TRAVEL BEHAVIOUR AND VEHICLE OWNERSHIP IN CANBERRA

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ABSTRACT: *Important statistical information on car ownership levels and travel patterns of different socio-economic groups in Canberra has been obtained using the home interview survey data. These groups are based on age, sex, income, occupation, household size and structure, dwelling type, residential and work location etc. Disaggregate choice models of car ownership and travel mode have also been developed. These studies, being carried out for all capital cities in Australia on a uniform and comparable basis, are designed to proivde a prescriptive and theoretical base for national energy consumption modelling.*

TRAVEL BEHAVIOUR AND VEHICLE OWNERSHIP

INTRODUCTION

The home interview survey (HIS) undertaken in conjunction with the Canberra Short Term Transport Planning Study (1975-76) collected valid information on 2,253 households, 6,374 persons and 25,319 trips. For each household interviewed, general information about the dwelling, its occupants and their vehicles was recorded. Personal particulars of each person over 5 years of age in the household were also obtained. Trip data including destination, time, mode, purpose, fare, parking, etc was also recorded for each trip made by each person in the household on the day of interview. These three data sets .... household, person and trip ..... contain over a million elements of validated information.

This home interview survey data has been used by P.G. Pak-Poy and Associates Pty. Ltd. and John Paterson Urban Systems Pty. Ltd. (1977) for the preparation of a short term transport plan for Canberra and involved the development of travel demand projection models as well as behavioural travel choice models.

The analysis presented in this paper is from a different perspective and is being carried out for all capital cities in Australia on a uniform and comparable basis. It aims at obtaining important statistical information on car ownership levels and travel patterns of different socio-economic groups in an urban area. Simple behavioural choice models capable of generalisation and aggregation have also been developed. The objective is to see if some common travel patterns and choice-making behaviour emerge from these studies and to provide a prescriptive and theoretical basis to the energy consumption modelling project currently in progress at this university with financial support from NERDDC (See Figure 1).

METHODOLOGY

Raw HIS data was obtained on tape from the National Capital Development Commission. This tape was mounted on the James Cook University's computer system and successfully read. A sample of data was checked with the printout supplied by NCDC and found to correspond.

This data was supplied in one file, structured as groups of household, person and trip records for each interview. The household record was identified by a unique key consisting of the residential zone and the sample number within that zone. Each person in the household was identified by the household key in addition to a person number, whilst each trip made by a person in the household was identified by the person key in addition to a trip number. These keys allowed the household, person and trip records to be separated whilst retaining the linkages between them.

Data was stored and manipulated using Data Base Management System 1022. This allows efficient data storage, retrieval, combination and security and forms a ready interface to statistical packages such as SPSS.

1022 required identical formats for each record in the data set, so the three dissimilar record types in the raw data were separated by a small program into three files - household, person and trip - and loaded into separate 1022 data sets.

A number of data manipulations were performed using 1022. These included:

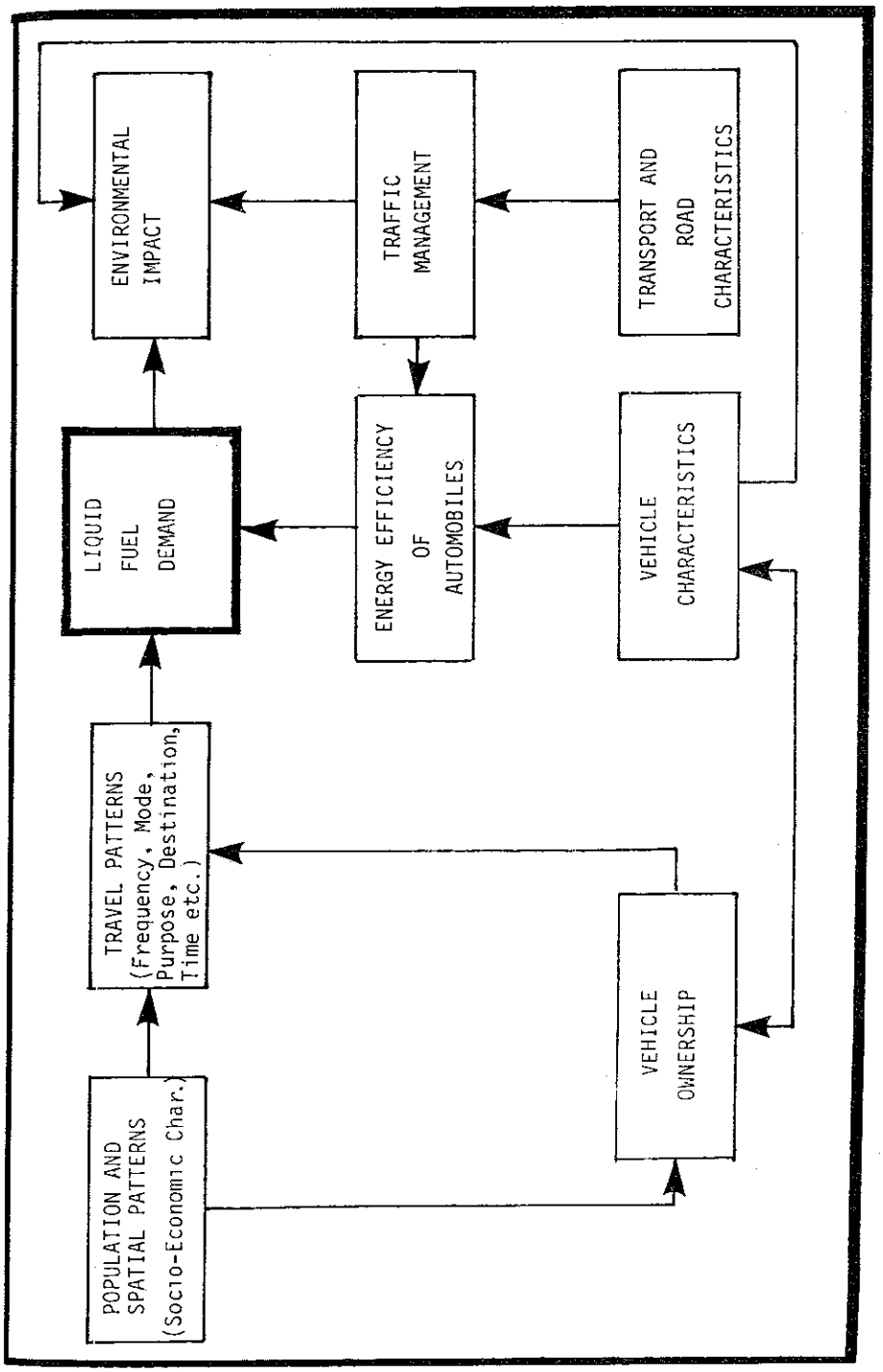

Figure 1. Framework for Transport-Energy Systems Modelling at an Urban Area Level.

Household set: Recalculation of household income from relevant personal incomes, derivation of number of cars from vehicle ownership information, inclusion of information on household vehicle.

Person set: Transfer of household vehicle data to person controlling vehicle.

Trip set: Calculation of trip purpose from purpose from and purpose to. Calculation of trip length in minutes.

Data was then extracted from each data set and used to obtain frequency plots and cross-tabulations of selected variables. The frequency plots were used to check the validity of the data and to check the correspondence between household, person and trip data.

In the next phase, selected variables from each of the three sets (household, person and trip) were combined into a single, large data set. System 1022 has facilities which allow SPSS compatible files to be produced directly from the data set. The selection commands in 1022 allow the contents of these SPSS files to be tailored to the analyses required.

Two sets of discriminant analysis were performed, both investigating vehicle ownership levels; one for personal vehicle ownership, and the other for household vehicle ownership levels. The models estimated were tested using half of the cases for estimation and the remainder for classification.

For modal choice modelling, a discrete choice logit estimation package, BLOGIT has been used (Crittle and Johnson, 1980). This program required a raw data set and a control file for its use. It is less user friendly and is not as well documented or supported as the SPSS system. Considerable difficulties have been found in its use for this project.

Modal choice modelling efforts have concentrated on the work trip (home based and non-home based); nearly 6000 such trips were recorded in the HIS. The BLOGIT program has been run on a sample of this size, but was found to be expensive in computer time so model testing has been confined to random samples of the data (10, 25 and 50 percent). Segmentation of work zone and vehicle availability have also been undertaken. (i) (ii)

The overall data analysis methodology is shown in Figure 2 as a flow chart representation. (iii)

CAR OWNERSHIP ANALYSIS

Household Car Ownership

Socio-economic factors which purport to influence the level of car ownership in a household include dwelling type and tenancy; sex, age, major activity and occupation of the household head; household income; size of the household and its stage in the family life cycle; and the number of full-time and part-time workers. The distribution of car ownership levels with socio-economic attributes of the household is shown in Table 1. It has been found that the average household car ownership levels: (iv) (v)

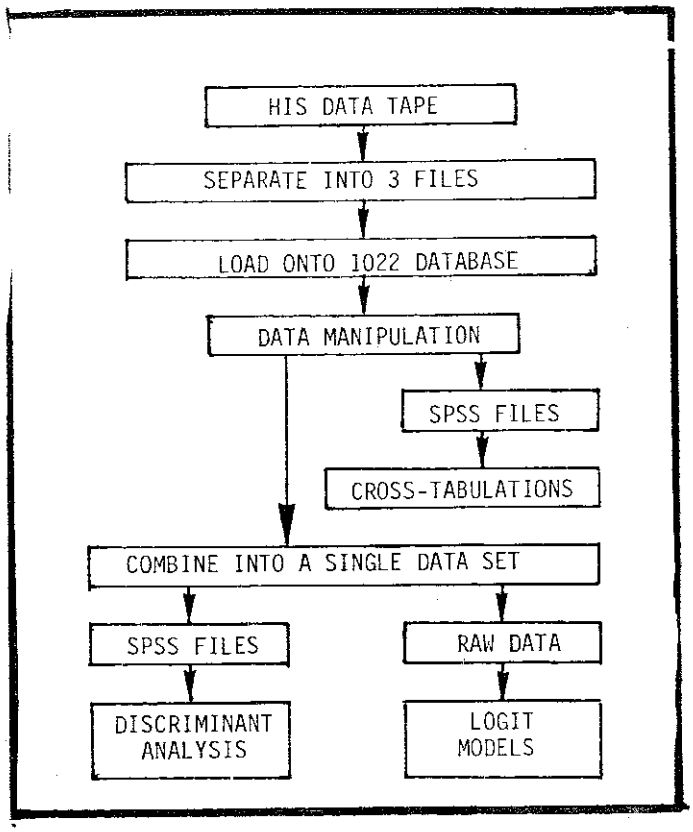

Figure 2. Data Analysis Methodology

(i) are significantly higher for households in detached dwellings than in flats and hostels; the average ownership levels being 1.43, 0.92 and 0.40 respectively.

(ii) are similar for those owning or purchasing a home (1.46 cars per household) but are significantly lower for those in the private and governmental rental accommodation (1.15 and 0.85 respectively).

(iii) increase from about 0.46 for a household with one person only to 2 cars per household with 8+ persons. On a per person basis, however, the highest car ownership is for a two-person household and lowest for a 8+ person household.

(iv) increase steadily as the household income rises. Single car ownership increases with income up to $8000 per annum (1975) and then decreases as at higher income levels, a larger proportion of households are multi-car owners.

(v) increase as the number of drivers in the household increases. For over 95% of the households, the number of cars owned is not greater than the number of licensed drivers in the household. Average car ownership is found to rise by 0.5 for every additional license holder over one in the household.

TABLE 1

Distribution of Household Car Ownership Levels with Socio-Economic Attributes

Socio-economic attribute	% Household with car				Av. car ownership/ household	No. of cases
	0	1	2	3+		
A. Dwelling type						
Detached	5.50	54.40	32.85	7.25	1.43	1720
Flats	24.30	60.50	14.00	2.04	0.92	329
Hostel	59.60	40.40	0.00	0.87	0.40	199
B. Tenancy type						
Owned	8.80	47.20	35.00	9.10	1.46	386
Being purchased	2.90	56.20	34.50	6.40	1.46	917
Private rent	18.70	54.10	22.50	4.70	1.14	427
Government rent	30.80	55.80	11.00	2.40	0.85	500
Other	55.60	38.90	5.60	0.00	0.50	18
C Sex of household head						
Male	7.54	56.05	30.28	6.13	1.36	1909
Female	47.63	42.31	7.40	2.67	0.66	338
D. Major activity of h/h head						
Full time employment	7.89	56.04	30.01	6.07	1.35	1913
Other	46.11	42.22	8.68	3.00	0.69	334
E. Occupation of h/h head						
Administrative/Clerical	8.67	53.59	31.17	6.78	1.38	738
Sales and Service	15.57	51.64	27.04	5.74	1.23	122
Transport, Mining & Tradesmen	7.17	59.32	27.06	6.45	1.33	558
Professional & Defence	8.50	56.60	30.08	4.52	1.32	553
F, Stage in family life cycle						
No children LT 5	17.35	49.54	26.54	6.58	1.24	1643
Children LT 5	3.31	66.12	27.90	2.98	1.31	605
G. Age of household head						
<20	57.27	30.00	10.00	2.73	0.59	110
21-30	12.82	60.81	22.48	3.89	1.19	694
31-45	4.75	59.02	32.02	4.21	1.36	737
46-65	10.14	47.25	32.13	10.48	1.45	582
>65	51.43	39.05	6.67	2.86	0.61	105
H. Number of licenses available						
0	96.87	3.12	0.00	0.00	0.03	160
1	20.54	76.94	2.02	0.51	0.83	594
2	2.08	57.94	38.74	1.24	1.39	1203
3	1.36	21.82	48.18	28.64	2.06	220
4+	0.00	9.86	26.76	68.38	2.79	71

·Economic

Av. car ownership/ household	No. of cases
1.43	1720
0.92	329
0.40	199
1.46	386
1.46	917
1.14	427
0.85	500
0.50	18
1.36	1909
0.66	338
1.35	1913
0.69	334
1.38	738
1.23	122
1.33	558
1.32	553
1.24	1643
1.31	605
0.59	110
1.19	694
1.36	737
1.45	582
0.61	105
0.03	160
0.83	594
1.39	1203
2.06	220
2.79	71

TABLE 1 (Cont'd)

Socio-economic attributes	% Household with car				Av. car ownership/ household	No. of cases
	0	1	2	3+		
I. Household size (No. of persons)						
1	54.10	45.90	0.00	0.00	0.46	364
2	11.10	60.40	27.90	0.40	1.17	535
3	3.90	57.10	31.60	7.40	1.43	408
4	4.00	55.10	32.50	8.40	1.48	452
5	2.80	53.40	34.80	9.00	1.52	322
6	1.90	46.60	38.80	12.70	1.63	103
7	4.20	35.40	39.60	20.70	1.81	48
≥8	0.00	31.30	43.80	25.10	2.00	16
J. Annual household income						
0-2000 (A $ in 1975	76.09	21.74	2.17	0.00	0.26	140
2000-5000	60.45	36.57	2.99	0.00	0.43	134
5000-7000	26.03	65.57	7.53	0.68	0.83	146
7000-9000	14.29	72.35	12.44	0.92	1.01	217
9000-12000	9.33	65.60	23.32	1.75	1.18	343
12000-15000	4.35	64.43	28.85	2.37	1.30	253
15000-18000	2.53	55.23	37.91	4.33	1.44	277
18000-25000	3.44	47.09	41.53	7.93	1.54	378
>25000	1.60	27.81	43.85	26.74	2.05	187
K. Number of full time workers (no part time worker)						
0	51.6	45.3	3.2	0.0	0.52	243
1	13.0	66.2	19.7	1.1	1.09	1099
2	4.8	50.4	41.1	3.7	1.43	635
3+	3.7	17.0	43.9	35.5	2.11	183
L. Number of part time workers (no full time workers)						
0	51.6	45.3	3.2	0.0	0.52	243
1+	29.1	56.4	7.6	6.9	0.92	36

(vi) rise with the household head's age and peak at 1.45 in the 46-6[illegible] age group.

(vii) are significantly different between households having male and female heads. The average ownership is 1.36 and 0.66 cars respectively. Percentage of zero-car owning households is also much higher at 47.63% for those with female heads compared to only 7.54% with male heads.

(viii) are found to be fairly similar among households irrespective of the occupation of the household head.

(ix) are not significantly different for households with or without young children (under 5 year olds). The only striking difference is the higher percentage of zero car ownership for households with no young children.

(x) are twice as high for a household with a head who has full time employment compared to the average of all other categories.

Person Car Ownership and Availability

The probability of owning a car by a person with certain socio-economic characteristics has been statistically estimated from the HIS data. The results of this analysis are shown in Table 2. Some of the salient findings including the variation in car availability with changes in transport system characteristics are as follows:

(i) a household head has a very much greater probability (0.823) of owning a car than does a person who is not a household head (0.260).

(ii) a head of an economic unit (person earning a separate income in the household) has also a high probability of owning a car, though slightly less than that for a household head.

(iii) males have a much higher probability of car ownership than females (0.614 and 0.304) respectively.

(iv) non-availability of license has a strong and obvious correlation with zero car ownership.

(v) full time workers are more likely to own a car than persons in any other activity.

(vi) persons in administrative/management category have the highest probability of car ownership (0.915) reducing to a low of 0.611 for the sales worker category.

(vii) the probability of car ownership tends to increase with increase in personal income.

(viii) persons with low public transport accessibility (measured by walk time to public transport, walk time from public transport to destination and number of transfers on journey to work/education) tend to have higher probability of car ownership. Increase in the number of transfers has the most marked effect.

TABLE 2

Probability of Car Availability vs Socio-Economic Attribute

Socio-economic attribute	Probability of car availability	No of Cases
Household head	0.823	2248
Economic unit head	0.760	2901
Male	0.614	3184
Female	0.304	3169
Licence holder	0.730	3948
Non-licence holder	0.035	2405
Major Activity		
Full time worker	0.769	2981
Home duties	0.367	1157
School	0.008	1688
Tertiary education	0.356	205
Unemployed	0.347	75
Retired	0.358	201
Sick	0.611	28
Occupation		
Administrative/managerial	0.915	316
Clerical	0.651	833
Sales worker	0.611	211
Transport and communications	0.869	122
Tradesman, process worker	0.842	638
Service, sports and recreation sector	0.665	200
Defence	0.871	85
Professional/technical	0.778	683
Income (A $, 1975)		
No income	0.157	2867
<2000	0.285	200
2000-5000	0.398	412
5000-7000	0.641	640
7000-9000	0.748	662
9000-12000	0.862	567
12000-15000	0.888	349
15000-18000	0.928	238
18000-25000	0.919	124
>25000	0.959	41
Age		
5-14	0.000	1496
15-19	0.193	722
20-24	0.586	846
25-39	0.709	2086
40-65	0.680	1539
>65	0.338	300

TRAVEL BEHAVIOUR AND TRIP PATTERNS

For the purpose of this analysis, trip purposes were compressed into five categories: home-based work, home-based shopping, home-based education, home-based other and non home-based trips. The original 12 modes were similarly collapsed into seven alternatives: car driver, car passenger, bus, taxi, motor cycle, bicycle, and walk.

The trip pattern analysis included trip frequency, trip purpose, trip length and travel modes and their relationship to the socio-economic characteristics of the trip maker.

Trip Frequency (Trip Generation)

Trip frequency, as expressed in trips per capita per day, was found to be 4.09 for the sample population over the age of 5 years. The variation in trip frequency due to socio-economic attributes of the trip maker are discussed below:

(a) Age. Trip frequency is seen to increase with age up to the 20-24 years age group and decreases with further increase in age.

(b) Sex. Trip frequency for males peaks at 5.41 in the 20-24 years age group and for females at 4.73 in the 30-39 years age group. The average trip frequency for males is 4.26 while for females, it is 3.92 per capita per day.

(c) Income. Trip generation is found to rise with income to a local peak at around $10,500 per year (1975), falls slightly and then rises to the overall peak of 4.74 trips in the $25,000+ income group (1975).

(d) Car availability. Trip frequency for trip makers with car available (4.57) is significantly higher than for those without a car (3.64). The distribution of trip frequency by various modes is also markedly different for car owners and non-owners. Non-car owners make four times as many trips as car owners by all modes other than the car driver mode.

(e) Trip purpose. Number of trips per capita per day for work, education, shopping, other purposes and non-home based trips are 0.93, 0.61, 0.53, 1.21 and 0.81 respectively for the Canberra population.

Trip Purpose Analysis (Trip Generation)

A summary of travel task in Canberra by trip purposes and an analysis of modal split for each trip purpose is presented in Table 3. Some important observations are stated below:

(i) Car is the most predominant mode for work trips accounting for over 83% of the total. Public transport gets about 9% share of work trips while all other modes share the remaining 8%.

(ii) Public transport, bicycle and walking account for about 75% of all education trips. This is not unexpected as these three modes represent the only independent choices available to the majority of school-goers.

Modal Split for Various Trip Purposes

Mode	Work Trips	Education	Shopping	Other	Non home-based
Car Driver	67.5	7.9	57.2	62.7	64.7
Car Passenger	15.6	17.9	22.3	24.3	19.4
Bus	9.0	13.2	5.2	2.3	3.8
Taxi	0.4	0.0	0.4	0.4	0.3
Motor Cycle	1.8	0.3	0.8	1.1	1.0
Bicycle	0.6	8.1	1.6	1.1	0.6
Walk	5.1	42.6	12.5	8.1	10.2
% of all trips	22.7	14.9	12.9	29.6	19.9

(iii) The distribution of shopping trips is not very dissimilar to work trips. There is, however, a greater share of walk trips for shopping at the expense of bus trips. Moreover, the share of car passengers is slightly higher indicating a higher car occupancy factor for shopping compared to work trips.

The socio-economic analysis of trip purposes in Canberra show

(i) Age is an important parameter in the need to travel for various purposes. Majority of education trips (88%) are undertaken by those aged between 5 and 19 years old whilst most work trips are made by respondents between 19 and 60 years of age. Interestingly, the distribution of shopping trips is fairly uniform for all age groups.

(ii) Education and other trips (social, recreation, etc as well as non-home based) are fairly equally distributed among males and females. However, males predominate in work trips while females lead in the shopping trips.

(iii) Proportion of work trips undertaken on public transport and as car passengers is more than twice as large for females as for males. Trends for shopping and other trips are also similar. However, there is no significant difference in the use of various modes for education trips between males and females.

Trip Lengths (Trip Distribution)

Variations in trip lengths (measured in travel time in minutes) for various trip purposes, travel modes, and the age and sex of the trip maker are discussed below.

(i) Over 60% of shopping trips in Canberra are less than 10 minutes in length. By comparison, less than 35% of work trips are of this length. Similarly, almost 90% of all shopping trips are of less than 20 minutes duration whereas for work trips, this proportion is close to 70%. Trip length distribution for education lies between work and shopping trips.

(ii) About 50% of public transport trips, 80% of car trips and 90% of bike and walk trips are shorter than 20 minutes.

(iii) There appears to be no significant difference in trip lengths between male and female trip makers.

Travel Mode Analysis

The modal split summary for the total travel task of Canberra respondents is given in Table 4, along with the distribution of trips by various modes for different trip purposes.

Table 4

Distribution of Trips by Mode and Purpose

	Car Driver	Car Pass.	Bus	Taxi	Motor Cycle	Bicycle	Walk
Home-based work	28.1	16.8	27.2	15.2	37.8	6.2	8.8
Home-based education	2.1	12.7	44.0	3.4	4.4	56.5	47.5
Home-based shopping	13.2	13.5	9.6	22.8	13.1	13.9	16.9
Home-based other	33.1	38.7	8.3	18.3	16.7	10.3	7.7
Non home-based trips	23.5	18.3	10.9	40.3	28.0	13.1	19.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
All trips	54.6	21.0	7.5	0.3	1.1	2.1	13.4

It is obvious from the above table that:

(i) vast majority of all trips (76%) are made by private car.

(ii) education trips form a significant proportion of trips by bus, bicycle and walking.

(iii) motor cycle can be viewed as a commuter-based mode.

(iv) significant proportion of taxi trips are for non-home based and shopping trips.

The socio-economic analysis of travel modes in Canberra confirms the following rather intuitive findings:

(i) The choice of mode is greatly influenced by age due to its relation

to the availability and physical capacity to travel by various modes.

(ii) Females patronise public transport more than males.

(iii) The proportion of female car passengers is twice that of males with a corresponding change in car driver mode.

(iv) There is an increasing use of car driver mode as personal income increases while an opposite trend exists for car passenger mode. Use of public transport and other modes (bike, walking, motor cycle) is much higher for low income groups.

(v) There is a strong relationship between car ownership and the trip mode used. Non-car owners account for between 75-90% of all trips by modes other than the car driver mode.

(vi) Flexible work schedule encourages use of cars while for formal flexitime (work schedule determined by employees) public transport usage is seen to be higher.

(vii) Car driver trips for education purposes are low at only 9% since most students are age - or income-captive to non-car driver modes. For full time workers and persons in home duties, car driver is the most predominant mode accounting for between 62 and 72% of all trips.

DISAGGREGATE BEHAVIOURAL CHOICE MODELLING

The basis of disaggregate behaviour choice modelling is the hypothesis that individuals make travel choices on the basis of the comparison of alternative levels of service provided by the transportation/activity system modified by the characteristics of the individual. The main characteristics of these models are the following:

(a) Disaggregated. The basic unit of observation and decision-making is the individual trip maker and not a traffic zone.

(b) Behavioural. The theoretical basis of these models is founded in the economics of consumer behaviour and the psychology of choice behaviour.

(c) Probabilistic. Models of this type usually assign a probability to each possible outcome of a particular travel decision for a specific (or potential) traveller.

Two types of disaggregate choice models have been developed for Canberra. These are discriminant analysis and multinomial logit. Discriminant analysis has been applied to car ownership decisions while logit analysis has been used to model modal choice behaviour for work trips.

Discriminant Analysis

This analysis is designed to statistically distinguish between "groups" (choices) by selecting a collection of discriminating variables that measure characteristics on which the groups are expected to differ (Klecka, 1975). No single factor is usually capable of perfect differentiation but by taking several factors (attributes) and mathematically

combining them, a single dimension (discriminant score) is derived on which individuals can be classified into groups.

Discriminant functions of linear form are developed so that

(a) the discriminant score for the individuals within a particular group are fairly similar and

(b) the separation of groups is maximised.

Once the discriminant functions have been derived, the model permits the classification of any individual with unknown group into one of the choice groups. The model also serves to identify variables which contribute most to differentiation. It also performs statistical tests to indicate how well the analysis is capable of predicting right groups.

Person as well as household vehicle ownership choice models have been developed. The structure of alternative models is shown in Figure 3 Person car ownership is a binary choice, i.e. whether or not an individual owns a car while the household car ownership decision has a choice set described by the number of vehicles.

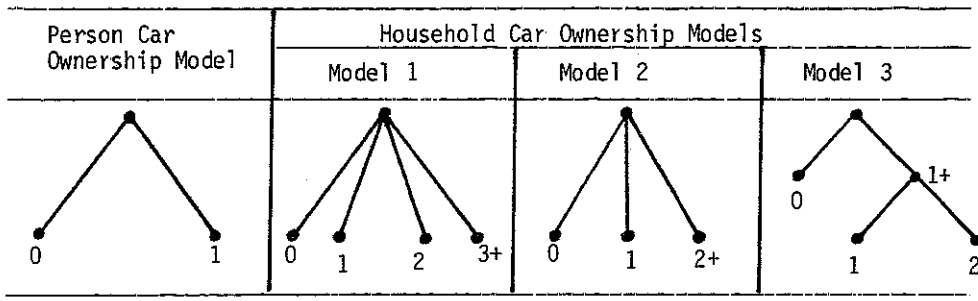

Figure 3 Structure of Car Ownership Models using Discriminant Analysis

Nine discriminating variables were tried for person car ownership modelling. Age, sex, major activity, personal income and economic unit status of the individual as well as the walk time to public transport entered the discriminant function in this order reflecting the relative significance of these variables in discriminating between car owners and non-owners. This function was able to correctly classify over 80% of all cases.

The standardised canonical discriminant function coefficients for all household ownership models along with its classification success rate is given in Table 5.

TABLE 5

Logit Analysis

The logit model form is $P_i = \dfrac{\exp(V_i)}{\sum_{j \in A} \exp(V_j)}$

where P_i is the probability of choosing alternative i from set A and V_i is the representative utility of alternative i. V_i is taken as a linear sum of utilities afforded by each component attribute of alternative i. Thus

$$\sum_k \beta_{ik} X_{ik}$$

TABLE 5

Standardised Canonical Discriminant Functions Coefficients (Household Car Ownership Modelling)

Discriminating Variables (Household Characteristics)		Model 1		Model 2		Model 3	
		DF 1	DF 2	DF 1	DF 2	A	B
AGE	Age of household head	NE	NE	NE	NE	0.08649	NE
CHILD	Children aged less than 5	- 0.10107	0.26077	- 0.14035	- 0.34216	- 0.20596	NE
FTIM	Full time workers	- 0.49880	- 0.24022	- 0.44772	0.41846	- 0.27947	- 0.61209
GT18	Persons older than 18	- 0.35131	- 0.32778	- 0.21994	0.08962	- 0.19633	- 0.23927
HINC	Household income	- 0.15246	- 0.18010	- 0.12029	0.31704	NE	- 0.26570
HOWN	Home ownership	- 0.24482	0.30385	- 0.30824	- 0.20761	- 0.36626	- 0.16743
NMALES	No. of males	- 0.11500	- 0.56877	0.09244	0.12363	0.11555	NE
PERS	Persons older than 5	- 0.17014	0.28501	- 0.27213	0.02537	- 0.25589	- 0.24258
SEX	Sex of household head	- 0.16956	0.83307	- 0.38069	- 0.59521	- 0.52400	NE
WZONE	Work location of household head	- 0.03589	0.32220	- 0.09499	- 0.39724	- 0.20398	0.07790
Variance explained (%)		79.28	18.81	87.81	12.19	100	100
% correctly classified		60.14		64.37		89.07	71.60

NE - Not entered
DF 1 - Discriminant Function 1.
DF 2 - Discriminant Function 2.

NOTE: The relative significance of a discriminating variable is given by the absolute value of its coefficient. Thus FTIM has the highest significance in discriminant function DF 1 of Model 1 and WZONE has the lowest.

where X_{ik} = level of k th attribute of alternative i for an individual

and β_{ik} = coefficient of the k th attribute in the utility function for alternative i

For derivation of the model form and a comprehensive treatment of the theory of disaggregate choice modelling, see Ben-Akiva (1973), Domencich & McFadden (1975), and Hensher & Johnson (1980).

The model coefficients of the utility function used in this model are estimated by the method of maximum likelihood. It is based on the idea that (i) a given sample could be generated by different populations, and (ii) a particular sample is more likely to come from one population than another. The maximum likelihood estimates are the set of population parameters which are most likely to have generated the observed sample. It is necessary to determine the significance of the coeffiecients and the goodness of fit. The computer program (see Crittle and Johnson, 1980) used for estimating the model parameters includes tests for the statistical validity of the model. The overall quality of the model is judged by two statistics; a comparison between the choice distribution forecast by the model and that implicit in the model (% right) and the so-called pseudo R^2. This later test statistic is bounded by 0 and 1; higher values generally indicate better models.

A number of models of the work trip model choice were estimated by using the BLOGIT package. A typical logit model form is shown in Table 6. The performance of selected models of modal choice developed in this study is summarised in Table 7. It will be noticed that factors like work zone (CBD or otherwise) and car availability have been incorporated by data segmentation.

TABLE 6
Typical Logit Model Form

TABLE 7
Logit Models Performance

Model Description	Pseudo R^2	% correct
1. Sample Size (Basic Model)		
(a) 50%	0.16	48.4
(b) 25%	0.16	48.4
(c) 10%	0.16	49.6
2. Choice Set		
(a) 4 modes	0.16	48.4
(b) 3 modes (two car modes combined)	0.20	75.6
3. Segmentation		
(a) Car ownership . . . car owned	0.05	53.2
. . . no car	0.20	33.8
(b) Work zone . . . CBD	0.29	47.0
. . . other	0.13	50.2
4. Hieracrchical		
(a) Public transport and car	0.21	86.0
(b) Car driver and car pass.	0.11	62 0

TABLE 6

Typical Logit Model Form

Alternative		Utility Function Definition										
		ASC's			ASV'S							
		β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
Car driver	1	1			TIMEDR						HINC	WZONE
Car passenger	2		1			TIMEPS				AUTO AVAIL	HINC	WZONE
Public transport	3			1			TIMEPT		FARE	AUTO AVAIL	HINC	WZONE
Bike/Walk	4							TIMEBW		AUTO AVAIL		

Specified utility function V(i) are of the form

$$V(1) = \beta_1 + \beta_4 \text{ TIMEDR} + \beta_{10} \text{ HINC} + \beta_{11} \text{ WZONE}$$
$$V(2) = \beta_2 + \beta_5 \text{ TIMEPS} + \beta_9 \text{ AUTO AVAIL} + \beta_{10} \text{ HINC} + \beta_{11} \text{ WZONE}$$
$$V(3) = \beta_3 + \beta_6 \text{ TIMEPT} + \beta_8 \text{ FARE} + \beta_9 \text{ AUTO AVAIL} + \beta_{10} \text{ HINC} + \beta_{11} \text{ WZONE}$$
$$V(4) = \beta_7 \text{ TIMEBW} + \beta_9 \text{ AUTO AVAIL}.$$

β_1 to β_{11} are the coefficients estimated by the BLOGIT packages

WZONE = Work Zone
HINC = Household Income
TIMEDR = Travel Time for driven mode.
TIMEPS = Travel time for private pass. mode
TIMEPT = Travel time for public transport
TIMEBW = Travel time for bike/walk

AUTO AVAIL = Auto availability to work
FARE = Fare to work by public transport
ASC = Alternative specific constant
ASV = Alternative specific variable

Notes: (i) Complete mode choice set used is car driver, car passenger, public transport and bike/walk

(ii) Work trip sample size is 5965

DISCUSSION

Household Car Ownership

On a household basis, the average car ownership in Canberra in 1975-76 was 1.39 cars. The level of car ownership in a household was found to vary with the number of persons in the household, number of licensed drivers, household income, and the age, sex and major activity of the household head. Households purchasing or owning a house had more cars than did tenants.

Person Car Ownership

The average car ownership in Canberra in 1975-76 was 0.43 cars per person or 430 cars/1 000 population. Analysis has shown that the probability of a person owning a car increases with personal income; and is generally higher for the head of an economic unit or a household, for males, for full time worker and for those with a driving licence. As public transport accessibility worsens, the probability of car ownership increases.

Travel Patterns

Trip frequency. The average trip frequency in Canberra in 1975-76 was 4.09 trips per capita per day. The level of trip generation was found to be influenced by age, sex and personal income of the trip maker. Car availability had also a significant effect on trip generation rate.

Trip purposes. Home-based work, education, and shopping accounted for 23%, 15% and 13% of all trips respectively. Car is the most predominant mode for work trips accounting for over 83% of the total. Shopping trips have also similar modal distribution though the proportion of car passenger mode is slightly higher. About 75% of all education trips are by public transport, bike and walking. Not surprisingly, age and sex of the trip maker are found to be important parameters in the need to travel for various purposes.

Trip length. The average trip length in Canberra was found to be approximately 21 minutes. Shopping and education trips were generally shorter than work trips, while public transport trips were longer than car, bike or walk trips. Age and sex of the trip maker did not appear to have a significant effect on trip length.

Travel modes. Car trips accounted for over 75% of all trips, while the share of other modes were: walk(14%), bus(7.5%), bicycle(2.1%), and taxi(0.3%). Young children and those over 70 years made more use of public transport and walk modes. Use of car passenger and bus modes was larger for females while car driver mode was more prevalent for males. As personal income increased, the use of car driver mode increased at the expense of public transport and car passenger modes. Over 80% of all trips by respondents whose major activity was full time work or home duties were made by car while students made more use of public transport and bike/walk modes.

Discriminant Analysis of Vehicle Ownership

Discriminant functions have been derived to classify individuals into car owning and non car owning groups and to classify households into groups according to the number of cars owned.

Age, sex, major activity, personal income and economic unit status of the individual as well as the walk time to public transport entered the discriminant function in this order reflecting the relative significance of these variables in discriminating between car owners and non-owners. This function correctly classified 80% of all cases tested.

Among the several alternative discriminant functions and models for classifying households, number of full time workers in the household, sex of the household head, home ownership and number of persons greater than 18 years old had high discriminating power. Household income and age of the household head had the least influence in most cases. However, for differentiating households with 1 and 2+ cars, household income and persons older than 5 were found to be very important. These models were able to correctly classify between 60 and 70% of households. The hierarchical model structure was found to be marginally superior.

Logit Models of Modal Choice

A number of logit models for work trip modal choice were estimated for this study. The variations included the size of the modal choice sets, segmentation by work zone and car availability, hierarchical choice structure, as well as the size of the sample used in estimation. In view of the aggregate nature of the level of service variables estimated in this study, the values of pseudo R^2 and percent correctly grouped are rather low for all models. Models with smaller choice sets and with hierarchical structure appear to perform better. Segmentation has, however, not increased the predictive ability of logit models nor has a smaller sample size reduced their performance.

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