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# The Determinants of Mode of Transport to Work in the Greater Dublin Area[1]

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*Abstract*: Rapid economic and demographic change in the Greater Dublin Area over the last decade, with associated increases in car dependence and congestion, has focused policy on encouraging more sustainable forms of travel. In this context, knowledge of current travel patterns and their determinants is crucial. Here we concentrate on travel for a specific journey purpose, namely the journey to work. We employ cross-section micro-data from the 2006 Census of Population to analyse the influence of travel and supply-side characteristics, as well as demographic and socio-economic characteristics on the choice of mode of transport to work in the Greater Dublin Area.

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# The Determinants of Mode of Transport to Work in the Greater Dublin Area

## 1. Introduction

As a result of rapid economic and demographic change over the last decade, and the resulting increase in car ownership, Ireland has experienced many of the problems associated with increasing levels of car dependence. The effects in the Greater Dublin Area (GDA)[2] have been particularly pronounced. Over the period 1996-2006, the population of the GDA grew by 18.3 per cent while the numbers in employment increased by 48.9 per cent, much of which was due to large increases in the rate of female participation in the labour force and the influx of foreign workers. In terms of the implications for transport, the most striking is the increase in the number of new vehicle registrations, which increased by over 60 in the GDA per cent over the period (Central Statistics Office, 2007). Data for journeys to work, school and college confirm this shift towards the private car; the proportions driving their car to work in the GDA increased from 46.7 per cent in 1996 to 51.8 per cent in 2006 (see Figure 1), while the proportion of primary school students travelling as a passenger in a car increased from 29.5 per cent in 1996 to 46.9 per cent in 2006, overtaking the proportions walking (36.4 per cent), which has traditionally been the primary means of transport to school for this age-group. The resulting levels of congestion impact on all those using the road and public transport network; in the Dublin area for example, average journey speeds in the morning peak for car and bus[3] decreased by 12.4 per cent and 6.2 per cent respectively between 2003 and 2004 (Dublin Transportation Office, 2005). There are also wider economic impacts, with carbon dioxide emissions from transport rising by 88.7 per cent between 1996 and 2006 (Lyons *et al.*, forthcoming). By European standards, Dublin is a low density city (see European Environment Agency, 2006) with the bus being the main form of public

[2] The Greater Dublin Area refers to Dublin city and county as well as the surrounding 'commuter' counties of Kildare, Meath and Wicklow. In 2006, the population of the GDA was 1.7m, which amounted to 39.2 per cent of the population of the Republic of Ireland (Central Statistics Office, 2008).
[3] Bus speeds on Quality Bus corridor routes (that is, routes with dedicated road space for buses) only.

transport. A number of radial commuter rail lines, as well as a coastal suburban rail line and two surface tram lines comprise the rail network.

[insert Figure 1 here]

Environmental considerations imply a need to reverse or at the very least to halt this shift in favour of the private car. In the past, the dominant strategy was to "predict and provide", that is, to respond to the projected increase in travel demand by increasing capacity, principally on the road network. The failing of continued investment in infrastructure is that it often gives rise to latent demand so that the alleviation of congestion is considerably less than envisaged (Madden, 2001). Recent thinking has moved away from the emphasis on increasing road capacity towards a variety of measures that seek to limit or redirect travel demand in the short- to medium-term and alternative more sustainable land-use strategies in the longer term (see Department of Transport, 2008a, 2008b, Dublin Transportation Office, 2001, 2006a, 2006b, European Commission, 2007, FitzGerald *et al.*, 2008, Morgenroth and FitzGerald, 2006). Investment in public transport and measures which seek to use existing infrastructure more efficiently such as improved cycle and bus lanes, parking restrictions, road pricing, carpooling *etc*. are all considered necessary if a shift away from the private car towards more sustainable methods of transport such as walking, cycling and public transport is to be achieved.

In the context of attempting to manage travel demand to encourage more sustainable forms of travel, knowledge of the factors influencing the demand for passenger transport is crucial, particularly in terms of forecasting but also for policy purposes (for example, promotional campaigns or planning) and for assessing the distributional impacts of various policy measures. Button, 1993 identifies a number of factors, namely income, price, price of alternatives and tastes and preferences4, which influence the demand for transport. In this paper we concentrate on transport demand for a specific journey purpose, namely the journey to work, and examine the influence of these various factors

[4] Button, 1993 interprets tastes and preferences to include primarily the socio-economic characteristics of the decision-maker.

on this decision. Data for the UK indicate that leisure trips account for the majority of trips per person per annum (26.1 per cent in 2006), with shopping journeys and the journey to work coming in second and third place with 21.1 per cent and 18.8 per cent of total journeys respectively (Department for Transport, 2007). Analyses of modal choice in the literature typically focus on the journey to work, rather than for other journey purposes, for a number of reasons. Levels of traffic congestion are highest during the morning and evening peaks meaning that work-related journeys cause the greatest challenge to transportation planners. However, due to the routine and repetitive nature of the journey, the potential for targeting individuals to travel by alternative non-car modes is greater than for less routine journeys (Kingham et al., 2001 and Pooley and Turnbull, 2000). In addition, survey data on commuting journeys are relatively easy to collect as individuals find it easy to recall a journey that is made on a regular basis over the same route, by the same mode and at the same time of day.

The purpose of this paper is therefore to analyse the demographic, socio-economic and supply-side determinants of the choice of mode of transport for the journey to work in the Greater Dublin Area in 2006 using discrete choice econometric methodologies. We extend previous Irish research to consider a wider range of supply-side influences on modal choice by exploiting the recent release of detailed micro-data on the full population of working individuals from the 2006 Census of Population (COP). Section 2 discusses previous literature in the area, both international and Irish. Section 3 describes the data and provides some descriptive statistics, while Section 4 describes the econometric methodology employed. Section 5 presents empirical results and Section 6 summarises, concludes and provides some suggestions for future research.

## 2. Previous Research

The analysis of travel behaviour is increasingly based on disaggregated data that reflects the travel behaviour of individuals. Due to the nature of the decisions under consideration, discrete or qualitative choice methods are typically employed. Discrete choice models estimate the probability that an individual decision maker will choose a particular alternative from a set of alternatives, as a function of the attributes of the choice and the demographic and socioeconomic characteristics of the individual. The models are grounded in consumer utility theory whereby the individual chooses among alternatives with the aim of maximising personal utility. The models differ in the functional form used to relate the observed data to the probability (see also Section 4).

Two approaches dominate the literature on modal choice decisions, namely, the multinomial logit (MNL) or conditional logit (CL) methodology[5] and the nested multinomial logit (NMNL) methodology.[6] Ben-Akiva and Lerman, 1975 and Hausman and Wise, 1978 employ the MNL methodology to the choice between a number of different alternatives for the journey to work in Washington. In addition to the modal choice question, the MNL methodology has been extensively applied to other transport decisions such as the number of cars to own (Alperovich *et al.*, 1999, Bhat and Pulugurtha, 1998 and Cragg and Uhler, 1970), the choice of car type (Lave and Train, 1979 and McCarthy, 1996), tourist destination (Eymann and Ronning, 1997) and the choice of departure time (McCafferty and Hall, 1982). Asensio, 2002, De Palma and Rochat, 2000, Dissanayake and Morikawa, 2005, Thobani, 1984 and Train, 1980 all use the NMNL methodology to estimate modal choice for the journeys to work in Barcelona, Geneva, Bangkok, Karachi and San Francisco respectively. The NMNL model overcomes the restrictive requirement of the MNL methodology to have distinct and independent alternatives, and also allows for the incorporation of higher-level decisions such as car ownership or household/work location. While modal choice for the journey to work is the primary focus of attention, a number of studies have analysed mode choice for other journey purposes (see Cohen and Harris, 1998 for trips made to visit friends and relatives, Domencich and McFadden, 1975 for shopping trips, Ewing *et al.*, 2004 for mode choice for the journey to school and McGillivray, 1972 for a number of additional journey purposes including personal business, visiting friends and relations, shopping and other recreation).

[5] The MNL and CL models differ in the type of explanatory variables that can be included; the CL model can support individual-specific as well as alternative-specific variables while the MNL can only support the former.

[6] De Donnea, 1971, Domencich and McFadden, 1975, Lave, 1970 and Madan and Groenhout, 1987 all use the binary logit methodology but the ability of the CL, MNL and NMNL methods to incorporate more than two categories of the dependent variable means that they are favoured in applied work relating to modal choice. Bhat and Pulugurtha, 1998 and Hausman and Wise, 1978 estimate multinomial probit models, but the computational complexity of this model means that it is rarely applied.

Previous research on Irish travel patterns is more limited. Morgenroth, 2002 uses gravity models to analyse the determinants of inter-county commuting flows, concentrating on the links between commuting and the housing and labour markets. Keane, 2001 similarly relates commuting to issues of job search and the development of local labour market areas to develop a theoretical model of commuting distances and labour market interactions between different areas. Nolan, 2003 examines the income and socio-economic determinants of household car ownership, car use and public transport use in the Dublin area, using micro-data from the 1987, 1994 and 1999 Irish Household Budget Surveys. McDonnell *et al.*, 2006 focus on the determinants of bus use, and carry out a stated preference modal choice study in a particular QBC (quality bus corridor) catchment area in Dublin. They find that the key to attracting commuters to bus is shorter journey times at peak times, even in high income areas. To our knowledge, only four previous studies have used earlier versions of the Census of Population data we employ in this paper. Horner, 1999 examines aggregate travel to work data from the 1981-1996 Census of Population and finds a substantial increase in car-based long distance commuting across the country. Walsh *et al*., 2005 describe patterns of travel to work using the disaggregated micro-data from the 2002 Census of Population, concentrating on the gateways and hubs identified in the National Spatial Strategy. They too highlight a substantial phenomenon of long-distance commuting (defined as greater than 30 miles). Vega and Reynolds-Feighan, 2006 estimate a simultaneous model of residential location and mode of transport to work (car versus public transport) in the Dublin area, and find significant effects for alternative characteristics such as travel time, as well as individual socio-economic characteristics. In a later paper, also using the 2002 Census of Population micro-data, Vega and Reynolds-Feighan, 2008 concentrate on four employment sub-centres in the Dublin area, and find that the spatial distribution of employment exerts a large and significant influence on the choice between car and public transport for the journey to work.

This paper extends previous Irish research to consider the full population of working individuals using micro-data on travel to work from the 2006 Census of Population, as well as making use of much more detailed information on place of residence and work to consider a wider range of supply-side variables in the analysis. We use the conditional logit methodology to assess the influence of individual-specific, as well as alternative-specific variables such as travel time, on the choice of mode of transport to work. Future work will incorporate more formally the car ownership decision using nested models, as well as further extending the analysis to other areas of the country (see also Section 6).

## 3. Econometric Methods

For the journey to work, an individual must choose between a set of discrete alternatives (transport modes). In this paper, we specify a conditional logit model, a particular type of discrete choice econometric method. The conditional logit model extends the multinomial logit model to include variables that describe the attributes of the choices (such as travel time), as well as variables that describe the attributes of the individuals (such as age or gender). Assume each individual $i$ faces a choice between a set of $J$ alternatives ($j = 1, 2, ......, J$), with the attributes of the choices described by $z_{ij}$ and the characteristics of the individual described by $x_i$. The model is based on McFadden's random utility framework (see McFadden, 1974), in which each individual $i$ aims to maximize their utility. The (unobserved) utility of each alternative is assumed to be a linear function of various independent variables and an error term as follows:

$$U_{ij}^{*} = x_i'\alpha_j + z_{ij}\beta + \varepsilon_{ij} \tag{1}$$

where $U_{ij}^{*}$ is the unobserved utility individual $i$ derives from alternative $j$, $x_i$ is the vector of individual-specific independent variables, $\alpha_j$ is the vector of estimated parameters for the individual-specific variables, $z_{ij}$ is the vector of alternative-specific variables, $\beta$ is the vector of alternative-specific parameters and $\varepsilon_{ij}$ is the error term. An individual $i$ chooses alternative $j$ if it gives the highest utility among all possible alternatives. The distributional assumptions concerning the random error component $\varepsilon_{ij}$ determine the form of the model. The most common assumption is that the error terms are independently and identically distributed with a Type 1 Extreme Value (or Weibull) distribution, which results in the following probability of individual $i$ choosing alternative $j$:

$$\Pr(y_i = j) = \frac{\exp(x_i\alpha_j + z_{ij}\beta)}{\sum_{k=1}^{K}\exp(x_i\alpha_k + z_{ik}\beta)} \tag{2}$$

Conditional logit regression methods (using the 'asclogit' command in STATA 10) are used to obtain estimates of the parameters $\alpha_j$ and $\beta$. The conditional logit model reduces to the multinomial logit model when all independent variables are individual-specific. As with the multinomial logit, a restrictive feature of the conditional logit model is the assumption of 'Independence from Irrelevant Alternatives' (IIA). The property implies that the relative probabilities between a pair of alternatives are specified without reference to the nature of the other alternatives in the choice set. In our case, we assume that the IIA assumption holds, although we also estimate a version of the model with three alternatives, formed from the merger of similar alternatives. Future work will refine the testing for IIA in our models.

In order to estimate the model, the data must be constructed in such a way that there are J observations for each individual i. We estimate two versions of our model; one with the full set of seven alternatives (walk, cycle, bus, train, car driver, car passenger, motorcycle), and the other with an aggregated set of three alternatives (walk/cycle, bus/train and car driver/car passenger/motorcycle). As there are 45,783 individuals in our sample with complete information on all variables of interest (see Section 4 below), this results in sample sizes of 320,481 for the seven-alternative model and 137,349 for the three-alternative model. Estimation results are presented in terms of odds ratios, with values greater than unity indicating an increased probability of observing the alternative in question, and values smaller than unity a reduced probability of observing the alternative in question.

## 4. Data

The data employed in this paper are micro-data from the Place of Work Census of Anonymised Records (POWCAR) from the 2006 Census of Population. The Census of Population is carried out every five years by the Central Statistics Office and includes all individuals present in the country at a specified point in time, namely, the last Sunday in April. For the first time, the micro-data for 2006 constitute the entire population of working individuals aged 15 years and older surveyed at home in private households. In total 1,834,472 individuals are included in the micro-data file. For this paper, we are concerned only with those living and working in the Greater Dublin Area, which reduces the population of interest to 590,317. After excluding observations where the individual works from home, where the place of employment was mobile and where "other means"[7] and lorry/van were recorded for mode of transport, the final sample for estimation is 547,625 individuals. To ease the computational burden, we take a 10 per cent random sample, which leaves a sample of 54,763 individuals. Complete information on all variables of interest is available for 45,783 individuals.

Each individual observation contains information on demographic and socio-economic characteristics such as age, gender, household type, housing tenure, marital status, education level, socio-economic group and industrial group, as well as variables relating to county and electoral division (ED8) of residence, county, ED and geo-code of place of work, distance travelled, time of departure and dominant mode of transport. All variables are self-reported. The COP does not contain information on income or prices. Mode of transport refers to the usual mode of transport for the outward journey to work. Where more than one mode of transport is used, the mode of transport used for the greater part of the journey (by distance) is recorded. Table 1 presents modal shares for 2006, and indicates that the majority of workers travelled by car (57.6 per cent), followed by walking (12.9 per cent) and travelling by bus (12.7 per cent).

[insert Table 1 here]

Independent variables are individual- as well as alternative-specific. While (self-reported) travel times for the individual's chosen mode are available in POWCAR, travel times for alternative modes are not. To estimate travel times for the non-chosen modes, we regress time on distance for each mode, and use the fitted values to predict average travel times for each of the alternative modes for each individual (see De Palma and Rochat, 2000 and Hole and FitzRoy, 2004 for a similar application). See Appendix A for these regression results. Cost information is not available in POWCAR. We tried to construct a simple alternative-specific (monetary) cost per kilometre variable using information on public transport fares and car operating costs (including fuel). However,

[7] These observations are excluded as the modelling approach requires that alternatives be distinct and independent.
[8] The electoral division (ED) is the smallest administrative area for which population statistics are published. There are 3,440 EDs in the state.

as we assume zero costs for the walking and cycling modes (in common with others in the literature; see for example, Hole and FitzRoy, 2004), and the lowest monetary cost is found for the most popular, motorised modes (car driver and car passenger), the estimated cost coefficient is always positive which is contrary to expectations. We therefore include the travel time variable as the sole alternative-specific variable in our research, but future work will attempt to refine the measure of cost and travel time to come up with a more accurate 'generalised cost' indicator for each alternative mode.

Individual-specific independent variables include the age of the individual (classified using a nine-category variable representing five-yearly age groups) and gender (with males regarded as the reference category). We also include a seven-category household composition variable to identify households with children, single parent households, other households *etc*. This is important as POWCAR does not include household identifiers, meaning that we cannot link household members. Individuals that are married[9] are indicated by a binary variable for marital status, as are individuals with third level education as their highest level of education completed. The socio-economic group of the individual is represented by a four-category variable that identifies individuals in the three highest socio-economic groups (A – employers and managers, B – higher professional and C – lower professional), with those in all other socio-economic groups regarded as the reference category. Finally, we include a four-category indicator for industrial group, in an attempt to proxy job characteristics such as flexibility in working hours, provision of company vehicles *etc*. Individuals working in the commercial sector, in public administration and defence, and in education, health and social services are included in the regressions, with those in all other industrial groups (agriculture, forestry and fishing, manufacturing, construction, transport, storage and communications and other industries) regarded as the reference category.

As household car ownership is a potentially endogenous predictor of modal choice, we use the predicted level of car ownership as an instrument for actual levels of car ownership (with the predicted level of car ownership calculated from a regression of car ownership levels on a variety of individual and household socio-economic variables, with

[9] Co-habitation is not recorded in the Census.

housing type and tenure regarded as the ‘identifying’ variables)[10]. We also include a dummy indicator for those working in Dublin city centre. This variable is included to proxy (very crudely) public transport availability and parking provision with the expectation that those working in the city centre will have better public transport options and/or poorer parking availability at work than those that for example, commute from one suburban location to another.

We also construct a number of supply-side variables based on ED-level data: rail availability, presence of park-and-ride facilities in the individual’s ED of residence and the presence of a QBC in the individual’s ED of residence. Rail availability is a binary variable based on a rail availability index, which records the percentage of addresses (residential and commercial) in each ED that are within two kilometres of the nearest rail (DART, commuter rail or LUAS) station. Our variable identifies individuals who live and work in EDs with 100 per cent of addresses within two kilometres of a rail station. Park-and-ride availability is based on whether the individual’s ED of residence contains a park-and-ride facility. Similarly, a binary variable is constructed to identify individuals living in EDs with a QBC (quality bus corridor, that is, a route with dedicated road space for buses). Potentially important omitted variables include cycle lane facilities and kilometres and public transport quality, accessibility and frequency, although matching such variables to EDs is difficult. Future work will consider the construction and inclusion of such variables.[11] Variable definitions and summary statistics are presented in Table 2.

[insert Table 2 here]

Table 3 presents some descriptive statistics on the proportions driving to work, walking and travelling by bus (the top three modes, which together account for over 80 per cent of all commuters), by selected individual characteristics. For example, the proportion of the working population driving to work is higher among males, those in the higher socio-economic groups and those working outside the city centre. On the other

[10] Results from this auxiliary regression are presented in Appendix B.
[11] See Ewing *et al*., 2004 for a discussion of the effect of footpaths and cycle lanes on choice of mode of transport to school in Florida.

hand, the proportions travelling by bus are higher among females, those in the lower socio-economic groups and those living in areas with a QBC. While the broad descriptive statistics are in agreement with expectations, a multivariate analysis is needed in order to ascertain whether variations in modal choice by age, gender, socio-economic group, area of residence and place of work *etc*. persist when all influences on commuting behaviour have been taken into account.

[insert Table 3 here]

While the initial analysis is restricted to those living and working in the Greater Dublin Area, it is still possible that each individual does not have access to the full range of alternative modes. For this reason, we also impose a number of restrictions on the choice set and estimate a second specification of the model with a restricted choice set. We consider walking to be "unavailable" for those who must travel over five kilometres to work, cycling to be "unavailable" for those who must travel 10 kilometres or more to work, rail to be "unavailable" for those living in EDs with fewer than 50 per cent of addresses within two kilometres of a rail station and car to be "unavailable" for those living in households without a car (see also Ewing *et al*., 2004 and Hole and FitzRoy, 2004). Regression results are presented in Appendix C and reference to these results is made in the discussion and presentation of results in Section 5.

## 5. Empirical Results

Tables 4 and 5 present estimation results from two specifications of the model:

a) conditional logit model of choice between three alternatives (walk/cycle, bus/train, car driver/car passenger/motorcycle)
b) conditional logit model of choice between seven alternatives (walk, cycle, bus, train, car driver, car passenger, motorcycle)

We also estimate model b) on a restricted choice set (see Section 4), and while the detailed results are presented in Appendix C, reference to these findings is made below.

Focusing on the results for the three-alternative model in Table 4, age is a significant predictor of choice of mode of transport to work. In comparison with those aged 15-24 years, all age groups are significantly less likely to walk or cycle or to take public transport to work, with the effects particularly strong for those aged 60+. Being female is associated with a significantly increased probability of travelling by bus or train to work, with a significant negative effect for walking and cycling.

Household composition is significant in determining mode of transport to work, with households comprised of couples with young children significantly less likely to walk or cycle or take public transport to work. Marital status and education level are both highly significant, with married individuals significantly less likely to walk, cycle or take public transport to work. Given the association between income and education, it is perhaps surprising that the probability of walking or cycling to work, or travelling by public transport, is significantly higher for those with third level qualifications. A possible explanation for this result is that those with higher levels of education may be more aware of the detrimental environmental effects of car driving and seek to modify it by choosing more environmentally friendly methods of transport.[12] Alternatively, people with higher education may work closer to home or in places that are better served by public transport (apart from the city centre, which is controlled for); or may be able to afford homes that are well served by public transport (apart from the rail availability dummy) (Mayor *et al*., 2008).

Individuals in the top three socio-economic groups (employers and managers, higher professionals and lower professionals) are significantly less likely to walk or cycle or travel by public transport to work. As socio-economic group is to an extent acting as a proxy for household resources, the results are consistent with expectations. Education may then be picking up tastes and preferences associated with higher levels of education, such as concern for the environment (and the odds ratios for education are larger than those for socio-economic group). Industrial group is included to proxy job-specific factors such as flexibility in departure time, the probability of part-time vs. full-time work, provision of company vehicles, location of work *etc*. The results suggest that those working in commerce or public administration and defence are significantly more likely to walk or cycle, or travel by public transport to work. The latter effect is surprising, given that those working in public administration and defence are more likely to be

[12] Johansson-Stenman (2002) includes membership of an environmental organisation as an independent variable in their model of choice of mode of transport to work, but finds an insignificant effect.

working in the city centre (this effect has been controlled for)[13]. However, it is possible that public servants are more likely to avail of subsidised public transport (through which commuters can avail of tax relief on the cost of monthly and annual public transport costs at their marginal rate of tax[14]). Individuals working in education, health or social work are however significantly less likely to travel by public transport to work, perhaps reflecting the variable nature of the hours (and locations) worked, and the poor provision of public transport to cater for these needs.

In terms of the ED-level transport characteristics, those working in the city centre are significantly more likely to walk, cycle or use public transport to work, as are those who live and work in areas with good rail coverage. The provision of park-and-ride facilities is associated with a significantly increased probability of travelling by public transport although the availability of QBCs is associated only with an increased probability of walking or cycling to work. It is possible that this effect is driven by the effect on cycling, with QBCs doubling as cycle lanes, and as such, disaggregating the categories will enable us to test this proposition (see the results in Table 5). As expected, individuals living in households with higher car ownership levels are significantly less likely to walk or cycle or travel by public transport to work. Our sole alternative-specific variable, average travel time per mode, is also highly significant and suggests that modes with higher journey times are significantly less likely to be chosen.

Moving on to results from the seven-alternative model in Table 5, the results are largely similar to those for the three-alternative model. However, while females are now significantly more likely to walk to work than males, they are significantly less likely to cycle[15], divergent effects that are masked by the aggregation of the categories (females are also significantly less likely to travel by motorcycle to work). Pooley and Turnbull (2000), who examine changes in mode of transport to work in Britain since 1890 and also find that females are significantly less likely to cycle than males, explain this trend by arguing that females are more conscious of safety risks associated with cycling in urban

[13] In addition, a recent survey by the Dublin City Business Association suggested that up to 60 per cent of car parking spaces in Dublin city centre were used by public servants, the majority of whom have free parking (Irish Times, June 16th, 2008).
[14] In 2004, over 40,000 commuters in 1,500 companies across Dublin availed of tax relief on public transport costs (Dublin Bus, 2005).
[15] Lunn and Layte, 2008 find the same for cycling as a sport.

traffic, they are more conscious of looking smart for work and they often have to undertake other tasks after work such as shopping or collecting children which would be difficult to accomplish by bicycle. Interestingly, education also has divergent effects on the probability of travelling by bus and train to work. While those with a third level education are significantly less likely than those with lower levels of education to travel by bus, they are significantly more likely to travel by train. It is possible that this reflects a preference among the well-educated for public transport alternatives of higher quality (that is, not subject to congestion, resulting in punctual services with more predictable journey times). It may also reflect the fact that the train generally has a better image than the bus (Webster and Bly, 1980), perhaps due to its comparative time and comfort advantages.

Consistent with prior expectations, the probability of travelling by train to work is significantly increased for those living and working in an area with good rail connections. The provision of park-and-ride facilities exerts a similar effect. Individuals living in areas with QBCs are significantly more likely to travel by bus, but significantly less likely to travel by train or by foot (divergent effects that are masked by an insignificant effect in the three-alternative model). The possibility that QBCs also encourage cycling is discounted, with QBCs having no significant effect on the probability of cycling to work, perhaps suggesting that the quality impact of QBCs doubling as cycle lanes is outweighed by the effect on the quality of the bus as a mode of transport. QBC provision has a significant positive effect on the probability of travelling by motorcycle to work, reflecting the importance of dedicated road space to users of this mode. Household car ownership and travel time are both highly significant, and consistent with expectations.

The results in both Tables 4 and 5 suggest that the dominant influences on modal choice are city centre work location, car availability, age, marital status and household composition. While car ownership, work location and ED-level characteristics such as rail availability, park and ride facilities and QBC availability are very important in determining choice of mode of transport to work, the significance of individual and household characteristics creates more complicated challenges for policymakers.[16] The significance of family circumstances (and specifically the presence of young children) suggests that a car may be perceived as a necessity for certain individuals, and that any attempts to make other modes of transport more attractive must consider this perception, although noting that in Ireland in the past, and in other countries at present, young children were/are walked or cycled to day care and school. While income information is unavailable, the divergent effects of education and social group on the probability of travelling by bus and train to work suggest that the bus may suffer from an image problem, and therefore that continuing investment in measures such as QBCs and express bus services for commuters are necessary in order to improve the attractiveness of bus as a mode of transport to work.

## 6. Summary and Conclusions

Despite the limitations associated with using Census of Population data to examine modal choice decisions (see Section 4), the results highlight the importance of individual demographic and socio-economic characteristics, as well as regional and travel variables such as rail availability, travel time and car ownership in explaining modal choice for the journey to work. Those working in the city centre are significantly more likely to walk or cycle, or take public transport to work, indicating the effect of public transport availability and city centre parking difficulties and restrictions. The significant positive results observed for public transport use by those working in the city centre may also add weight to the argument for the development of a more concentrated employment district in the city centre, to reverse the trends of employment suburbanisation and urban sprawl, which are considered to increase car dependence. In addition, in comparison with those with poor rail availability, those living and working in EDs with good rail facilities are significantly more likely to travel by rail (and indeed walk and cycle to work). This reflects the importance of public transport provision in influencing modal choice, even when car ownership, work location and travel time have been taken into account. Furthermore, the existence of park-and-ride facilities and QBC bus routes in an

[16] We also estimated the seven-alternative model on a restricted choice set (see Section 3 and Appendix C). The results are very similar to those presented in Table 5, with city centre work location, car availability, rail availability and age being most significant in determining mode of transport to work.

individual's ED is associated with a significantly increased probability of travelling by public transport to work. Note, however, that QBCs do reduce the probability of commuting on foot and by train. The insignificance of QBCs for bicycle use indicates that they should not be considered as a substitute for dedicated cycle lanes.

The significance of gender, household type and marital status in determining choice of mode of transport to work highlights the importance of household or family interactions in determining modal choice. While women are significantly less likely to walk or cycle to work (driven in large part by the significantly lower probability of women cycling to work), they are significantly more likely than men to take public transport to work. Individual modal choice decisions are often made with reference to other members of the household, in particular with regard to the needs and schedules of school-age children and/or the availability of the household car. In recent years, the proportion of schoolchildren being driven to school has increased substantially, and while the results here are static, the results for household type and marital status to some extent reflect this situation with individuals in households with young children being significantly less likely to walk, cycle or take public transport to work.

While a number of studies assume that modal choice decisions are independent of other decisions such as home/work location and car ownership, modal choice decisions are in fact part of a wider decision process incorporating choice of car ownership and residential and work location. For this paper, we assume that residential and work location are fixed[17], but in future work will incorporate the car ownership decision by estimating a nested logit model of car ownership and choice of mode of transport to work. Future research would also exploit the additional information contained in the 2006 POWCAR to gain a fuller understanding of travel to work patterns in not only the Greater Dublin Area, but also the wider commuter belt around Dublin, other urban areas and finally, rural areas. This would allow for an investigation into how different regions in Ireland vary in terms of the travel alternatives available to them, and the way in which

[17] We test for the plausibility of the latter assumption, by estimating the model on a sample of those working in 'public administration and defence' on the assumption that their place of work is an exogenously determined factor. With the exception of some significance levels which fall due to the smaller sample size, and the positive odds of choosing rail for those in the higher socio-economic groups, the results remain the same in sign and significance. See Appendix D.

their mode choices differ in response to their individual and alternative specific attributes. Our travel time and cost variables need to be refined further. The incorporation of travel costs into future research may give further insight into the degree to which different households are sensitive to price changes in alternative transport modes. This may help to explain how potential policy measures, such as the introduction of congestion charging, or a reduction in bus and rail fares, are likely to affect modal choice behaviour.

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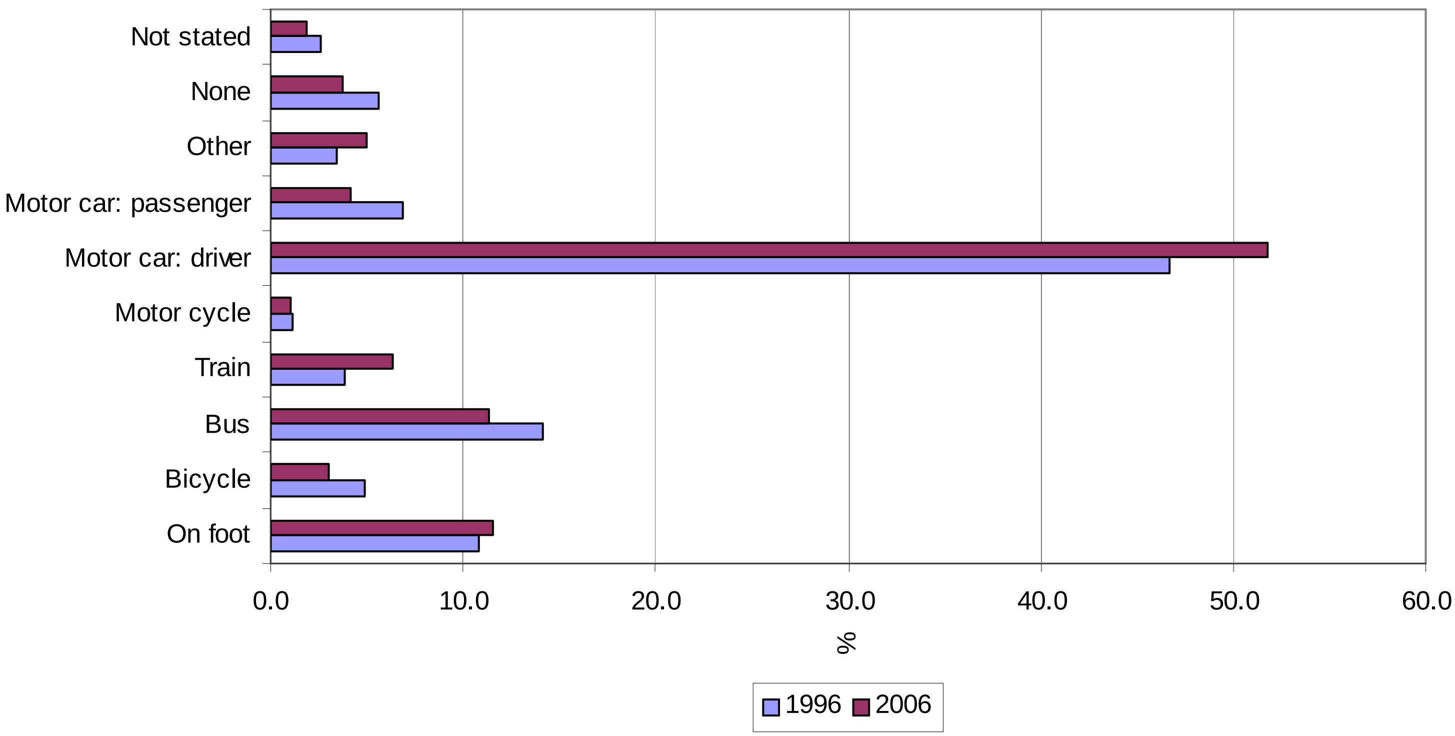
## FIGURES AND TABLES

Figure 1 Mode of Transport to Work in the Greater Dublin Area, 1996 and 2006




*Note*: None indicates those working from home, while 'other' includes those commuting by lorry or van.

*Source*: CSO Census Interactive Tables (www.cso.ie)

Table 1 Mode of transport to work in the Greater Dublin Area, 2006 (full population of working individuals 15+ years)

| | % |
|---|---|
| On Foot | 12.9 |
| Bicycle | 3.5 |
| Bus | 12.7 |
| Train | 7.8 |
| Car driver | 57.6 |
| Car passenger | 4.3 |
| Motorcycle, scooter | 1.2 |
| | |
| Total | 100.0 |

The samples exclude those who stated that they work at home, travelled by “other” means (including lorry or van), or did not answer the question (see also Section 4).
Source: 2006 POWCAR

Table 2 Variable definitions and summary statistics, 2006

| | Definition | % |
|---|---|---|
| Age 25-29 | =1 if aged 25-29 | 18.3 |
| Age 30-34 | =1 if aged 30-34 | 16.1 |
| Age 35-39 | =1 if aged 35-39 | 12.7 |
| Age 40-44 | =1 if aged 40-44 | 11.2 |
| Age 45-49 | =1 if aged 45-49 | 10.0 |
| Age 50-54 | =1 if aged 50-54 | 8.4 |
| Age 55-59 | =1 if aged 55-59 | 6.1 |
| Age 60-64 | =1 if aged 60-64 | 3.3 |
| Age 65+ | =1 if aged 65+ years | 1.0 |
| | (Reference category = aged 15-24 years) | 12.9 |
| | | |
| Female | =1 if female | 50.6 |
| | (Reference category = male) | 49.4 |
| | | |
| Lone parent with at least one resident child under 19 | =1 if lone parent with children under 19 years | 4.9 |
| Lone parent with resident children but none under 19 | =1 if lone parent with children over 19 years | 4.0 |
| Couple with at least one resident children under 19 | =1 if couple with children under 19 years | 35.0 |
| Couple with resident children but none under 19 | =1 if couple with children over 19 years | 11.9 |
| Couple with no resident children | =1 if couple with no resident children | 17.9 |
| Other households | =1 if other household types | 17.7 |
| | (Reference category = single households) | 8.5 |
| | | |
| Ever married | =1 if married, separated/divorced, widowed | 52.7 |
| | (Reference category = single) | 47.3 |
| | | |
| Third level | =1 if highest level of education completed is third level | 50.5 |
| | (Reference category = less than third level) | 49.5 |
| | | |
| Employers or managers | =1 if employer or manager | 19.9 |
| Higher professional | =1 if higher professional | 10.3 |
| Lower professional | =1 if lower professional | 16.3 |
| | (Reference category = all other socio-economic groups) | 53.5 |
| | | |
| Commerce | =1 if works in commerce | 39.4 |
| Public administration | =1 if works in public administration or defence | 7.3 |
| Health, education, social | =1 if works in health, education or social work | 19.5 |
| | (Reference category = all other industrial groups) | 33.8 |
| | | |
| Detached* | =1 if living in a detached house | 20.9 |
| Semi-detached* | =1 if living in a semi-detached house | 40.2 |
| Terraced* | =1 if living in a terraced house | 23.4 |
| | (Reference group = living in an apartment, flat, bedsit, mobile home or temporary structure) | 15.4 |

Table 2 continued

| | Definition | % |
|---|---|---|
| Owner-occupier* | =1 if owner-occupier (owned outright or mortgage) | 76.9 |
| | (Reference category = renting) | 23.1 |
| Working in city centre | =1 if works in Dublin County Borough (city centre) | 47.9 |
| | (Reference category = works elsewhere) | 52.1 |
| Rail available | =1 if lives and works in an ED where 100 per cent of addresses are within 2 kilometres of a rail station | 27.6 |
| | (Reference category = does not live and work in such an ED) | 72.4 |
| Park and ride | =1 if lives in an ED with park and ride facilities | 18.0 |
| | (Reference category = does not live in an ED with park and ride) | 82.0 |
| QBC | =1 if lives in an ED with a QBC | 59.2 |
| | (Reference category = does not live in an ED with a QBC) | 40.8 |
| Household cars | Predicted number of household cars per household member | 1.6** |

* Used in the auxiliary regression predicting household car ownership (see Appendix A)
** sample average

Table 3 Proportion walking, travelling by bus and driving a car to work by individual-specific characteristics, 2006

| | On foot | Bus | Car driver |
|---|---|---|---|
| Age 25-29 | 16.4 | 16.8 | 46.2 |
| Age 30-34 | 11.5 | 11.4 | 59.0 |
| Age 35-39 | 9.7 | 9.1 | 65.8 |
| Age 40-44 | 9.5 | 8.2 | 68.6 |
| Age 45-49 | 10.5 | 8.9 | 67.3 |
| Age 50-54 | 10.7 | 9.4 | 66.8 |
| Age 55-59 | 11.4 | 9.7 | 66.2 |
| Age 60-64 | 11.2 | 9.9 | 67.0 |
| Age 65+ | 12.6 | 9.4 | 66.4 |
| | | | |
| Male | 10.3 | 10.9 | 59.9 |
| Female | 15.3 | 14.4 | 55.4 |
| | | | |
| Single Person | 15.5 | 13.1 | 56.7 |
| Lone parent with at least one resident child under 19 | 18.4 | 14.5 | 56.4 |
| Lone parent with resident children but none under 19 | 13.4 | 19.3 | 50.8 |
| Couple with at least one resident children under 19 | 7.8 | 8.1 | 69.5 |
| Couple with resident children but none under 19 | 9.6 | 14.3 | 58.2 |
| Couple with no resident children | 10.6 | 10.9 | 59.1 |
| Other households | 24.5 | 20.5 | 34.5 |
| | | | |
| Ever married | 9.5 | 8.1 | 68.4 |
| Single | 16.7 | 17.8 | 45.6 |
| | | | |
| Third level education | 11.7 | 11.8 | 58.1 |
| Less than third level | 13.9 | 13.6 | 57.4 |
| | | | |
| Employers and managers | 7.7 | 8.3 | 69.2 |
| Higher professional | 11.6 | 9.6 | 57.9 |
| Lower professional | 11.3 | 10.9 | 60.9 |
| All other socio-economic groups | 15.5 | 15.5 | 52.2 |
| | | | |
| Commerce | 13.9 | 14.8 | 51.8 |
| Public administration and defence | 8.5 | 15.1 | 55.5 |
| Health, education and social work | 14.6 | 9.4 | 63.6 |
| All other industrial groups | 11.6 | 11.6 | 61.5 |
| | | | |
| Working in the city centre | 15.2 | 18.2 | 44.2 |
| Not working in the city centre | 10.7 | 7.7 | 69.9 |

Table 3 continued

| | On foot | Bus | Car driver |
|---|---|---|---|
| Rail available | 25.1 | 15.2 | 36.7 |
| Rail not available | 8.2 | 11.8 | 65.6 |
| | | | |
| Park and ride available | 9.8 | 8.0 | 58.5 |
| No park and ride available | 13.5 | 13.7 | 57.4 |
| | | | |
| QBC | 15.1 | 16.8 | 51.0 |
| No QBC | 9.6 | 6.8 | 67.2 |
| | | | |
| No household car | 40.0 | 34.0 | 1.4 |
| One or more household cars | 9.1 | 9.7 | 65.4 |
| | | | |
| Average | 12.9 | 12.7 | 57.6 |

Table 4 Conditional Logit Estimates (Odds Ratios – Reference Choice is Car Driver, Car Passenger and Motorcycle)

| | On Foot/Bicycle | Bus/Train |
|---|---|---|
| *Individual-specific variables* | | |
| Age 15-24 | ref | ref |
| Age 25-29 | 0.72 *** | 0.67 *** |
| Age 30-34 | 0.59 *** | 0.53 *** |
| Age 35-39 | 0.44 *** | 0.41 *** |
| Age 40-44 | 0.46 *** | 0.38 *** |
| Age 45-49 | 0.50 *** | 0.36 *** |
| Age 50-54 | 0.54 *** | 0.40 *** |
| Age 55-59 | 0.46 *** | 0.38 *** |
| Age 60+ | 0.38 *** | 0.34 *** |
| | | |
| Male | ref | ref |
| Female | 0.87*** | 1.26 *** |
| | | |
| Single Person | ref | ref |
| Lone parent with at least one resident child under 19 | 0.33 *** | 0.43 *** |
| Lone parent with resident children but none under 19 | 0.57 *** | 0.88 |
| Couple with at least one resident children under 19 | 0.37 *** | 0.42 *** |
| Couple with resident children but none under 19 | 0.52 *** | 0.70 *** |
| Couple with no resident children | 0.81 *** | 0.88 ** |
| Other households | 1.12 | 1.03 |
| | | |
| Single | ref | ref |
| Ever married | 0.79 *** | 0.68 *** |
| | | |
| Less than third level | ref | ref |
| Third level | 1.12 *** | 1.16 *** |
| | | |
| Employers and managers | 0.67 *** | 0.76 *** |
| Higher professional | 0.98 | 0.80 *** |
| Lower professional | 0.83 *** | 0.86 *** |
| All other socio-economic groups | ref | ref |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

Table 4 continued

| | On Foot/Bicycle | | Bus/Train |
|---|---|---|---|
| Commerce | 1.34 *** | | 1.55 *** |
| Public administration and defence | 1.45 *** | | 1.60 *** |
| Education, health and social work | 1.02 | | 0.68 *** |
| All other industrial groups | ref | | ref |
| | | | |
| Working in the city centre | 2.66 *** | | 5.05 *** |
| | | | |
| Rail available | 1.63 *** | | 1.33 *** |
| | | | |
| Park and ride facilities | 1.03 | | 1.69 *** |
| | | | |
| Quality bus corridor | 0.84 *** | | 1.03 |
| | | | |
| Number of household cars per person (predicted) | 0.13 *** | | 0.18 *** |
| | | | |
| *Alternative-specific variables* | | | |
| Travel time (minutes) | | 0.79 *** | |
| | | | |
| Number of Observations | | 137,349 | |
| Number of Individuals | | 45,783 | |
| Log-Likelihood | | -28,705.442 | |
| Wald $\chi^2$ (57) | | 11,598.09 | |
| Prob > $\chi^2$ | | 0.00 | |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

Table 5 Conditional Logit Estimates (Odds Ratios – Reference Choice is Car Driver)

| | On Foot | Bicycle | Bus | Train | Car passenger | Motorcycle |
|---|---|---|---|---|---|---|
| *Individual-specific variables* | | | | | | |
| Age 15-24 | ref | ref | ref | ref | ref | ref |
| Age 25-29 | 0.59 *** | 0.73 *** | 0.55 *** | 0.65 *** | 0.44 *** | 0.86 |
| Age 30-34 | 0.42 *** | 0.82 * | 0.44 *** | 0.49 *** | 0.36 *** | 1.19 |
| Age 35-39 | 0.30 *** | 0.62 *** | 0.33 *** | 0.38 *** | 0.29 *** | 1.17 |
| Age 40-44 | 0.30 *** | 0.68 *** | 0.29 *** | 0.36 *** | 0.18 *** | 1.14 |
| Age 45-49 | 0.36 *** | 0.59 *** | 0.29 *** | 0.33 *** | 0.25 *** | 0.77 |
| Age 50-54 | 0.41 *** | 0.62 *** | 0.37 *** | 0.28 *** | 0.27 *** | 0.62 ** |
| Age 55-59 | 0.34 *** | 0.44 *** | 0.34 *** | 0.29 *** | 0.22 *** | 0.35 *** |
| Age 60+ | 0.28 *** | 0.39 *** | 0.32 *** | 0.22 *** | 0.22 *** | 0.35 *** |
| | | | | | | |
| Male | ref | ref | ref | ref | ref | ref |
| Female | 1.35 *** | 0.33 *** | 1.41*** | 1.12 *** | 1.70 *** | 0.15 *** |
| | | | | | | |
| Single Person | ref | ref | ref | ref | ref | ref |
| Lone parent with at least one resident child under 19 | 0.25 *** | 0.29 *** | 0.36 *** | 0.39 *** | 0.51 *** | 0.69 |
| Lone parent with resident children but none under 19 | 0.52 *** | 0.61 *** | 0.88 | 0.79 * | 1.34 | 1.30 |
| Couple with at least one resident children under 19 | 0.28 *** | 0.49 *** | 0.34 *** | 0.53 *** | 1.14 | 0.59 *** |
| Couple with resident children but none under 19 | 0.49 *** | 0.60 *** | 0.68 *** | 0.80 ** | 2.13 *** | 1.00 |
| Couple with no resident children | 0.82 ** | 0.81 * | 0.86 ** | 1.03 | 2.50 *** | 0.95 |
| Other households | 1.14 | 1.22 * | 1.04 | 1.09 | 1.90 *** | 0.82 |
| | | | | | | |
| Single | ref | ref | ref | ref | ref | ref |
| Ever married | 0.77 *** | 0.74 *** | 0.61 *** | 0.75 *** | 1.00 | 0.95 |
| | | | | | | |
| Less than third level | ref | ref | ref | ref | ref | ref |
| Third level | 0.99 | 1.28 *** | 0.90 *** | 1.58 *** | 0.64 *** | 0.83 * |
| | | | | | | |
| Employers and managers | 0.65 *** | 0.60 *** | 0.62 *** | 0.94 | 0.57 *** | 0.56 *** |
| Higher professional | 0.83 ** | 1.11 | 0.61 *** | 1.04 | 0.50 *** | 0.99 |
| Lower professional | 0.77 *** | 0.95 | 0.74 *** | 1.09 | 0.84 ** | 1.01 |
| All other socio-economic groups | ref | ref | ref | ref | ref | ref |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

Table 5 continued

| | On Foot | Bicycle | Bus | Train | Car passenger | Motorcycle |
|---|---|---|---|---|---|---|
| Commerce | 1.41 *** | 1.10 * | 1.34 *** | 1.86 *** | 0.91 * | 1.02 |
| Public administration and defence | 1.35 *** | 1.51 *** | 1.39 *** | 1.94 *** | 0.87 | 1.06 |
| Education, health and social work | 0.96 | 1.03 | 0.68 *** | 0.62 *** | 0.76 *** | 0.62 *** |
| All other industrial groups | ref | ref | ref | ref | ref | ref |
| Working in the city centre | 2.76 *** | 3.08 *** | 4.48 *** | 6.35 *** | 1.22 *** | 2.64 *** |
| Rail available | 1.73 *** | 1.35 *** | 0.90 *** | 2.69 *** | 0.95 | 1.18 |
| Park and ride facilities | 0.96 | 0.87 * | 0.93 | 2.80 *** | 0.97 | 0.86 |
| Quality bus corridor | 0.88 *** | 1.00 | 1.38 *** | 0.69 *** | 0.87 ** | 1.80 *** |
| Number of household cars per person (predicted) | 0.09 *** | 0.16 *** | 0.11 *** | 0.26 *** | 0.23 *** | 0.52 ** |
| *Alternative-specific variables* | | | | | | |
| Travel time (minutes) | | | 0.87 *** | | | |
| Number of Observations | | | 320,481 | | | |
| Number of Individuals | | | 45,783 | | | |
| Log-Likelihood | | | -44,460.787 | | | |
| Wald $\chi^2$ (169) | | | 15,808.30 | | | |
| Prob > $\chi^2$ | | | 0.00 | | | |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

**APPENDIX A**

Table A1 OLS Regression Results for Calculation of Predicted Travel Times (coefficients)

| | On foot | Bicycle | Bus | Train | Motorcycle | Car driver | Car passenger |
|---|---|---|---|---|---|---|---|
| 7-alternative model | | | | | | | |
| Distance (kms) | 6.62 *** | 2.35 *** | 1.44 *** | 1.03*** | 0.96 *** | 1.08 *** | 1.14 *** |
| | | | | | | | |
| Number of individuals | 52,033 | 16,803 | 55,837 | 37,135 | 5,984 | 278,519 | 19,783 |
| R-squared | 0.57 | 0.58 | 0.33 | 0.36 | 0.46 | 0.42 | 0.43 |
| | | | | | | | |
| 3-alternative model | | | | | | | |
| Distance (kms) | 2.83 *** | | 1.18 *** | | 1.08 *** | | |
| | | | | | | | |
| Number of individuals | 68,836 | | 92,972 | | 304,286 | | |
| R-squared | 0.37 | | 0.34 | | 0.42 | | |

Run on the full sample of working individuals living and working in the GDA

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

**APPENDIX B**

Table B1 OLS model of Household Car Ownership (Coefficients - Reference Choice is No Car)

| | Coefficients |
|---|---|
| Age 15-24 | ref |
| Age 25-29 | -0.06 *** |
| Age 30-34 | -0.17 *** |
| Age 35-39 | -0.22 *** |
| Age 40-44 | -0.23 *** |
| Age 45-49 | -0.15 *** |
| Age 50-54 | -0.10 *** |
| Age 55-59 | -0.10 *** |
| Age 60+ | -0.17 *** |
| | |
| Male | ref |
| Female | 0.07*** |
| | |
| Single Person | -0.81 *** |
| Lone parent with at least one resident child under 19 | -0.45 *** |
| Lone parent with resident children but none under 19 | -0.35 *** |
| Couple with at least one resident children under 19 | ref |
| Couple with resident children but none under 19 | 0.30 *** |
| Couple with no resident children | -0.27 *** |
| Other households | -0.18 *** |
| | |
| Single | ref |
| Ever married | -0.07 *** |
| | |
| Less than third level | ref |
| Third level | 0.11 *** |
| | |
| Employers and managers | 0.21 *** |
| Higher professional | 0.18 *** |
| Lower professional | 0.09 *** |
| All other socio-economic groups | ref |
| | |
| Commerce | 0.01 |
| Public administration and defence | -0.02 |
| Education, health and social work | -0.00 |
| All other industrial groups | ref |
| | |
| Detached | 0.64 *** |
| Semi-detached | 0.41 *** |
| Terraced | 0.20 *** |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

Table B1 continued

| | Coefficients |
|---|---|
| Owner-occupier | 0.45 *** |
| Working in the city centre | -0.10 *** |
| Rail available | -0.15 *** |
| Park and ride facilities | -0.03 *** |
| Quality bus corridor | -0.08 *** |
| Number of individuals | 52,025 |
| R-squared | 0.32 |
| F (31, 51993) | 773.36 |
| Prob > F | 0.00 |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level

**APPENDIX C**

Table C1 Conditional Logit Estimates with Restricted Choice Set (Odds Ratios – Reference Choice is Car Driver)

| | On Foot | Bicycle | Bus | Train | Car passenger |
|---|---|---|---|---|---|
| *Individual-specific variables* | | | | | |
| Age 15-24 | ref | ref | ref | ref | ref |
| Age 25-29 | 0.54 *** | 0.67 *** | 0.50 *** | 0.58 *** | 0.38 *** |
| Age 30-34 | 0.37 *** | 0.71 *** | 0.40 *** | 0.43 *** | 0.30 *** |
| Age 35-39 | 0.26 *** | 0.52 *** | 0.29 *** | 0.33 *** | 0.22 *** |
| Age 40-44 | 0.26 *** | 0.58 *** | 0.26 *** | 0.31 *** | 0.13 *** |
| Age 45-49 | 0.30 *** | 0.48 *** | 0.25 *** | 0.27 *** | 0.18 *** |
| Age 50-54 | 0.34 *** | 0.48 *** | 0.31 *** | 0.23 *** | 0.18 *** |
| Age 55-59 | 0.28 *** | 0.35 *** | 0.28 *** | 0.22 *** | 0.15 *** |
| Age 60+ | 0.24 *** | 0.29 *** | 0.26 *** | 0.17 *** | 0.15 *** |
| | | | | | |
| Male | ref | ref | ref | ref | ref |
| Female | 1.40 *** | 0.33 *** | 1.52 *** | 1.15 *** | 1.79 *** |
| | | | | | |
| Households with no children | ref | ref | ref | ref | ref |
| Households with at least one resident child under 19 | 0.41 *** | 0.66 *** | 0.52 *** | 0.70 *** | 0.76 *** |
| Households with resident children but none under 19 | 0.70 *** | 0.81 ** | 1.04 | 1.08 | 1.37 *** |
| | | | | | |
| Single | ref | ref | ref | ref | ref |
| Ever married | 0.89 * | 0.87 * | 0.69 *** | 0.92 | 1.46 *** |
| | | | | | |
| Less than third level | ref | ref | ref | ref | ref |
| Third level | 1.07 | 1.40 *** | 0.94 | 1.64 *** | 0.68 *** |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level
Due to the restricted choice set, some of the household composition categories had to be aggregated. In addition, as the rail availability variable was used to restrict the choice set, it is dropped from the model.

Table C1 continued

| | On Foot | Bicycle | Bus | Train | Car passenger |
|---|---|---|---|---|---|
| Employers and managers | 0.71 *** | 0.65 *** | 0.66 *** | 0.98 | 0.61 *** |
| Higher professional | 0.93 | 1.23 ** | 0.68 *** | 1.11 | 0.54 *** |
| Lower professional | 0.81 *** | 1.01 | 0.77 *** | 1.13 *** | 0.86 * |
| All other socio-economic groups | ref | ref | ref | ref | ref |
| | | | | | |
| Commerce | 1.47 *** | 1.14 ** | 1.38 *** | 1.78 *** | 0.94 |
| Public administration and defence | 1.42 *** | 1.60 *** | 1.44 *** | 1.92 *** | 0.91 |
| Education, health and social work | 0.96 | 1.00 | 0.68 *** | 0.61 *** | 0.74 *** |
| All other industrial groups | ref | ref | ref | ref | ref |
| | | | | | |
| Working in the city centre | 2.89 *** | 3.60 *** | 5.25 *** | 5.53 *** | 1.43 *** |
| | | | | | |
| Rail available | 1.65 *** | 1.22 *** | 0.88 *** | 1.13 *** | 0.93 |
| | | | | | |
| Park and ride facilities | 0.99 | 0.91 | 0.90 ** | 2.10 *** | 0.96 |
| | | | | | |
| Quality bus corridor | 0.78 *** | 0.85 ** | 1.28 *** | 0.54 *** | 0.78 *** |
| | | | | | |
| Number of household cars per person (predicted) | 0.14 *** | 0.27 *** | 0.19 *** | 0.48 *** | 0.47 *** |
| | | | | | |
| *Alternative-specific variables* | | | | | |
| Travel time (minutes) | | | 0.90 *** | | |
| | | | | | |
| Number of Observations | | | 200,653 | | |
| Number of Individuals | | | 45,185 | | |
| Log-Likelihood | | | -37,196.012 | | |
| Wald $\chi^2$ (121) | | | 10520.80 | | |
| Prob > $\chi^2$ | | | 0.00 | | |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level
Due to the restricted choice set, some of the household composition categories had to be aggregated. In addition, as the rail availability variable was used to restrict the choice set, it is dropped from the model.

**APPENDIX D**

Table D1 Conditional Logit Estimates for Individuals working in Public Administration and Defence (Odds Ratios – Reference Choice is Car Driver)

| | On Foot | Bicycle | Bus | Train | Car passenger | Motorcycle |
|---|---|---|---|---|---|---|
| *Individual-specific variables* | | | | | | |
| Age 15-24 | ref | ref | ref | ref | ref | ref |
| Age 25-29 | 0.75 | 2.08 | 0.58 ** | 0.74 | 0.35 ** | 1.57 |
| Age 30-34 | 0.67 | 2.19 | 0.53 ** | 0.55 * | 0.38 ** | 1.98 |
| Age 35-39 | 0.98 | 1.80 | 0.57 ** | 0.71 | 0.14 *** | 1.84 |
| Age 40-44 | 0.57 | 2.28 | 0.51 ** | 0.56 * | 0.31 *** | 1.99 |
| Age 45-49 | 0.63 | 1.33 | 0.49 *** | 0.70 | 0.24 *** | 2.40 |
| Age 50-54 | 1.13 | 1.72 | 0.52 ** | 0.79 | 0.59 | 1.45 |
| Age 55-59 | 0.87 | 2.29 | 0.56 * | 0.66 | 0.51 | 0.67 |
| Age 60+ | 0.82 | 1.30 | 0.59 | 0.48 * | 0.21 ** | 1.70 |
| | | | | | | |
| Male | ref | ref | ref | ref | ref | ref |
| Female | 1.51 *** | 0.43 *** | 2.19 *** | 1.53 *** | 2.63 *** | 0.07 *** |
| | | | | | | |
| Households with no children | ref | ref | ref | ref | ref | ref |
| Households with at least one resident child under 19 | 0.34 *** | 0.57 ** | 0.40 *** | 0.57 *** | 0.64 | 1.08 |
| Households with resident children but none under 19 | 0.56 ** | 0.77 | 0.94 | 0.69 ** | 0.70 | 1.02 |
| | | | | | | |
| Single | ref | ref | ref | ref | ref | ref |
| Ever married | 0.51 *** | 0.72 | 0.50 *** | 0.79 | 0.77 | 0.62 |
| | | | | | | |
| Less than third level | ref | ref | ref | ref | ref | ref |
| Third level | 1.11 | 1.29 | 0.90 | 1.34 ** | 0.63 ** | 1.11 |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level
Due to the smaller sample size, some of the household composition categories had to be aggregated.

Table D1 continued

| | On Foot | Bicycle | Bus | Train | Car passenger | Motorcycle |
|---|---|---|---|---|---|---|
| Working in the city centre | 2.12 *** | 4.65 *** | 6.93 *** | 10.39 *** | 1.11 | 2.36 *** |
| Rail available | 2.01 *** | 1.47 ** | 0.93 | 2.52 *** | 0.69 | 1.08 |
| Park and ride facilities | 0.55 ** | 0.87 | 0.76 | 3.68 *** | 0.96 | 1.03 |
| Quality bus corridor | 1.00 | 1.54 * | 1.53 *** | 0.54 *** | 1.14 | 1.57 * |
| Number of household cars per person (predicted) | 0.14 *** | 0.33 ** | 0.23 *** | 0.42 ** | 0.23 ** | 0.61 |
| *Alternative-specific variables* | | | | | | |
| Travel time (minutes) | | | 0.89 *** | | | |
| Number of Observations | | | 26,019 | | | |
| Number of Individuals | | | 3,717 | | | |
| Log-Likelihood | | | -3984.1608 | | | |
| Wald $\chi^2$ (109) | | | 1331.85 | | | |
| Prob > $\chi^2$ | | | 0.00 | | | |

*** Significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level
Due to the smaller sample size, some of the household composition categories had to be aggregated.

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