Urban Passenger Travel: The Role of the Electric Car

Occasional Paper

This report examines the market for battery powered electric passenger vehicles suitable for use in major urban areas in Australia. A typical specification for an electric passenger vehicle has been used as the basis of the analysis. The study was commissioned following the considerable interest shown in the Electric Car Conference conducted jointly by the Bureau and the Australian Electric Vehicle Association in 1975.

BUREAU OF TRANSPORT ECONOMICS

URBAN PASSENGER TRAVEL: THE ROLE OF THE ELECTRIC CAR

J.W. GRAVES
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF MELBOURNE

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1978

Printed by Watson Ferguson and Co., Brisbane

FOREWORD

There is increasing interest in alternative energy sources for motor vehicle transport, at a time when the prices of conventional oil-based fuels are showing an upward trend.

This report examines the market for one such alternative - battery powered electric passenger vehicles suitable for use in major urban areas in Australia. A typical specification for an electric passenger vehicle has been used as the basis of the analysis.

The study was commissioned following the considerable interest shown in the Electric Car Conference conducted jointly by the Bureau and the Australian Electric Vehicle Association in 1975.

The report was prepared by Mr J.W. Graves in consultation with Dr D.W. Bennett of the Department of Civil Engineering, University of Melbourne, and was supervised by Mr L. Lawlor of the Transport Engineering Section, Bureau of Transport Economics.

The BTE does not necessarily accept the findings of the Consultant's report, but considers that the information will be of value to many people concerned with the analysis of transport energy alternatives.

R.H. Heacock
Acting Assistant Director
Transport Engineering Branch

Bureau of Transport Economics
Canberra
December 1977

CONTENTS

SUMMARY

In order to evaluate the market for limited range automobiles, particularly electric automobiles, a survey of 679 households in ten selected Melbourne municipalities was carried out. The home interview survey gathered information on the members of each household, the vehicles they used, and the trips they made on the previous weekday. From this survey it was found that income, number of licenced drivers, and household location were the factors most closely correlated with the availability and use of cars. The effects of income, vehicles and household size on household trips were examined.

From a review of the literature on battery electric cars, it was concluded that the maximum range possible with present technology is about 80 km before recharging. It was argued that vehicles with this maximum daily range would usually travel on average about 40km/day and not more than 10 000 km/year. In order to be a reasonable candidate for replacement by an electric car, a car should belong to a multi-car household, and travel more than 80 km/day fewer than 12 times per year. Given these restrictions, it was found that 13% of surveyed cars could be replaced by electric cars. By assuming that only one vehicle in such a household could be replaced by an electric car, this proportion was reduced to 11%.

The potential electric vehicles travelled on average 16 km/day and 5 700 km/year, compared to the whole sample car population which travelled 34 km/day and 15 800 km/year. These vehicles tended to be older, less valuable and smaller than the car population as a whole. They were driven mainly by women, and were used mainly for shopping and social purposes or travel to work.

CHAPTER 1 - INTRODUCTION

BACKGROUND

Shortly after the turn of the century, battery electric cars were an important segment of the automobile market in countries such as the United States. As the internal combustion engine was improved, battery electric cars disappeared from the market place due to their relative disadvantages in terms of cost and performance.

However, in recent years there has been a revival of interest in battery electric cars. This situation arose at first because of the growing awareness of the environmentally harmful effects of internal combustion automobiles. More recently, concern about the availability and cost of petroleum fuels has led to a search for alternative sources of energy for private vehicles to supplement or replace liquid petroleum fuels.

One of the principal disadvantages of battery electric automobiles is their limited range. In order to assess the potential market for these vehicles, it is necessary to have detailed data on the usage patterns of automobiles, both daily and longer term. This potential market should not be equated with the level of market penetration which these vehicles may achieve, which would undoubtedly be lower.

An area of research interest pursued by the Transport Section within the Department of Civil Engineering at the University of Melbourne concerns energy usage in transport. Consequently, an assessment of vehicle usage patterns in the urban context was a logical extension of this work. It was hoped that data on the usage of vehicles might complement actual development work on electric vehicles in progress in Australia and elsewhere. Furthermore, such data might be helpful for optimizing an electric vehicle's characteristics with regards to range, performance and cost.

SCOPE OF THE STUDY

The aim of the present study was two-fold; firstly, to record the factors which might influence car ownership and use, identify the most significant of these factors, assess the effect of each, and gain an appreciation of the general relationships involving car ownership and use.

The second aim of this study was to evaluate the market for electric cars. This was accomplished by collecting data on daily and longer term usage patterns for cars, and using these to identify cars which might potentially be replaced by electric cars. Published data was used to define parameters which describe the present capability of electric vehicles. These parameters were then used to screen the data and find the size of the possible market for electric vehicles, given these parameters describing their performance.

The methodology of this study involved collecting data from a random selection of 1 000 households in ten representative municipalities in Melbourne. The form of the data collection was to employ interviewers to conduct personal interviews at these households. The data cover information about the members of the household, the vehicles available to it, and the trips made by household members on the previous weekday.

This report begins with a review of the literature on car availability, use and trip making, followed by a review of the literature on electric vehicles, and a discussion of the capabilities of a possible electric vehicle. The methodology of the survey, the editing procedure, and data preparation are then explained. Certain socioeconomic data of the sample are then compared with the published census data, and the validity of the sample assessed. In the next section of the report, vehicle availability and use are analyzed. Then, using the parameters developed in an earlier chapter, the extent of the electric car market is explored. A set of potential electric cars is identified within the car population, and the characteristics of this set are discussed.

CHAPTER 2 - PREVIOUS STUDIES OF FACTORS INFLUENCING AUTO AVAILABILITY, USAGE AND TRIP MAKING

INTRODUCTION

Models which predict the availability and usage of automobiles are relevant to many fields. Although these models were first developed in connection with transportation studies, they now find application in such areas as automobile industry policy, petroleum usage projections, and pollution modelling. Thus, the purpose of developing a model of automobile availability may range from providing an explanation of present or future auto availability levels in a given urban area, to a prediction of national auto distance travelled twenty years hence.

AUTOMOBILE AVAILABILITY

In the traditional transportation planning process, auto availability has often been used as one of the variables to account for and predict trip generation rates. Auto availability is a useful variable because it has been found to be the variable most highly correlated with trip generation[(1)(2)].

Before examining the models which have been developed in this field, it is necessary to make a distinction between certain terms. The first of these distinctions is between "availability" and "ownership". Transportation surveys[(1)] usually include a question asking how many cars are owned by persons living at a given address. The question would seem to be straightforward; however, the question specifies that company owned (and presumably govern-

(1) Oi, W.Y. and Shuldiner, P.W., An Analysis of Urban Travel Demands, Northwestern University Press, Evanston, Illinois, 1962.

(2) Deutschman, H.D., Auto ownership revisited: a review of methods used in estimating and distributing auto ownership, Highway Research Record, 205, 31.

ment owned) cars are to be included. Thus, the number of cars reported as "owned" actually includes some cars which are not privately owned. In one paper[(1)] the authors even state that they use the terms "ownership" and "availability" interchangeably. Conceptually, the vehicles available to the household are the ones which can be used for making trips. Thus the term "availability" will be used throughout this section, even in reviewing work in which the original authors used "ownership".

There is also a confusion in the literature between the terms "vehicle" and "auto". An "auto" (or "car") is commonly defined as a passenger car or station wagon, while "vehicle" (meaning motor vehicle), is a broader term, which includes also vans, trucks, and in some cases, even motorcycles. In spite of this distinction, it is quite common to find, in a section on "car" (or "auto") availability, graphs of "vehicles" per dwelling unit[(2)] or equations with "vehicles" per household in them[(3)]. In this and subsequent sections, the term "auto" (or "car") will be used to denote passenger cars and station wagons, and "vehicle" to denote all motor vehicles except motorcycles.

In a study[(4)] using national survey data, several factors were identified which influenced car availability and use in the U.S. Using time series data, they found that the proportion of households at a given income level (in constant dollars), which had one or more cars available, did not change appreciably between 1956 and 1965. However, the proportion of multi-car households rose at all income levels throughout the period surveyed (1950 - 1965). They ascribed this increase in multiple auto availability of households to an increasing proportion of women who were licensed, and also, of women who worked, as well as to the increasing suburbanization of the population.

(1) Deutschmann, H.D. and Jaschik, N.L., Income and related transportation and land use planning implications, Highway Research Record, 240, 52.
(2) Oi W.Y., and Shuldiner P.W., op. cit.
(3) Deutschmann, H.D., op. cit.
(4) Lansing, J.B. and Hendricks, G. Automobile Ownership and Residential Density, Survey Research Centre, Institute for Social Research, University of Michigan, Ann Arbor, Michigan, 1967.

Two types of models of automobile availability have been developed using transportation study data. The earlier type was based on zonal aggregates of household data, and typically relied on regression equations to develop a relationship between various zonal characteristics and the observed levels of auto availability[1][2]. Recently, there have been some attempts to relate auto availability to various factors, using non-zonal aggregates of households. Dunphy[3], for example, found a relationship between transit accessibility and auto availability when households were grouped by income and family size.

Lerman and Ben-Akiva[4] have recently developed a logit model to explain the joint auto availability - mode of travel to work decision. They identified market segments according to the stage of a household's life cycle and whether the head of the household was a blue or white collar worker. They then used household data to estimate a set of parameters for each of the market segments.

YEARLY AUTOMOBILE USE AND DISTANCE TRAVELLED

Most models of yearly automobile use have been developed in conjunction with large scale forecasts, typically of total annual distance travelled by vehicles[5][6]. They were concerned with the overall average annual distance per vehicle, rather than with their relationship with such household factors as income and number of cars in the household, though some data on these differences were presented. As expected, most surveys showed that the

(1) Deutschmann, H.D., op. cit

(2) Deutschmann, H.D. and Jaschik, N.L., op. cit.

(3) Dunphy, R.T., Transit accessibility as a determinant of automobile ownership. Highway Research Record. 472, 63.

(4) Lerman, S.R. and Ben-Akiva, M., Disaggregate behavioural model of automobile ownership, Transportation Research Record, 569, 34.

(5) Tanner, J.C., Forecasts of vehicles and traffic in Great Britain: 1974 revision. Department of the Environment, Transport and Road Research Laboratory, Report LR 650, Crowthorne, U.K., 1974.

(6) Maring, G.E., National highway travel forecasts, Transportation Engineering Journal, 102, No. TE4, 759.

distance travelled per auto increases as household income increases, when the number of autos per household is held constant, and also that total annual distance per household rises as income rises[1].

Another factor influencing annual distance travelled per auto is the age and sex of the driver. It has been shown, using travel surveys in the U.S., that males in the 30 - 34 age group drive the greatest distance[2]. These surveys also showed that females of all ages drive appreciably less distance per annum than males.

Lansing and Hendricks[3] identified three factors which were the most closely related to the annual distance travelled by a family. Income was found to be the best predictor of annual auto distance. This is not surprising, considering the relationship of income to auto availability described previously. The other two factors which were related to auto distance travelled were place of residence and age of the head of household. Income was highly correlated with both the place of residence (central city versus suburb) and the age of the head of household, so that it is not clear how much of the variation in auto distance is explained by these factors after income is taken into account, since there were no graphs of other factors presented in which income was held constant.

In a recent study, Maring[1] used several methods to analyse aggregated U.S. data to produce a range of forecasts of future U.S. car travel. One method examined several assumptions about the projected growth in numbers of licensed drivers (particularly women), and the annual distance per driver. In the "medium" projection, for example, the percentage of women in a given age group licensed to drive was increased to within five percentage points of the corresponding percentage for males, and the average

---

(1) Maring, G.E., op. cit.
(2) Motor Vehicle Manufacturers Association, Motor Vehicle Facts and Figures, '76, Detroit, Michigan, 1976.
(3) Lansing, J.B. and Hendricks, G. op. cit.

annual distance per woman increased to 60% of the corresponding male values for each age group. The percentage increase in car travel in the three projections was from 33.4% to 140% in the 18 years to 1990.

Another forecasting method used a projected 1990 income distribution to calculate the number of households in each income group. The National Personal Travel Survey data for cars per household by income group, and travel per household, were then used to derive the total distance travelled by cars. This method predicted a 64% increase in car travel by 1990.

The last method assumed various proportions of car sizes, fuel consumption by size, and total distance per vehicle by size. Assumptions about the change in fuel consumption and distance per vehicle for different size classes were used to make projections, with some of these projections constrained by fuel availability. The predicted increase in total auto distance ranged from 35% to 66%, between 1972 and 1990.

The consensus from the estimates of these different methods was that there will be an annual growth rate in total annual auto distance of 2 - 3% p.a., in the U.S., to 1990. This compares with the historic growth rate in the U.S. of 4.6% p.a. over the last 20 years. The projected growth in total annual car travel was in the range of 50 - 80% over the 18 years to 1990.

Using data from Britain and many other countries, Tanner[1] has made predictions of the growth of vehicle numbers and vehicle distance travelled in Great Britain. He calculated a saturation level of cars per person in the range of 0.3 - 0.5, using time series data, plots of percent increase versus cars per person by countries, and calculations based on an assumed maximum of cars per person combined with the age distribution of the population. He then constructed a set of three logistic models of the growth in

---

(1) Tanner, J.C., op. cit.

cars per person over time by using a combination of elasticity assumptions, and the changes with time of Gross Domestic Product and car ownership cost. For example, he predicted that there would be 0.36 - 0.41 cars per person in 1990 in Great Britain, compared to 0.23 in 1972.

Tanner then multiplied the ranges of car ownership from the above forecast by official population forecasts to give a range of predicted car numbers for future years. Using a fairly conservative figure of 0.1 for income elasticity of annual distance travelled per car, and a relationship of distance per car to possible travel speed (represented by the length of motorway per 1000 cars), he derived an equation to describe the increase in individual car travel with time. This relationship yielded a 6% increase in travel per car in the 18 years between 1972 and 1990. Multiplication of cars by distance per car gave a range of car-kilometres for future years. He forecast that by 1990, for example, there would be a 64 - 94% increase in total annual car kilometres compared with 1972.

MODELS OF TRIP GENERATION

Before describing the models which have been developed for trip generation, a few terms should be clarified. A "trip" is defined in the classical transportation study[1] as a one way movement by a person from a particular origin to a particular destination for a given purpose, using one mode of travel. The modes included are usually the so-called "mechanical" ones; i.e. excluding walking or bicycling. This definition is a rather restrictive one, since when a person talks of making "a trip" to work, he often means a journey using at least two modes; e.g. travel by car to a parking place, and then walk from the parking place to the factory or office. Only the auto trip would be recorded by the preceding definition. In some studies, the various "legs" of a trip (e.g. a

(1) Oi, W.Y. and Shuldiner, P.W., op. cit.

journey to work by train and then tram) are combined into a "linked trip". This combining process results, of course, in fewer total trips than if individual legs of trips are counted.

The model most widely used for trip generation in earlier transportation studies was multiple linear regression. In this model, a dependent variable (Y) is assumed to be a linear function of certain explanatory variables (X_1, X_2,...X_k). The form of the relationship is

$$Y = b_0 + b_1X_1 + b_2X_2 \dots . + b_kX_k + U \qquad (2.1)$$

where b_0, b_1. .... b_X are the parameters of the model[1][2]. Thus for any given set of observations X_1, X_2, ... X_k, there exists a corresponding observation Y which differs from the regression line by the amount U. A set of parameters is estimated which minimizes the sum of squares of the error terms, ΣU_i^2. The U terms are usually referred to as the disturbance terms.

The use of least square regression analysis requires that several important assumptions be made about the independent variables and the distributions which are involved[1][2]. Briefly stated, these assumptions are as follows:

- The dependent variable is a linear function of the independent variables (however, transformations, such as logarithms, of some of the independent variables are acceptable).

- There is no correlation between the independent variables, and their effects on the dependent variable are additive.

---

(1) Douglas, A.A. and Lewis, R.J., Trip generation techniques. 1. Introduction, Traffic Engineering and Control, 12, 362.
(2) Oi, W.Y. and Shuldiner, P.W., op. cit.

- The least squares model estimates the mean value of the dependent variable from fixed values (rather than from estimates) of the independent variables.

- The disturbance terms have a mean and covariance of zero, a constant variance, and a normal distribution.

In the classical transportation study, the urban area is divided into traffic zones on the basis of land use. From sample surveys and other existing data, the trip generation rate of a zone is calculated, and various socioeconomic characteristics are determined. The characteristics used for the subsequent analysis include variables such as population, dwelling units, median family income, average home value, auto registration and labour force(1). An equation is then developed from some of these characteristics to fit the observed trip production rate.

The use of zonal least squares regression equations has been criticised on a number of grounds(2)(3)(4). One fundamental problem of using zonal level data is that most of the variation between households is lost before a model is developed. Fleet and Robertson(2) found that 80% of the total variation was lost when the data was aggregated at the zonal level. This means that an equation which "fits" the zonal data well does not necessarily explain much of the household variation. Another problem which occurs is that trip rate equations often contain parameters which

---

(1) Urban Planning Division, Guidelines for Trip Generation Analysis. U.S. Department of Transportation, Federal Highway Administration, Urban Planning Division, 1967.

(2) Fleet, C.R. and Robertson, S.R., Trip generation in the transportation planning process, Highway Research Record, 240, 11.

(3) Hutchinson, B.G., General problems in urban trip generation analysis, papers on Trip Generation presented at the 1973 Roads and Transportation Association of Canada Meeting, Hutchinson, B.G. (ed). Transport Group, Department of Civil Engineering, University of Waterloo, Ontario, Canada, 1974.

(4) Douglas, A.A. and Lewis, R.J. Trip generation techniques. 2. Zonal least squares regression analysis, Traffic Engineering and Control, 12, 428.

have an inappropriate sign, usually due to problems of collinearity of variables used in the equation[1]. The use of aggregate variables rather than zonal means in trip equations has also been shown to violate the assumption that the error terms have a constant variance[2].

Other problems have occurred using least squares equations. One has been a tendency to "overfit" the data, using many independent variables in order to obtain a high r^2 value. There is often little improvement in the r^2 value after two or three variables are included, and when more variables are used, the dangers of collinearity are greater[3]. Another problem is that the equations developed are often unique to a given transportation study, and not comparable with models developed elsewhere. This is particuarly true when the independent variable is trips per zone, since the zone sizes determine the magnitude of the parameters.

An alternative to trip analysis at the zonal level is analysis based on the household unit and its trip rate. The household appears intuitively to be a more logical grouping than the zone, since differences in trip rates to be accounted for by a model largely reflect differences in household type. The households are grouped into categories based on such variables as persons per household, vehicles per household, and income, and average trip

---

(1) Hutchinson, B.G., General problems in urban trip generation analysis, papers on Trip Generation presented at the 1973 Roads and Transportation Association of Canada Meeting, Hutchinson, B.G. (ed). Transport Group, Department of Civil Engineering, University of Waterloo, Ontario, Canada, 1974.

(2) Douglas, A.A. and Lewis, R.J. Trip generation techniques. 2. Zonal least squares regression analysis, Traffic Engineering and Control, 12, 428.

(3) Urban Planning Division, op. cit.

rates are determined for each group[1][2][3]. This type of analysis is commonly referred to as category analysis, or non-parametric analysis. The zonal rate can be computed by multiplying the trip rates for each household category by the number of households of each type in the zone. A minimum of survey data may be used by formulating the joint distributions of household categories mathematically, rather than obtaining them by direct survey[3].

The assumption of stability of trip generation rates for each household type is crucial to category analysis. The forecasts will be affected to a greater or lesser degree by changes in the trip rate for all classes of household. These rates can be monitored every few years, and any observed changes incorporated into the forecasts.

Where there is a large number of categories and a skewed distribution, there may be certain categories of households which are poorly represented in the survey data, such as small households with high car availability. Some of these classes of household may be the very ones which are expected to become more numerous in the forecast year. Therefore, if the data is to be useful for predictions, special efforts may be necessary to sample adequately such households. Another problem is the difficulty of incorporating into the model variables such as residential density, which are known to have an effect on trip making, but may not be part of the classification system.

---

(1) Urban Planning Division, op. cit.
(2) Fleet, C.R. and Sosslau, O.E., Trip generation procedures: an improved design for today's needs, Traffic Engineering, 46, 17.
(3) Douglas, A.A. and Lewis, R.J., Trip generation techniques. 4. Category analysis and summary of trip generation techniques, Traffic Engineering and Control, 12, 532.

Douglas and Lewis[1] and Oi and Shuldiner[2] have suggested that least squares regression analysis applied to the household may also be used for trip generation studies. The form of the model uses trips per household as the dependent variable, and certain household characteristics as independent variables. These characteristics are similar to those used for category analysis, and include family size, number of employees per household, number of cars per household, and household income. Some of these variables do not appear to have a linear influence on trips per household, and must either be transformed to yield a linear relationship, or else divided into discrete classes and entered as dummy variables[1]. In order to obtain trip rates for zones, the zonal averages for each variable are multiplied by their relevant parameters in the regression equation. Where dummy variables occur, the number of households in a class for that zone is used in the equation.

A serious limitation to this procedure is that the error variance is not constant[1]. White[3] has suggested that the problem could be eliminated by a transformation procedure, but although this does seem to be the case, it is not known whether it would be workable in a transportation study.

The use of category analysis at the individual level has recently been proposed by Ochojna and Macbriar[4]. Analysis of variance tests were performed to find the personal characteristics which best accounted for variation in trip rate. Age and employment

---

(1) Douglas, A.A. and Lewis, R.J., <u>Trip generation techniques. 3. Household least-squares regression analysis</u>, Traffic Engineering and Control, <u>12</u>, 477.
(2) Oi, W.Y. and Shuldiner, P.W., <u>op. cit.</u>
(3) White, M.T., <u>An examination of residual distributions in ordinary least squares (OLS) household-based trip generation models</u>, Transportation Research, <u>10</u>, 249.
(4) Ochojna, A.D. and Macbriar, I.D., <u>A pragmatic application of category analysis to small scale household travel surveys</u>, Traffic Engineering and Control, <u>17</u>, 293.

status were found to have the most influence on trip rate, and on this basis they allocated people into nine "similar mobility groups". The trip rates for persons within each of these groups was found to be similar in two different cities, lending support to this basis for allocation. It remains to be seen whether these groups have similar trip rates over a broader sample of cities.

CONCLUSION

Models of automobile availability were originally developed using data at the zonal level. More recently, the emphasis has shifted to household based models. Likewise with trip generation models, the zonal regression model has been replaced by models based on individual households using the approaches of category analysis or individual household regression.

Most models of annual vehicle distance travelled have been directed toward large scale forecasts, rather than of individual vehicle usage predictions. This emphasis on large scale forecasting is not surprising since the models were designed to predict such things as total annual vehicle distance travelled or fuel consumption, rather than the behaviour of single vehicles. By nature, however, these models are of little use in understanding the behaviour of individual households.

In the absence of suitable models, a disaggregated approach has been considered appropriate for the required analysis. The degree of disaggregation is of course limited by the size of the data set collected.

CHAPTER 3 - CHARACTERISTICS OF PRESENT ELECTRIC VEHICLES

INTRODUCTION

The recent revival of interest in electric vehicles started in the 1960's, and was subsequently given a major boost by the increasing concern about automobile pollution toward the end of the decade. As emission control regulations were imposed on autos, a power source which produced little pollution at the point of use seemed an attractive alternative to the internal combustion engine. More recently, as a result of the "Energy Crisis", concern has mounted about the future scarcity of crude oil, and the dependence on foreign sources of supply. Electrically powered cars do seem to provide solutions to these problems. Their operation is almost pollution-free, and generation of electricity to power them requires (in most regions) non-oil based, indigenous fuels. In spite of the impetus given to the electric car development by these concerns in the past decade, there is still no satisfactory electric car which is being mass produced and sold today, mainly because no satisfactory battery has been developed.

Since battery capability is such a limiting factor, the first section of this chapter contains calculations of the energy and power required of an urban electric vehicle, while the second section analyses the capabilities of lead-acid and other batteries. The next section considers controllers and motors, and following this there is an examination of the performance and deficiencies of two present day vehicles. A discussion of possible future developments in urban vehicles follows, and finally, the characteristics of a battery automobile which might be available in the near future are defined.

PARAMETERS OF AN URBAN VEHICLE

One method of assessing electric car capabilities is to define a set of parameters for the requirements of urban travel and then calculate the power and energy characteristics of batteries which could meet these requirements. Cairns and McBreen[1] have used a value for acceleration capability (0 to 50 km/h in 10 seconds) to calculate a power requirement of 25 kW/tonne. Using data obtained in city traffic conditions, Milkins[2] has calculated that 19kW/tonne is required to satisfy 99%, and 33 kW/tonne to satisfy 99.9% of the driving requirements.

Cairns and McBreen[1] have calculated that the energy requirement for an urban vehicle is about 0.17 kWh/tonne-km at moderate speeds (30 km/h). This value is quite similar to that obtained by Whitford[3] for a recently tested prototype vehicle. Thus, a one tonne vehicle with a range of 80 - 100 km must be capable of storing about 17 kWh (100 x 0.17) of energy. If a maximum of 30% of vehicle mass is allowed for batteries, the required energy density of the battery is 17 kWh/0.3 tonne (≏57 Wh/kg). The required peak power density, calculated using the peak power value obtained by Cairns and McBreen[1], is 80 W/kg (25 kW/0.3 tonne).

The figure for the required energy density might well be an under-estimate for a vehicle which experiences a great deal of stop-start driving or higher speed driving, since both of these conditions reduce range[4]. On the other hand, lower energy and power density are required of the battery if the fraction of the vehicle weight devoted to batteries can be increased above the assumed maximum of 30%.

CAPABILITIES OF BATTERIES

The ability of a lead-acid battery to store electrical energy is ultimately determined by the electro-chemical nature of the cell

---

(1) Cairns, E.J. and McBreen, J., Batteries power urban autos Industrial Research, 17, 56.
(2) Milkins, E.E., Automotive fuels of the future - engines, vehicles and traffic, Presented at SAE Australasia Annual Conference, Perth, 1976.
(3) Whitford, D., (1976),Personal communication.
(4) Automotive Engineering, Electric vehicle development, 84, 39.

itself. In designing lead-acid batteries, one of the principal trade-offs is between energy density (Watt-hours/kg), power density (Watts/kg) and battery life (number of operating cycles). The higher the energy density of the battery, the further the vehicle can go between charges; the higher the power density, the better the performance. The present limits for lead-acid batteries are an energy density of 30-40 Wh/kg at a power density of 16 W/kg, and a peak power density of 70 - 100 W/kg[1]. An improved lead-acid battery may be capable of about 50 Wh/kg with a reasonable cycle life[2]. This energy density would still leave it far short of the energy density of petrol which (at 20% thermal efficiency) is 2 600 Wh/kg.

Several different types of batteries have been proposed as replacements for the lead-acid battery in electric cars. The zinc-nickel oxide cell is presently being developed by General Motors[1] among others, and the possible capability is 60 Wh/kg with a specific power up to 125 W/kg. The sodium-sulphur battery is another possibility for the future[2][3] having a projected energy density of 200 Wh/kg and power density of 200 W/kg. One disadvantage of this cell is that the sodium and sulphur must be kept molten for operation, so it must remain at 300° C. Other cells which are under development are the zinc or iron-air[2] and the zinc-chlorine[4]. Both these latter types of cell operate at room temperature, but there are considerable development problems before either is practicable for an electric vehicle.

---

(1) Cairns, E.J. and McBreen, J. op. cit.
(2) Waters, M.H.L.; and Porter, J., A review of market prospects for battery electric road vehicles - part 1, Department of the Environment, Transport and Road Research Laboratory, Report 630, Crowthorne, U.K., 1974.
(3) Brooman, E.W., Clifford, J.E. and Semones, D.E. Batteries: prospects for electric vehicles. Automotive Engineering, 83, 30, 1975
(4) Jacobson, R.A., EV power sources: Waiting for a superbattery, Machine Design, 46, No. 25, 149.

Thus, in spite of much developmental work, the lead-acid cell remains the only battery likely to be available for electric vehicles in the near future. The improved version would almost be capable of meeting the requirements (55 Wh/kg specific energy, 80 W/kg specific power) of an electric vehicle defined in the previous section.

MOTORS AND CONTROLS

There are many possible designs for motors and control systems for electric vehicles. However, certain features of the electric vehicle have meant that particular types have been most commonly used. Since batteries produce direct current (dc), most systems have used dc motors, usually of the series wound type, i.e. with the field in series with the armature. This type of motor has the desirable characteristic that the torque is highest at lowest speeds, but has also the disadvantage that the current drawn from the battery is very high under these conditions[1]. This heavy current load increases I^2R losses of the system, which means that efficiency suffers. Another disadvantage of the conventional series wound motors is that it has a fairly low power to weight ratio[2].

Another possible motor for electric vehicles is an alternating current (ac) squirrel-cage induction motor. An inverter would be required to convert the battery dc to ac, but this could be part of the control device used to vary the motor speed by varying the frequency of the ac power. This type of motor has a higher power to weight ratio than a series wound dc motor, because the motor is smaller and operates at higher speed[1].

The motor controller is usually designed in conjunction with the motor and transmission. The simplest type used for dc systems

---

(1) Leonard, M., E.V. Motors: DC now AC later. Machine design, 46, No. 25, 129.

(2) Bureau of Transport Economics Electric Cars. Australian Government Publishing Service, Canberra, 1974.

employs multiple battery taps or variable resistors to produce different voltages at the motor. The system using multiple battery taps tends to be jerky in operation and the resistance system wastes power through the resistors. More recently, thyristors have been used to "pulse" the power to the motor with variable width pulses. This has the effect of giving different average power levels to the motor, depending on the fraction of the time the power is on(1). This system provides smooth control of vehicle power but is considerably more costly than the earlier, simpler, control systems.

Regenerative braking is usually considered to be desirable feature of electric vehicles(2)(3). The principle is fairly straightforward; the field current (of a dc motor) is reversed and this turns the motor into a generator, which then returns power to the battery. Unfortunately, at high braking rates, the power is often too high for the lead-acid batteries to accept, and also, at low speeds the efficiency is too low to be very useful(2). Thus, a regeneration system which is able to return a reasonable amount of power to the batteries is usually complex and costly(3).

There are several forms of transmission usually used for electric vehicles. The simplest electric car has no transmission at all and relies on the torque properties of a dc traction motor (high torque at low speeds)(4). In other vehicles, the motor is connected to a conventional manual automotive transmission. This is fairly straightforward, but the transmission is heavy and accounts for some loss of efficiency. A third type of car has no clutch and uses a relatively simple two speed transmission to reduce current

---

(1) Bryson, F.E., EV controllers: Semiconductors mean extra range, Machine Design, 46, No. 25, 135; 1974.
(2) Automotive Engineering, op. cit.
(3) Whitford, D., (1974), The electric vehicle: a new approach, Science and Technology, 11, 18.
(4) Dann, R.T., EV Transmissions: How many speeds? Machine Design, 46, No. 25, 139.

draw, and boost acceleration over that of a vehicle with no transmission. The ultimate development may be a variable ratio transmission to keep output torque at an optimal level over a wide speed range.

CHARACTERISTICS OF TWO EXISTING ELECTRIC CARS

The features of two electric cars are described in this section. The first vehicle to be described is the Sebring Vanguard "CitiCar". Some hundreds of these cars are being produced per year, and they are being marketed by dealers in various parts of the United States. The CitiCar body is made of light plastic, and the car accommodates two adults and a small amount of luggage. The car weighs 640 kg, and has a top speed of about 52 km/h. It requires about 20 seconds to accelerate to 50 km/h, twice as long as the 10 seconds specified previously. The 4.5 kW motor uses about 0.27 kWh of electrical energy per kilometre. Its range is only 52 km, and the vehicle cost $US 3 396. Thus, the CitiCar is a rather small, underpowered and overpriced urban vehicle.

The CitiCar failed an evaluation made recently by Consumer Reports[1]. The most serious fault found was that one of the brakes fell apart when the car was stopped suddenly. Other faults reported include very bad handling, poor seat comfort, bad seat belt design and high interior noise. Consumer Reports concluded that it was a very unsatisfactory vehicle, even for limited urban use.

The other vehicle is the Mark II Flinders Electric Vehicle[2]. Since it is a converted Fiat 127, it is virtually a conventional small automobile, unlike the CitiCar. Conversion (replacement of the internal combustion engine and clutch with an electric motor, controller and batteries) increased the car's weight by several hundred kilograms to 1 020 kg. The top speed of this car is about 60 km/h, achieved in about 30 seconds, a considerably longer time

(1) Consumer Reports, The electric Citicar, 41, 572.
(2) Whitford, D., (1976), op. cit.

than that needed by the comparable petrol powered car. The range in normal city driving is 60-80 km, and the car consumes 0.15 kWh/km. The cost in a production run of 500 is estimated to be some hundreds of dollars more than the comparable internal combustion engine vehicle. The Flinders vehicle is therefore similar to the small conventional car from which it was derived, except that it is heavier, and the acceleration and top speeds are not nearly as good. Presumably the ride and internal noise level are not too different from the original internal combustion car.

Thus, these two currently available electric vehicles are restricted in their range to 80 km or less, and have performance characteristics inferior to those of internal combustion vehicles. Along with these performance penalties, the Flinders Electric Vehicle would cost many hundreds of dollars more than its petrol powered counterpart.

POSSIBLE FUTURE DEVELOPMENTS

As discussed in the introduction to this chapter, the main limitation on electric car performance is imposed by the inadequacies of the battery. Some improvement in lead-acid battery performance is possible, which may give the battery an energy density of 50 Wh/kg, 50% greater than that of present lead-acid batteries. Any further improvement in energy density will require a new type of battery, such as the zinc-nickel oxide cell or the high temperature sodium-sulphur cell. Until such batteries are available for electric vehicle use, the battery car will remain a limited range, low powered vehicle.

One energy storage system which has been given some attention recently is the flywheel. Post and Post[1] have described a flywheel which would offer energy storage capabilities more than three times as great as those possible with lead-acid batteries.

---

(1) Post, R.F., and Post. S.E., Flywheels, Scientific American, 229, 17.

The flywheel would power an ac drive motor through a sophisticated control system, and allow regenerative braking. The authors consider that a vehicle with a 130 kg flywheel could have a range of 300 km, but, while this might be a long term possibility, a more realistic near term target for a first generation flywheel powered auto might be 100 km.

A compromise vehicle which has been proposed incorporates both a lead-acid battery and a flywheel(1). This vehicle would use the lead-acid battery for most of its energy supply and make use of the flywheel only for peak power and regenerative braking. Thus, the vehicle would have higher acceleration capabilities, and its range would be superior to that of a vehicle powered only by a battery. A disadvantage of this system would, however, be the requirement for more expensive controls and power systems than for a more conventional battery vehicle.

Various types of hybrid vehicles have been proposed in which heat engines are combined with batteries(2)(3). The heat engine would run at a power level which optimizes a mix of fuel economy, emissions and power output. The batteries would provide peak acceleration power and would store regenerative braking energy. Against the presumed benefits of good fuel economy and low emissions are the disadvantages of a complex control system, the cost of two power systems, and the extra vehicle weight due to the batteries.

Among the possible alternative motor vehicle power plants, a conventional spark ignition engine powered by hydrogen has been

---

(1) Automotive Engineering, op. cit.
(2) Winkelman, J.R., and Frank, A.A. Computer Simulation of the University of Wisconsin hybrid-electric vehicle concept, Society of Automotive Engineers, Automobile Engineering Meeting, Detroit, Michigan, May 1973.
(3) Lindsley, E.F., Turbine electric car recharges the batteries on the run, Popular Science, 207, 62.

claimed to provide the maximum level of fuel economy[1]. The hydrogen could be produced directly from electricity through the hydrolysis of water, or from some biological source, and burned in a slightly modified internal combustion engine. When a hydrogen engine of this type is used to power a low performance vehicle, the energy efficiency is claimed to be 4.5 times as high as for a battery powered vehicle[1]. The main problems with such a vehicle are that the mass and bulk of tanks required at present for hydrogen storage limit the range of possible present day vehicles[2].

CONCLUSION

From published data, it was concluded that an urban automobile of almost adequate capability can be built, using an improved lead-acid battery. This vehicle would have a range of about 80 km in urban driving conditions, and the power to meet urban driving needs. In the near future, it would probably cost many hundreds of dollars more than a comparable conventional vehicle. The batteries would normally be recharged overnight, although it would be possible to give the vehicle a quick charge during the day to extend its range.

This urban vehicle would have to be designed from the start according to the capabilities of its power, control and motor systems. It should be designed to be as light, efficient and streamlined as possible to minimize road load.

The electric car promises to be a vehicle generating little noise or air pollution, and to be particularly suitable for urban travel. Since it operates on electricity, it is able to use a great variety of primary sources of energy. To be acceptable to a segment of the car market, it must have other desirable features (such as low operating and maintenance costs) to offset its higher

(1) Watson, H.C. and Milkins, E.E., Future fuels and engines. Paper No. 26, Transportation (2nd Automotive Engineering Conference of the Society of Automotive Engineers - Australasia, and the Society of Automotive Engineers of Japan), Melbourne, November, 1975.

(2) Roleff, P., Personal communication to Mr E.E. Milkins, 1976.

capital cost and its operational limitations. Thus the electric car will be a vehicle specifically designed for the particular task of urban travel, and the purchasers of such vehicles will be buying them for this specific use.

CHAPTER 4 - SURVEY METHODOLOGY

INTRODUCTION

In order to investigate the potential market for limited range vehicles, it was decided to conduct a survey of vehicle availability and usage.

The survey was designed to collect data related to the following questions:

- What is the present pattern of vehicle availability in terms of distribution of motor vehicles between households?
- How are these vehicles used and how does this use relate to the pattern of trip making by households?
- What is the potential market for limited range (battery powered) vehicles?

Because of the complexity of the required data, it was decided to undertake a home interview survey rather than a mail survey, even though the cost of the home interview survey, using paid interviewers, would be much higher. With an interviewer administering the questionnaire, difficult questions could be explained more fully and the answers would be more reliable. It was also expected that the response rate would be higher and hence there would be fewer problems with a biased response rate, especially given the length and detail of the questionnaire.

THE QUESTIONNAIRE

The questionnaire was divided into four forms (Appendix A, Forms 1 through 4). The cover sheet (Form 1) related to the household itself. The information collected included the location of the household, the dwelling type, date of interview and number of persons and vehicles in the household. Only the last two questions were asked of the interviewee.

The personal part (Form 2) of the questionnaire recorded socio-economic information on each member of the household who was 5 years of age or over. There were questions on age, sex, marital status and relationship to the head, that indicated a person's place in the household structure. Other questions were about the employment status, income, occupational group and educational status of each member of the household. (The income and occupational groups were specified on a separate card (Appendix B) which was handed to the senior member of the household present). The form also noted whether each person was a licenced driver, and what was his main mode of travel to work or school (including vehicle used) if applicable. The family's telephone number was requested so that data could be verified. This was done in a few cases. The information on four persons fitted on one sheet, and additional forms could be used if needed.

Two pages of the questionnaire were concerned with the household's vehicles (Form 3 of Appendix A). In one section, basic information was collected about each vehicle such as make and model, year of manufacture, and the owner (private, or company, government, etc.). This was followed by questions about the use of the vehicle. In this part were such questions as who was the usual driver, how far the vehicle travelled per year, what percent of the travel was outside the metropolitan area, and what the main use of the vehicle was. Other questions dealt with how often the vehicle went outside the metropolitan area (see map, Appendix C), how frequently it travelled more than 80 km per day, the alternatives for non-metropolitan travel in that vehicle, the distance travelled on a typical weekday, etc. These questions were designed to give a profile of the use of the vehicle, and to establish the feasibility of the replacement of that vehicle by a limited range vehicle.

The number of questions meant that the vehicle part of the questionnaire took up two pages. There were two columns, however, so that information for two vehicles could fit on these two pages. Additional forms were used for households with more than two vehicles.

The last form (Form 4 of Appendix A) was for recording all trips made by family members on the previous weekday. The definition of trip used was: "any trip by a household member using a private vehicle as a driver or passenger, or public transport, and all walk trips of greater than 0.4 km". The exception to the distance criterion was that all walk trips to work or school, no matter how short, were to be recorded. The one class of trips not recorded were those made by persons in trucks or vans in the course of a day's work (but the trips to and from work were recorded in these instances).

The trip form had questions on the person number (coded to match the numbers on the personal form) making the trip, the origin and destination, and starting and arrival times of the trip, the distance travelled, and <u>from</u> and <u>to</u> purposes. In the question on mode of travel, provision was made to identify the vehicle used for private vehicle driver or passenger trips. There were also questions on the number of occupants and type of parking for car driver trips.

The trip sheet had space for information about six trips, and additional sheets were used for recording further trips. The information on the trip forms was quite useful in checking data from the person and vehicle records.

Because of the complexity of the forms, the average interview took about 50 minutes (including time travelled within the area). The pay scale was $2.00 per interview plus $1.50 per hour spent interviewing and travelling in the area. The total cost of the survey was $3 190.40, giving an average cost per interview for the usable returns of $4.70, of which $3.25 represents payment to the interviewer and the remainder covered distribution and travel expenses.

SELECTION OF HOUSEHOLDS

The objective of the survey was to conduct 1 000 interviews in ten municipalities around Melbourne. The number of interviews per municipality was considered sufficient to achieve a reasonable geographical coverage as well as sufficient sample numbers in a municipality, with an average of 100 households interviewed per municipality.

The original plan was to use the ten municipalities sampled in 1972 by the Metropolitan Transportation Committee (MTC) in a follow-up survey to the 1964 Melbourne Transportation Study(1). It was hoped that the data collected in this study could be compared to the 1972 data and verified, as well as further conclusions drawn by scaling up the information by reference to that data. However, when several criteria were used to examine the selection of Local Government Areas (LGAs), the coverage was not felt to be representative of Melbourne.

The principal criterion for evaluating the MTC's selection was the stage of a municipality's growth cycle as defined by Paterson(2) Using 1954 through 1966 census data, he grouped municipalities into five types. The first was the Central Group, consisting of Melbourne and five adjacent municipalities which included all of the original "Village Reserve". The Inner Ring of 12 municipalities lay just outside the reserve and were developed for agricultural and pastoral use soon after Melbourne was founded.

---

(1) Don, P.A., The new models I: trip generation, trip distribution mode choice, In Workshop, Revised Transportation Models for Melbourne, The Institution of Engineers, Australia, Victoria Division. Transportation and Highways Branch, 1975.

(2) Paterson, J., The Dynamics of Urban Change, in Special Report No. 5, Analysis of Urban Development, N. Clark (ed), Proc. Tewkesbury Symposium, Transport Section, Department of Civil Engineering, University of Melbourne, 1970.

The Established Group of ten municipalities were those which grew in population after World War 2 but whose growth had stopped by the 1966 census. A fourth Continued Growth Group of 13 municipalities were the major areas for urban expansion between 1947 and 1966. In the Fringe Group he put the fragments of predominately rural municipalities that were experiencing urban expansion in 1966.

Using Paterson's classification, one can calculate how well different groups were represented in the 1972 resurvey. None of the central group was included, even though on a percentage basis one should have been surveyed. Of the inner ring group, four of the 12 (33%) were included even though they represented only 22% of the 55 municipalities in the metropolitan area in 1972. In the established group, none of the ten municipalities was sampled. In the continued growth group, four of the 13 municipalities (31%) were selected, though they were only 24% of the metropolitan total. Only two (14%) of the fringe municipalities were sampled, though by 1972 there were fourteen (25%) in this category. Thus certain classes of municipalities were omitted or under-represented (central, established, fringe) while other classes of municipalities were greatly over-represented (ring and growth). While presumably the Melbourne Transportation Committee had specific reasons for its selection of municipalities, the sample is not representative of all types of municipalities in Melbourne.

In the selection of municipalities for the present survey, geographical and socioeconomic criteria were used in addition to Paterson's classification. By 1975, there were 56 municipalities in Melbourne so the respective group percentages were: Central - 11%, Inner Ring - 21%, Established - 18%, Growth - 23%, Fringe - 27%. The municipalities included in this survey were: Doncaster and Templestowe, Fitzroy, Footscray, Frankston, Keilor, Kew, Knox, Lillydale, Oakleigh and Preston (see Figure 4.1). In the group selected, there were one central, two inner ring, two established,

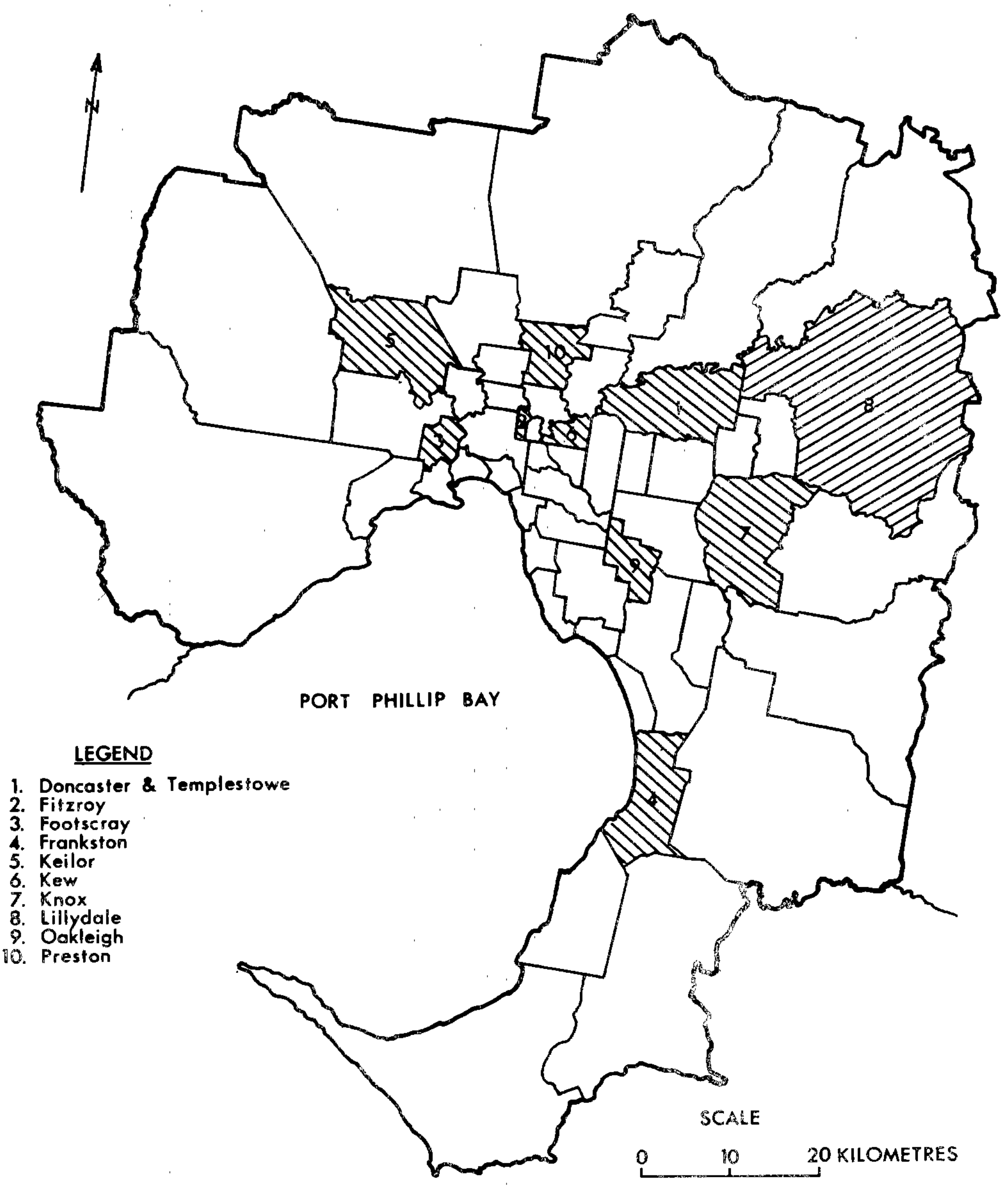


FIGURE 4.1

MUNICIPALITIES SAMPLED IN THE MELBOURNE STATISTICAL DIVISION three growth and two fringe municipalities. These numbers were quite close to their percentage representations in the metropolitan area except that growth municipalities were slightly over-represented and fringe slightly under-represented.

There were two geographical criteria used. One was that there should be a scattering to avoid choosing municipalities which were along the same transport corridor or shared too much of a common boundary. The other was to achieve a rough balance between sectors. Kinnear(1) used a fairly standard division of Melbourne into five sectors: Central (6 municipalities), Western (6), Northern (9), Eastern (15), and Southern (19). The number of Central, Western and Northern municipalities sampled (19%) was in proportion to the overall sampling percentage of 18% (10 of 55 municipalities).

In the Eastern sector, four of 15 municipalities (27%) were sampled, and thus it was over-represented, while in the Southern sector only two of 19 municipalities (11%) were sampled.

The final selection criterion was the socioeconomic status score for each municipality. This score was calculated by Kinnear(1) using the factor coefficients of Humphries(2). The factor coefficients originally were determined at the Census Collectors' District level and subsequently were applied by Kinnear at the LGA level to calculate a socioeconomic status score for each municipality. The scores for all Melbourne LGAs were adjusted to give a population weighted sum of zero.

In order to be representative, the selection of municipalities for the survey was made to give an average score close to zero, using a population weighting of the scores for the municipalities selected. The weighted average for the ten municipalities for

---

(1) Kinnear, R.L., Some Equity Implications of Changing Patterns of Accessibility, Unpublished M. Eng. Sci. Thesis, Monash University, 1975.

(2) Humphries, J., Intra-Urban Migration and Residential Structure Monash Publications in Geography, No. 6, Melbourne.

1971 was only -23, (See Appendix D where the standard deviation of Kinnear's[1] average was 45). With the population and socio-economic scores changing fairly quickly with time, it was desirable to have the net average change of score between 1966 and 1971 close to zero for the ten municipalities, with the expectation that the 1975 weighted average would be close to zero. In fact, the net average change of status weighted by 1971 populations was only -6.

As a check that the municipalities were representative of differences of growth in dwelling numbers between municipalities, the growth rate was calculated by dividing the 1973-74 completions of residential dwellings[2] by the 1971 stock of residential dwellings in each municipality[3]. It would have been slightly more accurate to use the 1973 stock of dwellings, but the 1971 figures were the latest available. The results of the dwelling growth index were plotted in a histogram (Figure 4.2) and this showed that there were three major groupings of municipalities; namely those with dwelling growth rates of greater than ten percent per annum, those with growth rates of between five and ten percent per annum, and those with dwelling growth rates below five percent per annum. The numbers and percentage of municipalities in each group were 6 (11%), 17 (31%), and 32 (58%) respectively. In the actual sample, there was one municipality (Lillydale) in the high growth group, four (Doncaster & Templestowe, Frankston, Keilor, Knox) in the medium growth group, and five (Fitzroy, Footscray, Kew, Oakleigh, Preston) in the low growth group, which were close to the above proportions.

Having chosen the municipalities to be sampled, the next problem was to determine the actual sampling procedure. The sample was to be dwelling (or household) based, since the aim of the survey was to gather information about households. The procedure had to ensure that there was as close as possible to an equal probability

(1) Kinnear, R.L., op. cit.
(2) Australian Bureau of Statistics (1975), Unpublished data.
(3) Commonwealth Bureau of Census and Statistics, Characteristics of the Population and Dwellings, Local Government Areas, Bulletin 7, Part 2, Victoria, CBCS, Canberra, 1973.

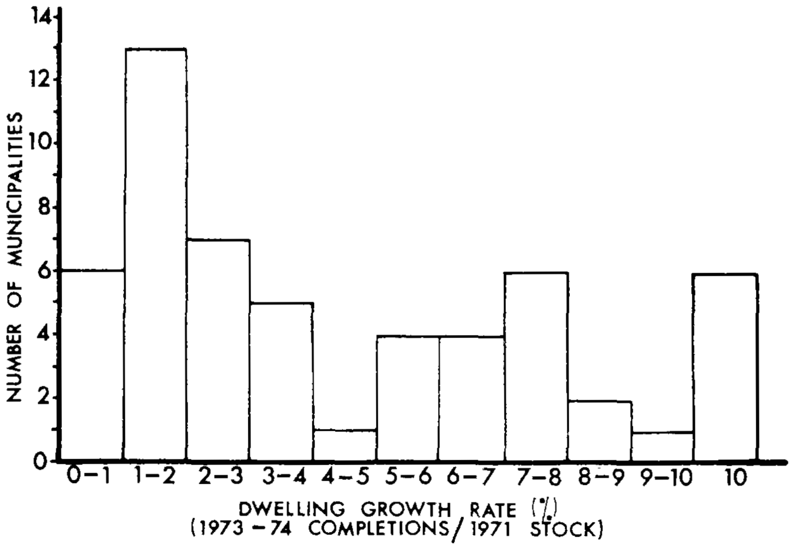


FIGURE 4.2

DIAGRAM OF DWELLING GROWTH RATE (1973 - 74) FOR MUNICIPALITIES OF THE MELBOURNE STATISTICAL DIVISION of selection of each household in the ten LGAs. At the same time, the practical difficulties of sampling 1 000 households over a wide area had to be taken into account. In deciding on the sampling method, much valuable advice was provided by the Australian Bureau of Statistics.

A detailed description of the sampling methodology is given in Appendix E. The basic principle was to sample clusters of 15 households in selected Census Collectors' Districts (CDs) within the municipalities. The total number of CDs to be sampled was thus 67 (1 000/15). The number of CDs to be sampled in each municipality was determined by the proportion of dwellings in a municipality to the total dwellings in the ten selected municipalities. Thus, Doncaster contained 12.1% of the dwellings in the 10 LGAs, so the number to be sampled was 8 CDs (0.121 x 67). The number of CDs sampled ranged from three in Fitzroy, to ten in Preston.

After the Census Collectors' Districts were selected, the actual households had to be chosen (see Appendix E). Briefly, one "block" of the CD, which contained 50 - 100 households, was selected and a suitable "skip" interval was chosen so that the 15 households to be interviewed were scattered throughout that part of the CD. Thus, if the part contained about 75 houses, a skip interval of 5 (i.e. every fifth house sampled) would cover that "block" of the CD. The "block" might, in fact, cover several physical blocks, depending on the density of dwellings and streets in the area.

A letter was delivered at this time to the selected households (Appendix F), and the house number, and often a description of the house was written down for later reference by the interviewer (who usually was not the person who delivered the letter). The process of household selection, delivery of letters and recording took 20-30 minutes per CD.

For reasons of cost, it was decided to use tertiary students for the distribution of letters and interviewing. Consequently, recruiting was done at Melbourne, Monash and La Trobe Universities, Footscray Institute of Technology, and the State College of Victoria, Frankston. The original plan was to recruit about 40 students to conduct an average of 25 interviews each to achieve the goal of 1 000 interviews. However, the actual average was only 14.4 interviews per person with only 11 of the interviewers conducting more than 20. Many students found the work not to their liking, and stopped work after only a few interviews. The interviews were to take place in August and September, 1975. However, as the work stretched into the examination period, the number of students who had time to spare became more limited and it became difficult to recruit students to complete the work.

COMMENTS CONCERNING THE SURVEY

The layout of the forms was satisfactory with the exception of a few details. One omission was made which was not corrected until about 200 interviews had been completed, namely the question of the total number of people in the household. This number was recorded in the later interviews as an entry under question B (no. of vehicles) on the cover sheet.

The other problems with the form concerned the format of several questions. On Form 2 (personal information), the question of Employment Status (G) had an entry for "Other" that should have specifically included students, as this was the status of most of the people in the "Other" group. In question 14 (Gross Income), the range of the lowest group (1) was from $0 to $1 599 per annum (see Appendix B), so that some people with no income were included in group 1. The range should have started at $1 to eliminate this ambiguity. One of the occupational groups for question (I), Occupational Group, was not defined in accordance with census groupings. Under "Craftsman, etc." (group 8), there should have been an example of process workers and labourers so that these workers were not (incorrectly) put in Group 11 (Other). This mistake meant that there were too few workers in group 8 (Craftsmen, etc.) and too many in group 11 (Other).

The coding of Mode of Travel to work or school on Form 2 and Mode of Travel on Form 4 could have been less ambiguous. The question was fairly complicated in that it asked both the mode (car driver, passenger, walk, etc.) and also the number of the vehicle used for vehicle drivers, passengers or car pools. The two digit entry used the first digit for the vehicle number (from Form 3) and the second for the mode in the case of vehicle drivers, passengers or car pools. Thus a person driving car 3 to work would be coded as mode 31 (car 3, mode 1, driver). A less ambiguous way would have been to put the mode first and the vehicle number second so that a driver of car 3 would be coded as using mode 1 (driver), vehicle 3 (or 13). These comments apply also to Form 4 where the same coding system was used.

In Form 3 (Vehicle Information) there were several questions that should have been clearer. Question number 4 (Year of Manufacture) had 1960-1964 as group (2) and 1964-1969 as group (3). Obviously, group (3) should have been 1965-1969 to avoid overlap. Question number 9, Length of Time Owned, should have specified years and months. This was important for checking the relationship among questions 6, 9, 10 and 12 (Present Odometer Reading, Length of Time Owned, Reading at Purchase and Distance per Year). The approximate relationship is Distance per Year times Years Owned equals Present Reading minus Reading at Purchase. This relationship is only approximate, but it was a help in checking the consistency of the various figures. If a vehicle has been owned for say 1 year 6 months, it makes a 100% difference to the check whether it is recorded as having been owned for 1 year or 2 years.

In question 13, (Percent of Distance outside the Metropolitan Area), the distance aspect should have been emphazised, since many people gave responses that seemed too low and possibly represented a percentage of days rather than distance. The yearly distance was frequently more than 500 times the daily distance for a given vehicle. However, the Percentage of Distance outside the Metropolitan Area was often given as only about 10 - 15%. The actual figure would appear to be more like 30 - 40% of yearly distance, though a lesser percentage of days in all probability. Another possibility was that people really do underestimate the percentage of travel outside Melbourne.

In conclusion, there were some problems with the data that could have been avoided by more careful design of the forms. However, these did not present serious difficulties to the analysis of the data.

CHAPTER 5 - EDITING OF DATA AND COMPARISON WITH CENSUS DATA

INTRODUCTION AND DESCRIPTION OF SAMPLE

This chapter describes the preparation of data for analysis, and the comparisons made with census data. The various editing procedures, both manual and computer-based, are listed. This is followed by a description of the programs used to create the final data files for analysis. The results of comparisons made between the data and 1971 Census data for the 10 sampled municipalities are presented.

The original survey design involved sampling 1 005 households in the ten selected municipalities (Table 5.1 refers). The actual number of households sampled was 685 which represented an overall sampling percentage of 68.2%. The final data set consisted of 679 valid questionnaires (or 67.6% of the design number), with a further six questionnaires not usable. The percentage of valid samples varied between 51% and 82% for individual municipalities. Much of the shortfall in sample numbers was due to the lack of personnel to sample particular Census Collectors' Districts (CDs). There were four CDs which were not visited at all, and six which were incompletely covered. The total number of households in this class was 96, which meant that the percentage of completed questionnaires obtained from the 909 households actually visited was 75%, a good sampling rate for this type of survey.

TABLE 5.1 - RESPONSE TO THE SURVEY

	No.	Percent
Households in Sample	679	67.6
Unable to Contact	78	7.8
Refusals	146	14.5
Schedules completed but unusable	6	0.6
Households not visited	96	9.6
Total	1 005	100.0

Of the households visited, 146 (16%) refused to participate, and a further 78 households (9%) could not be contacted, or were impossible to survey because of language difficulties. The refusal rate varied between 4% for Lillydale and 29% for Oakleigh. It was generally higher in the lower socioeconomic status municipalities, except for Fitzroy, in which it was only 9%. This low percentage of refusals was probably due to the work of two particularly able interviewers in this municipality.

MANUAL EDITING OF DATA

The data was checked in two different ways. The first was a manual edit performed with the help of an assistant and the second a machine edit. In the manual procedure, the forms were read through thoroughly to ensure that all information was entered in the correct space. The forms were numbered consecutively above the recording of municipality, so that they all cross referenced later with the data file. The numbers of persons, vehicles and trips were recorded at the top of the relevant form to indicate to the computer how many records of a given type were to follow.

There were several places where information often had been omitted or incorrectly recorded, and had to be added or corrected. For instance, persons who were students (question J) were often entered as "Unemployed" rather than "Other" in question (G), Employment Status, and these entries had to be corrected. Also entries of 19 (not applicable) frequently had to be inserted in questions on "Income", "Occupational Group", and "Main Mode of Travel to Work". As discussed previously the question of "Mode of Travel to Work" was often answered incorrectly, and had to be corrected by reference to information in the vehicle and trip records.

In the vehicle information sheet (Form 3), the numbers of vehicles recorded were compared with the vehicle numbers used in the mode questions (Forms 2 and 4) and any obvious discrepancies corrected. The "Length of Time Owned" was also checked against the year of manufacture to ensure that there were no vehicles which were recorded as having been purchased before they were manufactured. The relationship between the answers to questions (6), "Present Odometer Reading", (9), "Length of Time Owned, (10), "Odometer Reading at Purchase", and (12), "Distance Travelled per Year" was examined. It would be expected that (6) - (10) = (9) x (12). Questionnaires which showed any large discrepancies in this relationship were checked further to discover the reason or reasons for the inequality, and adjustments to an incorrect figure could sometimes be made. The relationships among the answers to questions (12) "Distance Travelled per Year", (13), "Percentage of Travel Outside the Metropolitan Area", (15), "How Often the Vehicle goes Outside the Metropolitan Area", (17), "How Often the Vehicle goes more than 80 km per Day", and (18), "Distance Travelled on a Typical Weekday" were examined. The main check was to determine whether the yearly travel (12) which was not accounted for by the total of the daily distances, given approximately by 300 x (18), was accounted for by the frequency of longer trips recorded. If the extra distance could not be accounted for, then minor adjustments were made to correct inconsistencies.

The trip data were examined for consistency with the data recorded on the preceding forms of the questionnaire. Since the question of "Mode of Travel" was complex, this particular question was checked carefully to make sure, for instance, that the number designating a vehicle recorded as having been used in a trip was not greater than the total number of vehicles in the household. Various other checks were made to ensure that household members were not recorded as having been "stranded" away from home, and that the day's journeys were not incompatible for some reason (time, vehicle used, etc.).

This manual editing process was much more time consuming and exacting than had been anticipated, because there were so many different types of checks to be made for each form, and because the errors detected were so diverse.

MACHINE EDITING OF DATA

After the manual editing process was completed, the data were converted to punched card form. A program, CHECK1, was developed to read through the data and ensure that the first card of each record type (person, vehicle, trip) specified how many records were present. Since there were different numbers of persons, vehicles, and trips for each house, a wrong number resulted in format errors in the reading of the data. Also, format errors resulted if the data were punched in the wrong columns. Thirty runs and considerable hand editing were required before the record length specifications and data positions were all correct.

The program CHECK2 was written to check that certain parts of the data were internally consistent. The data were examined to ensure that only one head of household was recorded, that a "Mode of Travel" was entered for each person going to work or school, that the principal user of each family vehicle was recorded as being licensed, and various other data were consistent. Many errors in the data were discovered by use of this program, and these were then corrected.

The final program written to edit the data was RANGE1. Its function was to ensure that the ranges of possible answers for various questions were not exceeded. The questions examined by the program were as follows:

- Questions B through K for each person on the Personal Information Form (see Appendix A).
- Questions 5, 7, 8, 14, 15, 17 on the Vehicle Information Form.

In addition, there were several checks on the consistency of data; e.g. between vehicle questions (2) and (3), "Make" and "Model", and (5), "Body Type". Many errors in range and consistency of the data were detected by use of this program, and these were corrected.

CREATION OF DATA FILES

The method of analysis involved creating four separate data files for household, vehicle, person and trip based on these different types of records. These were subsequently analysed, using the Statistical Package for the Social Sciences, SPSS[1]. Individual SPSS routines were written to perform analyses of the different files.

In order to create the four data files, four separate programs were necessary. The program PERMRG was used to create the file HHDATA, which was stored on disc. This is a household based file containing all the information from Form 1 (Cover Sheet, see Appendix A), plus a summary of information on other forms. Information such as the number of workers, number of licenced drivers, age of the head, number of autos, total distance per year, and number of trips on the previous weekday is included.

The program MERGE2 was written to create the vehicle file VEHICLEDATA, which was also stored on disc. This file is based on vehicle records, and contains all the information entered in Form 3 (Vehicle Information) as well as socioeconomic information on the usual driver and the household. Data about each trip made by the vehicle on the previous weekday is included for each vehicle.

The person file, PERSONFILE, was created on disc, using the program PERDTA. This file was person based, and contains the information from Form 2 (Personal Information) for each person, plus information on the location of the household. The main use of this file is to make comparisons of socioeconomic characteristics between the sample data and the 1971 census.

---

(1) Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H. Statistical Package for the Social Sciences, 2nd edition, McGraw Hill, inc., New York, 1975.

The fourth disc file, TRIPDATA, was created using the program TRIPMG. This file is vehicle trip based, and in addition to all the data about each trip from Form 4 (Trip Information), it contains household location information and some data on the person and vehicle which made the trip.

SAMPLE VALIDITY

As was mentioned in the previous section, the sampling rate varied over a wide range between municipalities. In order to compare the proportions of various characteristics found in the survey with those calculated from the 1971 census, the data from different municipalities was weighted to give a proportion of households similar to the actual census proportions. To keep the data in whole numbers, it was decided to scale the sample up to 100 000 households. The weights for the different municipalities are shown in Table 5.2, as well as the designed and actual sample numbers of households.

TABLE 5.2 - SAMPLING RATE AND WEIGHTING FACTOR FOR THE 10 SAMPLED MUNICIPALITIES

Municipality	Designed Sample Size	Actual Sample Size	Usable Sample Size	Usable Proportion of designed sample (percent)	Weighting Factor
Doncaster & Templestowe	120	84	84	70	145
Fitzroy	45	31	31	69	149
Footscray	105	64	64	61	169
Frankston	120	75	75	63	164
Keilor	105	62	60	57	170
Kew	60	47	47	78	127
Knox	120	98	98	82	118
Lillydale	90	65	64	71	128
Oakleigh	90	48	46	51	203
Preston	150	111	110	74	135
TOTAL	1 005	685	679	67.6	147 (av.)

The survey was designed so that various characteristics of the sample population and the published census data could be compared. The comparisons were either of proportions of persons or proportions of households in a given category. In the former class, the most fundamental comparison was the age and sex distribution of persons in the weighted sample population and the combined population of the ten municipalities from the 1971 census[(1)] and the Melbourne Statistical Division as a whole. The 1971 census age data was four years out of date compared to the sample, but was adequate for comparison unless there were large differences in numbers between consecutive age groups or there had been differential migration to or from the LGA. In Table 5.3 the proportions of the sample population by age and sex are given for the group of the ten municipalities sampled and the Melbourne Statistical Division (MSD). Confidence intervals of 95% are also shown for the proportions of the sample population. In three of the groups, (males 25-29, females 5-9 and females 65 and over), the census proportion was outside the 95% confidence limits of the sample for both the 10 LGA group and the MSD as a whole. In addition, the MSD census proportion was outside the confidence limits of the sample for males 65 and over and females 25 to 29 years of age.

Another comparison which was made was of the marital status proportions reported for the sample and the census population. In Table 5.4, the proportions of each group ("Now Married", "Never Married", "Other") in the weighted sample are shown, as well as in the group of ten municipalities as a whole and the MSD. Somewhat surprisingly, none of the proportions reported in the census for the ten municipalities of the MSD fell within the 95% confidence limits of the sample, with the "Never Married" class under-represented, and the other two classes over-represented in the sample.

An inspection of the survey data showed some mistakes in recording this question by the interviewers. When the age group 10-17 years

---

(1) Commonwealth Bureau of Census and Statistics, op. cit.

TABLE 5.3 - COMPARISON OF AGE AND SEX DISTRIBUTION FOR THE 10 SAMPLED MUNICIPALITIES AND THE MSD (b)

Age Group	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion 10 LGAs (percent)	Proportion MSD (percent)
MALES				
5-9	5.8	4.8 - 6.8	6.0	5.2
10-19	10.3	9.0 -11.6	10.1	9.9
20-24	5.3	4.3 - 6.3	4.4	4.8
25-29	5.5	4.5 - 6.5	4.4 (a)	4.3 (a)
30-64	22.0	20.2 -23.8	22.1	21.7
65+	2.6	1.9 - 3.3	3.1	3.6 (a)
TOTAL	51.5	49.3 -53.7	50.1	49.5
FEMALES				
5-9	3.8	3.0 - 4.6	5.6 (a)	5.0 (a)
10-19	9.8	8.5 -11.1	9.7	9.5
20-24	4.9	4.0 - 5.8	4.7	5.0
25-29	5.3	4.3 - 6.3	4.5	4.2 (a)
30-64	21.6	19.8 -23.4	20.9	21.3
65+	3.1	2.3 - 3.9	4.5 (a)	5.5 (a)
TOTAL	48.5	46.3 -50.7	49.9	50.5

(a) 1971 census percentage not within confidence limits.
(b) N = 2038.

TABLE 5.4 - COMPARISON OF MARITAL STATUS OF PERSONS[a] IN THE 10 SAMPLED MUNICIPALITIES AND THE MSD[b]

Category	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Inverval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
Now Married	59.0	56.9 - 61.1	54.3	53.0
Never Married	33.7	31.6 - 35.8	40.1	40.3
Other[c]	7.3	6.2 - 8.4	5.6	6.7
TOTAL	100.0		100.0	100.0

(a) 5 years of age and over

(b) N = 2 038

(c) Divorced and Widowed

old was examined for people coded as "Other", (i.e. divorced or widowed), more than 50 cases were discovered. While there may have been a few divorced 17 year olds, the most likely explanation is that these persons should have been coded as "Never Married". This coding error would thus account for the low proportion of "Never Married" persons reported in the sample and the higher than expected proportion of "Others". However, it does not explain the greater than expected percentage of married people in the sample (59%) as compared to the census (54.3%).

The educational status of the sample population was similar to that of the census populations (Table 5.5). The proportion of the 10 LGA census population attending school full time was at the upper end of the 95% confidence band, and the proportion of those not attending an institution was also somewhat higher than in the sample population. Conversely, the proportion of the sample population attending another institution was 7.0% rather than the 4.3% reported in the 10 LGAs. In comparison with the MSD, a higher proportion of the sample population was attending another institution and a lower proportion was not attending. These discrepancies may be due to the broader definition of "attending" used in the sample as compared to the census questionnaire, which was more concerned with people seeking specific qualifications, rather than just attending a higher institution.

A comparison of the employment status of the sample population with the 1971 population (Table 5.6) showed the expected differences. The percent unemployed in the sample was 2.2% rather than 0.7% found in the 1971 census of the 10 LGAs and the 0.8% in the MSD. Given the general increase in the unemployment rate in Victoria in those four years (from 1.2% to 4.3%), the three-fold difference is quite reasonable. The proportions of persons "Employed" in 1971 were within the 95% confidence interval of the sample in the 10 LGAs but the proportion of persons "Not in Work Force" was only within the 99% confidence interval in spite of the increase in unemployment.

TABLE 5.5 - COMPARISON OF EDUCATIONAL STATUS OF PERSONS[a] IN THE 10 SAMPLED MUNICIPALITIES AND THE MSD[b]

Category	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
Attending school full time	23.2	21.4 - 25.0	24.9	23.1
Attending other institutions	7.0	5.9 - 8.1	4.3	4.8
Not attending	69.8	67.8 - 71.8	70.8	72.1
TOTAL	100.0		100.0	100.0

(a) 5 years of age and over
(b) N = 2 038

TABLE 5.6 - COMPARISON OF EMPLOYMENT STATUS OF PERSONS[a] IN THE 10 SAMPLED MUNICIPALITIES AND THE MSD[b]

Category	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
Employed	47.6	45.4 - 49.8	46.4	47.5
Unemployed	2.2	1.6 - 2.8	0.7	0.8
Not in Work Force	50.2	48.0 - 52.4	52.9	51.7
TOTAL	100.0		100.0	100.0

(a) 5 years of age and over
(b) N = 2 038

A more sensitive measure than employment status is the proportion of persons of the population engaged in various occupations. As mentioned in Section 4.4, the definition used for "Craftsman, etc." (group 8) did not include process workers and labourers, so that in order to obtain a category comparable to that of the census classification, group 8 ("Craftsmen, etc.") and 11 ("Other") had to be combined. In addition, the occupations of "Farmer" (group 5) and "Miner" (group 6) were combined, and the "Armed Services" (group 10) was added to "Craftsmen" and "Other" because of the small number in those occupations.

This grouping gave nine occupational categories which are listed in Table 5.7. For four of these groups, the 1971 percentages for the 10 LGAs were within the 95% confidence intervals of the sample, while the proportions of two other groups ("Transport Workers", and "Craftsmen, Armed Services, and Others") were within the 99% confidence intervals. The only categories outside the confidence bands were "Farmers and Miners", "Professionals" and "Unemployed". The weighted sample frequency of "Professionals" was 12.8%, while the 1971 census frequency was 9.6%. The difference in proportions may have been due to the net movement of professionals into such areas as Fitzroy, and Doncaster and Templestowe since the 1971 census.

Closer agreement was observed between the proportions in various occupational categories in the sample and the Melbourne Statistical Division as a whole. In six of the groups, the 1971 MSD proportions were within the 99% confidence intervals. Only the unemployed group was outside the range, and as has been previously explained, this was to be expected.

At the level of the individual municipality, a chi-square test was performed on the age and sex distribution of the sample population. The expected proportions used were the 1971 Census proportions, even though these would have been somewhat different from the expected proportions at the time of the sample because of the ageing of the population, and the differential migration into and

TABLE 5.7 - COMPARISON OF OCCUPATIONAL GROUPS OF PERSONS IN THE WORK FORCE IN THE 10 SAMPLED MUNICIPALITIES AND THE MSD[(a)]

Category	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
Professional	12.8	10.8 - 14.8	9.6[(b)]	11.1
Administrative	7.2	5.6 - 8.8	6.5	7.1
Clerical	15.7	13.5 - 17.9	15.8	17.9
Sales Worker	7.5	5.9 - 9.1	7.8	8.0
Farmer & Miner	0.8	0.3 - 1.3	1.7[(b)]	1.5[(c)]
Transport Worker	3.6	2.5 - 4.7	4.9[(c)]	4.8[(c)]
Service Worker	5.5	4.1 - 6.9	6.4	6.5
Craftsman, Armed Services, Other	42.5	39.5 - 45.5	45.8[(c)]	41.5
Unemployed	4.4	3.2 - 5.6	1.5[(b)]	1.6[(b)]

(a) N = 960
(b) Not within the 99 percent confidence limits of the sample
(c) Within the 99 percent confidence limits of the sample

out of municipalities. The results of the chi-square test are given in Table 5.8. The deviations from the expected distribution in seven of the ten municipalities were not significant at the 5% level. For the other three municipalities, the deviations from expected values were significant at the 1% level. There was no obvious feature, such as growth rate, which distinguished these three municipalities from the others in the sample. Perhaps the 1976 census may show a greater change in composition of the population (due to differential migration) in these three municipalities.

At the household level, there are several sample characteristics which can be compared to the actual population. The most important one for the purposes of this study is the proportion of households having various numbers of vehicles available. This is one characteristic which had clearly changed in the years between the 1971 census and the 1975 sample. Using an Australian Bureau of Statistics publication[1] the number of motor vehicles (excluding motorcycles) per 1 000 population in Victoria can be derived. This had risen from 386.4 in June, 1971, to 449.7, in June, 1975; a rise of 16% in just four years. Unfortunately, there is no way of knowing how the increase in average number of motor vehicles per capita translates to the proportion of households with 0, 1, or 2 or more vehicles.

A comparison of the survey data with the 1971 census data for ten LGAs and for Melbourne, is given in Table 5.9. The sample data showed that 13.2% of the surveyed households had no vehicle available, whereas 19.7% of the households in the census group of ten LGAs were in this class. This apparent 33% reduction in households without a vehicle available is greater than would be expected, even allowing for the growth in the number of vehicles per capita mentioned in the previous paragraph.

---

(1) Australian Bureau of Statistics, Motor Vehicle Registrations for Year Ended 31 December 1975, Canberra, 1976.

TABLE 5.8 - CHI-SQUARE TEST OF THE AGE AND SEX DISTRIBUTIONS OF PERSONS[(a)] IN EACH OF THE 10 SAMPLED MUNICIPALITIES

Municipality	χ^2 obs.	d.f.	χ^2 exp. at P=5%	Probability and Significance
Doncaster & Templestowe	19.3	11	19.7	>5% no
Fitzroy	43.8	9	16.9	<1% yes
Footscray	11.4	11	19.7	>5% no
Frankston	8.8	11	19.7	>5% no
Keilor	28.4	10	18.3	<1% yes
Kew	15.6	10	18.3	>5% no
Knox	30.8	11	19.7	<1% yes
Lillydale	11.7	11	19.7	>5% no
Oakleigh	14.6	10	18.3	>5% no
Preston	8.6	11	19.7	>5% no

(a) 5 years of age and over

The proportion of households with one vehicle available apparently increased from 50.1% to 53.8% between the census and the sample. In addition, the proportion of households with two or more vehicles available apparently increased from 30.2% to 32.9%. However, the 1971 census values for the 10 LGAs were within the 95% confidence intervals of the sample, so the size of these trends must be treated with some caution.

The data on vehicle availability for Melbourne as a whole showed even greater differences from the sample data. The proportion of households with no vehicle available was 174% of that for the survey population, while the proportion of multi-vehicle households was 16% less. While some of this difference was due to the growth of the vehicle population in the four years between samples, there was a real difference in vehicle availability between the ten LGAs and the Melbourne Statistical Division. This is shown by the different proportions of 0, 1, and 2+ vehicle households from the 1971 census (Table 5.9). The proportion of households with no vehicle available was 14% lower and the proportion of multi-vehicle households 9% higher for the 10 LGAs compared to the MSD.

The comparison of proportions of housing type in the sample with those reported for the ten LGAs of the census is given in Table 5.10. Since proportions of housing type change more slowly than do vehicle numbers, comparisons between the sample and the census data are more meaningful. As Table 5.10 shows, the census proportions of semi-detached houses, flats, and other dwellings were within the 95% confidence intervals of the sample. The proportion of separate houses was only within the 99% confidence intervals. It is important that these sample proportions be close to the census proportions, since housing type is related to car ownership and use[(1)].

---

(1) Lerman, S.R. and Ben-Akiva, M., op. cit.

TABLE 5.9 - VEHICLE AVAILABILITY FOR THE 10 SURVEYED MUNICIPALITIES AND THE MELBOURNE STATISTICAL DIVISION

Municipality	No. of Households	Vehicles/ Household from Survey	Vehicles/ Household from 1971 Census	Proportions of Households with specified number of Vehicles/ Household		
				0	1	2+
Doncaster & Templestowe	84	1.62	1.57	1	48	51
Fitzroy	31	0.61	0.52	45	48	7
Footscray	64	0.75	0.83	35	56	9
Frankston	75	1.51	1.29	6	42	52
Keilor	60	1.20	1.25	10	63	27
Kew	47	1.02	1.16	19	60	21
Knox	98	1.58	1.33	2	51	47
Lillydale	64	1.58	1.30	4	48	48
Oakleigh	46	1.13	1.13	9	69	22
Preston	110	1.18	1.05	20	55	25
Weighted Sample of the 10 LGAs	679	1.27	-	13.2	53.8	33.0

1971 Census

10 LGAs			1.17	19.7	50.1	30.2
Melbourne Statistical Division			1.10	23.0	40.4	27.6

(a) This value was calculated by assuming that the 2+ vehicle households had the survey average of 2.21 vehicles per 2+ vehicle household.

TABLE 5.10 - COMPARISON OF HOUSING TYPES IN THE 10 SURVEYED MUNICIPALITIES AND THE MSD[a]

Category	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
Separate House	87.2	84.7 - 89.7	82.4[b]	73.3[c]
Semi-detached House	4.1	2.6 - 5.6	5.3	7.5[c]
Flat	8.3	6.2 - 10.4	10.2	19.0[c]
Other	0.3	0 - 0.7	0.3	0.2

(a) N = 679
(b) Within 99% confidence limits of sample
(c) Not within 99% confidence limits of sample

There were marked differences in the proportion of different housing types between the 10 LGAs and the Melbourne Statistical Division (Table 5.10). The proportion of separate houses was 12% greater for the ten LGAs while all other categories were smaller. Of the other housing categories, the proportion of flats was only 54% as great in the ten LGAs as for the MSD as a whole. As mentioned previously, these housing type differences probably correlate with the differences in auto availability shown in Table 5.9.

The final comparison between the sample and the census data was of the numbers of persons per household. As can be seen in Table 5.11, the census proportion in the 10 LGAs fell within the 95% confidence intervals for the sample in four of the eight cleases, and in one other class, the proportion fell within the 99% interval. The most serious deviation was in the proportion of two persons households, which was 28% higner in the sample than expected from the census. This difference may be partially explained by the change in household size in the years between the census and the sample. The other two groups outside the confidence intervals were households with seven, and eight or more persons, which together represented 5.3% of the census households, but only 1.9% of the sample households.

The proportions of households of various sizes in the sample and the MSD showed the greatest discrepancies in small and large household sizes. The proportion of single person households was only 50% as large in the sample as in the MSD, while the proportion of 7 and 8+ person households was similarly low. In contrast, the proportions of 2, 3 and 4 person households were higher in the sample than in the MSD as a whole.

SUMMARY

From these comparisons it may be concluded that there was reasonably good agreement between the weighted sample and the 10 LGA census data for the age - sex, employment status, and occupational

TABLE 5.11 - COMPARISON OF PERSONS PER HOUSEHOLD IN THE 10 SURVEYED MUNICIPALITIES AND THE MSD[(a)]

No. of Persons/ Household	Weighted Sample		1971 Census Data	
	Proportion (percent)	95 percent Confidence Interval	Proportion of 10 LGAs (percent)	Proportion of MSD (percent)
1	6.7	4.4 - 9.0	9.5[(b)]	13.4[(c)]
2	29.6	25.5 - 33.7	23.1[(c)]	26.0
3	20.6	16.9 - 24.3	18.6	18.2
4	24.0	20.1 - 27.9	22.2	19.3[(b)]
5	11.8	8.9 - 14.7	14.2	12.3
6	5.4	3.4 - 7.4	7.1	6.2
7	1.1	0.2 - 2.0	3.0[(c)]	2.6[(c)]
8+	0.8	0 - 1.6	2.3[(c)]	2.0[(c)]

(a) N = 468
(b) Within 99% confidence limits of sample
(c) Not within 99% confidence limits of sample

distributions. Some deviation was found when the marital status groupings were compared, but this was at least partly due to coding problems. The proportions of housing types and household sizes in the sample also agreed reasonably well with the census data. The household vehicle classes, as expected, showed a shift to fewer zero vehicle households in the four years between the census and the survey. There was a corresponding rise in one and multiple vehicle households in the sample population compared to the census population.

The agreement between the weighted sample and the 1971 census data for the Melbourne Statistical Division as a whole was, as might be expected, not as good as for the 10 LGAs. The greatest differences in proportions were in the housing type and household size comparisons. The vehicle availability distributions also showed discrepancies, especially in the proportion of zero vehicle households. The other demographic comparisons gave reasonable agreement between the sample population and the MSD as a whole.

Thus the weighted sample appears to have been representative of the ten LGAs surveyed, but different from the MSD in certain proportions, particularly single person, zero vehicle and flat dwelling households.

CHAPTER 6 - RESULTS CONCERNING VEHICLE AVAILABILITY, USAGE AND TRIP MAKING

INTRODUCTION

This chapter is concerned with the general findings of the survey. The results are all given in weighted form, i.e. representative of the group of ten municipalities sampled. However, this does not necessarily mean that they are representative of Melbourne, since the characteristics of the sample population are different from the Melbourne Statistical Division in some important features (see Chapter 5).

The terms used in this chapter have been defined in the section dealing with Automobile Availability in Chapter 2. The term "vehicle" (used to mean any motor vehicle except a motorcycle or scooter) is used in this Chapter. The analysis was based on vehicles, rather than on cars, because household mobility is influenced by all vehicles used by the household. However, in the Section: ANNUAL DISTANCE PER YEAR which follows, the term "car" is used since the analysis is concerned with automobiles only. The reason for this is that the yearly travel patterns of other vehicles (vans, utilities, trucks, etc) differ markedly from those of autos, and the observed relationships would be altered by inclusion of these vehicles. The last section of this chapter is concerned with trips made by mechanical means (i.e. not by walking or bicycling) on the previous weekday. In this section, all vehicle trips were included except those made during the course of a day's work by persons driving vehicles other than autos.

VEHICLE AVAILABILITY

The findings of the survey concerning average vehicle availability by LGA were presented in Table 5.9. In addition to weighted data for the group of ten municipalities, 1971 Census data[1] at the LGA

(1) Commonwealth Bureau of Census and Statistics *op. cit.*

level was shown. The weighting of responses was the same as that described in Chapter 5.

A comparison of the number of vehicles per household in the weighted sample and in the census data for the 10 LGAs showed that the value had apparently risen from 1.17 vehicles per household in 1971, to 1.27 vehicles per household in 1975. The proportion of zero vehicle households had fallen from 19.7% to 13.2%, while that of two or more vehicle households had risen from 30.2% in the census to 33.0% in the survey.

There was a wide variation in number of vehicles per household between municipalities, from 0.61 for Fitzroy, to 1.62 for Doncaster and Templestowe, representing a 2.7-fold difference. Four municipalities (Doncaster and Templestowe, Frankston, Knox and Lillydale) had average vehicle availability levels above 1.5 per household. The proportion of zero vehicle households in these areas was conversely, very low, ranging between 1% and 6%. There were two municipalities (Fitzroy and Footscray) with vehicle availability levels of less than one per household. In the low availability areas, the percentage of households without a vehicle was 45% for Fitzroy, and 35% for Footscray. The LGAs in the middle range of vehicle availability levels had percentages of zero vehicle households between 9% and 20%.

The situation was the opposite for the percentage of multi-vehicle households. In the high availability areas, the percentage of multi-vehicle households was in the range of 47% to 52%. The low availability areas had less than 10% multi-vehicle households, while the suburbs in the middle range all had 20 - 30% multi-vehicle households. Thus, the proportions of multi-vehicle households fell into three very discrete bands: less than 10%, 20 - 30%, and around 50%.

There was a general trend in the surveyed municipalities toward increasing numbers of vehicles per household, compared to the 1971 Census data. However, three of the municipalities (Footscray, Keilor and Kew) showed an apparent drop of up to 0.14 vehicles per household. The proportions of two or more vehicle households in the sample and the 1971 Census were, respectively, 9% and 16% for Footscray, 27% and 31% for Keilor, and 21% and 32% for Kew. These differences in multi-vehicle households accounted for most of the variation in the numbers of vehicles per household between the sample and the census values. When the 95% confidence limits were calculated for the proportion of multi-vehicle households in the municipalities sampled, the census value was within the limits in each case. Thus, in the absence of further evidence, the apparent decrease in multi-vehicle availability may be considered to have been due to a statistical artefact and does not necessarily indicate a trend to lower vehicle availability in these three municipalities.

It was interesting to examine the relationship between the vehicle availability levels of the municipalities surveyed, and various socio-economic characteristics of the municipalities. The high vehicle availability municipalities, Doncaster and Templestowe, Frankston, Keilor, Knox and Lillydale, were all situated toward the edge of the metropolitan area (see Figure 4.1). They were all poorly served by public transport and have low levels of local employment opportunities[(1)]. In Table 6.1 are listed some socio-economic characteristics of the municipalities, as well as their vehicle ownership levels. Three of the high availability municipalities (Doncaster and Templestowe, Frankston, and Knox) had the three highest mean numbers of persons per household, but in the other one (Lillydale) this was only average. The average income level in the high availability municipalities tended to be in the top group except for Frankston, where it was somewhat below average. This income effect might reflect the relatively low numbers of workers per household in Frankston. The one characteristic which did seem to be consistently associated with high numbers of vehicles per household was the high number of licensed drivers per household, and the four high availability municipalities had the highest numbers of licensed drivers per household.

(1) Kinnear, R.L. op. cit.

TABLE 6.1 - SELECTED HOUSEHOLD CHARACTERISTICS FOR THE 10 SURVEYED MUNICIPALITIES

Municipality	Vehicles/ Household	Persons/ Household	Average Gross Income/ Household	Workers/ Household	Licensed Drivers/ Household
Doncaster & Templestowe	1.62	3.75	$12 173	1.49	1.93
Fitzroy	0.61	2.90	$10 454	1.48	1.13
Footscray	0.75	3.03	$ 8 768	1.27	0.95
Frankston	1.51	3.63	$10 570	1.25	1.80
Keilor	1.20	2.88	$11 186	1.50	1.48
Kew	1.02	2.64	$10 823	1.21	1.36
Knox	1.58	3.49	$13 178	1.60	1.78
Lillydale	1.58	3.31	$12 871	1.56	1.72
Oakleigh	1.13	3.31	$11 347	1.50	1.43
Preston	1.18	3.43	$10 372	1.44	1.35
Weighted value for the 10 LGAs	1.27	3.31	$11 155	1.42	1.52
No. in Sample	679	468	631	679	679

If a comparison of characteristics was made for the six municipalities with below average vehicle availability, again, no clear pattern was evident. Two of the municipalities with below average vehicle availability (Keilor and Oakleigh) had above average income per household. These same two municipalities had, as might be expected, high numbers of workers per household. Only the number of licensed drivers per household corresponded closely with relative vehicle ownership level.

Another method of analysis involves determination of the amount of variation in vehicle availability which is explained by various socioeconomic variables. The coefficient of determination (r^2) is a measure of the degree of association between variables. A coefficient of 1.0 indicates that all the variation in vehicle availability is explained by a given variable, and a coefficient of 0.0 indicates that none of the variation is explained.

The coefficients of determination for a number of relationships are given in Table 6.2. It can be seen that the only variable which exhibited a satisfactory linear relationship with number of vehicles per household was the number of licensed drivers per household ($r^2 = 0.53$). The other four variables showed a much poorer relationship with number of vehicles per household and, of this group, only the relationship with household income gave a value of r^2 greater than 0.2. Thus, only the number of licensed drivers was highly related to the number of vehicles per household. In spite of the small r^2 values, all the variables showed a significant relationship to vehicle availability as shown by the F values and levels of significance in Table 6.2. When a multiple regression equation was used to predict vehicle availability, the multiple r^2 was only 0.01 better than the r^2 for the equation with licensed drivers alone.

This result for individual household data was similar to that found by examination of data averaged at the LGA level. In that case, also, it was found that the only variable which showed a consistent relationship with average number of vehicles per household was the

TABLE 6.2 - COEFFICIENTS OF DETERMINATION OF SOCIOECONOMIC FACTORS WITH VEHICLE AVAILABILITY AT THE HOUSEHOLD LEVEL

Variable	Coefficient of determination	F	Level of significance
Persons per household	0.13	11.5	<0.01
Workers per household	0.14	25.7	<0.01
Full time workers per household	0.11	57.4	<0.01
Licensed drivers per household	0.53	153	<0.01
Household income	0.23	189	<0.01

average number of licensed drivers per household. Average income showed some relationship to average number of vehicles per household, but there were several exceptions among the surveyed municipalities. The other variables such as number of workers per household exhibited little relationship with number of vehicles per household, and the averages did not behave consistently at the LGA level.

ANNUAL DISTANCE TRAVELLED BY CARS

This section is concerned with yearly distance travelled by cars, excluding other vehicles. Other vehicles were not included in the analysis of distance per year because their use differed from that of cars, as explained earlier in this Chapter.

The data on total car usage were first examined at the LGA level, as was done with the data on vehicle availability. Table 6.3 shows the average annual distance travelled by a household's cars (obtained by summing the yearly distance of all cars a household uses) grouped by LGAs. These results, like those for vehicle availability, indicated that households in the municipalities located toward the outer perimeter of Melbourne (Doncaster and Templestowe, Frankston, Keilor, Knox and Lillydale) had above average household car distances. The table shows that the same municipalities also had higher average numbers of cars per household except for Keilor, which differed from the other outer municipalities in its lower socioeconomic status.

As shown previously,(1) household income strongly influenced average annual household car distance. In the present study, households were divided into four income groups with approximately equal numbers, and the effect of income on annual household car distance was studied. Table 6.4 shows that average annual household car distance increased by almost 100% between the lowest and

---

(1) Lansing, J.B. and Hendricks, G., op. cit.

TABLE 6.3 - DISTRIBUTION OF AVERAGE ANNUAL CAR DISTANCE BY INDIVIDUAL CARS IN THE 10 LGAs

Municipality	Annual Average Distance per Household (All cars) (km) [a]	Average Cars/ Household	Average Distance per Car (km)
Doncaster & Templestowe	21 900	1.50	13 900
Fitzroy	14 900	0.58	14 100
Footscray	15 600	0.69	14 900
Frankston	25 800	1.33	19 000
Keilor	23 300	1.07	18 100
Kew	15 600	0.98	12 400
Knox	21 700	1.35	15 300
Lillydale	28 000	1.39	19 200
Oakleigh	17 900	1.07	14 900
Preston	18 600	1.05	13 900
Weighted value for 10 LGAs	21 100	1.14	15 800
No of cases	562	679	772

(a) Excluding zero car households.

TABLE 6.4 - EFFECT OF INCOME ON AVERAGE ANNUAL DISTANCE BY HOUSEHOLD CARS IN THE 10 LGAs[a]

Household Income Class (Gross)	Average Annual Car Distance per Household (km) [b]
$ 0 - $ 6 850	14 100
$ 6 851 - $10 000	18 700
$10 001 - $14 250	20 300
$14 251 +	27 600
All $11 155 (avg)	21 100

(a) N = 531
(b) Excluding zero car households.

and the highest income groups. Much of this effect was, of course, due to differences in household structure, such as number of workers and number of cars, both of which increased with income. Many of the households in the lowest group have heads who were retired, or who worked only part time.

Average distance travelled by a household was closely related to the number of cars in the household. Distance travelled by a three car household was about 2.5 times as great as that travelled by a single car household. The table shows that the one car in a single car household travelled 16 300 km per year on average, while the 'second' car in a two car household went 88% as far (14 300 km) and the 'third' car in a three car household travelled only 60% as far (9 800 km) as the first. As in the previous table, these figures also reflect differences in family structure, and therefore provide only indications of differences in car use.

Table 6.6 shows the change in average annual household car distance with income for a given number of cars per household. For single car households, there was a 42% increase in total car distance travelled between the lowest and highest income groups. Since two car households were insufficiently represented in the lowest income group, the most useful comparison between one and two car households was of the increase in total annual car distance travelled between the second lowest and the highest income groups, which was 25% for one car households, but much less (14%) for two car households. Thus, even when number of cars per household was held constant, total annual car distance increased with income.

Another way of analyzing the car usage data is to study the factors which influence individual car usage at the LGA level.

At the individual car level, several factors exerted a great influence on average annual distance travelled. Table 6.3 shows that only three municipalities had above average annual distance travelled per car. These three (Frankston, Keilor and Lillydale)

TABLE 6.5 - EFFECT OF NUMBER OF CARS ON AVERAGE ANNUAL DISTANCE BY HOUSEHOLD CARS[(a)]

Cars per Household	Average Annual Car Distances per Household (km)	Distance Increment per Car (km)
1	16 300	16 300
2	30 600	14 300
3	40 400	9 800
All	21 100[(b)]	-

(a) N = 562
(b) Excluding zero car households

TABLE 6.6 - EFFECT OF INCOME ON AVERAGE ANNUAL DISTANCE BY HOUSEHOLD CARS

N	Cars per Household	Household Income Class (Gross)	Average Annual Car Distance per Household (km)
379	(1	$ 0 - $ 6 850	13 900
	(1	$ 6 851 - $10 000	15 800
	(1	$10 001 - $14 250	15 900
	(1	$14 251+	19 800
120	(2	$ 6 851 - $10 000	29 100
	(2	$10 001 - $14 250	29 300
	(2	$14 251+	33 200

were all outer municipalities which also had high total annual distance per household, as discussed above. The two other outer municipalities (Doncaster and Templestowe, Knox) were below average in annual distance travelled per car, and Doncaster and Templestowe actually had the second lowest distance travelled per car. Perhaps its high socioeconomic status, combined with its relative proximity to the city centre, meant that households in this area (Doncaster and Templestowe) could afford more cars, and that these cars were not used so intensively.

As indicated in Table 6.7, the age of the car had a relatively strong effect on the average annual distance. There was some inconsistency in the trend for younger cars, but, generally, the older the car, the shorter the distance per year that it travelled. At the extreme, cars more than 15 years old travelled annually only 32% as far as new cars.

TABLE 6.7 - MEAN ANNUAL DISTANCE PER CAR BY AGE OF CAR[a]

Age in Years	Mean Annual Distance (km)
Current year	20 800
1	19 400
2	21 200
3	15 600
4	16 300
5	17 200
6 - 10	14 000
11 - 15	12 900
> 15	6 400
All	15 800

(a) N = 772.

The variation in average annual distance travelled with main use of the car is shown in Table 6.8. The greatest distance (27 100 km per year) travelled was by cars used for "Employer's Business". Following that class are "Other", with an average annual distance of 23 200 km. The other classes of use were grouped fairly close to the mean, except that the "Shopping, Social" and "Travel to School, University" classes of use were well below average. Among the usage categories, "Travel to Work" and "Shopping, Social" were the largest, with 56% and 22% of the total respectively.

TABLE 6.8 - MEAN ANNUAL DISTANCE PER CAR BY MAIN USE OF CAR[a]

Main Use of Car	Proportion of Weighted Sample (percent)	Mean Annual Distance (km)
Travel to Work	56	16 600
Personal Business	5	16 600
Employer's Business	4	27 100
Travel to School/Uni	3	13 300
Shopping, Social	22	11 500
Recreational	9	17 800
Other	1	23 200
All	100	15 900

(a) N = 765.

The influence of the usual driver's occupation of car distance is examined in Table 6.9. This table shows that the highest average distance (20 700 km per year) was for "Professionals", followed by 19 700 km per year for "Farmer and Miner" (a category, however, with only small sample numbers). The two which follow were "Sales Worker" and "Administrative" workers, whose cars travelled 18 900 and 17 000 km per year respectively. At the low end of the annual distance range were "Unemployed" and "Not Employed" persons, whose cars travelled the lowest distances annually (10 700 and 11 900 km per year respectively).

The age of the usual driver also exerted some influence on average annual car distance (Table 6.10). The highest annual car distance (19 400 km) was travelled by persons 20 - 24 years old, but there may also have been other age groups with high annual distances in the 30 - 64 age group (e.g. 30 - 34) which could not be differentiated with the present data base.

TABLE 6.9 - MEAN ANNUAL DISTANCE PER CAR BY OCCUPATION OF PRINCIPAL DRIVERS[(a)]

Occupational Group	Proportion of Weighted Sample (percent)	Mean Annual Distance (km)
Professional	13	20 700
Administrative	8	17 000
Clerical	11	15 300
Sales Worker	5	18 900
Farmer & Miner	1	19 700[(b)]
Transport Worker	4	14 600
Service Worker	5	15 400
Craftsman, Other	30	16 600
Unemployed	2	10 700[(b)]
Not Employed	21	11 900

(a) N = 763
(b) Less than 20 cases

TABLE 6.10 - MEAN ANNUAL DISTANCE PER CAR BY AGE OF PRINCIPAL DRIVER[(a)]

Age Group	Proportion of Weighted Sample (percent)	Mean Annual Distance (km)
18 - 19	2	16 400[(b)]
20 - 24	14	19 400
25 - 29	16	18 000
30 - 64	63	14 900
65 +	5	11 100
All	100	15 900

(a) N = 759
(b) Less than 20 cases

The figure for average annual distance travelled per auto was somewhat lower than that published for Victoria by the Commonwealth Bureau of Census and Statistics[1]. The published figure was 16 400 km per year, compared to 15 800 km per year obtained in the present survey. This result is surprising at first sight, since annual distance travelled per vehicle would be expected to have increased in the four years between the surveys. However, the 1971 survey represented all cars and station wagons in Victoria, while the present study included only those garaged privately in 10 LGAs in the metropolitan area. Fleet vehicles which were kept at a place of business (e.g. rental cars, service and inspection vehicles) probably travelled a greater annual distance than did privately garaged cars. Also, non-metropolitan vehicles were likely to have travelled further than metropolitan vehicles, just as cars from the outer municipalities travelled a greater distance than those from inner ones. Thus, in the absence of a comparable recent survey, it was not possible to analyze the recent trends in average annual distance per car.

TRIPS PER DAY IN VEHICLES

In this section, the factors influencing trips made by so-called "mechanical" means are examined. As discussed in Chapter 2, there is a wide variety of definitions of the term "trip" in the literature. The most logical definition of a trip for the purposes of comparing trip rates is the "linked trip", in which all trips involving "change mode" as a purpose are linked to give a single trip, thus reducing the total number of trips, because a given journey is counted only once. A work trip involving a walk to a train, train trip and a walk to work would be combined into one "linked trip", rather than being counted as three individual trips.

---

(1) Commonwealth Bureau of Census and Statistics, <u>Survey of Motor Vehicle Usage, Twelve Months Ended 30 September 1971</u> (preliminary). CBCS, Canberra, 1973.

However, if linked trips are to be used, a computer program must be written to create them, or else they must be created manually from individual trips. An alternative used in the present study, was to count only "mechanical" trips, i.e. those made in some public transit vehicle (bus, tram, train) or private vehicle (e.g. car). This exclusion of all walking trips does mean that the household trip rate increases toward the outer suburbs, where more "mechanical" and fewer walking trips are made. On the other hand, since few journeys include trips with more than one "mechanical" mode, the problem of double counting multi-leg journeys was minimised. The present analysis was based on "mechanical" trips, rather than only private vehicle trips in order to give a picture of the factors influencing total trip making by the household. This in turn should give a better appreciation for total transportation requirements of the household, and thus the factors which might affect vehicle use. No analysis was made of the variation in LGA averages of trips per household, since, as was shown in Chapter 2, data averaged by zones have lost most of the between-household variation in trip rates.

Two factors which affected household trip making were household size and the number of vehicles in the household. Since only trips made by persons 5 or more years of age were recorded in the survey, the discussion of the number of persons per household will be restricted to such persons. Figure 6.1 and Table 6.11 show the effect of persons and vehicles jointly on household trip making. When the relationship between household size and number of trips per person for all vehicle classes was examined, it was found that the factor "trips per person" was greatest for one- and two-person households and then decreased as the size of household increased, particularly for households of over four persons.

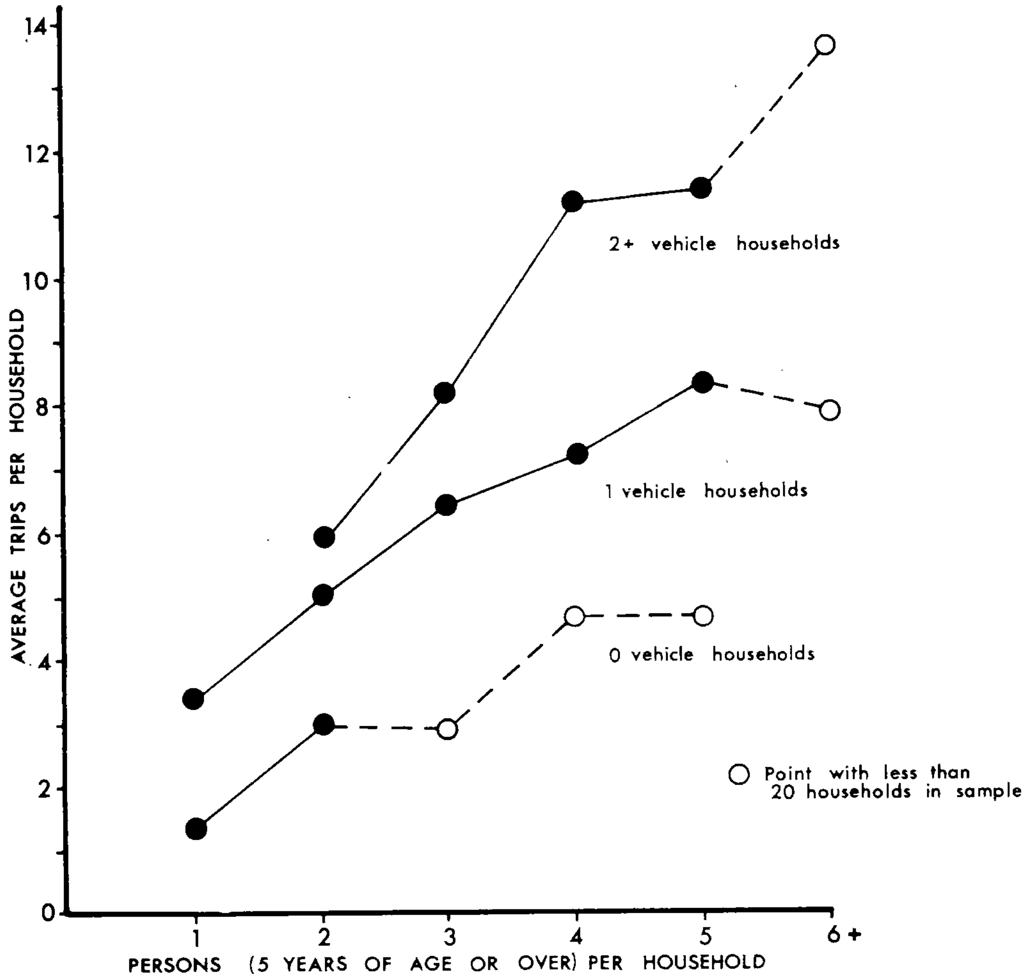


FIGURE 6.1

VARIATION IN AVERAGE TRIPS PER HOUSEHOLD WITH HOUSEHOLD SIZE AND VEHICLE AVAILABILITY

TABLE 6.11 - MEAN TRIP RATES FOR HOUSEHOLDS WITH DIFFERENT NUMBERS OF PERSONS AND VEHICLES[(a)]

Persons, 5 yrs and older, per household	Vehicles/Household			All Households	
	0	1	2+	Trips/ Household	Trips/ person
1	1.38	3.37	-	2.35	2.35
2	2.97	5.04	5.89	4.93	2.47
3	2.90[(b)]	6.44	8.13	6.72	2.24
4	4.70[(b)]	7.22	11.17	8.96	2.24
5	4.67[(b)]	8.31	11.31	9.70	1.96
6+	-	7.92[(b)]	13.54[(b)]	10.63	1.73
All	2.76	5.89	9.27	6.57	2.20

(a) N = 663
(b) Less than 20 households in sample

For a given number of vehicles, the total number of household trips increased in all vehicle classes as the size of the household increased. However, there appeared to be little increase in trips per household when household size was increased from 4 to 5 persons in a given vehicle class. For each household size, the average number of trips increased as the vehicle availability increased from zero to two or more, probably reflecting the substitution of vehicle trips for walking trips to some extent.

Figure 6.2 and Table 6.12 show the effect of income on mechanical trip making for different household sizes. Within each income class, there was a consistent rise in the number of trips per household as the size of the household increased, except for one category with insufficient data. There was also a quite consistent increase in trips per household with increase in income, though the differences between the two highest income groups were small.

TABLE 6.12 - MEAN TRIP RATES FOR HOUSEHOLDS WITH DIFFERENT NUMBERS OF PERSONS AND DIFFERENT INCOMES [(a)]

Persons, 5 yrs and older, per Household	Gross Household Income ($)				
	0-6 850	6 851-10 000	10 000-14 250	14 251+	All
1	1.99	4.20 [(b)]	3.10 [(b)]	-	2.52
2	3.26	4.77	5.61	6.65	4.96
3	4.13	6.01	7.73	8.17	6.75
4	5.78 [(b)]	7.82	8.98	10.03	8.83
5+	6.25 [(b)]	7.23 [(b)]	9.18	12.48	9.98
All	3.45	5.92	7.05	9.13	6.56

(a) N = 622
(b) Less than 20 households in sample

CONCLUSION

The survey data were examined to identify the factors influencing vehicle availability, auto use and "mechanical" trip making. At the level of individual households and LGA averages, vehicle

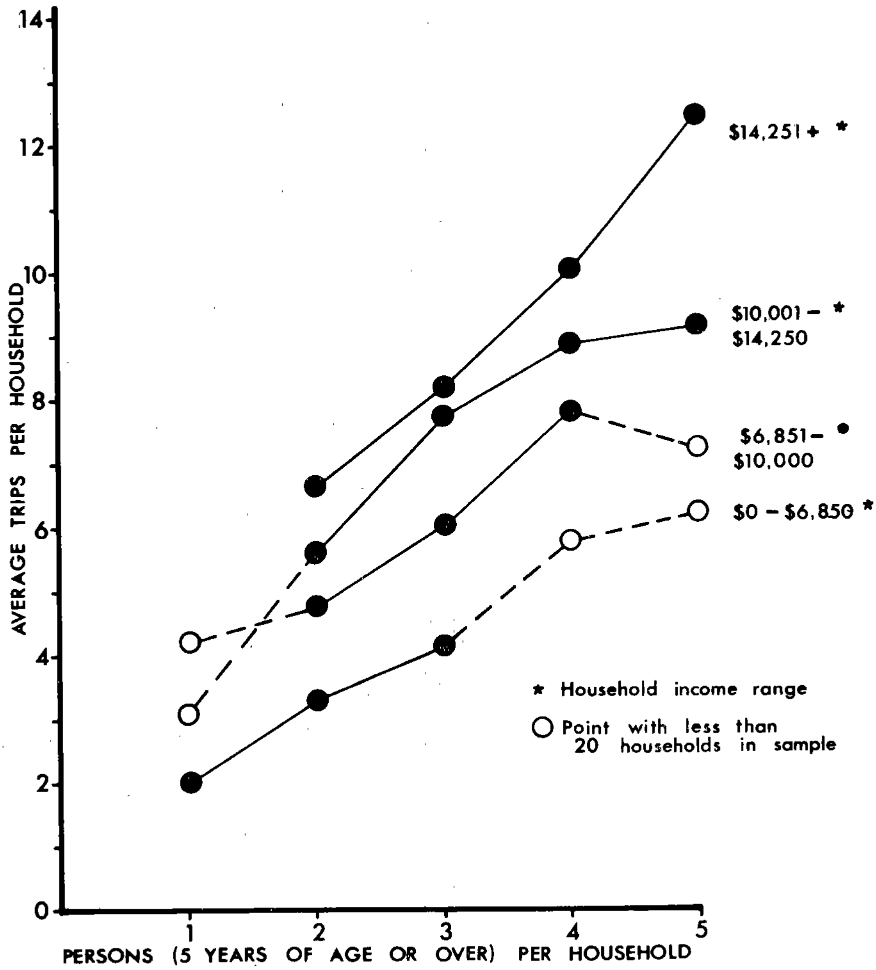


FIGURE 6.2

VARIATION IN AVERAGE TRIPS PER HOUSEHOLD WITH HOUSEHOLD SIZE AT FOUR INCOME LEVELS availability was most strongly associated with number of licensed drivers. Vehicle availability was also related to income, but the relationship was not as strong as that with numbers of licensed drivers. The location of the household also affected vehicle availability; average availability was high in all the municipalities toward the perimeter of the metropolitan area.

The use of cars by households was also influenced by income and location of the household. The average annual distance travelled by all cars in a household increased with number of cars, and increased also with income, even when the number of cars was held constant. There was a decrease in the yearly distance travelled per car as more cars were available to a household.

Average individual car travel was affected by characteristics of the car and its use. The average annual distance travelled was found to decrease with increasing age of the vehicle. The main use of the car had a major effect on annual distance travelled; for instance, cars used for employers' business travelled an annual distance of 27 100 km, while cars used mainly for shopping and social purposes travelled an annual distance of only 11 500 km. The occupation and age of the principal driver also influenced the distance travelled. Cars used by professionals, farmers and miners, sales workers and administrative workers travelled the greatest average annual distance. The age of the driver also influenced the annual total distance travelled by a car; cars with drivers in the 20 - 24 age bracket had the greatest annual distance of all age groups.

Household trip rates were found to increase fairly consistently with household size for a given car ownership or income class. However, the number of trips per person decreased with household size, particularly for households having more than four persons.

CHAPTER 7 - THE POTENTIAL MARKET FOR ELECTRIC CARS

INTRODUCTION

In this chapter, the survey results are discussed in relation to the potential market for electric cars. Several parameters relevant to electric vehicle substitution were examined, beginning with the daily distance travelled. The distribution of these parameters in the total car population was then analysed. Finally, a set of parameters was developed in order to define a car which could be replaced by an electric car (termed a "potential electric car - PEC"). These parameters were then used to segregate potential electric cars from the total population of cars, to enable their usage characteristics to be analysed.

SIGNIFICANT PARAMETERS FOR ELECTRIC CAR SUBSTITUTION

As discussed in Chapter 3, the parameter which most restricts the potential market for electric cars is their limited range. This limitation determines several other characteristics of car use in households which might potentially purchase electric cars.

Modern cars, with their effectively unlimited range, provide a very flexible form of transport. For instance, a car which is used primarily for driving short distances within the city could at any time be used for a longer weekend or holiday trip outside the metropolitan area, or even interstate. Given that travel reservations are not necessary, that no planned schedule need be followed, and that fuel is readily available throughout the country, a person or family may set out for a long car journey with little preparation. Of course, this sort of trip may not be a very common use of a car, but it illustrates the flexibility of the petrol-powered motor car.

In a single-car household, a limited range vehicle could impose severe limitations on spontaneous trip making, or indeed on any extended trips within, or outside of the metropolitan area. For this reason, the electric car may not yet be practical for households which have only one car, except for those which rarely or never make extended journeys by car. There may be some single car households which own a second vehicle (e.g. a van) which is used for non-urban travel, but these households would be a small minority of the single car households at present. Thus, an initial market for limited range electric cars may be assumed to be confined to households with at least two cars available for use. In the 10 surveyed municipalities, 25.3% of the households had more than one car available.

For a conventional car to be replaced by an electric car, it should be an urban car, that is, confined essentially to an urban area. Such an urban car would be required never to exceed the range of a typical electric car (assumed in Chapter 3 to be 80 km per day).

If an electric car was used to the limit of its assumed range (80 km) on each weekday for a year, it would travel approximately 20 000 km per annum. However, the nature of urban travel is such that most drivers would not travel a constant distance every day, let alone travel exactly 80 km per day. Thus some proportion of the potential annual distance of a PEC can never be realised.

In order to allow for a spread of average daily distance travelled by urban cars, a mean distance of 40 km per usual weekday has been arbitrarily selected as a starting point for calculation of the proportion of PECs. Assuming little weekend travel, daily travel of 40 km for approximately 250 days per annum is equivalent to 10 000 km per annum. As an alternative to this assumption, weekday travel of 50 km and annual travel of 12 500 km have also been considered.

Other parameters which may be used to determine whether a car could be replaced by an electric car relate to the amount and frequency of travel for longer distances. The first of these parameters is the annual frequency with which daily trips greater than 80 km are made, since this distance would exceed the projected range (without recharging) of an electric car. The other characteristics are the frequency of travel outside the metropolitan area and the proportion of travel outside the metropolitan area. The latter two parameters of auto use depend to some extent on the location of the household which uses the car. Households in municipalities on the fringe of Melbourne (e.g. Lillydale) are very close to the border of the metropolitan area (Appendix C), and cars owned by such households could therefore reach destinations outside the metropolitan area by making relatively short trips, whereas this would not be possible for cars travelling from an inner city municipality like Fitzroy. Although the latter two of these three characteristics are influenced by location, they all give an indication of the proportion of travel for which an electric car would not be suited.

DISTRIBUTION OF SIGNIFICANT PARAMETERS IN THE SURVEYED CAR POPULATION

The results of the survey presented in this and subsequent sections were all derived from data weighted as in Chapter 5. The purpose of using this weighting factor was to scale up the household data differentially according to municipality in order to make it representative of the ten surveyed municipalities.

As has been previously discussed, the most significant parameter for the identification of potential electric cars was the distance travelled on an average weekday. The survey results for the usual distance travelled per day are shown in Figure 7.1 and Table 7.1. It can be seen that on a typical weekday, 69% of the cars travelled 40 km or less on a typical week day while 93% travelled 80 km or less. Thus, the usual daily distance travelled for 69% of the cars in the ten LGAs was well within the projected capability of electric cars.

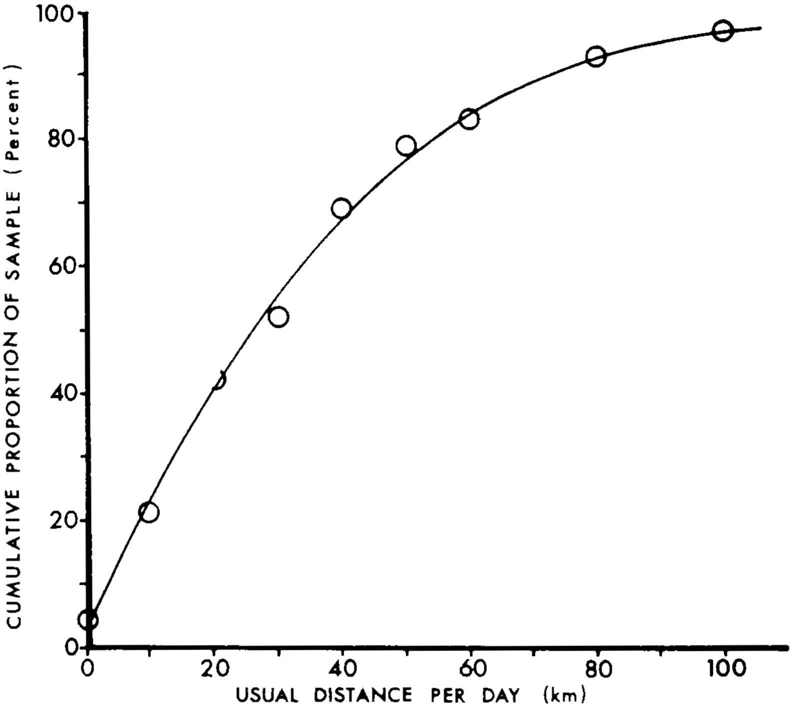


FIGURE 7.1

DISTANCE PER DAY FOR SAMPLE AUTOS (WEIGHTED)

TABLE 7.1 - DISTRIBUTION OF USUAL DISTANCE PER WEEKDAY FOR WEIGHTED SAMPLE OF AUTOS[a]

Usual Distance per Weekday (km)	Proportion of Sample (percent)	Cumulative Proportion of Sample (percent)
0	4	4
1 - 10	17	21
11 - 20	21	42
21 - 30	10	52
31 - 40	17	69
41 - 50	10	79
51 - 60	4	83
61 - 80	10	93
81 -100	4	97
101+	3	100

(a) N = 783.

The distance per year criterion restricts much more severely the percentage of cars which could be replaced by electric cars. As Figure 7.2 shows, only 32% of the surveyed cars travelled less than 10 000 km per year, a distance which relates to the 40 km of assumed average weekday travel. If the possible annual distance could be increased by future technical advances, the proportion of cars included in this category would accordingly be greater; for instance, Table 7.2 shows that 47% of cars would be included if the annual distance travelled could be increased to 15 000 km. Almost 80% of cars were found to travel 20 000 km or less per year, and 90% travelled 25 000 km or less per year. The difference in the proportions of vehicles in corresponding categories in Tables 7.1 and 7.2 (with 40 km per day corresponding to 10 000 km per year) can be explained by the fact that weekend and holiday travel have not been included in the usual weekday distance travelled.

TABLE 7.2 - DISTRIBUTION OF DISTANCE PER YEAR FOR WEIGHTED SAMPLE OF AUTOS[(a)]

Distance per Year (km)	Proportion of Sample (percent)	Cumulative Proportion of Sample (percent)
0 - 5 000	11	11
5 001 - 10 000	21	32
10 001 - 15 000	15	47
15 001 - 20 000	31	78
20 001 - 25 000	12	90
25 001 - 30 000	3	93
30 001 - 40 000	5	98
40 001 - 50 000	1	99
50 001+	1	100

(a) N = 772.

Strictly speaking, a car to be replaced by an electric car must never travel more than 80 km on any single day without midday recharging, since this distance exceeds the range of its electric

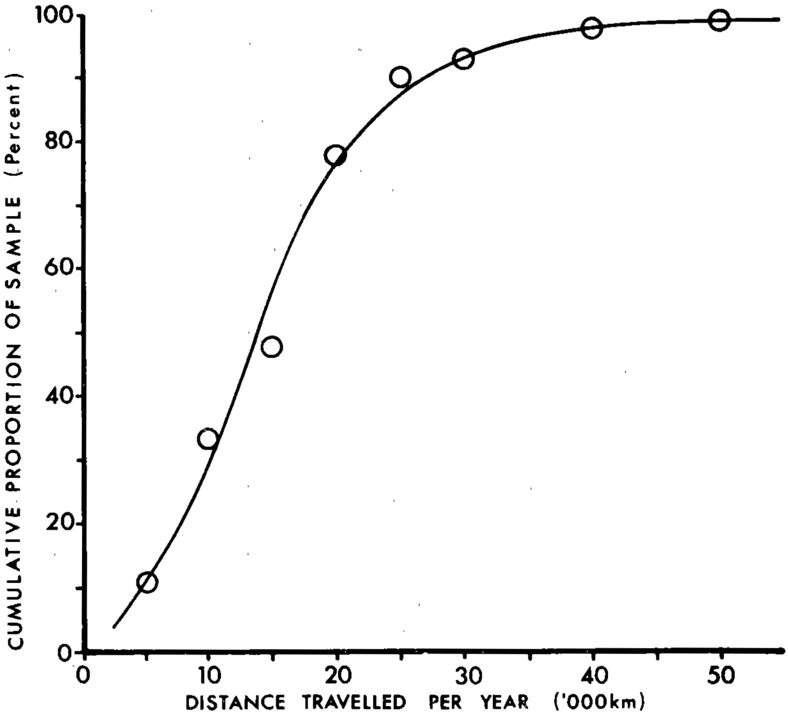


FIGURE 7.2
DISTANCE PER YEAR FOR SAMPLE AUTOS (WEIGHTED)

energy powered replacement. However, a limited range car may be practicable if some rearrangement of individual car use in a multi-car household is made. A frequency of 3 - 11 times a year for travel outside the range of an electric car was therefore chosen as the acceptable limit. Table 7.3 shows the distribution of the frequencies with which autos were reported to travel more than 80 km per day. From this table it can be seen that 40% of the cars made fewer than 12 of these longer trips per year. Thus, fewer autos were excluded on this criterion than on the the criterion of annual distance travelled, indicating the influence of a few long trips on annual distance travelled.

TABLE 7.3 - DISTRIBUTION OF FREQUENCY OF TRAVEL OF MORE THAN 80 KM PER DAY FOR WEIGHTED SAMPLE OF AUTOS[a]

Frequency per year of Travelling 80 km/day	Proportion of Sample (percent)	Cumulative Proportion of Sample (percent)
Never	11	11
1 - 2 Times/year	10	21
3 -11 Times/year	19	40
1 - 3 Times/month	26	66
1 - 4 Times/week	24	90
5 - 7 Times/week	10	100

(a) N = 785.

The final parameters examined were the frequency with which a car was driven outside the metropolitan area, and the percentage of total distance travelled outside the metropolitan area. The distribution of these two variables is given in Tables 7.4 and 7.5 respectively. As was mentioned in the previous section, the amount of travel outside the metropolitan area is influenced by the proximity of the household which uses a car to the boundaries of the metropolitan area. This factor makes the answers to this question more difficult to interpret than the data discussed previously in this section. Nevertheless, the results helped to identify cars which were suitable for replacement by electric

TABLE 7.4 - DISTRIBUTION OF FREQUENCY OF TRAVEL OUTSIDE THE METROPOLITAN AREA FOR WEIGHTED SAMPLE OF AUTOS[a]

Frequency of Travel Outside Met. Area	Proportion of Sample (percent)	Cumulative Proportion of Sample (percent)
Never	18	18
1 - 2 Times/year	13	31
3 - 11 Times/year	27	58
1 - 3 Times/month	27	85
1 - 4 Times/week	13	98
5 - 7 Times/week	2	100

(a) N = 785.

TABLE 7.5 - DISTRIBUTION OF PROPORTION OF TRAVEL OUTSIDE THE METROPOLITAN AREA FOR WEIGHTED SAMPLE OF AUTOS[a]

Proportion of Travel Outside Met. Area (percent)	Proportion of Sample (percent)	Cumulative Proportion of Sample (percent)
0	17	17
1 - 5	22	39
6 - 10	18	57
11 - 20	11	68
21 - 30	10	78
31 - 40	4	82
41 - 50	8	90
51 - 75	6	96
76+	4	100

(a) N = 783.

vehicles. Table 7.4 shows that 58% of the cars travelled outside the metropolitan area 11 times per year or less. A similar proportion (57%) of cars, travelled 10% or less of their annual distance outside the metropolitan area (Table 7.5). Thus, these two parameters each place only moderate restrictions on the potential market for electric cars.

Of the usage characteristics examined, the limitation on annual distance travelled restricted the market for electric cars most severely. Only 32% of cars surveyed travelled 10 000 or fewer km per year. The other parameters imposed less stringent restrictions on the potential market, with 40% of cars travelling seldom (11 or fewer times per year) more than 80 km per day. A large proportion (69%) of the cars were within the usual daily distance capabilities (40 km), while over half (57%) of the cars obeyed the non metropolitan travel restrictions imposed by use of electric cars.

DEVELOPMENT AND APPLICATION OF A SET OF PARAMETERS FOR IDENTIFICATION OF POTENTIAL ELECTRIC CARS

Although the individual parameters are useful for evaluating the potential market share for electric cars, no single one of them gives a full description of the usage of an individual car. For this reason, the first three usage characteristics discussed above (Tables 7.1, 7.2, 7.3) have been given various values in order to show the resultant variation in the proportion of Potential Electric Cars (PECs). This variation is shown in Table 7.6. Four major sets of alternatives were considered, for each of which the proportion of PECs in the weighted sample was calculated.

Alternative A covered single and multi-car households, with no travel over 80 km per day permitted. The usual weekday distance was varied from 40 to 50 km, while annual distance was varied from 10 000 to 12 500 km. Alternative B combined two criteria together. Vehicles from single car households which never travelled over 80 km/day were combined with vehicles from multi-car households which travelled more than 80 km/day on less than 12 occasions per year. The effect of this was to retain the restriction of no weekday travel over 80 km for single car households, but allowed for some rearrangement of vehicle usage in multi-car households.

Alternative C restricted the assessment to multi-car households only, and compared the rigid 80 km per weekday limit with limited travel over this limit. Alternative D further restricted Alternative C by only selecting one PEC from each multi-car household.

Table 7.6 shows that a wide range of proportions of PECs was obtained with the various alternative assumptions. The lower limit was around 6% of autos in the weighted sample for a number of alternatives, while the upper limit was 17%. Because of the large number of alternatives available, Alternative C.2 was selected for further analysis. This alternative represented the lower level of weekday and annual travel, allowed for some rearrangement of vehicle usage within multi-car households, and did not limit the number of PECs per household. As stated earlier in this Chapter, Alternative C was assumed to be an appropriate scenario for the initial stages of the marketing of electric cars.

Alternative C.2 indicates that 13% of the autos in the weighted sample would be potential electric cars. Thus only 41% of the 32% of the vehicles which travelled 10 000 km per year or less fulfilled the other conditions required of potential electric cars. Table 7.6 indicates that the majority of PECs came from multi-car households.

From a marketing point of view, the assumption should be tested that only one potential electric car would be replaced by an electric car, in an initial phase. Alternative D.2 indicates that the proportion of PECs would fall to 11% from the 13% of Alternative C.2 in such a case.

TABLE 7.6 - PROPORTIONS OF POTENTIAL ELECTRIC CARS (PECs) DERIVED FROM ALTERNATIVE ASSUMPTIONS OF USAGE

Alternative No:	Household type (No of cars/ household)	Usual Daily Distance (km)	Annual Distance ('000 km)	Frequency/Year of travel over 80 km/day	Proportion of PECs (percent)
A.1	Single and multi	40	10.0	Never	8.0
A.2	Single and multi	50	12.5	Never	8.6
B.1	(Single	40	10.0	Never)	15.4
	(and multi	40	10.0	Less than 12)	
B.2	(Single	50	12.5	Never)	17.2
	(and multi	50	12.5	Less than 12)	
C.1	Multi only	40	10.0	Never	6.0
C.2	Multi only	40	10.0	Less than 12	13.4
C.3	Multi only	50	12.5	Never	6.5
C.4	Multi only	50	12.5	Less than 12	15.1
D.1	Multi only (1 PEC per household)	40	10.0	Never	5.5
D.2	Multi only (1 PEC per household)	40	10.0	Less than 12	11.3
D.3	Multi only (1 PEC per household)	50	12.5	Never	6.0
D.4	Multi only (1 PEC per household)	50	12.5	Less than 12	12.8

NOTE: In Alternative B, separate criteria are used for single and multi-car households. See text.

: In Alternatives A, B and C, there was no limit to the number of PECs per multi-car household.

One important check on the usefulness of the joint selection criteria for identifying potential electric cars is the percentage of these cars which were reported in the trip records to have travelled further than 40 km, and also further than 80 km on the previous weekday. The results showed that on the previous weekday only 9% of the potential electric cars travelled further than 40 km and only 1% travelled further than 80 km (the range of an electric car). These results indicated that there was a fairly good relationship between the usual and actual distances reported, and that the joint screening criteria were useful in identifying potential electric cars.

CHARACTERISTICS OF POTENTIAL ELECTRIC CARS

Other important questions which can be answered using the joint criteria concern the age and value of the potential electric cars. Since an electric car would compare in size to a small auto, it is useful to check the proportion of the potential electric cars which are of this size. A small car is defined as being less than 4 200 mm in length and 1 600 mm in width. The proportion of small cars among the potential electric cars was 26%, which was over 50% greater than their proportion (16%) in the sample car population (See Table 7.7). In these calculations, only sedans were included in the small car category, as the proportion of small station wagons was very low (1.6% of all station wagons).

TABLE 7.7 - SIZE DISTRIBUTION OF POTENTIAL ELECTRIC CARS (PECs) AND ALL SAMPLE AUTOS (WEIGHTED)

Size category	PEC fleet [a] (percent)	All Autos [b] (percent)
Small sedans	26	16
Other sedans	60	66
Station wagons	14	18
TOTAL	100	100

(a) N selected in accordance with Criterion C.2 (Table 7.6 refers).
(b) N = 784

These findings do not necessarily eliminate larger cars from consideration for replacement by electric cars, since owners of the larger cars might be induced by some of the other advantages of electric cars to drive a smaller car. However, a person who already drives a car of roughly comparable size would be a more likely customer for an electric car, since he would be sacrificing little in carrying capacity.

Other important parameters of potential electric cars are their value, age and ownership. The data on value of cars (as given by their owners in late 1975) show that 87% of the potential electric cars were worth less than $2 000. In contrast, only 58% of cars from the whole sample were valued at less than $2 000. The age distribution data (Table 7.8) show that 81% of the potential electric cars were more than five years old, while only 50% of the total car population were above this age. Potential electric cars also differed slightly in the proportion which were owned by the household rather than by others, (a company, a government body, etc.) in that all but 3% of potential electric cars were owned by the household, whereas 7% of the total car population were owned by others (Company, Government, etc). These results indicated that cars which were used as short range urban vehicles were mostly older, less valuable cars, and were somewhat more likely to be owned by the household.

TABLE 7.8 - AGE DISTRIBUTION OF POTENTIAL ELECTRIC CARS (PECs) AND ALL SAMPLE AUTOS (WEIGHTED)

Age (years)	PEC fleet[a] (percent)	(cum. percent)	All Autos[b] (percent)	(cum. percent)
>15	9	9	4	4
11-15	29	38	14	18
6-10	43	81	32	50
1-5	17	98	44	94
Current	2	100	6	100
TOTAL	100	-	100	-

(a) N selected in accordance with Criterion C.2 (Table 7.6 refers).
(b) N = 784

PRESENT USAGE AND USERS OF POTENTIAL ELECTRIC CARS

Vehicles selected as potential electric cars were examined for the purpose for which they were used, and the number of days per week on which they were idle. Table 7.9 shows the distribution of the main use of these cars and of all cars in the sample. The most frequent use (42%) of these potential electric cars was for shopping and social purposes, and this was over double the percentage (22%) for the use of cars for these purposes in the sample population. Travel to work was almost as frequent a purpose, making up 39% of the total; this compared to 56% of the sample population. A suprisingly frequent (10%) use of potential electric cars was for recreation, about the same proportion as for the sample population. Since the joint criteria eliminated cars which frequently travelled more than 80 km per day, it was difficult to account for this high percentage unless the recreation was a relatively short distance from home (e.g. metropolitan beaches, parks or sporting facilities).

TABLE 7.9 - MAIN USE OF POTENTIAL ELECTRIC CARS (PECs) AND ALL SAMPLE AUTOS (WEIGHTED)

Main Use of Auto	PEC Fleet[a] (percent)	All Autos[b] (percent)
Travel to Work	39	56
Personal Business	3	5
Employer's Business	0	4
Travel to School/Uni	5	3
Shopping, Social	42	22
Recreational	10	9
Other	1	1
TOTAL	100	100

(a) N selected in accordance with Criterion C.2 (Table 7.6 refers).
(b) N = 783

The number of days per week on which potential electric cars were idle reflected a somewhat less intensive use of these vehicles. The data show that 34% of the potential electric cars were idle for three or more days per week, while only about half as many (18%) vehicles in the total car population were idle for this much of the time.

The market for electric cars may be further evaluated by examining the characteristics of the usual drivers of potential electric cars. Table 7.10 shows the distribution of occupations (using the categories grouped as in Chapter 5) among the usual drivers of potential electric cars, and among drivers of all cars sampled. The most numerous occupational group among potential electric car drivers was "Not Employed", a category which would consist mostly of housewives, as well as students and retired/invalid people. It represented 39% of the drivers of these cars, but only 21% of the total population of usual drivers. The next most numerous group was that of "Craftsmen etc. and Others", which represented 17% of the drivers of these cars, but 30% of the total usual drivers.

As might have been expected from the large percentage of "Not Employed" persons, it was found that 68% of the usual drivers of potential electric cars were females, more than double their representation (32%) among total usual drivers. Thus, the largest group of drivers of potential electric cars were women who were housewives, while the remainder of the usual drivers were fairly representative of other occupational groups, except that "Craftsmen etc. and Other" were under-represented.

CONCLUSION

A set of criteria has been developed for defining cars whose usage patterns make them suitable for replacement by electric cars. A number of alternative sets of assumptions were examined. The broadest criteria selected, from both single and multi-car households, vehicles which usually travelled no more than 50 km on a weekday and 12 500 km per year. Cars from single car

TABLE 7.10 - DISTRIBUTIONS OF OCCUPATIONS OF USUAL DRIVERS OF POTENTIAL ELECTRIC CARS (PECs) AND ALL SAMPLE AUTOS (WEIGHTED)

Occupational Group	Proportion of PEC Drivers[(a)] (percent)	Proportion of All Drivers[(b)] (percent)
Professional	10	13
Administrative	5	8
Clerical	12	11
Sales Worker	7	5
Farmer & Miner	2	1
Transport Worker	3	4
Service Worker	3	5
Craftsman, Armed Services, Other	17	30
Unemployed	2	2
Not Employed	39	21
TOTAL	100	100

(a) N selected in accordance with Criterion C.2 (Table 7.6 refers).
(b) N = 782

households were not permitted to travel over 80 km on a weekday, while cars from multi-car households were allowed to travel over 80 km on a weekday on less than 12 occasions per year. The narrowest set of criteria, selected from suitable multi-car households, only one potential electric car which usually travelled no more than 40 km on a weekday and 10 000 km per year, and which never travelled over 80 km on a weekday. These criteria provided a range of proportions of PECs from 6% to 17% of the car population.

An initial market for PECs has been assumed within the above range. The relevant criteria selected vehicles from multi-car households, used the lower daily and annual distances travelled (40 and 10 000 km) and allowed for less than 12 trips per year of over 80 km per day. This "moderate" set of assumptions results in 13% of cars becoming potential electric cars. If only 1 PEC was selected from each multi-car household, the proportion of PECs would reduce to 11%.

In terms of the vehicles actually sampled, PECs tended to be older, less valuable and smaller cars than the parent population. The potential electric cars were driven mostly by women (68%) and were used principally by the not-employed occupational group (39%). They were mainly used for shopping and social purposes (42%) and travel to work (39%).

CHAPTER 8 - CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

OVERALL CONCLUSIONS

The aim of this study was to explore the potential market for electric cars. The range of characteristics of individual auto ownership and use among 679 households in ten municipalities was defined by means of a household interview survey. The average number of cars available per household was found to be 1.14, and the average annual distance travelled per car was 15 800 km.

The effects of household income, location and household on the above variables were investigated. Income was found to be a major factor in determining the number of cars in a household, and the use made of these cars. Location of the household was also important; households in municipalities toward the edge of the city had the highest levels of vehicle availability, and cars in these households tended to travel higher annual distances. The number of vehicles was most closely related to the number of licenced drivers in the household. The average number of trips made in vehicles by members of a household was related to the number of persons, number of vehicles, and the household income.

A review of the literature on electric cars showed that there are no really satisfactory vehicles available at present. Even when a well designed production vehicle becomes available which uses present battery and control technology, it would still suffer from the problems of limited range (about 80 km) between charges, and the long time needed for recharging (up to 5 hours).

With these limitations in mind, the potential market for electric cars was investigated using the survey data. A set of criteria was developed to segregate a group of limited use urban cars (potential electric cars) from the total auto population of the sample. The joint criteria applied to the sample were the following:

- The car belongs to a multi-car household
- The car travels 40 km or less on a typical weekday
- The car travels 10 000 km or less per year
- The car rarely (less than 12 times per year) travels more than 80 km in a day.

These criteria, when examined separately, each imposed different limitations on the size of the potential market for electric automobiles. Firstly, only 25% of the households surveyed had two or more cars available for use, and thus would be likely to replace one with an electric car. The criterion limiting annual travel by a vehicle to a maximum of 10 000 km per year, when applied alone, eliminated all but 32% of the cars from consideration for replacement by electric vehicles. The other two driving pattern criteria imposed less severe restrictions on the potential market. The limitation on number of longer trips (further than 80 km in a day) to fewer than 12 times per year removed 60% of the vehicles from consideration. On the other hand, the criterion that the vehicle usually travelled 40 km or less per day eliminated only 31% of the vehicles in the survey. Thus, the occasional use of a car for longer trips eliminated more cars from consideration than did small variations from its usual driving pattern.

When the criteria were applied jointly, it was found that 13% of the automobiles in the sample of ten municipalities fulfilled all four criteria. However, 36% of these cars came from households having more than one car which satisfied the four criteria. Since it is unlikely that many households would purchase more than one electric vehicle, it would be more realistic to assume that only one vehicle in such households could be replaced by an electric vehicle in the early stages of marketing electric cars. Making this assumption, it was found that 11% of the surveyed vehicles could be replaced by electric vehicles.

The cars identified as potential electric vehicles tended to be older and less valuable than the average car in the sample population. A large percentage (26%) of the potential electric cars were small sized. The average daily distance travelled by the potential electric cars was 16 km, compared to 35 km for the sample car population as a whole. The yearly distance travelled by these vehicles averaged 5 700 km, compared to 15 800 km for the total sample car population. The principal uses of the potential electric cars were for shopping and social purposes, and for travel to work. Women were the drivers of 68% of these autos, and the most frequent occupation of the principal driver was housewife.

As was discussed in Chapter 3, the cost of a limited range electric vehicle would probably be many hundreds of dollars more than a petrol powered vehicle of similar size. Thus the marketing problem is to convince housewives and other potential electric car users to replace their cheaper, older automobiles with new electric vehicles, which should be cheaper to run, but have a limited range.

There are several ways in which the market for electric vehicles could be expanded. The first is related to socioeconomic factors, and depends on an increase in the proportion of households with two cars, one of which might be used principally for urban travel. As was shown in Chapter 6, larger numbers of vehicles per household are associated with higher household income and increased number of workers and licenced drivers per household. Thus, the potential market for electric vehicles should expand if the trend continues for more married women to enter the workforce.

The other developments which could expand the market for electric vehicles are technical, and concern improvements in range and recharging time of the vehicle. If battery development reaches the point at which it is possible to produce a vehicle with a range of 300 km between charges, electric cars will be potential replacements for more than just "urban" vehicles. Some single car households might then purchase an electric car as their sole vehicle.

Many other aspects of electric vehicle use need to be investigated before such vehicles can come onto the mass market. The amount of electric power required to recharge their batteries must be determined, and projections made of future generating capacity available for electric vehicles. A complete vehicle maintenance and servicing industry would have to be developed. Government policy with respect to electric vehicles needs to be clarified, including such issues as whether the users of electric vehicles should make a contribution to revenue similar to the excise tax on petrol, and if so, how this should be levied.

The Government and the electricity supply authorities would need to develop a policy regarding the pricing of off-peak power to recharge electric car batteries, and the provision of public recharging points. The decisions on these policy issues will greatly affect the running costs and convenience of electric vehicles, and this will, in turn, affect the size of the market.

The success of electric cars as replacement vehicles for petrol-powered cars thus depends on the development and production of a vehicle which would satisfy a segment of the automobile market with regard to capital cost, performance, safety and reliability. It is also desirable that the Government be convinced of the merit of electric cars for urban travel, and encourage them through appropriate policies regarding electricity cost, sales and excise taxes, and other charges.

FURTHER RESEARCH

The next step in exploring the market for electric cars might be to put together the specifications for an electric vehicle, possibly based on the Flinders Electric Vehicle[(1)]. Using these specifications, the families which are potential customers could be interviewed. and their reaction to the features of the vehicle (such as its limited range and limited carrying capacity, the

(1) Whitford, D. (1976), op. cit.

simplicity of its maintenance, and its low running cost) could be assessed. The households identified in the present survey could be used by linking their addresses (recorded separately) to the locality code on the questionnaires. From such a survey, it might be possible to list the features which produce the greatest sales resistance, and which therefore must be given careful consideration in technical development of an actual electric car. Also the garaging arrangements and ease of recharging cars could be investigated.

Another extension of this survey is to examine the auto owning history of a selected group of households. It would be necessary to use an extensively detailed format of in-depth interviews, to explore the factors which most influenced the household's decision, regarding the number of cars owned at any given stage in its life cycle. Selection techniques would have to be developed to achieve reasonably large samples of such groups as childless married couples in their twenties, couples with teenage children below driving age, and retired couples. It would be interesting to see what effect the use of cars by young women has on the family's later car availability pattern. For instance, does a women who has been accustomed to having use of a car before marriage ensure that she never becomes a "typical" suburban housewife, confined to the house by children and the lack of an available car.

Using the data base from the present survey, there are several other areas which could be explored. The sampled trips, for instance, of the potential electric cars could be examined to find the occupancy pattern of the car, the proportion of distance two or more people travelled in the car, and so forth. The characteristics of those cars which exceeded the usual daily distance criterion of electric cars could be checked to discover any feature differentiating them from the rest of the potential electric cars.

The data from the present study should permit the development of a preliminary disaggregated model of vehicle availability. A major problem with a small scale study such as this is that once households are divided into different categories, the number represented in any one category decreases quite considerably. Nevertheless, there should be sufficient data to choose a model of appropriate structure, which could then be refined using data obtained in further studies.

APPENDIX A

TELEPHONE
345 1844

TELEGRAMS
UNIMELB PARKVILLE

CONFIDENTIAL

University of Melbourne
DEPARTMENT OF CIVIL ENGINEERING
Transport Section

Parkville, Victoria 3052

VEHICLE USAGE SURVEY

Form 1 - Cover Sheet

Municipality _____
C.D. _____
Dwelling No. _____
Dwelling Type _____
(see list)

Dwelling Type

Separate House	1
Semi-detached House	2
1 - 8 Flats	3
9 or more Flats	4
Other	5

(Fill in before knocking on door)

INTRODUCTORY REMARKS

1. You will probably have received a notice in the past few days concerning a survey of car usage being conducted by the Transport Section of the University of Melbourne.

2. The results of this survey will be used to determine the patterns of car usage in Melbourne.

3. Would this be a convenient time to ask the members of your household about these subjects? (If not arrange a convenient time).

A. Date of Interview . . . . _____

B. How many vehicles do you have at the disposal of members of the household? _____

C. Number of persons in household _____
(If none (B) goto personal information form. Otherwise, write down makes and models on vehicle information form and refer to these vehicle numbers for questions on mode of travel, then go to Form 2.)

Authorized by
Dr. D. W. Bennett
Head of Transport Section

VEHICLE USAGE SURVEY

CD ___ ___ ___

Household ___ ___ ___

Form 2 - Personal Information
(all family members 5 or over)

A. Person no.	__	__	__	__
B. Relationship to head of household Head 1 Brother/sister/in law 4 Spouse 2 Parent/in law 5 Son/daughter/in law 3 Other 6	__	__	__	__
C. Marital Status Now Married 1 Never Married 2 Other 3	__	__	__	__
D. Sex Male 1 Female 2	__	__	__	__
E. Age 0 - 4 1 20-24 5 5 - 9 2 25-29 6 10 - 17 3 30-64 7 18 - 19 4 65 or over 8				
F. Licensed Driver Yes 1 No 2 Not Eligible 3	__	__	__	__
G. Employment Status More than one job 1 Retired/Invalid 5 Full time 2 Home duties 6 Part time 3 Other 7 Unemployed 4	__	__	__	__
H. Gross Income last week (or Gross Income Last Year) (Show card) Group	__ __	__ __	__ __	__ __
I. Occupational Group (refer to card)	__ __	__ __	__ __	__ __
J. Educational Status Full time school 1 Part time Sch/Uni/Coll 3 Full time Uni/Coll 2 Not attending insti. 4	__	__	__	__
K. Number of trips/week to work/school/Uni./Coll......	__ __	__ __	__ __	__ __
L. Main mode of travel to work	__ __	__ __	__ __	__ __
Car No. __ Driver of car/Ute/truck kept at this address _1 Passenger of car/ute/truck kept at this address _2 Car pool (including use of car from this household) _3 Driver or passenger of car/ute/truck not kept here 04 Motorcycle 05 Train 06 Tram 07 Bus 08 Taxi 09 Bicycle 10 Walk 17 Other 18 N/A 19				
M. Main mode of travel to school/Uni./Coll.(from above)	__ __	__ __	__ __	__ __
N. Present for interview Yes 1 No 2	__	__	__	__

May I have your phone number in case we need to verify any of this information? ______________

Form 3 - Vehicle Information (for each vehicle)

CD ____
Household ____

1. Vehicle no.

2. Make

3. Model

4. Year of Manufacture

Pre 1960	1	1972	6
1960-1964	2	1973	7
1964-1969	3	1974	8
1970	4	1975	9
1971	5	N/A	10

5. Body Type

Sedan	1	Camper Van	5
Station Wagon	2	Truck	6
Utility	3	Motor cycle	7
Panel Van	4	Other	8

6. Present Odometer reading . . . .

mi. 1 km. 2

7. Ownership of vehicle

Owned 1 Company/Government 2 Other 3

--------Go to question 11, if vehicle not owned ------------

8. Current Value

Under $1,000	1	$3,000-3,999	4
$1,000-1,999	2	$4,000-4,999	5
$2,000-2,999	3	$5,000 and over	6

9. Length of time owned ____________years.

10. Odometer reading at purchase . . . . (don't know 999999)

mi. 1 km. 2

11. Who is the usual driver? Person no. _____ (refer to personal info. form)
(Other 99)

12. Distance traveled per year . . . .

Mi. 1 Km. 2

13. What is the percentage of the annual distance traveled outside the metropolitan area?

14. What is the main purpose for which the vehicle is used?

Travel to work	1	Shopping, social	5
Personal Business	2	Recreation	6
Employer's Business	3	Other	7
Travel to School	4		

Continued on Page 2.

CD ____

Household ____

	Vehicle no. (from previous page)	__	__
15.	How often does the vehicle travel outside the metropolitan area? (Show map) 5-7 times/week 1 — 3-11 times a year 4 1-4 times/week 2 — once or twice a year 5 1-3 times/month 3 — never 6	__	__
16.	What were the alternatives for making the most frequent non-metropolitan trips? Other family vehicle 1 Borrow relatives/friends vehicle 2 Passenger in relatives/friends vehicle 3 Bus 4 Train 5 Airplane 6 Other 7 Couldn't have made trips 8 Hire a car 9 N/A 10	__	__
17.	How often does this vehicle go more than 50 miles (80 km.) in a day? 5-7 times/week 1 — 3-11 times/year 4 1-4 times/week 2 — once or twice a year 5 1-3 times/month 3 — never 6	__	__
18.	What is the distance travelled on a typical weekday? . . . mi. 1 km. 2	__	__
19.	How many days a week is the vehicle idle (or used for only a short trip (e.g. to shop)? ____________.	__	__
20.	What is your estimate of the weekly cost of running this vehicle? . . . . dollars. (including maintenance, petrol, etc.) (No idea - 99)	__ __	__ __

Date of trips

Form 4 - Trip Information (for each trip by household members five or over)

CD ____

Page no.___

Household ____

A Person No.	B Trip No.	C Where did this trip begin (origin) Place or Street Address	D Where did this trip end (destination) Place or Street address	E What time did you Start	E Arrive	F What was the distance traveled	G What are the purposes of The trip From	G	G To	H Mode of Travel	If Auto Driver: I No. in Car	If Auto Driver: J Type of Parking
01	01									Car Dr. _1		
02	02						01	Home	01	Car Pass. _2		St. Free 1
03	03	street	street	a.m.	a.m.	miles	02	Work	02	Car Pool _3		St. Meter 2
04	04						03	Employ. Bus.	03	Dr/Pass Oth 04		Lot free 3
05	05	suburb state	suburb state	p.m.	p.m.		04	Soc-Rec.	04	Motorcycle 05		Lot paid 4
06	06						05	Eat-Meal	05	Train 06		Co. Park 5
07	07	home	home				06	Med-Dent	06	Tram 07		Serv. Lot 6
08	08						07	Pers. Bus.	07	Bus Pass. 08		Res. Prop 7
09	09						08	Shop	08	Taxi Pass. 09		Cruised 8
10	10						09	School	09	Bicycle 10		Not Parked 9
							10	Serve Pass	10	Walk 17		NA 0
							11	Change Mode	11	Other 18	NA9	
__	__	____	____	__	__	___	__		__	Car No.__	__	__

A Person No.	B Trip No.	C	D	E Start	E Arrive	F	G From	G	G To	H	I	J
01	01									Car Dr. _1		
02	02						01	Home	01	Car Pass. _2		St. Free 1
03	03	street	street	a.m.	a.m.	miles	02	Work	02	Car Pool _3		St. Meter 2
04	04						03	Employ. Bus.	03	Dr/Pass Oth 04		Lot free 3
05	05	suburb state	suburb state	p.m.	p.m.		04	Soc-Rec	04	Motorcycle 05		Lot paid 4
06	06						05	Eat Meal	05	Train 06		Co. Park 5
07	07	home	home				06	Med-Dent	06	Tram 07		Serv Lot 6
08	08						07	Pers. Bus.	07	Bus Pass. 08		Res. Prop 7
09	09						08	Shop	08	Taxi Pass. 09		Cruised 8
10	10						09	School	09	Bicycle 10		Not Parked 9
							10	Serve Pass	10	Walk 17		NA 0
							11	Change Mode	11	Other 18	NA9	
__	__	____	____	__	__	___	__		__	Car No.__	__	__

A Person No.	B Trip No.	C	D	E Start	E Arrive	F	G From	G	G To	H	I	J
01	01									Car Dr. _1		
02	02						01	Home	01	Car Pass _2		St. Free 1
03	03	street	street	a.m.	a.m.	miles	02	Work	02	Car Pool _3		St. Meter 2
04	04						03	Employ. Bus.	03	Dr/Pass Oth 04		Lot free 3
05	05	suburb state	suburb state	p.m.	p.m.		04	Soc Rec	04	Motorcycle 05		Lot paid 4
06	06						05	Eat Meal	05	Train 06		Co. Park 5
07	07	home	home				06	Med Dent	06	Tram 07		Serv Lot 6
08	08						07	Pers. Bus.	07	Bus Pass. 08		Res Prop 7
09	09						08	Shop	08	Taxi Pass. 09		Cruised 8
10	10						09	School	09	Bicycle 10		Not Parked 9
							10	Serve Pass	10	Walk 17		NA 0
							11	Change Mode	11	Other 18	NA9	
__	__	____	____	__	__	___	__		__	Car No.__	__	__

APPENDIX B

WEEKLY/ANNUAL GROSS INCOME

Weekly ($)	Annual ($)	Group	Weekly ($)	Annual ($)	Group
0 - 29	0 - 1 599	1	150 - 169	7 900 - 8 949	8
30 - 49	1 600 - 2 649	2	170 - 189	8 950 - 9 999	9
50 - 69	2 650 - 3 699	3	190 - 209	10 000 - 11 099	10
70 - 89	3 700 - 4 749	4	210 - 229	11 100 - 12 149	11
90 - 109	4 750 - 5 799	5	230 - 249	12 150 - 13 199	12
110 - 129	5 800 - 6 849	6	250 - 269	13 200 - 14 249	13
130 - 149	6 850 - 7 899	7	270 or Over	14 250 or Over	14
				N/A	19

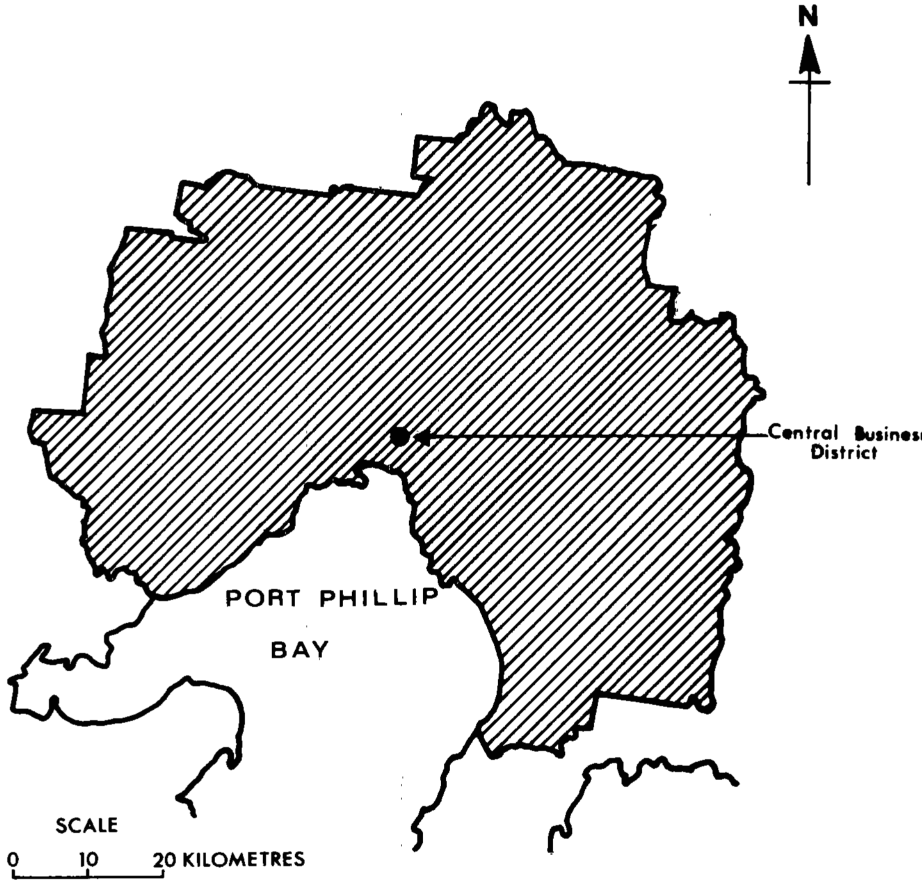
(Side 1 of Card)

OCCUPATIONAL GROUPS

Professional - Doctor, Engineer, Teacher etc.	1	Craftsmen - Plumber Carpenter, etc.	8
Administrative - Manager Executive, etc.	2	Service Workers etc. - Police, Postman	9
Clerical	3	Armed Services	10
Sales Workers	4	Other	11
Farmers	5	N/A	19
Miners	6		
Transport Workers	7		

(Side 2 of Card)

APPENDIX C



MELBOURNE METROPOLITAN REGION

APPENDIX D

1971 SOCIOECONOMIC STATUS SCORES (SES) FOR THE 10 SELECTED MUNICIPALITIES

Municipality	1971 Pop. (X10^5)	1971 ΔSES	Pop.Wtd. ΔSES (X10^5)	1966-1971 ΔSES	Pop.Wtd. ΔSES (X10^5)
Doncaster & Templestowe	64	+513	+328	+23	+15
Fitzroy	25	-697	-174	+170	+42
Footscray	57	-358	-204	-26	-15
Frankston	59	+182	+107	-3	-2
Keilor	55	-191	-105	+33	+18
Kew	32	+472	+151	-43	-14
Knox	56	+108	+60	+27	+15
Lillydale	36	+87	+31	+37	+13
Oakleigh	57	-126	-72	-81	-46
Preston	91	-272	-248	-66	-60
	532		-125		-32
Pop. Weighted ΣSES/ΣPop.			-23		-6

Note: Socioeconomic Status Score Data taken from Kinnear, R.L., *op. cit.*

APPENDIX E

SELECTION PROCEDURES FOR VEHICLE USAGE SURVEY[1]

POPULATION COVERED BY THE SURVEY

1. The Melbourne Statistical Division (MSD) is split into 56 Local Government Areas (LGA's). Each LGA is split into "Parts" then "Collectors Districts" (CD's). It is possible to get quarterly estimates of the number of dwellings per CD.

2. When only 10 LGA's are selected (and these are not chosen randomly) from the MSD, the results obtained from the survey can only be generalised to the 10 LGA's sampled. The selection procedure described below ensures that every dwelling within these 10 LGA's has an approximately equal chance of selection. The section on "Deficiencies" explains why the chance of selection is only approximately equal.

Terminology

3. Let the 10 selected LGA's be the population (P) covered by the survey.
Let P contain C CD's and D dwellings.
Let the i^{th} LGA contain C_i, CD's and D_i dwellings (i = 1, 2, ..., 10).

Let the j^{th} CD of LGAi contain d_y dwellings.

Then

$$\sum_{j=1}^{C_i} D_{ij} = D_i \qquad \sum_{i=1}^{10} D_i = D \qquad \sum_{i=1}^{10} C_i = C$$

Sample Procedure (to select 1 000 Dwellings)

4. The number of CD's, c_i, to be chosen from LGA_i is given by

$C_i = \frac{1\ 000}{d} \frac{D_i}{D}$, where d is the number of dwellings selected in each CD.

The method for selecting the required number of CD's from any LGA is demonstrated for Fitzroy below. This method is known as selection with probability proportional to size, i.e. proportional to the number of dwellings in the CD relative to the total number of dwellings in its parent LGA. $(\frac{D_{ij}}{D_i})$

5. From each selected CD, d dwellings are to be chosen with equal probability as described in paragraph 7. Determining the number of dwellings to be selected from each CD determines how many CD's should be sampled in each LGA. The more CD's sampled, the more the LGA is covered. However, for a fixed sample size, this means that very few dwellings would be selected in each CD, which creates practical difficulties. This is because the actual dwellings are chosen from a random starting point for each CD, with a skip interval $\frac{D_{ij}}{d}$ between selected dwellings. If this skip interval is too large it is hard for the interviewers to keep track of selected dwellings.

6. One way to overcome this problem is to split every selected CD into "blocks", say b "blocks", such that there are approximately equal numbers of dwellings in each block of the CD. Then, all the required dwellings for any CD come from one "block" selected randomly by numbering all blocks from 1 to b and choosing a random number between 1 and b. The new skip interval will be $\frac{D_{ij}}{bd}$, and should be no more than 5 or 7 for easy application by the interviewer.

7. From the chosen "block", d dwellings are to be randomly selected. One method to accomplish this is to choose a random starting number, r, between 1 and the skip interval $(\frac{D_{ij}}{db})$. From any dwelling in the chosen "block", apply the random start (i.e.

move on r dwellings) and this is now the first dwelling to be included in the sample. Interview at this and every following $\frac{D_{ij}}{bd}$ th dwelling until the random start has been reached. This means that d dwellings have been included in the sample, as required.

8. Table E.1 below gives December 1974 estimates of the number of dwellings and CD's in each selected LGA. Three different plans are given - for selecting 10, 15 and 20 dwellings per CD based on a total sample size of 1 000 interviews. Plan A, selecting 10 dwellings per CD, results in the selection of most CD's per LGA but requires more blocking of each CD so that the 10 dwellings can be selected using a reasonable skip interval. Plan B, selecting 15 dwellings per CD, covers less of the LGA but requires less blocking, and Plan C covers even less of the LGA but again requires less work in blocking the selected CD's.

<u>Example of Selection Method for Fitzroy</u>

9. There are 37 CD's in Fitzroy, containing a total of 8 464 dwellings (estimated December 1974). Of these dwellings, 23 are not assigned to any CD, so only 8 441 dwellings are in known CD's. These 23 dwellings can be ignored in the CD selection procedure. This assumes the 23 dwellings are distributed across the LGA in the same pattern as the 8 441 dwellings in known CD's.

10.. Tables 2(i), 2(ii) and 2(iii) were constructed using the method for selecting CD's with probability proportional to size. They correspond to Plans A, B and C and respectively provide for the selection of 5, 3 and 2 CD's from Fitzroy.

11. Having constructed these tables, the next step in the procedure is to select a random number between 1 and 8 441. In this example, the number chosen was 4 282. Then, if C CD's are to be selected from the LGA, the relevant "selection numbers" are 4 282, 4 282 + 8 441, 4 282 + 2 x 8 441, ..., 4 282 + Cx8 441.

TABLE E.1

	December 1974 No. dwellings in LGAi = Di	No. CD's in LGAi	Di/D	Number of CD's to be chosen from LGA		
				Plan A: Select 10 Dwellings per CD	Plan B: Select 15 Dwellings per CD	Plan C: Select 20 Dwellings per CD
Doncaster & Templestowe	22 261	82	0.1218	12	8	6
Fitzroy	8 464	37	0.0463	5	3	2
Footscray	19 819	73	0.1084	11	7	6
Frankstor	22 482	79	0.1230	12	8	6
Keilor	18 614	66	0.1018	10	7	5
Kew	10 924	47	0.0598	6	4	3
Knox	21 196	74	0.1159	12	8	6
Lillydale	14 917	65	0.0816	8	6	4
Oakleigh	17 089	72	0.0935	9	6	5
Preston	27 057	103	0.1480	15	10	7
	D = 182 823	1 398		100	67	50

e.g.	C=5	4 282, 12 723, 21 164, 29 605, 38 046
	C=3	4 282, 12 723, 21 164
	C=2	4 282, 12 723

12. For Plan A - selecting 5 CD's in Fitzroy and 10 dwellings per CD, the selected CD's were

	Part 1	CD3	Contains	375	dwellings
	Part 2	CD1	"	239	"
	Part 3	CD2	"	241	"
	Part 3	CD11	"	180	"
and	Part 4	CD6	"	224	"

13. For Plan B - selecting 3 CD's in Fitzroy and 15 dwellings per CD, the selected CD's were

	Part 1	CD5	Contains	231	dwellings
	Part 3	CD2	"	241	"
and	Part 4	CD4	"	291	"

14. For Plan C - selecting 2 CD's in Fitzroy and 20 dwellings per CD, the selected CD's were

	Part 1	CD9	Contains	239	dwellings
and	Part 4	CD1	"	416	"

15. Probably Plan B using 4 "blocks" per CD would be the easiest plan to implement. This would result in skip intervals of 4, 4, 5 for the selected CD's in Fitzroy.

16. The final step in the procedure is to randomly choose 1 "block" per selected CD and 15 dwellings per selected block as described in paragraphs 6 and 7.

Deficiencies

17. The above scheme has some deficiencies, the main one being the necessity to round the number of CD's chosen from each LGA. This means that some LGA's are slightly over-represented while other are under-represented, and consequently every dwelling has only an approximately equal chance of selection. Also, if the "blocks" within each CD only contain approximately equal numbers of dwellings, every dwelling has only an approximately equal chance of selection.

18. The number of dwellings in each CD is taken to be the December 1974 estimate, but this is expected to produce insignificant errors. Similarly, the effect of ignoring dwellings which are not coded to any CD in the selection of CD's to be sampled is not expected to significantly affect the results.

19. Summary of Selection Procedures (using Plan B)

(a) Sample c_i CD's from each LGA (obtain c_i from Table 1, Plan B),

and select these CD's with probability proportional to size (see examples in Table 2).

(b) Split every CD into 4 "blocks" containing approximately equal numbers of dwellings. Randomly choose one of these "blocks" to be sampled.

(c) Choose a random start, r, between 1 and the skip interval ($\frac{D_{ij}}{60}$) for every "block". From any dwelling in the "block", apply the random start (i.e. move on r dwellings) and commence interviewing. Interview every following $\frac{D_{ij}}{60}$ th dwelling until the random start point has been reached.

APPENDIX F

TELEPHONE
345 1844
Ext. 6771
TELEGRAMS
UNIMELB PARKVILLE

University of Melbourne

Transport Section

Parkville, Victoria 3052

Dear Sir/Madam,

As a part of a research project at The University of Melbourne, we are conducting a survey of the ownership and use of cars in Melbourne. From the results of this survey, we hope to find the patterns of car usage in individual families. We would greatly appreciate your assistance with the survey.

Within a few days, an authorized interviewer will call at your residence to ask a few simple questions about your family's use of cars and other forms of transport. Among the questions that would be asked about each family vehicle are: the distance it travels a year, the present mileage reading, its approximate value, and the percentage of travel outside Melbourne. You may wish to collect this information beforehand to make the interview easier.

Your home will be one of about a thousand sampled throughout Melbourne, and the results of the interviews will be pooled to give statistical information on car usage. No results from individual interviews will be released.

We hope you will assist us in this survey. Thank you for your cooperation.

Yours sincerely,

David W Bennett

Dr. D.W. Bennett,
Head of Transport Section

John W Graves

J.W. Graves,
Graduate Research Student

REFERENCES

Australian Bureau of Statistics (1975), Unpublished data.

Australian Bureau of Statistics, Motor Vehicle Registrations, Year Ended 31 December 1975. Canberra.

Automotive Engineering, Electric vehicle development, 84, 39.

Brooman, E.W., Clifford, J.E. and Semones, D.E. (1975), Batteries: prospects for electric vehicles. Automotive Engineering, 83, 30.

Bryson, F.E. (1974), EV controllers: Semiconductors mean extra range, Machine Design, 46, No. 25, 135.

Bureau of Transport Economics, Electric Cars. Australian Government Publishing Service, Canberra, 1974.

Cairns, E.J. and McBreen, J., Batteries power urban autos, Industrial Research, 17, 56.

Commonwealth Bureau of Census and Statistics, Characteristics of the Population and Dwellings, Local Government Areas. Bulletin 7, Part 2, Victoria, CBCS, Canberra, 1973.

Commonwealth Bureau of Census and Statistics, Survey of Motor Vehicle Usage, Twelve Months Ended 30 September 1971 (preliminary). CBCS, Canberra, 1973.

Consumer Reports, The electric Citicar. 41, 572.

Dann, R.T., EV Transmissions: How many speeds? Machine Design, 46, No. 25, 139.

Deutschman, H.D., Auto ownership revisited: a review of methods used in estimating and distributing auto ownership, Highway Research Record, 205, 31.

Deutschman, H.D. and Jaschik, N.L., Income and related transportation and land use planning implications, Highway Research Record, 240, 52.

Douglas, A.A. and Lewis, R.J., Trip generation techniques. 1. Introduction, Traffic Engineering and Control, 12, 362.

Douglas, A.A. and Lewis, R.J., Trip generation techniques. 2. Zonal least squares regression analysis, Traffic Engineering and Control, 12, 428.

Douglas, A.A. and Lewis, R.J., Trip generation techniques. 3. Household least-squares regression analysis, Traffic Engineering and Control, 12, 477.

Douglas, A.A. and Lewis, R.J., Trip generation techniques. 4. Category analysis and summary of trip generation techniques, Traffic Engineering and Control, 12, 532.

Don, P.A., The new models I: trip generation, trip distribution, mode choice. Workshop, Revised Transportation Models for Melbourne, The Institution of Engineers, Australia, Victoria Division, Transportation and Highways Branch, 1975.

Dunphy, R.T., Transit accessibility as a determinant of automobile ownership. Highway Research Record, 472, 63.

Fleet, C.R. and Sosslau, O.E., Trip generation procedures: an improved design for today's needs, Traffic Engineering, 46, 17.

Fleet, C.R. and Robertson, S.R., Trip generation in the transportation planning process, Highway Research Record, 240, 11.

Hagey, G. and Hamilton, W.F., Impact of electric cars for the Los Angeles intrastate air quality control region, Proceedings, 3rd International Electric Vehicle Symposium and Exposition, Washington, D.C., Feb. 1974.

Humphries, J., Intra-Urban Migration and Residential Structure, Monash Publications in Geography, No.6, Melbourne.

Hutchinson, B.G., General problems in urban trip generation analysis, Papers on Trip Generation presented at the 1973 Roads and Transportation Association of Canada Meeting, Hutchison, B.G. (ed). Transport Group, Department of Civil Engineering, University of Waterloo, Ontario, Canada, 1974.

Jacobson, R.A., EV power sources: Waiting for a superbattery, Machine Design, 46, No. 25, 149.

Kinnear, R.L., Some Equity Implications of Changing Patterns of Accessibility, Unpublished M. Eng. Sci. Thesis, Monash University, 1975.

Lansing, J.B. and Hendricks, G., Automobile Ownership and Residential Density, Survey Research Centre, Institute for Social Research, University of Michigan, Ann Arbor., Michigan, 1967.

Leonard, M., EV Motors: Dc now, ac later? Machine Design, 46, No. 25, 129.

Lerman, S.R. and Ben-Akiva, M., Disaggregate behavioural model of automobile ownership, Transportation Research Record, 569, 34.

Lindsley, E.F., Turbine electric car recharges the batteries on the run, Popular Science, 207, 62.

Maring, G.E., National highway travel forecasts, Transportation Engineering Journal, 102, No. TE4, 759.

Milkins, E.E., Automotive fuels of the future - engines, vehicles and traffic, Presented at SAE Australasia Annual Conference, Perth.

Motor Vehicle Manufacturers Association, Motor Vehicle Facts and Figures, '76, Detriot, Michigan.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H., Statistical Package for the Social Sciences, 2nd edition, McGraw Hill, Inc., New York.

Ochojna, A.D. and Macbriar, I.D., A pragmatic application of category analysis to small scale household travel surveys, Traffic Engineering and Control, 17, 293.

Oi, W.Y. and Shuldiner, P.W., An Analysis of Urban Travel Demands, Northwestern University Press, Evanston, Illinois, 1962.

Paterson, J., The Dynamics of Urban Change, in Special Report No. 5, Analysis of Urban Development, N. Clark (ed), Proc. Tewksbury Symposium, Transport Section, Department of Civil Engineering, University of Melbourne, 1970.

Post, R.F. and Post, S.E., Flywheels, Scientific American, 229, 17.

Roleff, P., Personal communication to Mr E.E. Milkins, 1976.

Tanner, J.C., Forecasts of vehicles and traffic in Great Britain: 1974 revision. Department of the Environment, Transport and Road Research Laboratory, Report LR 650, Crowthorne, U.K., 1974.

Urban Planning Division, Guidelines for Trip Generation Analysis. U.S. Department of Transportation, Federal Highway Administration, Urban Planning Division, 1967.

Urban Planning Division, Trip Generation Analysis, U.S. Department of Transportation, Federal Highway Administration, Urban Planning Division, 1975.

Waters, M.H.L. and Porter, J., A review of market prospects for battery electric road vehicles - part 1, Department of the Environment, Transport and Road Research Laboratory, Report 630, Crowthorne, U.K., 1974.

Watson, H.C. and Milkins, E.E., Future fuels and engines. Paper No. 26, Transportation (2nd Automotive Engineering Conference of the Society of Automotive Engineers - Australasia, and the Society of Automotive Engineers of Japan, Melbourne, November, 1975).

White, M.T., An examination of residual distributions in ordinary least squares (OLS) household-based trip generation models, Transportation Research, 10, 249.

Whitford, D., The electric vehicle: a new approach, Science and Technology, 11, 18.

Whitford, D., Personal communication.

Winkelman, J.R., and Frank, A.A., Computer simulation of the University of Wisconsin hybrid-electric vehicle concept, Society of Automotive Engineers, Automobile Engineering Meeting, Detroit, Michigan, May 1973.