31	1.49/0.85
Data refer to Figure No.	4	14	6	8	10	12	15

(1) Data measured from trip records; all other data estimates by respondents.
(2) Includes urban and non-urban travel.

NOTE: Data are in the form: MEAN/STANDARD DEVIATION.

TABLE 5 - RATIOS OF MEANS OF VEHICLE USAGE CHARACTERISTICS FOR EACH VEHICLE CLASS PAIR (SAMPLE DATA)

Characteristics	Vehicle Classes			
	Small Sedans vs Other Sedans & Station Wagons	Small Sedans vs Other Sedans Only	Other Sedans vs Station Wagons Only	All Sedans & Station Wagons vs Other Vehicles
Trips per Day(1)	0.96(2)	0.98	0.91	1.20
Distance per Trip(1)	0.87	0.89	0.92	0.63*
Distance per Typical Weekday	0.88	0.88	1.03	0.55*
Distance per Year	0.86*	0.87	0.94	0.62*
Days Idle per Week	0.97	0.97	1.01	0.94
Non Metropolitan Travel	0.62*	0.62*	1.00	0.89
Occupants per Vehicle(1)	0.90*	0.90*	0.99	1.17*

(1) Data measured from trip records; all other data estimated by respondents.

(2) For vehicle Class P vs. vehicle Class Q, data are in form:

Ratio $\frac{(\text{Mean (Class P)})}{(\text{Mean (Class Q)})}$

NOTE: * denotes significant difference at the 0.05 level between the vehicle classes compared.

Source: Tables 3, 4.

TABLE 6 - ANALYSIS OF WEEKDAY AND ANNUAL DISTANCES TRAVELLED X VEHICLE CLASS (SAMPLE DATA)

Vehicle Class	Estimated and Calculated Weekday Travel Ratio: (Distance on Typical Weekday)[1] / (Trips/Day)[2] X (Distance/Trip)[2]	Estimated Annual and Weekday Travel Ratio:[1] (Distance per Year) / (Distance on Typical Weekday[1])
A. Small Sedans	1.10	434
B. Other Sedans	1.09	436
C. Station Wagons	0.89	477
D. Other Sedans & Station Wagons (B+C)	1.04	445
E. All Sedans & Station Wagons (A+B+C)	1.05	443
F. Other Vehicles	1.46	391
G. All Vehicles	1.10	434

(1) Estimated by survey respondents.
(2) Calculated from trip records.
Source: Table 4.

TABLE 7 - ANALYSIS OF ESTIMATED URBAN AND TOTAL TRAVEL BY VEHICLES (SAMPLE DATA)

Vehicle Class	Total Annual Distance Travelled		Non-Metropolitan Travel Proportion	Annual Urban Distance Travelled	
	Distance ('000km)	Ratio(1) (per cent)	(per cent)	Distance ('000km)	Ratio(1) (per cent)
A. Small Sedans	13.9	88	12.3	12.2	95
B. Other Sedans	15.9	101	19.8	12.7	100
C. Station Wagons	16.9	107	19.8	13.6	106
D. Other Sedans & Station Wagons (B+C)	16.1	102	19.8	12.9	101
E. All Sedans & Station Wagons (A+B+C)	15.7	100	19.0	12.8	100
F. Other Vehicles	25.2	160	20.8	20.0	156
G. All Vehicles	16.7	106	18.8	13.6	106

(1) The ratio is calculated by dividing each row A through G by row E.

Source: Table 4

TABLE 8 - AGE ANALYSIS OF VEHICLES (SAMPLE DATA)

Vehicle Class	Age of Vehicle (years)					
	<1	1-5	6-10	11-15	>15	Total
Small Sedans	2	61	41	21	2	127
Other Sedans	38	231	161	61	24	515
Station Wagons	11	51	49	30	2	143
All Sedans and Station Wagons	51	343	251	112	28	785
Other Vehicles	5	40	25	12	6	88
TOTAL	56	383	276	124	34	873
Proportion (percent)	(6.4)	(43.9)	(31.6)	(14.2)	(3.9)	(100.0)

TABLE 9 - MEAN OF VEHICLE USAGE CHARACTERISTICS X VEHICLE AGE (ALL SEDANS AND WAGONS) (SAMPLE DATA)

Vehicle Age	Usage Characteristics				
	Trips per Day[1] (number)	Distance on Typical Weekday (km)	Distance per Year ('000 km)	Days per Week Idle (number)	Non-Metropolitan Travel Proportion (per cent)
Current	3.78/2.90	53.14/49.21	20.91/13.15	0.92/1.25	18.24/20.28
1-5 years	3.29/2.32	39.30/34.37	17.83/11.34	1.16/1.57	21.31/20.70
6-10 years	2.99/2.34	30.48/29.30	14.04/8.23	1.33/1.84	18.49/23.74
11-15 years	2.68/1.99	31.02/37.63	12.84/8.90	1.78/1.98	12.75/19.94
>15 years	2.27/1.99	19.26/17.41	6.66/4.81	2.11/1.95	9.70/16.20
All Vehicles	3.10/2.33	35.51/34.68	15.74/10.46	1.32/1.73	18.95/21.66
Ratio of means: (Current year)/(>15 years)	1.67	2.76	3.14	0.44	1.88

(1) Data measured from trip records; all other data estimated by respondents.

NOTE: Data are in the form; MEAN/STANDARD DEVIATION.

TABLE 10 - PROPORTION OF ESTIMATED WEEKDAY AND ANNUAL DISTANCE TRAVELLED X VEHICLE AGE (ALL SEDANS & WAGONS) (SAMPLE DATA)

Vehicle Age	Estimated Vehicle-km on Typical Weekday for Sample Fleet		Estimated Vehicle-km per Year for Sample Fleet	
	(per cent)	(cum. per cent)	(per cent)	(cum. per cent)
Current Year	9.6	9.6	8.5	8.5
1-5 years	48.5	58.1	49.9	58.4
6-10 years	27.4	85.5	28.3	86.7
11-15 years	12.4	98.9	11.6	98.3
>15 years	2.1	100.0	1.7	100.0
All Vehicles	100.0	100.0	100.0	100.0

Source: Derived from Tables 8 and 9.

TABLE 11 - MEAN TRIP LENGTH AND VEHICLE OCCUPANCY X USUAL DRIVER'S OCCUPATION (ALL SEDANS & WAGONS (SAMPLE DATA)

Occupation	Trip Length (1)		Occupants per Vehicle (1)	
	Mean	Std Dev	Mean	Std Dev
Professional	17.20	30.84	1.45	0.78
Administrative	14.88	11.91	1.41	0.82
Craftsman	12.22	12.82	1.35	0.80
Sales Worker	12.07	12.00	1.43	0.73
Transport Worker	11.23	10.92	1.35	0.70
Service Worker	10.01	8.25	1.38	0.75
Clerical	8.94	8.38	1.57	0.81
Not-Employed	7.22	11.50	1.88	1.12
Other	7.73	7.42	1.38	0.70
TOTAL	10.89	15.64	1.51	0.87

(1) Data measured from trip records.

TABLE 12 - MEAN TRIP LENGTH AND VEHICLE OCCUPANCY X TRIP DESTINATION PURPOSE FOR TRAVEL ON PREVIOUS WEEKDAY (ALL SEDANS & WAGONS) (SAMPLE DATA)

Trip Destination Purpose	Trip length (km)[1]		Occupants/Vehicle (number)[1]		Proportion of Trips (per cent)[1]
	Mean	Std Dev	Mean	Std Dev	
Employer-Business	14.32	26.98	1.19	0.69	3.8
Work	13.78	11.30	1.18	0.52	21.7
Home	11.84	19.68	1.48	0.87	40.0
Personal-Business	11.44	13.11	1.56	0.88	3.1
Social-Recreation	10.48	11.24	1.77	1.00	7.9
Serve-Passenger[2]	6.51	7.76	2.01	1.00	12.2
Shopping	4.90	4.77	1.72	0.94	8.5
Other	8.69	9.30	1.40	0.69	2.8
TOTAL	10.89	15.64	1.51	0.87	100.0

(1) Data measured from trip records.

(2) A serve-passenger trip was defined as a trip whose purpose was to convey or pick up one or more passengers.

TABLE 13 - ESTIMATED WEEKDAY PASSENGER TASK X TRIP DESTINATION PURPOSE (ALL SEDANS & WAGONS) (SAMPLE DATA)

Trip Destination Purpose	Proportion of Total Occupant-km	
	(per cent)	(cum per cent)
Home	44.2	44.2
Work	22.3	66.5
Serve-Passenger (1)	10.1	76.6
Social-Recreation	9.2	85.8
Shopping	4.5	90.3
Employer-Business	4.1	94.4
Personal Business	3.5	97.9
Other	2.1	100.0
TOTAL	100.0	100.0

(1) Serve-passenger trip was defined as a trip whose purpose was to convey or pick up one or more passengers.

Source: Table 12.

TABLE 14 - CLASSIFICATION OF VEHICLE USAGE CHARACTERISTICS USED IN CLASS AND AGE ANALYSES

Figure	Characteristic	Classified by	Classes of vehicles
3	Age of vehicle	Vehicle class	All (1)
4	Trips per day	Vehicle class	All
5	Trips per day	Vehicle age	Sedans & Wagons only
6	Distance travelled on typical weekday	Vehicle class	All
7	Distance travelled on typical weekday	Vehicle age	Sedans & Wagons only
8	Distance travelled per year	Vehicle class	All
9	Distance travelled per year	Vehicle age	Sedans & Wagons only
10	Days per week idle	Vehicle class	All
11	Days per week idle	Vehicle age	Sedans & Wagons only
12	Proportion of non-metropolitan travel	Vehicle class	All
13	Proportion of non-metropolitan travel	Vehicle age	Sedans & Wagons only
14	Trip length	Vehicle class	All
15	Occupants per vehicle	Vehicle class	All

(1) "All" denotes sedans, station wagons as well as "other" vehicles.

TABLE 15 - CLASSIFICATION OF VEHICLE USAGE CHARACTERISTICS USED IN OTHER ANALYSES

Figure	Characteristic	Classified by	Classes of vehicles
16	Trip length	Usual driver's occupation	Sedans & Wagons only
17	Trip length	Destination purpose	Sedans & Wagons only
18	Occupants per vehicle	Usual driver's occupation	Sedans & Wagons only
19	Occupants per vehicle	Destination purpose	Sedans & Wagons only

TABLE 16 - SUMMARY OF VEHICLE DATA ANALYSIS FOR NORMALIZED VEHICLE POPULATION (ALL SEDANS AND WAGONS)

Figure	Characteristic	Upper bounds of values of characteristics for which the cumulative proportion of vehicles in each vehicle class was equal to 80 and 90 per cent					
		Small Sedans (cum per cent)		Other Sedans (cum per cent)		All Sedans & Wagons (cum per cent)	
		80	90	80	90	80	90
4	Trips per day (No.)	4	6	4	6	5	6
6	Distance travelled typical weekday (km)	60	80	60	80	60	90
8	Distance travelled in a year ('000 km)	20	25	25	30	25	25
10	Days per week idle (No.)	2	4	2	4	2	4
12	Proportion of non-metropolitan travel (per cent)	30	50	50	50	30	50

TABLE 17 - SUMMARY OF TRIP DATA ANALYSIS FOR NORMALIZED VEHICLE POPULATION (ALL SEDANS AND WAGONS)

Figure	Characteristic	Upper bounds of values of characteristics for which the cumulative proportion of vehicles in each vehicle class was equal to 80 and 90 per cent					
		Small Sedans (cum per cent)		Other Sedans (cum per cent)		All Sedans & Wagons (cum per cent)	
		80	90	80	90	80	90
14	Trip length (km)	20	30	20	30	20	30
15	Occupants per vehicle (No.)	2	2	2	3	2	3

Figures 1-19

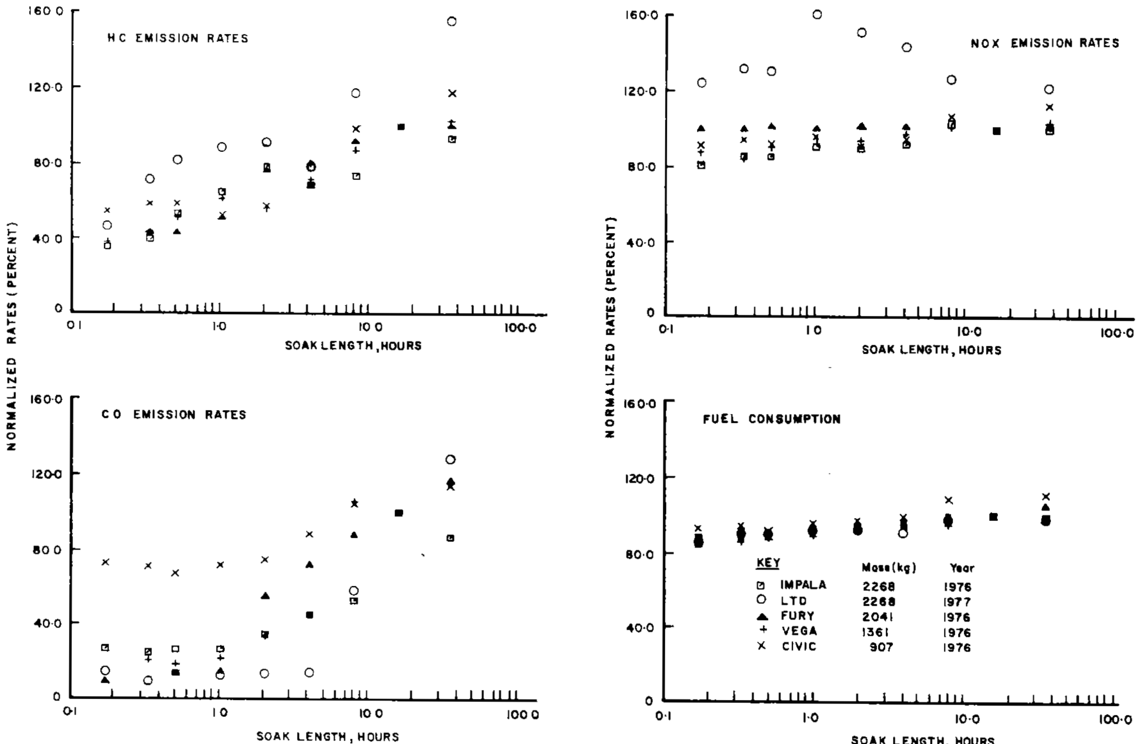

FIGURE 1.
NORMALIZED EMISSION RATES AND FUEL CONSUMPTION AS A FUNCTION OF ENGINE SOAK TIME

SOURCE Srubar R.L., Springer K.J., and Reineman M.E., Soak Time Effects on Car Emissions and Fuel Economy, SAE Paper 780083

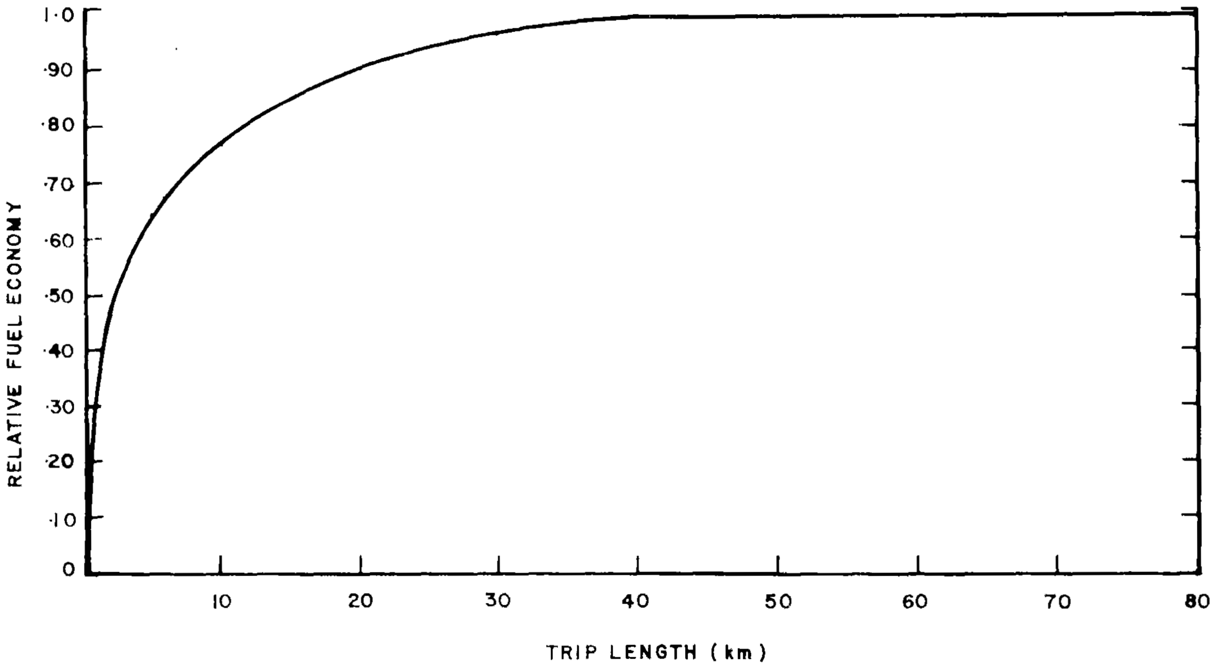

FIGURE 2.

RELATIVE COLD—HOT WEIGHTED FUEL ECONOMY

VS. TRIP LENGTH

SOURCE :– Austin T.C. and Hellman K.H., PASSENGER CAR FUEL ECONOMY AS INFLUENCED BY TRIP LENGTH, SAE Paper 750004

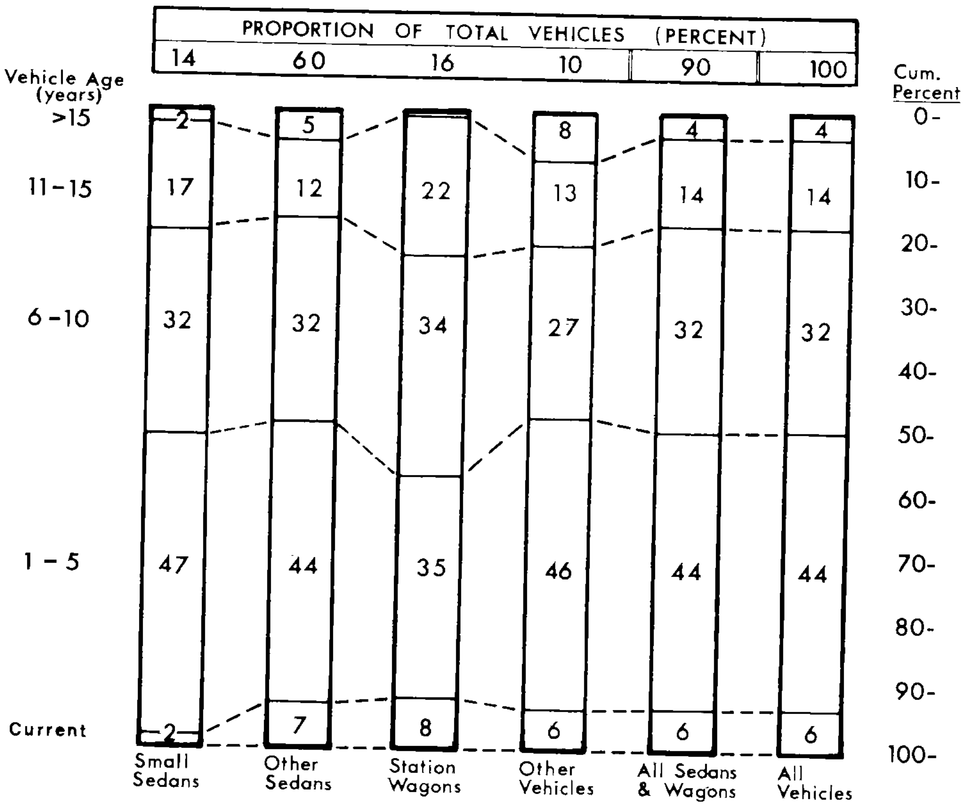

FIGURE 3

AGE OF VEHICLE X VEHICLE CATEGORY

FIGURE 4: TRIPS PER DAY X VEHICLE CATEGORY (ALL VEHICLES)

The Figure shows that in 1975, the other vehicle category had by far the largest proportion of vehicles in most cumulative trip groups, while station wagons had the smallest proportions in most such groups. Small sedans and other sedans were close to average in this respect.

Eighty per cent of sedans and station wagons taken as a group made up to 5 trips per (week)day, while 90 per cent of these vehicles made up to 6 trips per day.

Note: Data analysed in this Figure relate to the normalized vehicle population.

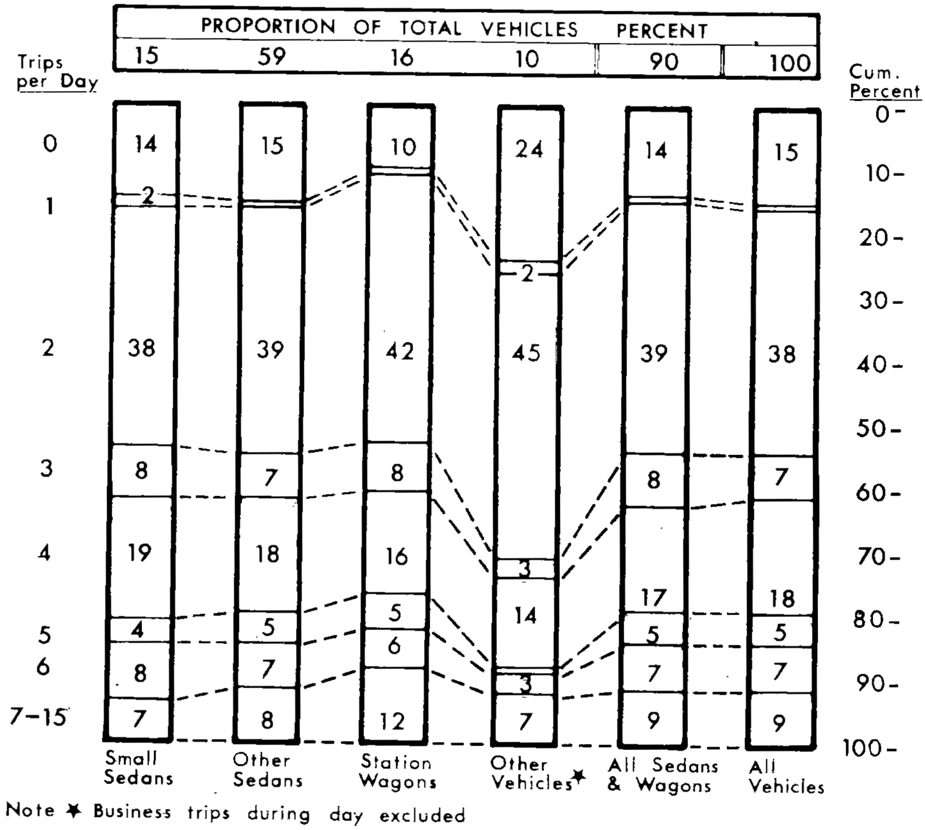

FIGURE 4

TRIPS PER DAY X VEHICLE CATEGORY

FIGURE 5: TRIPS PER DAY X VEHICLE AGE (ALL SEDANS AND WAGONS)

There were marked differences between vehicles of different age groups for this variable. The oldest vehicles had the greatest proportion of vehicles idle on weekdays, while current year vehicles had the smallest proportion idle on weekdays. Vehicles between 6 and 10 years old had trip frequences almost identical with those corresponding to the average for all sedans and station wagons taken together.

Eighty per cent of current year sedans and station wagons made up to 6 trips per day, while for such vehicles over 15 years old, the corresponding figure was up to 4 trips per day. Ninety per cent of current year vehicles made over 7 trips per day, while for the oldest of these vehicles, the corresponding figure was 5 trips per day.

Note: Data analysed in this Figure relate to the normalized vehicle population.

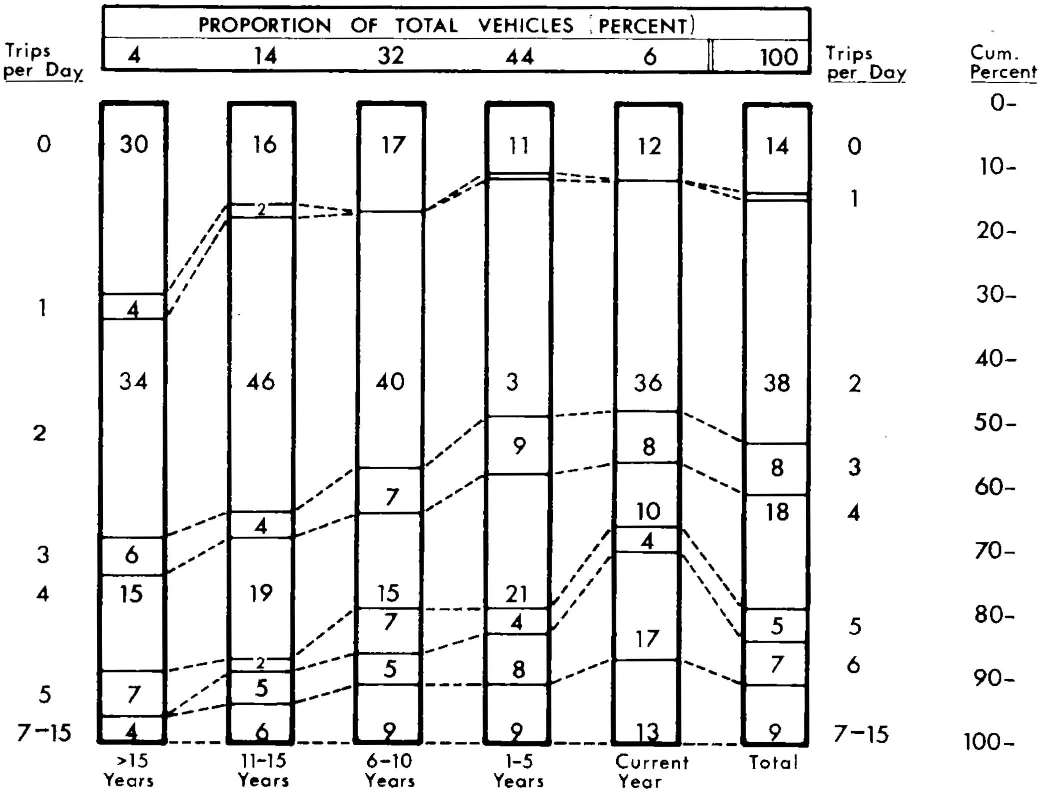

FIGURE 5

TRIPS PER DAY & VEHICLE AGE
(FOR ALL SEDANS AND WAGONS)

FIGURE 6: DISTANCE TRAVELLED ON A TYPICAL WEEKDAY X VEHICLE CATEGORY (ALL VEHICLES)

It can be seen that small sedans had proportionally more vehicles travelling in most cumulative distance groups than any other category of vehicle, and therefore would have travelled less distance per day than other sedans on average in 1975. The other vehicle category had considerably less vehicles in most cumulative distance groups than any other category of vehicle and would therefore have travelled greater than average distances per day. Data for other sedans and for station wagons showed similar characteristics to all sedans and station wagons as a group. Overall, 4 per cent of all vehicles were not in use on a typical weekday.

Whereas 80 per cent of other vehicles travelled up to 100 km per day, the maximum distance for 80 per cent of sedans and station wagons taken as a group was 60 km per day. It should be noted that business trips made during the day of the survey were not included in the distance travelled by other vehicles. Similarly, almost 90 per cent of other vehicles travelled a maximum distance exceeding 100 km per day, while for sedans and station wagons as a group, the corresponding distance was 80 km per day.

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

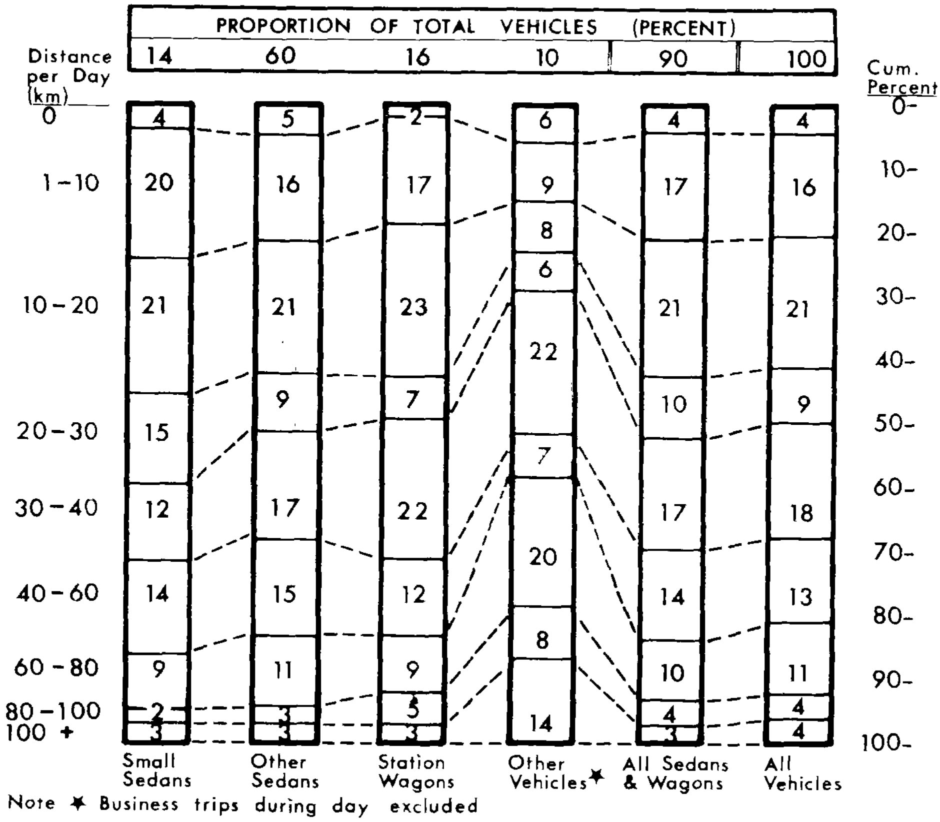

FIGURE 6

DISTANCE TRAVELLED ON TYPICAL WEEKDAY X VEHICLE CATEGORY

FIGURE 7: DISTANCE TRAVELLED ON TYPICAL WEEKDAY X VEHICLE AGE (ALL SEDANS AND WAGONS)

The data show a marked variation in daily distance travelled with the age of sedans and station wagons. Current year vehicles had by far the lowest proportions in most cumulative distance groups. No one age group of vehicles had characteristics identical to the average for all vehicles. However, if the 1-5 years old and 6-10 years old groups were combined, the combined characteristics would be close to the average. Vehicles between 6-10 years old and 11-15 years old had fairly similar characteristics.

While 80 per cent of current year sedans and station wagons travelled up to 80 km per day, vehicles over 15 years old only travelled up to half of this distance. Ninety per cent of current year vehicles travelled up to 100 km per day, while for vehicles over 15 years old, the corresponding figure was 60 km per day.

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

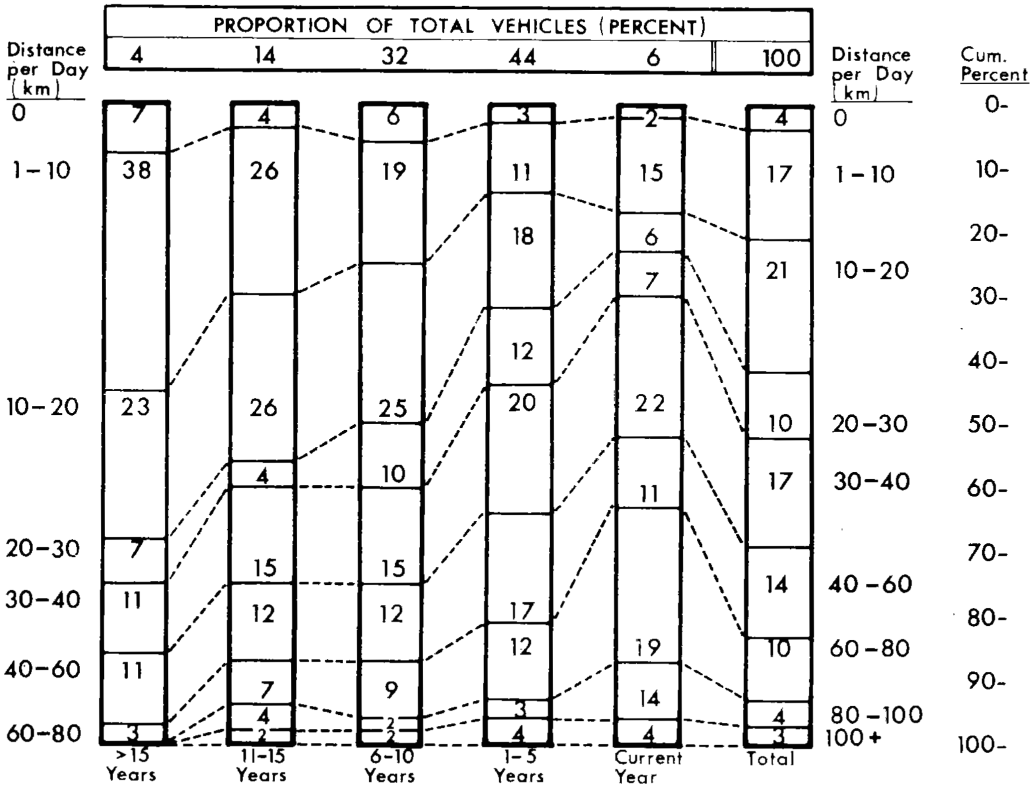

FIGURE 7

DISTANCE TRAVELLED ON TYPICAL WEEKDAY X VEHICLE AGE (FOR ALL SEDANS AND WAGONS)

FIGURE 8: DISTANCE TRAVELLED IN YEAR X VEHICLE CATEGORY (ALL VEHICLES)

In 1974/75, all vehicle categories apart from other vehicles had similar proportions of vehicles travelling 5 000 km or less per year, of around 11 per cent. Small sedans had the largest proportion of vehicles in most cumulative distance groups, followed by other sedans, station wagons, and other vehicles in that order. Thus small sedans would have travelled the lowest average annual distance while other vehicles would have travelled the greatest average annual distance.

Considering all sedans and station wagons as a group, it was found that both 80 per cent of vehicles and 90 per cent of vehicles travelled less than 25 000 km p.a.

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

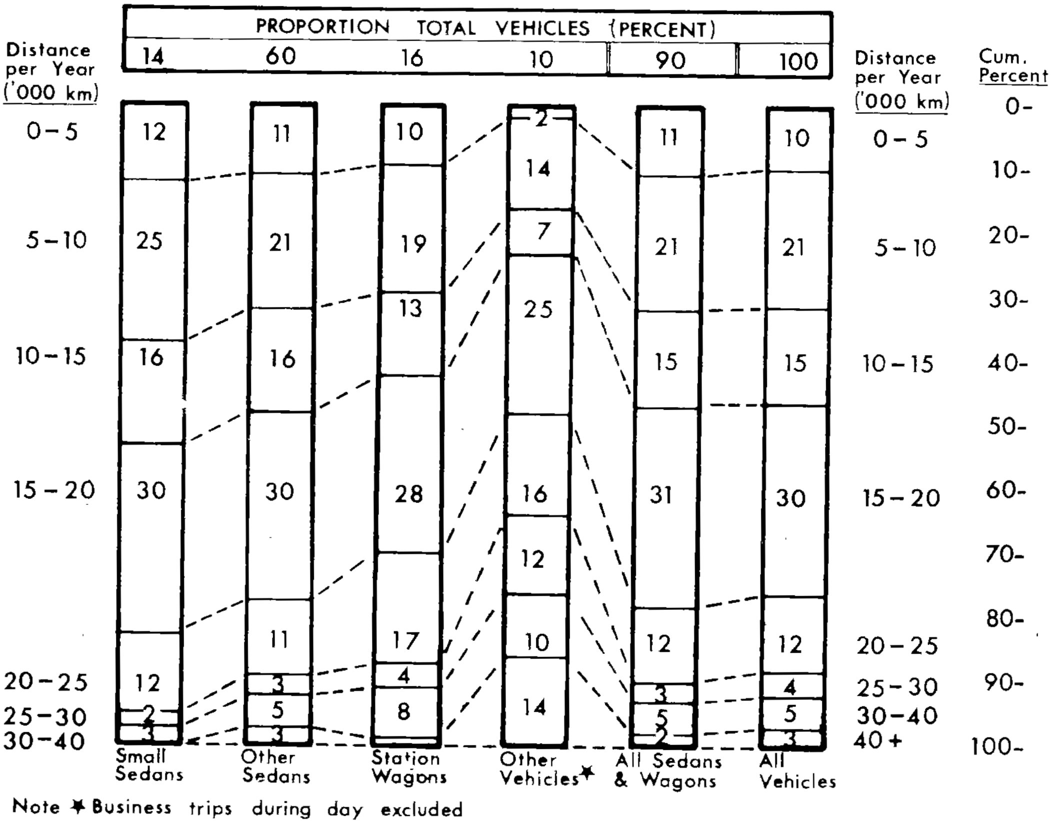

FIGURE 8

DISTANCE TRAVELLED IN YEAR X VEHICLE CATEGORY

FIGURE 9: DISTANCE TRAVELLED IN YEAR X VEHICLE AGE (ALL SEDANS AND WAGONS)

The diagram shows that the annual distance travelled decreased considerably with the age of the vehicles. Thus while 57 per cent of sedans and station wagons over 15 years old travelled less than 5 000 km p.a. in 1974/75, only 4 per cent of current year vehicles travelled less than this distance. Again, 80 per cent of vehicles over 15 years old travelled less than 10 000 p.a. while only 13 per cent of current year vehicles did so.

Eighty per cent of sedans and station wagons travelled less than 10 000 km p.a. (vehicles over 15 years old) and 25 000 km p.a. (current year vehicles). Ninety per cent travelled less than 20 000 km p.a., (vehicles over 15 years old) and 30 000 km p.a. (current year vehicles). The distances travelled by vehicles between 6-10 and 10-15 years old were almost steady at the 80 per cent and 90 per cent cumulative levels.

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

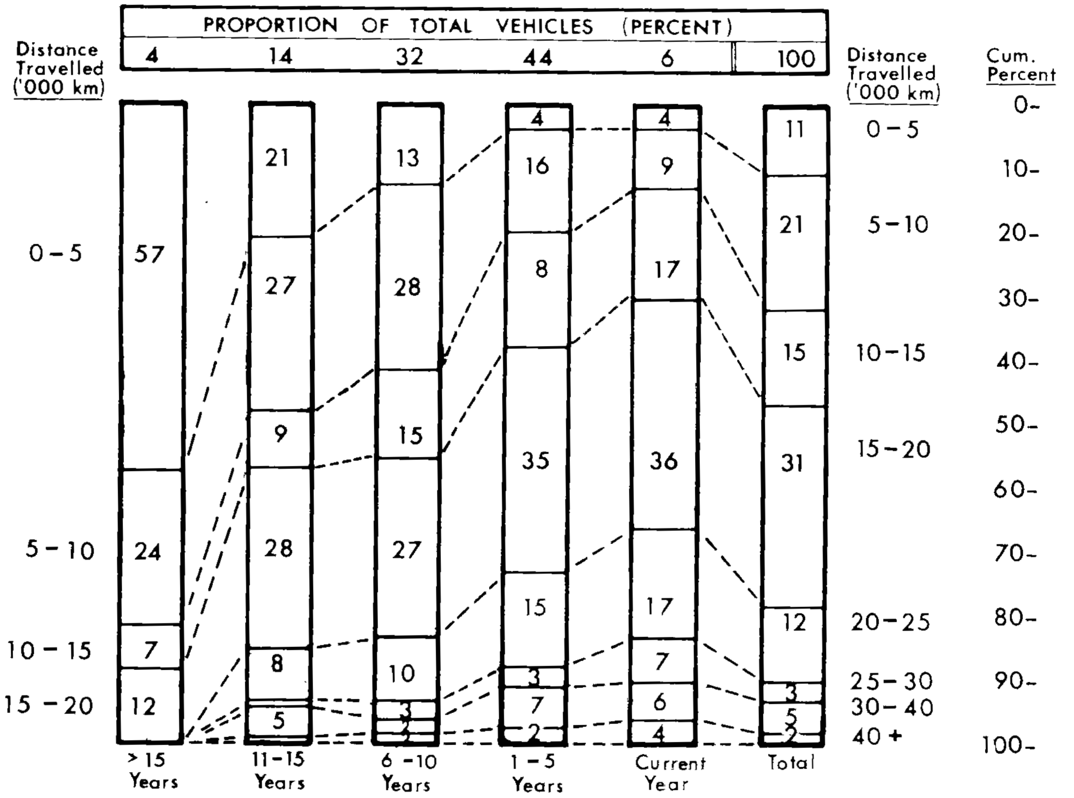

FIGURE 9

DISTANCE TRAVELLED IN YEAR X VEHICLE AGE
(FOR ALL SEDANS AND WAGONS)

FIGURE 10: DAYS PER WEEK IDLE X VEHICLE CATEGORY (ALL VEHICLES)

A vehicle was defined as being idle if it was not in use for the day or was used only for a short trip, such as for shopping. This diagram shows that an almost constant proportion of all vehicle categories were in use every day of the week in 1975, with the overall average being 46 per cent. Station wagons and other vehicles varied the most from average in the proportion of vehicles idle for 1 day per week.

The proportion of sedans and station wagons taken as a group in use every day or idle for only one day per week was 67 per cent. The proportion of these vehicles idle for 2 days or less per week (in use 5 or more days per week) was 80 per cent, while 90 per cent were idle up to 4 days per week (in use 3 or more days per week).

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

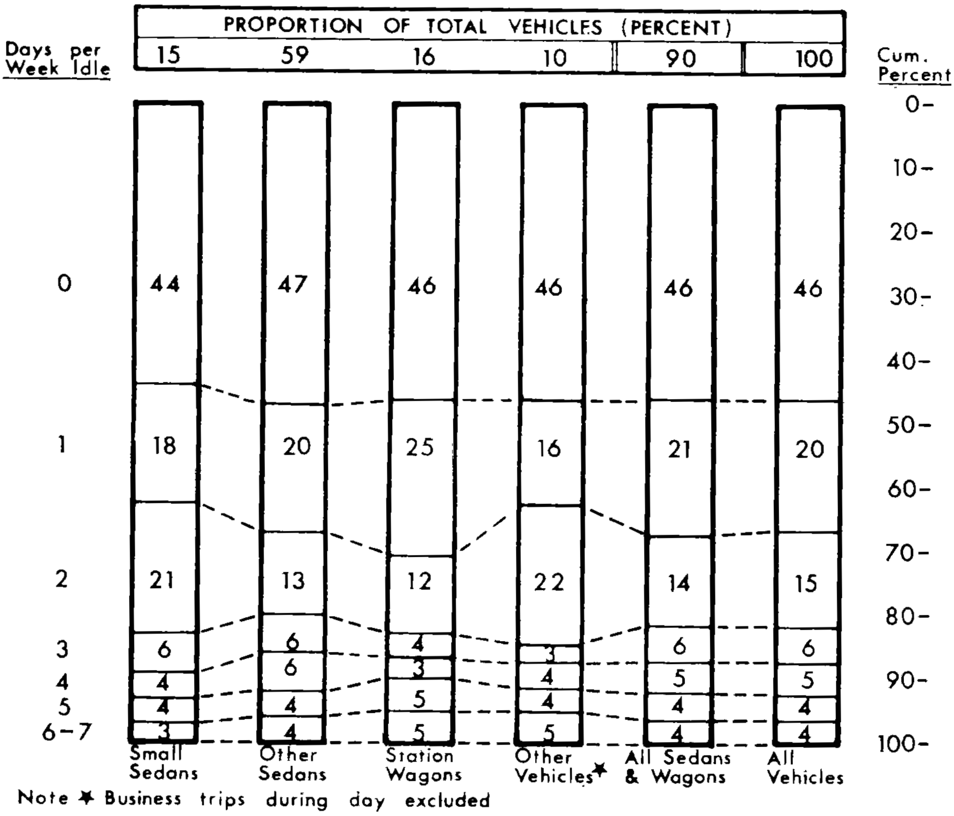

FIGURE 10

DAYS PER WEEK IDLE X VEHICLE CATEGORY

FIGURE 11: DAYS PER WEEK IDLE X VEHICLE AGE (ALL SEDANS AND WAGONS)

There was a general trend of increasing idleness of sedans and station wagons with increasing age in 1975. Idleness was defined as days per week on which no travel took place or only short trips such as shopping. The proportions of vehicles idle for 4 or more days per week (in use 3 or less days per week) ranged from 35 per cent for vehicles over 15 years old to 3 per cent for current year vehicles.

Almost one half of vehicles up to 10 years old were in use every day, with a further quarter being idle for only 1 day per week. Around 90 per cent of vehicles in each age category were idle for periods ranging up to 4 days per week (vehicles over 15 years old) and up to 2 days per week (current year vehicles).

Considering all age groups together, 80 per cent of sedans and station wagons were idle for up to 2 days per week (in use 5 or more days per week), while 90 per cent were idle on average up to 4 days per week (in use 3 or more days per week).

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

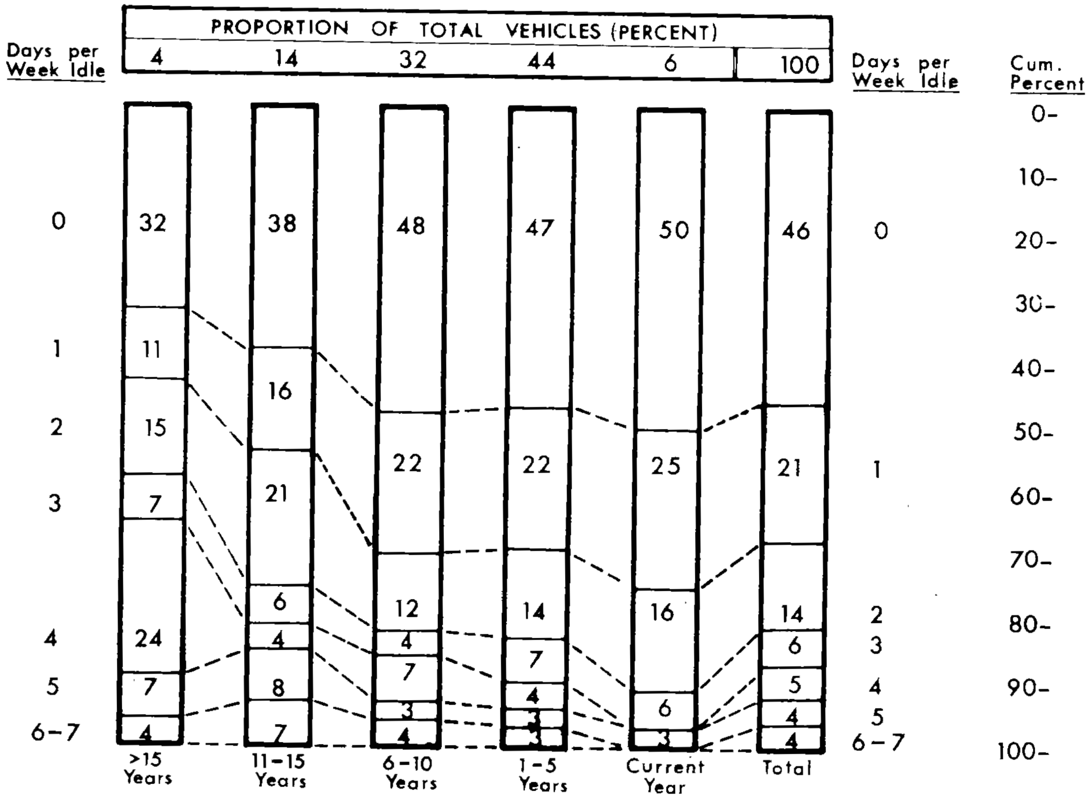

FIGURE 11
DAYS PER WEEK IDLE X VEHICLE AGE
(FOR ALL SEDANS AND WAGONS)

FIGURE 12: PROPORTION OF TRAVEL OUTSIDE METROPOLITAN AREA X VEHICLE CATEGORY (ALL VEHICLES)

The data indicate that the proportion of vehicles entirely captive to the Melbourne metropolitan area in 1975 varied from about 30 per cent for small sedans and other vehicles to around 15 per cent for the remainder, giving an overall average of 18 per cent. The proportion of vehicles travelling from 1-5 per cent of the time outside the metropolitan area was much more uniform among the vehicle types, at around 25 per cent.

Small sedans showed a marked tendency to travel less outside the metropolitan area than the average since they had the largest proportions of vehicles in most cumulative percentage groups. Other sedans and station wagons were fairly similar to each other in this respect and were close to average. Other vehicles had a larger proportion than average travelling less than 5 per cent and more than 20 per cent outside the metropolitan area.

Eighty per cent of all sedans and station wagons taken as a group travelled outside the metropolitan area up to 30 per cent of the time, while just over 90 per cent of these vehicles travelled outside the metropolitan area 50 per cent of the time or less.

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

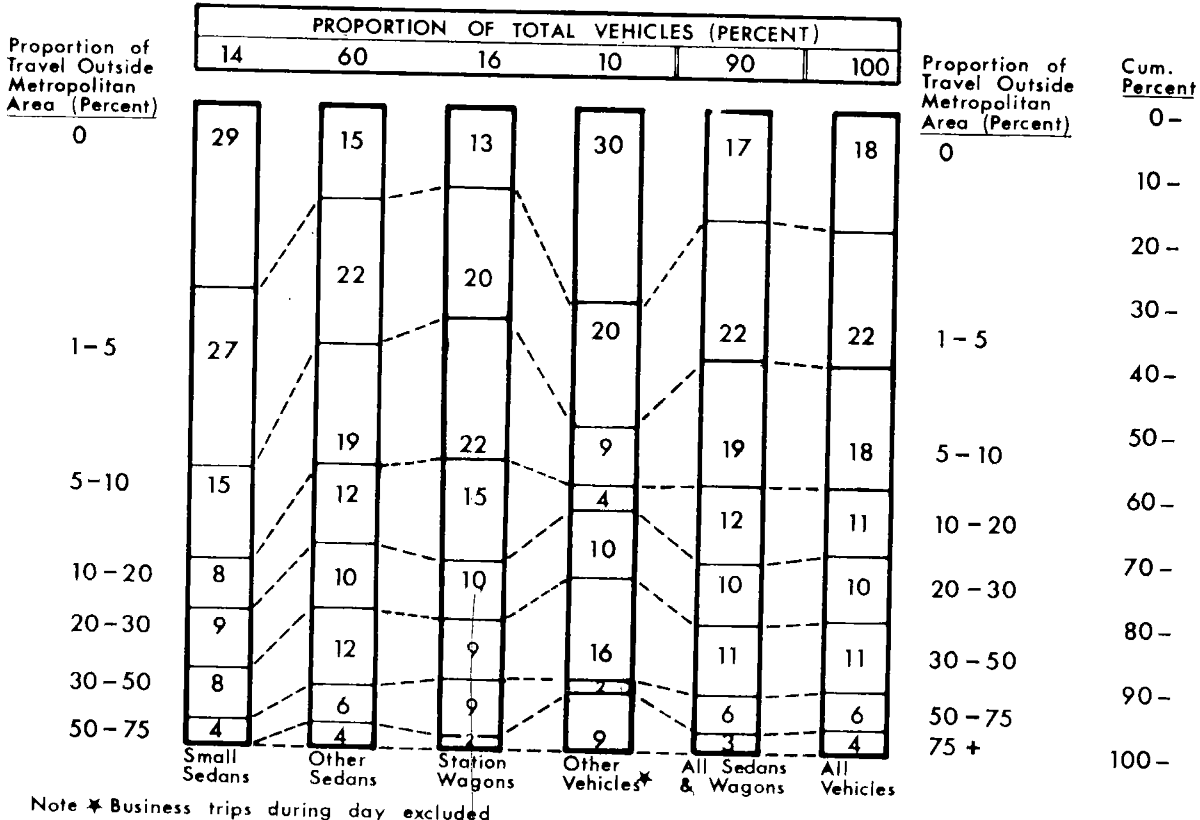

FIGURE 12

PROPORTION OF TRAVEL OUTSIDE METROPOLITAN AREA X VEHICLE CATEGORY

FIGURE 13: PROPORTION OF TRAVEL OUTSIDE METROPOLITAN AREA X VEHICLE AGE (ALL SEDANS AND WAGONS)

This diagram shows that the proportion of sedans and wagons fully captive to the Melbourne metropolitan area in 1975 increased with age of vehicle, being around 10 per cent for vehicles from 1-5 years old and nearly 50 per cent for vehicles over 15 years old. This trend was generally sustained for proportions of travel outside the metropolitan area up to 30 per cent. The trend was somewhat reversed in the case of current year vehicles, which had similar characteristics to vehicles 6-10 years old.

In 1975, 80 per cent of vehicles in each category travelled outside the Melbourne metropolitan area up to 20 per cent of the time (vehicles over 15 years old) and up to 50 per cent of the time (1-10 year old vehicles). Ninety per cent of vehicles travelled outside the metropolitan area for periods up to 30 per cent of the time (vehicles over 15 years old) and up to 75 per cent of the time (6-10 year old vehicles).

Note: Data analysed in this Figure relate to the normalized vehicle population.

: Data analysed in this Figure are subjective, being the perceived rather than the measured values for the vehicle population.

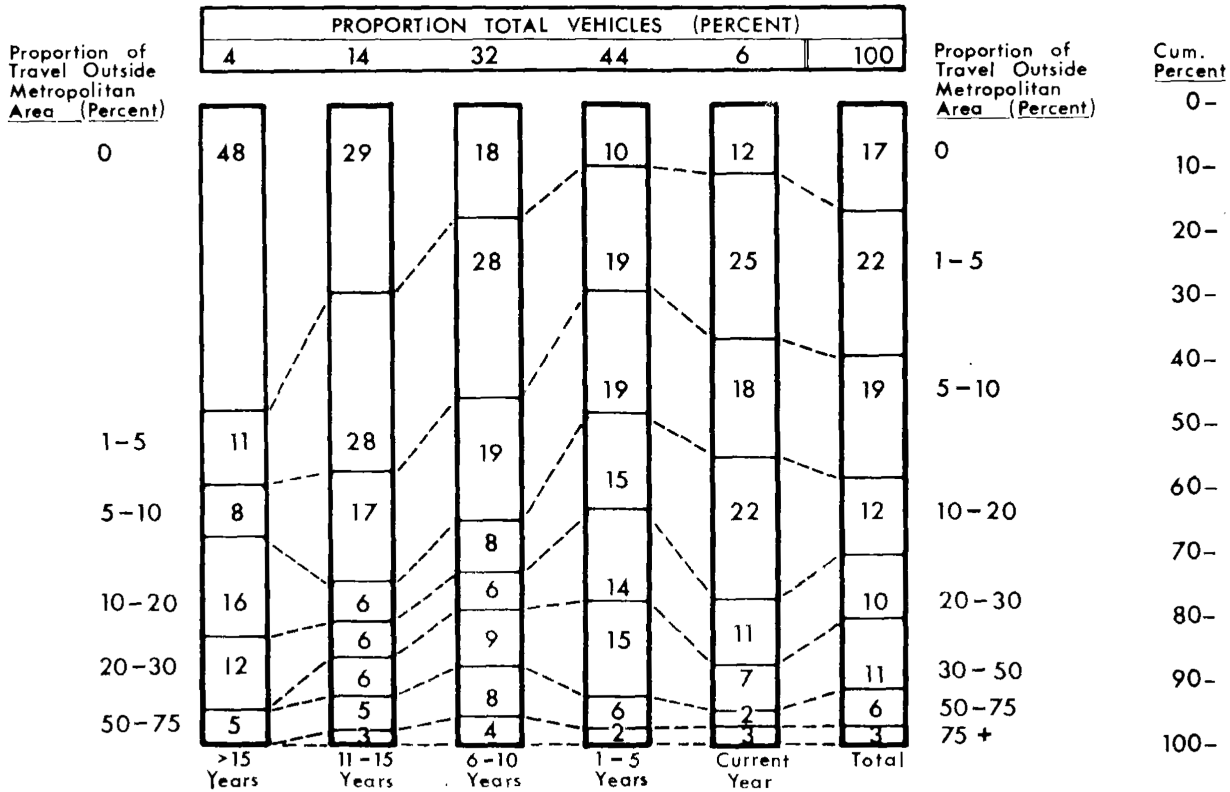

FIGURE 13

PROPORTION OF TRAVEL OUTSIDE METROPOLITAN AREA X VEHICLE AGE (FOR ALL SEDANS AND WAGONS)

FIGURE 14: TRIP LENGTH X VEHICLE CATEGORY (ALL VEHICLES)

Small sedans and other sedans had fairly similar distributions of trip length. Other vehicles, followed by station wagons, had lower than average proportions in most cumulative trip length groups.

Eighty per cent of trips for all sedans and station wagons as a group were up to 20 km in length, while 90 per cent of such trips were up to 30 km in length.

Note: Data analysed in this Figure relate to the normalized vehicle population.

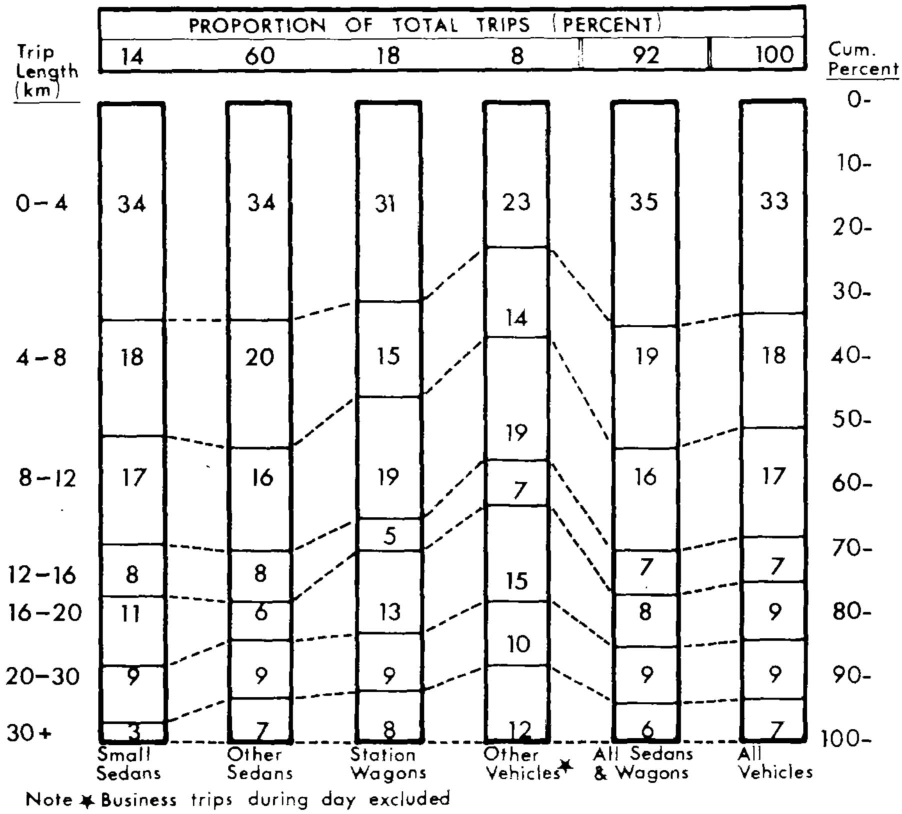

FIGURE 14

TRIP LENGTH X VEHICLE CATEGORY

FIGURE 15: NUMBER OF OCCUPANTS X VEHICLE CATEGORY (ALL VEHICLES)

While the proportions of trips performed by each category of vehicle with 2 occupants were almost constant, there was a degree of variation for trips with single occupancy and with 3 or more occupants in 1975. Small sedans which nominally have 4 seats had more than 2 occupants for only 6 per cent of trips. Similarly, other (larger) sedans (almost entirely 5 or 6 seat vehicles), had more than 2 occupants for only 12 per cent of trips. Other vehicles were quite different in their characteristics with an upper limit of 3 occupants for all trips.

Other sedans and station wagons taken in their separate categories were similar at the 80 per cent cumulative level, with occupancy of up to 2 persons per vehicle. However, occupancy for 90 per cent of trips varied from 2 persons for small sedans and for other vehicles to 3 persons for other sedans and for station wagons.

Note: Data analysed in this Figure relate to the normalized vehicle population.

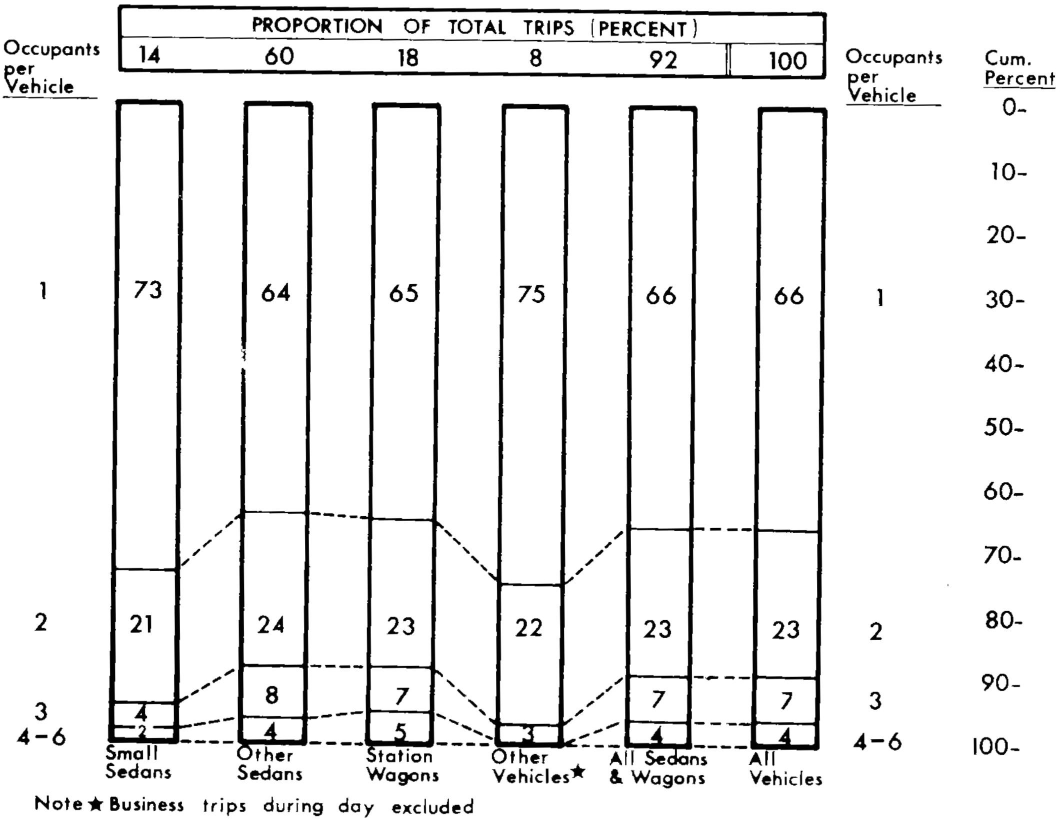

FIGURE 15

OCCUPANTS PER VEHICLE X VEHICLE CATEGORY

FIGURE 16: TRIP LENGTH X USUAL DRIVER'S OCCUPATION (ALL SEDANS AND WAGONS)

In 1975, the not-employed category had the largest proportion of the shortest trips, closely followed by the "other" occupation category. Drivers with professional and administrative occupations had the smallest proportions of total trips in most cumulative trip length groups.

Considering each occupation category, the proportion of trips less than 4 km in length was the largest for all occupation categories except for the administrative and service worker groups. Trips of up to 4 km accounted for from 18 to 50 per cent of trips, depending on the occupation category. Trips of 4-8 km were generally next largest in proportion and accounted for from 13 to 23 per cent of all trips. Fifty per cent of all trips were less than 8 km on average.

Eighty per cent of all trips were up to 20 km in length. For the not-employed and "other" categories, 80 per cent of trips were up to 12 km in length. For the craftsmen, professional and administrative categories, the corresponding distance was 30 km. Ninety per cent of all trips were up to 30 km in length. Ninety per cent of trips for the not-employed group were up to 16 km in length, while for the professional and administrative categories the corresponding distance was 40 km.

Note: Data analysed in this Figure relate to the normalized vehicle population.

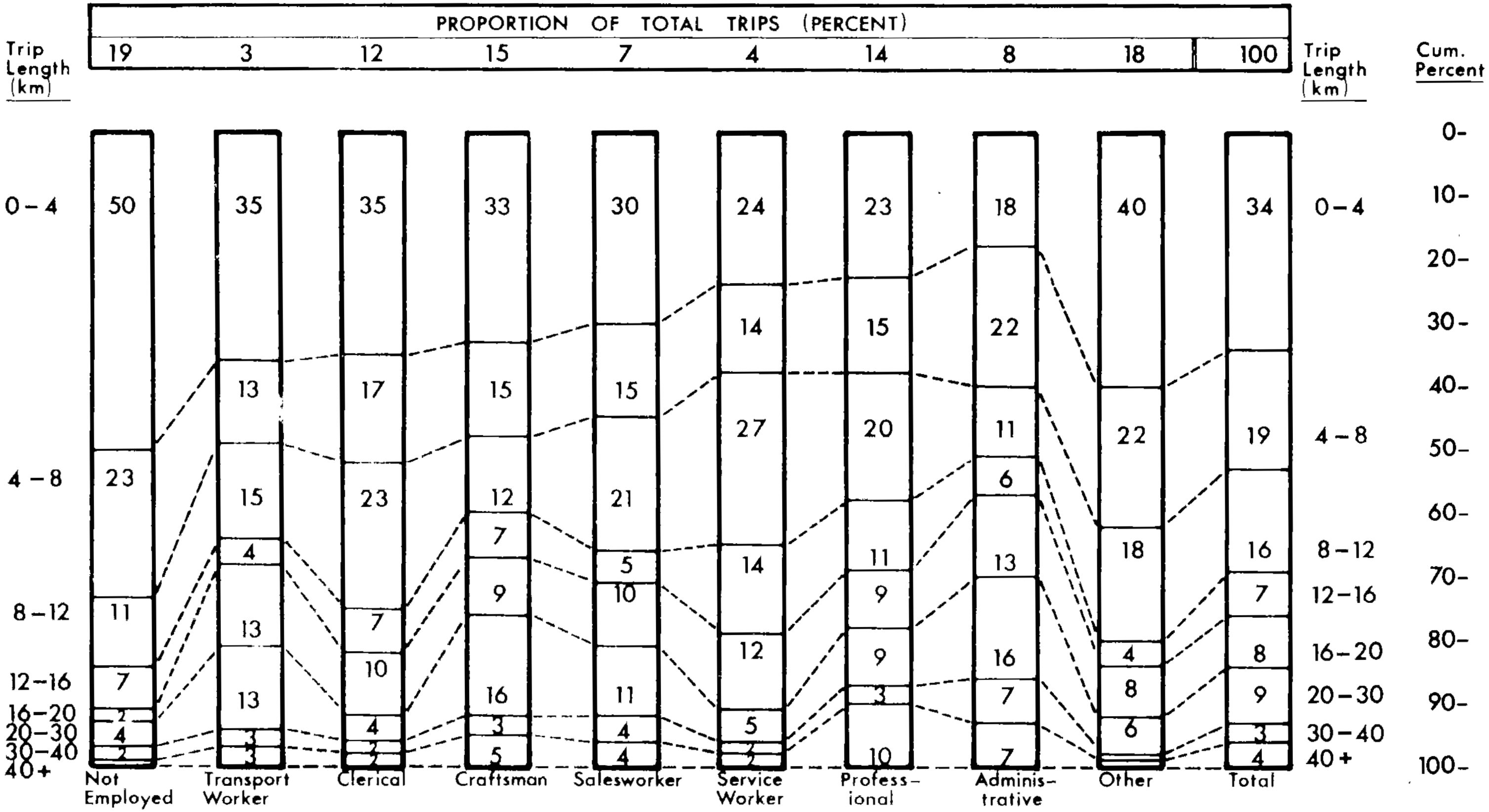

FIGURE 16

TRIP LENGTH X USUAL DRIVER'S OCCUPATION
(FOR ALL SEDANS & WAGONS)

FIGURE 17: TRIP LENGTH X DESTINATION PURPOSE (ALL SEDANS AND WAGONS)

Shopping trip purposes had the largest proportion of the shortest trips, with 55 per cent of trips being up to 4 km in length and with no trips over 20 km. Fifty four per cent of serve-passenger trips were also less than 4 km in length. At the other extreme, work trips had the smallest proportions of the shortest trips. Fifty five per cent of work trips were less than 12 km in length.

On average, 80 per cent of all trips were 20 km or less, with variation from 12 to 30 km for different destination categories, while 90 per cent of trips were up to 30 km in length, also with variation from 12 to 30 km for different destination categories.

Note: Data analysed in this Figure relate to the normalized vehicle population.

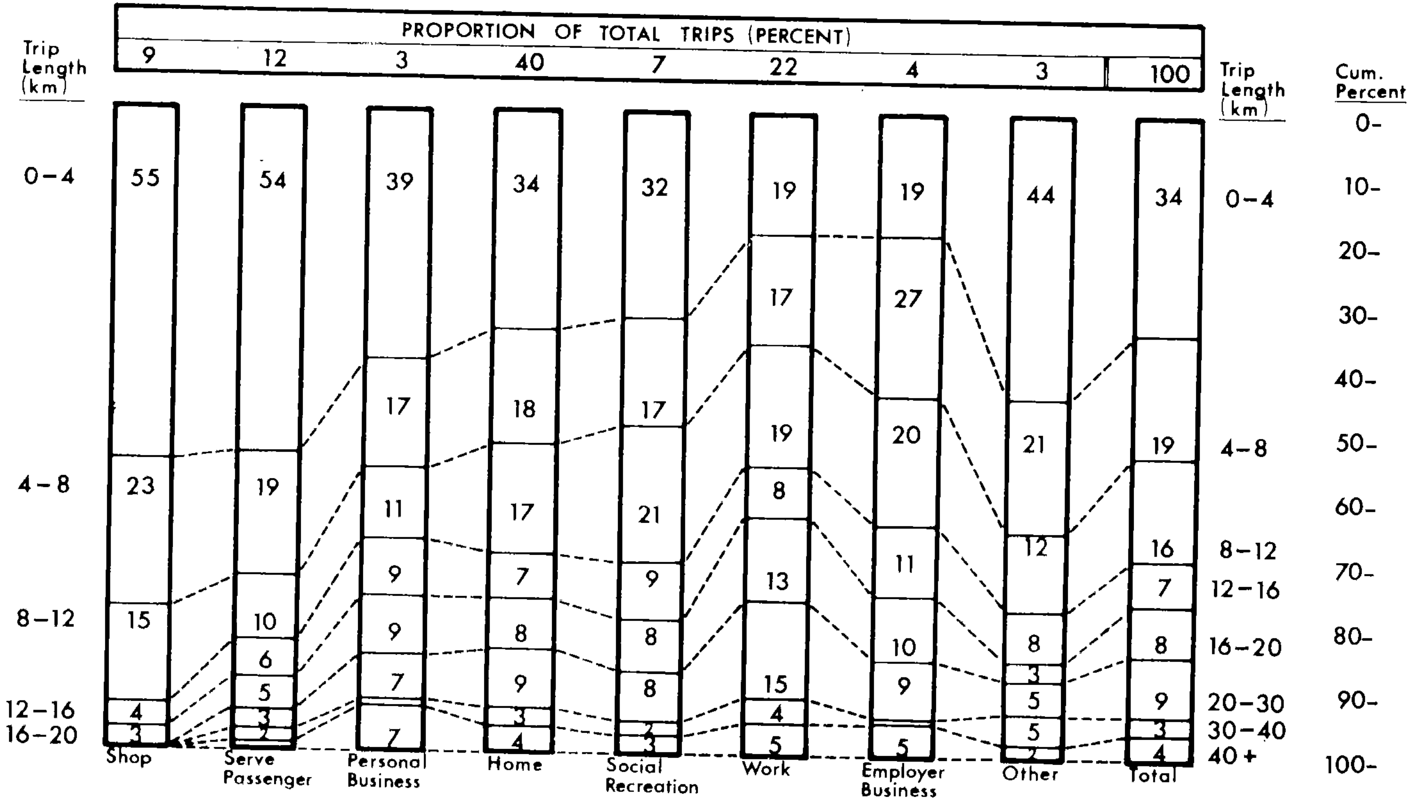

FIGURE 17

TRIP LENGTH X DESTINATION PURPOSE

(FOR ALL SEDANS & WAGONS)

FIGURE 18: OCCUPANTS PER VEHICLE X USUAL DRIVER'S OCCUPATION (ALL SEDANS AND WAGONS)

Apart from the not-employed category, all driver occupation categories made between 60 and 80 per cent of trips with only 1 occupant in 1975. The not-employed category was considerably lower with only 48 per cent of single occupant trips. There was also a wide range of variation with occupation in the proportion of trips involving 2 occupants. Proportions ranged from 16 per cent for craftsmen to 31 per cent for the not-employed category.

Trips involving 4-6 occupants accounted for 4 per cent of all trips, and considering each occupation category, were a maximum of 8 per cent for the non-employed category. Considering all drivers' occupations together, 80 per cent of trips had up to 2 occupants on average, while 90 per cent of trips had up to 3 occupants.

Note: Data analysed in this Figure relate to the normalized vehicle population.

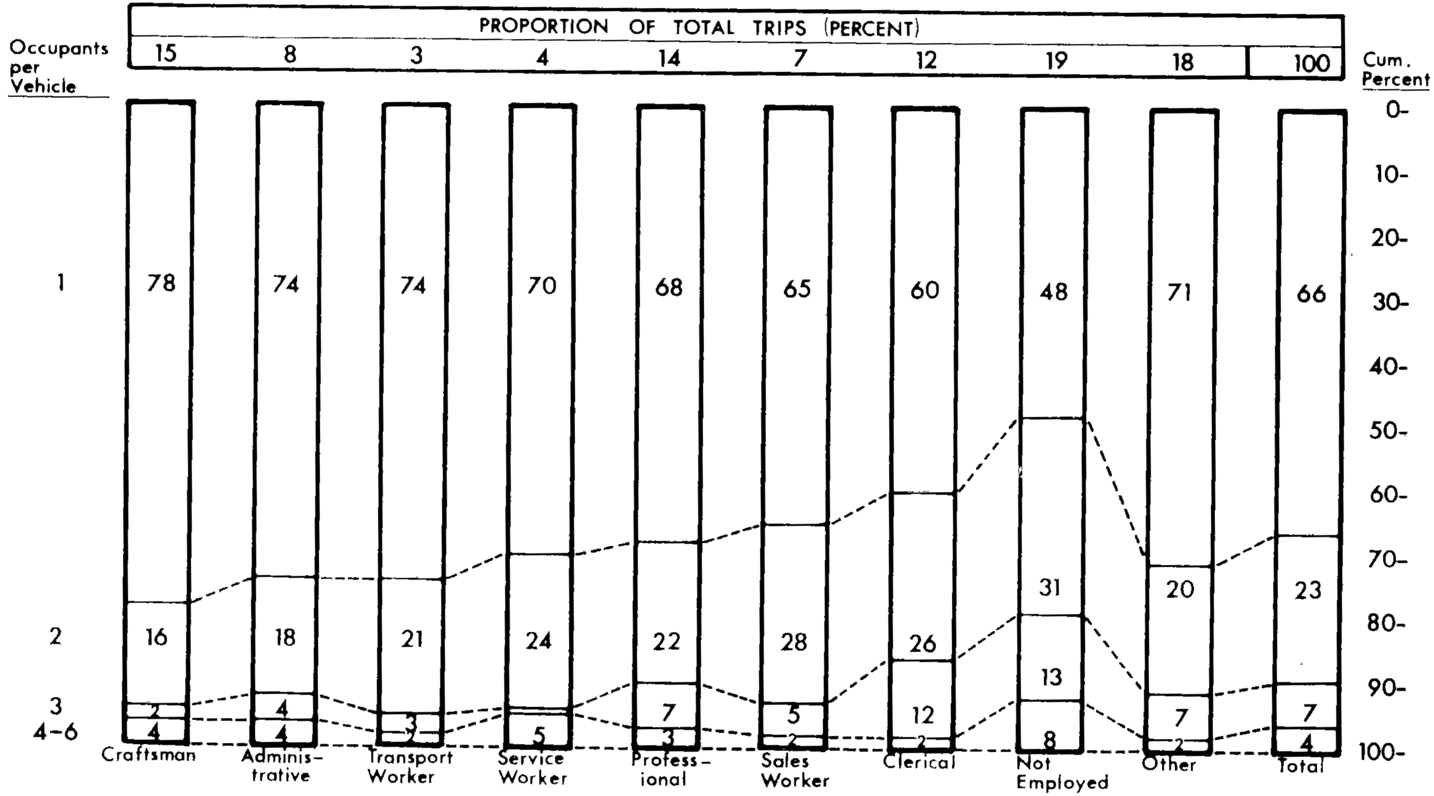

FIGURE 18

OCCUPANTS PER VEHICLE X USUAL DRIVER'S OCCUPATION
(FOR ALL SEDANS & WAGONS)

FIGURE 19: OCCUPANTS PER VEHICLE X TRIP DESTINATION PURPOSE (ALL SEDANS AND WAGONS)

The proportion of single occupant trips ranged from 90 per cent of employer-business destination trips to 36 per cent of serve-passenger destination trips, which latter, by definition, should have at least 1 passenger for much of the time.

Home and work destination trips accounted for 62 per cent of total trips in 1975, and had single occupancy for 67 and 86 per cent of all such trips respectively.

Eighty per cent of the various categories of trips had from 1 occupant (for employer-business and work trips) to 3 occupants (for serve-passenger trips). Ninety per cent of all categories of trips had from 1 occupant (for employer-business) to 3 occupants (for 4 destination purpose categories).

Occupancy of 4-6 persons was 4 per cent on average and considering each destination purpose category separately accounted for a maximum of 8 per cent of serve-passenger trips.

Note: Data analysed in this Figure relate to the normalized vehicle population.

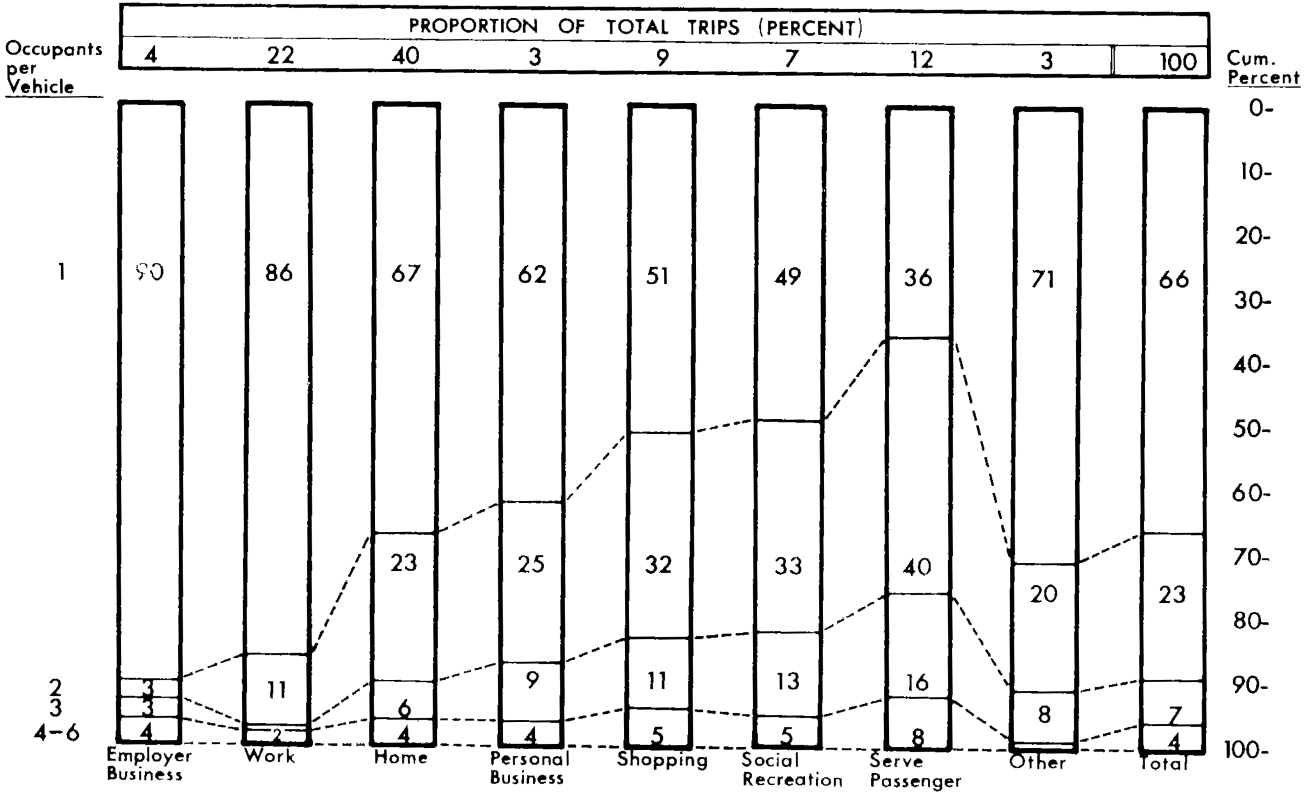

FIGURE 19

OCCUPANTS PER VEHICLE X DESTINATION PURPOSE
(FOR ALL SEDANS & WAGONS)