Land Use and Mobility

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Abstract

This paper analyses the effects of land use characteristics on mode choice and car ownership. The study is based on a large sample of individuals from the National Travel Survey of Great Britain for the years 1989-91 and 1999-2001. Land use characteristics are defined as population density, size of the municipality, accessibility to public transport and local amenities, such as shops and services. Mode choice (shares of total travel by car, public transport and walking) and car ownership are modelled using multinomial and binomial logit models respectively, which include a large number of socio-economic factors (income, age, gender, household structure and employment status) as well as land use indicators. The estimation results strongly support the importance of the land use factors considered on mode choice and car ownership.

Keywords: land use, mode choice, car ownership, travel demand modelling

Topic area: F1 Transport and Spatial Development

1 Introduction

The objective of this paper is to explore the extent to which land use and local services affect mode choice and car ownership. This is clearly an important question for policy makers in their attempts to reduce the negative effects of travel and to encourage more sustainable travel patterns.

The analysis is based on data from the British National Travel Survey (NTS), and the measures of land use are those that are available in this data set. Land use is defined in terms of the characteristics of the residential location of the individuals: population density, urban size, the proximity and frequency of public transport alternatives and distance to facilities for shopping, services, leisure, etc.

We would expect high-density areas to be associated with shorter, more frequent, trips, and a greater use of public transport, cycling and walking. Higher density is generally associated with more frequent and accessible public transport services and the proximity of possible destinations allows for short walk or bike trips. At the same time, traffic congestion and the scarcity and high cost of parking reduce the attractiveness and convenience of using private cars. Conversely, public transport services are generally very infrequent, and in many cases non-existent, in low-density areas. Similarly, the longer distances between home and place of work/education and commercial and social facilities discourage walking and encourage car use. The reliance on car travel in such areas will encourage a greater need for cars than in more densely populated areas.

The size or population of the place of residence will also have implications for travel patterns. The greater opportunities to participate in various activities provided in larger towns and cities will presumably encourage more trips and travel. Although small villages and rural areas will lack the diversity of activities, the effects on travel are not so clear-cut. On the one hand, individuals may limit their out-of-home activities or be more efficient in their travel, for instance by combining a number of activities in a given trip. On the other hand, the greater distance to various activities will result in longer trips, thereby increasing travel.

Although access to jobs, shops, services, leisure activities and other facilities is generally related to population density, density itself is insufficient in describing the amenities available locally and the distance to such facilities. We would expect travel distances to be lower for individuals living in close proximity to shops and higher for those living in areas where such facilities are farther away. We would expect less travel by car and more by foot, and less of a need for cars.

Earlier papers address some of these issues. Dargay & Hanly (2003a) considers the influence of land use measures on the number of journeys and kilometres travelled by all modes and kilometres travelled by car. The results show that total kilometres travelled and kilometres travelled by car declines consistently as population density increases and that travel distance declines as the size of the municipality increases. In addition, distance travelled by car declines as bus frequency increases and distance travelled by car and by all modes declines as the proximity to amenities increases. Dargay & Hanly (2003b) investigate mode choice in terms of shares of kilometres travelled by car, public transport and walking on the basis of single-equation OLS models. The current study improves upon these estimates by employing more appropriate models and estimation procedures. In addition, the impact of land-use measures on car ownership is investigated by estimation of a car ownership model.

Despite the number of studies addressing the issue of transport and land use, the empirical evidence is rather mixed. A brief literature review can be found in Dargay & Hanly (2003a). The advantage with our study is that it analyses the effects of land-use characteristics in the context of a comprehensive model of individuals' travel behaviour which also considers a wide range of socio-economic factors (such as income, household composition, etc.).

The outline of the paper is as follows. The next section gives a brief description of the NTS data and the various measures of land use employed in the study. This is followed in Section 3, by a presentation of the statistical model. Section 4 presents the empirical results and discusses the findings of the analysis. The paper ends with a summary of the conclusions regarding the impact of land use on mode choice and car ownership, and the implications of the results for transport policy.

2 The National Travel Survey

The NTS was first commissioned by the Ministry of Transport in 1965, with the objective of gaining a better understanding of the use of transport facilities by different groups in the population and to provide a basis for forecasting future demand. At first it was carried out sporadically every few years, but since 1988 it has been carried out on a continuous basis. The survey is based on a sample of private households in Great Britain, using a stratified multi-stage random probability approach. Each member of the household keeps seven-day travel diaries, with adults reporting for younger children and others unable to provide information on their own behalf. Data collected include information on the households, individuals, vehicles, long-distance journeys (including those made in the three weeks before the start of the seven day travel week), and journeys and stages of journeys made during the travel week. A special effort is made to include 'short walks', i.e. walks trips of less than 1 mile, and respondents are asked to include these trips on Day 7 of the diary only. The NTS data are not weighted, as the sample is presumed representative of the population based on the selection method.

In this study, we employ data on individuals from the survey years 1989 to 1991 and 1999 to 2001, excluding children under the age of 17. Three years are included in each period in order to ensure that the samples are representative of the population. This gives 20,398 (1989-91) and 17,621 (1998-2001) observations.

Some summary statistics for the data sample are presented in the following tables. Table 1 shows that car ownership (cars owned by the household and company car they have access to) has increased over the ten-year period: the proportion without cars has declined, while multiple-car ownership shows a considerable increase. This is also reflected in the substantial increase in licence holding. The number of individuals with access to a company car has declined, presumably as a result of the changes in taxation.

Table 1 Car availability and licence holding

% of individuals living in hh with number of cars	1989/91	1999/01
0	25.7	21.3
1	45.5	46.2
2	23.1	26.7
3+	5.7	5.8
Individuals with access to company car	4.5	3.8
Individuals with driving licence	63.6	70.7

The mean distance travelled overall and distance travelled by car, public transport and walking separately, on the seventh day of the NTS travel diary (so that short walk trips are included) are shown in Table 2. It can be seen that travel distance by all modes and by car has increased over the ten-year period, while distance travelled by public transport and walking has declined. The standard deviations are quite large indicating a considerable variation in travel distance and mode split amongst individuals.

Table 2 Travel measures – mean values on diary day 7 (including short walks of less than 1 mile), distance in miles

	1989/91		1999/01	
	Mean	Std. Deviation	Mean	Std. Deviation
Total distance all modes	19.6	40.0	20.4	39.8
Distance by car	15.5	33.4	16.8	35.5
Distance by public transport	2.6	21.1	2.3	14.5
Distance walking	0.7	1.4	0.6	1.7

As mentioned earlier, the measures of land use we consider in this study are limited to those available in NTS. The first of these is *population density*. This which is defined as the number of persons per hectare in the primary sampling unit (PSU) which is employed in the sampling process and encompasses an area of approximately 2,500 postal addresses. The definitions of the categories used in our study, along with mode shares and average car ownership for 1999-2001 are shown in Table 3. We see that the car share declines and the shares for public transport and walking rise as population density increases. Also, as expected, the average number of cars is inversely related to density. Similar numbers for the 1989-91 surveys show that the car share has increased and the public transport and walk shares decreased in most areas over the decade, while car ownership increased most in the least dense areas and remained stable in the most dense areas.

Table 3 Travel by population of municipality: percent of total distance travelled by mode and cars per household. Diary day 7. NTS 1998-2000.

		mode			cars per household
	persons per hectare	**car**	**public transport**	**walking**	
DENS1	**< 1**	0.92	0.06	0.02	1.42
DENS2	**1 – 14.99**	0.89	0.09	0.02	1.31
DENS3	**15 – 39.99**	0.84	0.13	0.03	1.14
DENS4	**40 +**	0.74	0.21	0.05	0.91

Note: motorcycle, cycle and "other modes are excluded.

The second measure is *size of the municipality.* which is based on the population of the conurbations in which the households reside. There are shown in Table 4, along with mode shares and car ownership. The Metropolitan areas are defined as Greater Manchester, the Liverpool, Tyneside, Glasgow, West Midlands and West Yorkshire conurbations. We see that mode shares vary substantially by size of municipality. The car share declines and the public transport and walk shares increase. This is clearly a consequence of the greater availability and convenience of public transport and the difficulties and costs associated with car use in larger urban areas. London is rather different from the other conurbations, with a much lower car share (66% as opposed to 85-90%) and a far greater use of public transport (29% compared to 7-12%). It should also be mentioned that the car share increased over the decade, while the shares for public transport and walking declined. This is true for most of the municipality sizes. Only in London do we find a reduction in the car share and an increase in the share for public transport, and in the smallest towns a slight rise in public transport. The greatest change is noted for the Metropolitan areas, where there appears to have been a considerable shift from public transport to the car.

Table 4 Travel by population of municipality: percent of total distance travelled by mode and cars per household. Diary day 7. NTS 1998-2000.

	mode			cars per household
persons per hectare	**car**	**public transport**	**walking**	
All GB	85.32	11.79	2.89	1.18
London	66.10	29.13	4.77	1.01
Metropolitan areas	84.03	12.29	3.67	1.02
Other over 100k	84.69	12.13	3.18	1.10
3k to 100k	89.15	8.43	2.42	1.27
Under 3k	91.23	7.25	1.52	1.49

Note: motorcycle, cycle and "other modes" are excluded.

Three measures of accessibility are used in this study: accessibility to amenities, distance to bus stop and bus frequency. These are discussed below.

Accessibility to amenities in terms of walking time is measured in the NTS for the following amenities and services: doctor, chemist, grocers, high street, post office and hospital. For example, respondents are asked whether walking to the doctor's falls within one of five time categories from "6 minutes or less" to "44 minutes or longer". Each walk category is assigned a code from 0 to 4. In order to model accessibility to these services, an index was constructed using responses for five of them – doctor, chemist, grocer, high street and post office. Access to hospital was omitted from the index since it is felt that on average people travel to the other services more frequently. To construct the index the responses to the question about walk time to each of the services/amenities were summed for each individual. The sample was divided into (approximate) thirds based on this sum in the 1989/91 data. The third of individuals with the lowest index number values is said to have a "short walk" on average to the services, the next third a "medium walk" and the third of individuals with the highest index number values a "long walk". A similar index was constructed for the 1999/01 data and then divided into 3 (unequal) groups according to the cut-off points derived from the 1989/91 sample. This thereby incorporates changes in accessibility between the two periods.

Table 5 shows the percent of households falling into the different categories in the two samples. The 1999/01 sample has a higher proportion of individuals living a long walk from the range of services and a smaller proportion living a short walk from services. This is probably explained both by a move to less built-up areas (suburbanisation) and the closing of small local shops and facilities. This change will have obvious implications for mode choice and travel requirements.

Table 5 Access to amenities (% individuals falling within given groups)

	1989/91	1999/01
Short walk	31.8	27.6
Medium walk	38.8	37.0
Long walk	29.4	34.9

The respondents in the NTS are asked to give the walking time to the nearest bus stop. As for walking time to amenities, there are five categories ranging from "0 to 6 minutes" to "44 minutes or more". We have divided these into 3 groups as shown in Table 6. A large majority of individuals fall in the "up to 6 minutes" category, which seems unexpectedly high. Because of this, we should be careful in interpreting the influence of this variable in the estimation. Comparing the two periods, it appears that the walking time to the bus stop has, on average, increased slightly.

Table 6 Walking time to bus stop.

	1989/91	1999/01
Low - up to 6 mins	88.8	86.7
Medium - 7 to 13 mins	8.2	10.0
High - over 13 mins	3.0	3.3

The respondents are also questioned about the frequency of the bus service and once again there are five response categories going from "at least 1 every quarter hour", through "at least 1 every half hour" up to "less than once a day". For the modelling work we have divided these into four groups as shown in Table 7. It appears that the proportion of individuals having a high frequency has declined (as well as the proportion with a seldom frequency to a lesser extent), while the proportion with a low bus frequency has increased. The average effect is a slight reduction in average bus frequency.

Table 7 Frequency of bus service

	1989/91	1999/01
Seldom - at least once a day	10.7	9.3
Low - at least one per hour	15.7	19.7
Medium - at least one every half hour	38.7	38.4
High - at least one every quarter hour	34.9	32.6

There are a number of other changes over the ten-year period that are apparent in the data. The proportion of individuals living in a household with one adult is higher in 1999/01, while the proportion with children is slightly lower. Both of these reflect the trend in Britain towards smaller households and fewer children. The proportion of individuals in full-time work is lower in the 1999/01 sample while the proportion of part-time workers is correspondingly higher, never the less, real incomes rose on average. In terms of age distribution the 1991/01 sample on average is slightly older than that of 1989/91. The proportion of individuals in the 17-34 age group declined, while the 35-64 age group increased most, with a smaller growth in the numbers aged 65 and over. In addition, the 1999/01 sample is more urban with the greatest differences being an increase in the proportion of people living in London, and a decrease in the proportion of people living in areas of under 3000 inhabitants.

3 The Econometric Models

The empirical work analyses both mode choice and car ownership. Mode choice is defined as the shares of total kilometres travelled by car, walking and public transport (PT). As opposed to Dargay and Hanly (2003b), travel by modes other these (cycle, motorcycle and 'other modes') are omitted from the total so that the shares for the included modes sum to one. The justification for limiting the analysis to the three main modes is that the omitted modes are marginal, and they not feasible alternatives for most individuals. The data used is travel reported by individuals on diary day 7, since this is the only day that includes information on short walks, which are of particular interest for the land-use issues addressed in this paper. Only individuals over the age of 16 are included. The mode shares are for car (c), walking (w) and public transport (p) are:

$$S_{ij} = f(x_{jk}) \qquad i = c, w, p$$

where the x_{jk} are k variables representing the characteristics of individual j which are identical for all modes. Characteristics of the modes are not considered.

Since the dependent variables lie between zero and one and the error terms of the share equations are likely to be correlated, single-equation OLS is not an appropriate estimator. In addition, the observations are clustered at both zero and one, which suggests the use of estimation techniques for censored dependent variables. Two different models have been estimated: a bivariate tobit model and a multinomial logit model. The tobit model allows for clustering at the upper and lower limits, which are specified as zero and one. Since the shares must sum to one, the bivariate tobit model is estimated for two of the three shares and the coefficients for the remaining share are calculated from those of the estimated shares. However, the bivariate tobit routine employed (LIMDEP 8.0) was unable to impose an upper limit, so the estimates are not ideal. The Multinomial Logit model requires the shares to lie between zero and one and to sum to one at each observation, but does not take account of clustering at the limits. Although there are some differences in the estimated parameters for the two models, the differences in the marginal effects are small and in all cases they agree in terms of sign and significance. Thus, only the results for the multinomial logit model are presented here.

The second model is for car ownership. The observation unit is the same as that for mode choice, individuals over the age of 16. Car ownership refers to that of the household to which the individual belongs: both to cars owned by the household and company cars to which its members have regular access. Car ownership is analysed in two stages; firstly, whether the individual belongs to a car-owning household or not, and secondly, for individuals in households with cars, whether they are single- or multi-car households. Both stages are represented as binomial logit models.

The explanatory variables used in the analysis are shown in Table 8. All of these variables are binary, equal to 1 if the condition holds and equal to zero otherwise. Because of the perfect collinearity of groups of variables, the estimation requires that one in each group be omitted. This is denoted as the reference group.

Although most of the variables are included in both the mode choice and the car ownership models, there are a few exceptions. The day of the week is included in the mode choice models to account for differences in travel during different days. Clearly, this has no bearing on car ownership. The next set of variables relates to socio-economic characteristics of the individual and their household: economic status (working full or part time or not working), age, gender, household type (number of adults and if there are children) and income. For the mode choice model both individual and household income are included since both can be expected to affect travel, particularly for non-working individuals. For the car ownership model, however, only household income is included because car ownership relates to the household rather than to the individual. Income is defined in nominal terms in the surveys, and is converted into to real terms so that the different years can be estimated simultaneously. This could only be done approximately since income is given only in categories. Land-use variables are as defined in the previous section: population density of the primary sampling unit (PSU) and municipality size which is given by the location variables that are based on the population of the conurbations or areas of residence. Access to public transport is captured by the bus variables: the frequency of the bus service and the walking distance to the bus stop. The access to shops and services is given by the amenities index described earlier.

The mode choice model is a reduced form since car ownership characteristics, which also affect mode choice, are excluded. This is preferable from an econometric point of view since car ownership is not exogenous to the model, but is itself determined by the other explanatory variables, particularly income but also urban size and density. By estimating car ownership separately, the impact of the exogenous variables, and most importantly, land-use characteristic, on car ownership can be determined. The model is also based on the assumption that residential location choice is exogenous, which, in the long run, is certainly not the case since residential location will, itself, be determined by, among other things, some of the factors which influence travel demand. This should not, however, affect our conclusions since we are interested in the effects of *given* locational characteristics on travel demand.

The models are estimated for two data samples, 1989 to 1991 and 1999 to 2001, simultaneously. The coefficients of each of the explanatory variables are allowed to differ for the two periods so that we can test if the influence of the variables has changed over the decade. The combined sample is just over 38 thousand individuals. All of these are included in the car ownership models, while only those who travel by car, PT or walking on the 7th diary day are included in the mode choice model, i.e., 29.8 thousand individuals.

Table 8 Definitions of the variables used in the analysis

	Binary variables = 0 otherwise
	Day of the week (reference day: Monday)
TUE7	= 1 if travel day is Tuesday
WED7	= 1 if travel day is Wednesday
THU7	= 1 if travel day is Thursday
FRI7	= 1 if travel day is Friday
SAT7	= 1 if travel day is Saturday
SUN7	= 1 if travel day is Sunday
	Working status variables (reference group: not working)
FT	= 1 if individual works full-time
PT	= 1 if individual works part-time
	Gender, age & household type variables (reference group man, 35 – 64 years, 2 adult hh)
A34	= 1 if 16 <age < 35
A64	= 1 if age > 64
WOMAN	= 1 if individual a woman
1 ADULT in HH	= 1 if number of adults in household=1
3 + ADULTS in HH	= 1 if number of adults in household=3 or more
1+KIDS	= 1 if household has children in year t-1
	Income: Individual's real income (year 2000 £s) (reference group 2:£4000-£12499)
IINC1	=1 if real individual income in 1st group (<£4000)
IINC3	=1 if real individual income in 3rd group (£12500 – £19999)
IINC4	=1 if real individual income in 4th group (£20000+)
	Household's real income (year 2000 £s) (reference group 2: £8000 - £17499)
HINC1	=1 if real household income in 1st group (<£8000)
HINC3	=1 if real household income in 3rd group (£17500 – £39999)
HINC4	=1 if real household income in 4th group (£40000 +)
	Population density quartile (reference group 2nd quartile)
DENS1	=1 if population density in 1st quartile
DENS3	=1 if population density in 3rd quartile
DENS4	=1 if population density in 4th quartile
	Location (reference group urban areas of 3k to 100k population)
LONDON	=1 if individual lives in Inner or Outer London
METS	=1 if individual lives in built-up areas of former Met. counties
OVER100K	=1 if individual lives in area of over 100,000 inhabitants
UNDER 3K	=1 if individual lives in rural area (< 3000 inhabitants)
	Frequency of bus service (reference group: "at least one bus every half hour"
Very low bus freq.	= 1 if bus service at least once a day or less than once a day
Low bus freq.	=1 if bus service at least once an hour
High bus freq	= 1 if bus service "at least one every quarter hour"
	Walking distance to bus stop (reference group 14 to 26 minutes)
Short walk to bus	=1 if walking distance is 13 minutes or less
Long walk to bus	=1 if walking distance is 27 minutes or more
	Walking access to amenities (reference group – medium walking distance)
Amenities short walk	= 1 if walking distance on average to amenities is in lowest third of index
Amenities long walk	= 1 if walking distance on average to amenities is in highest third of index

4 Discussion of the estimation results

The estimation results are presented in Tables A1 (for the mode shares) and A2 (for car ownership) in the appendix. The coefficients common to both periods, their standard errors and probability values are reported in the first columns, followed by the variables significant at the 0.10 level or greater for the 1989-91 period. The significance of these latter variables indicates a change in their effect between the two periods.

For all models, we see that the common parameters are significant at high probability levels. The car ownership models have the greatest number of significant coefficients, 70-80% are significant at the 5% level, while the comparable figure for the mode share model is 69%. The 1989-91 coefficients are significant for between 30 and 40% of variables, suggesting that there has been a statistically significant change in the relationship between the demand measures and some of the explanatory variables over the decade. For the mode share equations, the coefficients for the days of the week are not shown, but these are significantly different from zero only for Saturday and Sunday. As expected, the car share is higher and the public transport share is lower on the weekend than on weekdays. The walk share, however, is the same on all days. A summary of relevant statistics is given in the lower part of the tables. In general we see that the models perform reasonably well and that the car ownership models have a better fit than the mode choice model. Since the coefficients of the logit models cannot be interpreted directly, the remainder of our discussion focuses around the marginal effects.

Table 9 shows the marginal effects of individual and household characteristics for mode choice and car ownership. These are interpreted in relation to the reference groups, which are shown in the caption. Regarding *employment status*, working either full- or part-time increases the car share and reduces the walk share, but has no effect on the public transport share. Additionally, full-time workers have a greater car share and smaller walk share than part-time workers. Working increases the likelihood of car ownership, but does not in itself increase the number of cars.

Age also has a significant influence in all models. Both the under 35s and the over 65s have lower car shares and higher walk and PT shares than the middle-age (35-64) group. As seen from the car ownership models, this is explained by the lower car ownership of these two age groups, and reflects the life-cycle effect noted, for example, in Dargay and Vythoulkas (1999).

Household type (the number of adults and children in the household) is also of relevance in determining mode choice. Individuals who are the sole adult in the household are less likely to travel by car and more likely to use public transport and walk than are individuals in households with more than one adult. They are also less likely to own a car. Individuals in households with more than two adults are also less likely to own a car and travel by car than those in households with two adults, but the impact is much smaller. However, households with more than two adults who own cars are more likely to own more than one car. Individuals in households with children, on the other hand, are more likely to travel by car and less likely to choose public transport than those without children. They are also more likely to be car owners, but less likely to have more than one car than equivalent 2-adult households without children.

We see that *women* travel slightly more by public transport than do men, but there is little significant difference in mode choice between the genders. Women are also less likely to belong to car owning households.

Table 9 Marginal effects for individual and household characteristics. Reference group: male non-worker, aged 35-64, in household with 2 adults and no children.

	Share of kms. travelled by mode			Household car ownership	
	Car	Walk	PT	at least 1	2 or more
FT	**0.088**	**-0.100**	0.012	**0.050**	0.012
PT	**0.048**	**-0.044**	-0.004	**0.070**	***0.027***
A34	**-0.088**	**0.039**	**0.049**	**-0.077**	**-0.034**
A65	***-0.026***	0.004	**0.021**	**-0.067**	-0.190
1 Adult in HH	**-0.103**	**0.067**	**0.036**	**-0.194**	**-0.356**
2+ Adults in HH	**-0.047**	0.018	**0.029**	**-0.044**	**0.172**
1+ kids	**0.032**	-0.011	**-0.021**	**0.038**	**-0.030**
Woman	-0.010	-0.006	**0.016**	**-0.034**	-0.016

Note: bold denotes significant at the 5% level, bold italic at the 10% level; otherwise not significant at the 10% level.

As shown in Table 10, *income* is a very strong determinant of travel. The car share increases with both individual and household income, while the walk share decreases. The PT share also decreases, suggesting a negative income elasticity, but the effect is far smaller. It can also be seen that the car share does not rise for the highest income groups, suggesting a saturation at higher income levels. Individual income is more important than household income, with the exception of the lowest income groups, which are most likely single-income households. It is also clear that income is an important factor in determining car ownership and multi-car ownership.

Table 10 Marginal effects for income. Reference groups: IINC2 and HINC2.

	Share of kms. travelled by mode			Household car ownership	
	Car	Walk	PT	at least 1	2 or more
IINC1	**-0.038**	**0.037**	0.001		
IINC3	**0.087**	**-0.056**	**-0.032**		
IINC4	**0.071**	**-0.065**	-0.007		
HINC1	**-0.104**	**0.067**	**0.037**	**-0.147**	**-0.095**
HINC3	**0.051**	**-0.024**	**-0.027**	**0.138**	**0.248**
HINC4	**0.038**	**-0.030**	-0.008	**0.164**	**0.498**

Note: bold denotes significant at the 5% level, bold italic at the 10% level; otherwise not significant at the 10% level

The results discussed above for the socio-economic the variables are in line with expectations and generally support those obtained in other studies. The primary interest of this study, however, is with the impact of the land use and location measures. We now turn to a discussion of these.

Table 11 shows the marginal effects for the geographic variables. We see the significance is, in general, poorer than for the socio-economic variables. Regarding *population density*, the car share is lower and the walk and PT shares higher in the most densely populated areas in comparison with other areas. Otherwise there is little difference between the remaining areas. The same is true for car ownership. Households in the most-densely populated areas are less likely to own cars than those in other areas, and car households are less likely to have more than one car.

Table 11 Marginal effects for geographic variables. Reference groups: DENS4 and population 3- 100 thousand.

	Share of kms. travelled by mode			Household car ownership	
	Car	**Walk**	**PT**	**at least 1**	**2 or more**
DENS1	-0.022	**0.037**	-0.015	***-0.027***	**-0.032**
DENS3	***-0.020***	0.006	***0.014***	***-0.015***	**-0.030**
DENS4	**-0.095**	**0.059**	**0.036**	**-0.083**	**-0.071**
LONDON	**-0.108**	0.012	**0.096**	**-0.032**	**-0.048**
METS	-0.017	***-0.024***	**0.040**	**-0.037**	0.025
OVER100K	-0.003	-0.006	0.009	-0.002	***0.025***
UNDER 3K	0.019	-0.021	0.002	**0.042**	**0.075**

Note: bold denotes significant at the 5% level, bold italic at the 10% level; otherwise not significant at the 10% level.

Size of municipality has little significant influence on mode choice. The only exception is for those living in London, where car use is lower and PT use higher than in other localities, and for those in the Metropolitan areas, where PT is higher (though not as high as in London) and walking least likely. In general, however, the walk share is unrelated to urban size. Regarding the effects on car ownership, those living in London and the Metropolitan areas are less likely to be car owners, and those in municipalities under 3 thousand are most likely to own cars. There is no difference between the other areas. Multiple-car ownership is lowest in London and highest in the smallest towns, again with no difference between intermediate categories.

The effects of the accessibility measures are shown in Table 12. The *convenience of public transport* is captured by the frequency of the bus service and the walking time to the bus stop. We see that the car share declines as the frequency of the bus service increases and is higher when there is a long distance to the bus stop. Conversely, the public transport share is higher when the bus frequency is high and the bus stop is located nearer the home. This is as one would expect - a more convenient bus service encourages bus patronage and reduces travel by car. A low bus frequency and a long walk to the bus stop also reduce the walk share, presumably as in these instances individuals tend to use the car so that walking to access public transport is also reduced. Car ownership also decreases with bus frequency, as does multiple-car ownership. The distance to the bus stop has no bearing on whether the household has a car, but for households with cars, multiple-car ownership increases the farther away they live from a bus stop. In general, it appears that the frequency of the bus service, rather than the distance to the bus stop, is more important in determining public transport use.

The final land use measure is the *distance to amenities*. We see that this variable is more significant than most of the other land use measures. There is clear evidence that the car share increases and the walk share declines as the distance to shops and services increases. Conversely, when amenities are closer to home the car share is reduced and the walk share increases. The public transport share is also higher when amenities are farther away. There is thus clear support that local accessibility to shops etc. reduces car use (and travel by PT, to a lesser extent) and encourages walking. The existence of local amenities also decreases car ownership, and particularly multiple-car ownership.

Table 12 Marginal effects for accessibility variables. Reference groups: medium bus frequency, medium walk to bus stop and amenities.

	Share of kms. travelled by mode			Household car ownership	
	Car	**Walk**	**PT**	**at least 1**	**2 or more**
Bus frequency					
Very low	**0.091**	**-0.047**	**-0.044**	**0.072**	**0.121**
Low	0.010	0.005	***-0.015***	**0.033**	***0.035***
High	**-0.040**	***0.015***	**0.025**	**-0.054**	**-0.106**
Walk to bus stop					
Short	-0.012	-0.014	**0.026**	-0.001	***-0.029***
Long	**0.089**	**-0.090**	0.001	0.027	**0.087**
Amenities					
Short walk	**-0.060**	**0.052**	0.008	**-0.034**	**-0.056**
Long walk	**0.053**	**-0.070**	**0.016**	**0.030**	**0.042**

Note: bold denotes significant at the 5% level, bold italic at the 10% level; otherwise not significant at the 10% level.

Regarding the changes in the impact of the explanatory variables over the decade, the following can be noted. Firstly, the constant term for car ownership (Table A2) and for the car share (Table A1) have increased over the period, while that for the walk share (Table A1) has declined. The tendency towards increasing car ownership and car use are thus also a result of factors not included in our model, most likely the decline in the real price of motoring and changing preferences.

The difference in car ownership between households with 1 adult and those with 2 or more adults has decreased over the period so that more single adult households are likely to own cars than previously. Individuals with children were more likely to walk in 89-91 than they are in the later survey, due to the increased likelihood of car ownership.

There has been a significant change in the difference between the genders regarding travel. The tendency for more and more women to own and use cars has increased so that the gap between men and women appears to have been closed.

The influence of individual and household income on mode choice appears to have declined over the period, supporting the notion of a declining income elasticity due to saturation. However, this effect is not noted for car ownership. This may be the result of the approximate nature of our definition of real income groups in the two periods.

Regarding the land-use variables, the most notable change over the decade is the decrease in the effect of local amenities on car ownership. A decade ago the access to local services had a greater (negative) influence on car ownership than it has today.

In conclusion, it can also be mentioned that the results of the analysis of mode choice based on the multinomial logit model presented here do not differ to any great extent from those based on single equation OLS models (Dargay & Hanly, 2003b).

5 Conclusions

In summary, our results indicate that land use characteristics – population density, municipality size, local access to shopping and other facilities and accessibility of public transport - do play a significant role on car ownership and mode use. Car ownership and use increases and public transport use and walking decline as population density decreases. Municipality size is less important in determining mode share and car use. Most significantly, far lower car ownership and car use is noted for London, along with greater use of public transport. In addition, higher car ownership and multiple-car ownership is evident in towns under 3 thousand inhabitants. Access to public transport, as measured by bus frequency appears to be a more important determinant of mode choice and car ownership than proximity to the bus stop. As the frequency of service increases, the use of public transport increases and car use declines. Public transport frequency also affects car ownership: as the service increases, car ownership and multiple-car ownership also declines. Finally, access to amenities (shops, services etc.) is also important in travel decisions. Proximity to local amenities encourages walking in lieu of car travel and discourages car ownership and particularly multiple-car ownership. These results have clear implications for transport policy and sustainability: reducing car use and its negative external effects can be facilitated by a well-considered land use planning that encourages local shops and facilities and a frequent public transport service while and discouraging widely outspread residential development. The existence of local shops and facilities will also have wider effects on personal health and the quality of community life.

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Table A1 Regression results: multinomial logit model mode shares. (car normalised)

	Walk share				PT share			
	Coef.	S.E.	P-value	Coef. 89-91*	Coef.	SE	P-value	Coef. 89-91*
FT	-0.632	0.079	0.000		0.003	0.100	0.975	
PT	-0.290	0.074	0.000		-0.106	0.100	0.288	
A34	0.322	0.057	0.000	-0.327	0.642	0.068	0.000	-0.324
A65	0.058	0.073	0.430		0.259	0.098	0.008	
1 Adult in HH	0.488	0.070	0.000		0.518	0.084	0.000	-0.328
3+ Adults in HH	0.157	0.095	0.100		0.366	0.108	0.001	
1+ kids	-0.101	0.056	0.073	0.133	-0.266	0.070	0.000	-0.157
WOMAN	-0.019	0.053	0.723		0.183	0.064	0.004	0.246
IINC1	0.242	0.065	0.000		0.064	0.087	0.458	
IINC3	-0.406	0.079	0.000	-0.223	-0.455	0.097	0.000	
IINC4	-0.430	0.092	0.000	-0.298	-0.169	0.107	0.114	-0.306
HINC1	0.489	0.076	0.000		0.531	0.098	0.000	0.247
HINC3	-0.193	0.067	0.004		-0.354	0.089	0.000	
HINC4	-0.204	0.092	0.026	-0.400	-0.139	0.112	0.217	-0.250
DENS1	0.220	0.105	0.037		-0.130	0.167	0.435	
DENS3	0.059	0.064	0.354		0.172	0.083	0.038	-0.252
DENS4	0.433	0.077	0.000		0.513	0.094	0.000	
LONDON	0.212	0.086	0.014		1.155	0.097	0.000	
METS	-0.097	0.082	0.238		0.446	0.097	0.000	
OVER100K	-0.026	0.067	0.699		0.100	0.090	0.265	
LT3K	-0.135	0.114	0.235		-0.009	0.172	0.961	
V. low bus freq.	-0.368	0.117	0.002		-0.590	0.179	0.001	
Low bus freq.	0.009	0.070	0.892		-0.171	0.099	0.084	
High bus freq.	0.132	0.057	0.021		0.322	0.068	0.000	
Short walk to bus	-0.054	0.081	0.507		0.287	0.109	0.009	
Long walk to bus	-0.581	0.207	0.005		-0.117	0.255	0.647	
Amenities short walk	0.351	0.056	0.000		0.169	0.071	0.017	-0.263
Amenities long walk	-0.428	0.062	0.000		0.092	0.074	0.216	-0.182
Constant	-1.052	0.132	0.000	0.457	-2.808	0.000	0.000	
Pseudo R Square	0.12							
Log Likelihood	-22386							
Chi squared	61059	Prob.	0.000					
Observations	29809							

* Only those coefficients which are significant at at least the 10 percent level are shown.

Table A2 Regression results: binomial logit models for car ownership.

	Household has at least 1 car				Car households: 1 car vs. 2 or more cars			
	Coef.	**S.E.**	**P-value**	**Coef. 89-91***	**Coef.**	**SE**	**P-value**	**Coef. 89-91***
FT	0.404	0.070	0.000		0.055	0.059	0.346	0.293
PT	0.667	0.081	0.000		0.118	0.066	0.075	0.227
A34	-0.571	0.061	0.000	0.304	-0.155	0.046	0.001	
A65	-0.489	0.064	0.000		-0.972	0.078	0.000	0.221
1 Adult in HH	-1.204	0.054	0.000	0.128	-2.720	0.154	0.000	
3+ Adults in HH	-0.323	0.103	0.002	0.313	0.717	0.074	0.000	0.204
1+ kids	0.320	0.062	0.000	-0.186	-0.134	0.044	0.002	
WOMAN	-0.959	0.060	0.000	-0.229	-0.454	0.130	0.001	
HINC1	1.178	0.063	0.000		1.117	0.062	0.000	
HINC3	2.073	0.111	0.000	0.391	2.188	0.072	0.000	
HINC4	-0.203	0.112	0.071		-0.146	0.081	0.071	
DENS1	-0.117	0.064	0.069		-0.134	0.053	0.011	
DENS3	-0.597	0.075	0.000	0.196	-0.325	0.069	0.000	
DENS4	-0.243	0.083	0.004		-0.220	0.077	0.004	
LONDON	-0.274	0.076	0.000		0.111	0.071	0.118	-0.414
METS	-0.018	0.067	0.786		0.111	0.058	0.056	
OVER100K	0.380	0.127	0.003		0.322	0.085	0.000	
LT3K	-0.276	0.049	0.000		-0.071	0.044	0.108	
V. low bus freq.	0.707	0.127	0.000		0.511	0.085	0.000	-0.314
Low bus freq.	0.286	0.074	0.000		0.153	0.056	0.007	
High bus freq.	-0.416	0.055	0.000		-0.490	0.052	0.000	0.232
Short walk to bus	-0.009	0.081	0.907	-0.188	-0.127	0.067	0.060	
Long walk to bus	0.230	0.183	0.211		0.370	0.125	0.003	
Amenities short walk	-0.263	0.055	0.000	0.142	-0.252	0.053	0.000	0.138
Amenities long walk	0.245	0.060	0.000		0.184	0.049	0.000	
Constant	1.775	0.114	0.000	-0.265	-0.955	0.104	0.000	
Pseudo R-squared	0.33							
Log Likelihood	-13917				-15374			
Chi squared	13747	Prob.	0.000		8319	Prob.	0.000	
Correct predictions	83.8%				72.5%			
Observations	38019				29033			

* Only those coefficients which are significant at at least the 10 percent level are shown.