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# MODELLING THE RELATIONSHIP BETWEEN TRAVEL BEHAVIOUR AND SOCIAL DISADVANTAGE

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## RESEARCH HIGHLIGHTS

1. The paper models travel behaviour of socially disadvantaged population segments in the United Kingdom.
2. Results indicated significant differences in the trip patterns and distances travelled by low-income and other key indicators of social disadvantage.
3. While higher income groups travel more because they want to, some very low-income groups (such as lone parents) may travel more because they are obliged to.
4. Conversely, the non-white UK population seems to make significantly less weekly trips than the average population.
5. Understanding these differential behaviours is important in light of severe cutbacks in transport spending for economic austerity.

**ABSTRACT**

The purpose of this paper is to model the travel behaviour of socially disadvantaged population segments in the United Kingdom (UK) using the data from the UK National Travel Survey 2002-2010. This was achieved by introducing additional socioeconomic variables into a standard national-level trip end model (TEM) and using purpose-based analysis of the travel behaviours of certain key socially disadvantaged groups. Specifically the paper aims to explore how far the economic and social disadvantages of these individuals can be used to explain the inequalities in their travel behaviours.

The models demonstrated important differences in travel behaviours according to household income, presence of children in the household, possession of a driver's license and belonging to a vulnerable population group, such as being disabled, non-white or having single parent household status. In the case of household income, there was a non-linear relationship with trip frequency and a linear one with distance travelled. The recent economic austerity measures that have been introduced in the UK and many other European countries have led to major cutbacks in public subsidies for socially necessary transport services, making results such as these increasingly important for transport policy decision-making. The results indicate that the inclusion of additional socioeconomic variables is useful for identifying significant differences in the trip patterns and distances travelled by low-income.

*Keywords: travel behaviours, social disadvantage, income effects, models, transport policy*

## 1. INTRODUCTION

Currently, mathematical models of travel behaviour tend to dominate all levels of transport decision-making. This is due to their ability to offer policy-makers convenient *ex-ante* methods to justify broad-brush policies, detailed planned measures and national and local spending decisions (Van de Voorde and Vanelslander, 2010). It is widely acknowledged (even the key advocates of such models) that, despite their increasing complexity, most struggle to capture the intricate nuances of people's everyday experiences of the transport system (Hensher and Greene, 2003). This can be particularly important where it is evident that different sectors of the population exhibit fundamentally different travel behaviours, as is often the case with socially disadvantaged groups (Dargay, 2007).

The development of innovative methodological approaches is fundamental to an improved understanding of these travel behaviours. However, our aim in this paper is not to build new models of travel behaviour, rather we explore whether the *existing standard* transport models and datasets that are in everyday use by transport policy-makers (e.g., Ortúzar and Willumsen, 2011) can be readily adapted for this purposes. Our rationale is that the transport policy community may be more prepared to adopt familiar and simple models than they would to entirely new methodologies or more complex modelling approaches. It is particularly important that they do so in the context of rapidly changing patterns of car ownership and mode shares amongst low-income sections of populations in the developed and developing world (e.g., Crôtte et al., 2011).

Our research, which is based on analysis of the UK National Travel Survey 2002-2010, highlights that car ownership trends and trip-making patterns of low-income households differ from the average population. This is because they have greater suppressed travel demands (Duvarci and Mizokami, 2009). Yet many national and local transport models do not currently account for these disparities, partly due to their use of aggregated trends in travel behaviour models. As such, inaccurate predictions may result, which can have serious implications for policy decisions and investments in new transport systems (Goodwin, 2012).

The paper is divided into four main sections. The next section provides a background context and rationale for the study, based upon a review of the empirical literatures in this area. Section 3 describes the dataset for the analysis and the overall approach to model development. It then outlines the methods and results for two extended models that include new variables for household income and descriptors of social disadvantage. The final section of the paper sets out the next steps and future challenges for the research and discusses its implications for policy and practice in the UK and elsewhere.

## 2. LITERATURE REVIEW

A background review of the literatures for this research identifies that academic studies of the transport concerns of economically and socially disadvantaged populations have been prolific over the past ten or more years. There is also an increased policy interest in the contribution of transport to the social disadvantage of low-income population groups in the UK and elsewhere (Lucas, 2012). These concerns have become particularly acute in light of the recently introduced

economic austerity measures, which have led to severe cuts in public subsidies in several advanced economies, such as the UK. Concern about meeting the transport needs of low-income population groups is also prevalent in developing cities where there is increased evidence of unequal mobility and accessibility, despite the development of major new transport services (Manaugh and El-Geneidy, 2012; Jaramillo et al., 2012). However, few academic studies have *specifically* attempted to quantitatively model the influence of income and indices of social disadvantage on people's travel behaviours.

A review of the recent studies of the travel behaviours of socially disadvantaged population groups suggests that these can largely be classified as either: a) qualitative (largely focusing on the needs and concerns of these population groups) (see Lucas 2012 for a comprehensive review of this literature); or b) based around quantitative comparisons of the accessibility of different population groups (e.g. Neutens, 2012; Currie, 2010) and/or geographical areas (e.g. Páez et al., 2009; Cebollada, 2009). Predominantly, these studies have required dedicated survey data collection and/or the development of non-standard modelling methods. Such studies are extremely insightful in illustrating the complex interactions between travel behaviour and various aspects of social disadvantage (e.g. low income, disability, single parenthood, etc.). Nevertheless, in practice it is often difficult for policymakers to easily adopt these novel techniques within their everyday decision-making practices, due to both their complexity and the lack of suitable data to operationalize them. As such, policy progress to identify and address transport inequalities has been slow in practice. It is in response to this problem with practical delivery and assessment that we believe our research is most useful, because it offers a relatively straightforward way for transport planners to identify the likely effects of their policy decisions on the travel behaviours of socially disadvantaged population groups.

To date, very few studies have undertaken disaggregated modelled analysis of the travel behaviours of transport-disadvantaged population groups (e.g. older people, women, children, disabled people) and also controlled for income effects (Currie et al., 2009; 2010; Paez et al., 2009). Conversely, studies that have involved disaggregated income analysis rarely consider the additional influence of other variables of social disadvantage. In fact, although comprehensive studies regarding the elasticity of travel and income have been developed in the past (e.g., Dargay, 2007), these have not segmented in detail the specific effect of income on vulnerable segments of the population such as elderly, unemployed and disabled people. This is largely because it is generally accepted by policymakers that income is not a useful explanatory variable for predicting travel behavioural outcomes and that car ownership is a sufficiently adequate proxy measure for income effects.

An exception is Roorda et al. (2010), who showed non-linear income effects in their trip generation models, controlling for household structure, mobility tools, occupation, and urban form. Similarly, Mercado et al. (2012) report the difference on transport mode use in Quebec and Montreal for low-income groups, depending on aspects such as gender, educational achievement, household structure, and immigration status, controlling for geographical area. Variables of social disadvantage have been included across several different dimensions of travel behaviour, such as trip generation (e.g. Huntsinger et al. 2013), destination choice (Scott and He, 2012), mode

choice (e.g. Mercado et al, 2012; Schmöcker et al, 2008) and distance travelled (e.g. Morency et al, 2011; Mercado and Páez, 2009).

Less conventionally, some studies have included trip purposes (Páez et al, 2009: Johnson et al, 2011), propensity to perform activities (Páez and Farber, 2012) and activity duration or time-use (e.g. Limanond et al, 2011; Farber et al, 2011, Spinney, 2009). However, even within these studies, income arises either as a continuous variable or with too few categories (e.g. only low, medium and high levels are usually considered) to fully take account of its differential role across the full range of incomes. We will refer back to the findings of a number of these previous studies later in the paper in order to validate the results of our own models via these other useful comparators. To our knowledge, analysis of this type has never been undertaken within the context of the UK.

## 3. DATA AND METHODS

The research described in this paper forms part of a wider study to develop an integrated travel behaviour/accessibility/land use model for a local UK transport authority to utilise for the purposes of its policy scenario testing. The focus at this initial stage of the study was to develop standard multi-linear regression (MLR) trip-based models of travel behaviours differentiated by key indices of economic and social disadvantage, using publicly available data collected through the annual UK National Travel Survey (NTS). Its specific objective was to develop an approach that could be easily replicated by local transport policy-makers.

### *3.1 Descriptive analysis of the dataset*

The NTS is a significant data source for the analysis of travel behaviours at the national and sub-regional levels in the UK (data is not generally released below the geographical level of Government Office Region due to a number of issues including small and therefore non-robust sample sizes). The survey has been running continuously since 1988 and data is periodically archived and issued for analysis. The dataset used for this analysis is for the period 2002-2010. It includes records in each survey year for approximately 19,000 individuals from approximately 8,000 sampled households across the UK. Information is collected from all members of the household 11 years old or older and by proxy for younger children. Travel diaries include information on how, for what purpose, when and where they travel, as well as the key factors that affect people's travel behaviours, such as car availability, driving licence holding and access to key services.

Data is collected in two stages. In the first stage, face-to-face interviews collect information at the household level, about individual members within the household and for all the vehicles to which they have access. Each household member is then asked to record details of all their trips over a seven day period in a travel diary, allowing travel patterns to be linked with individual characteristics. Therefore, the total number of *individual trip records* for the years 2002-2010 is in excess of 300 thousand per year (more than 2.7 million in total for 2002-2010). NTS is a cross-sectional data survey, so the respondents are not the same for each surveyed year, which limits the ability to analyse the dynamic behaviours of specific population segments over time, although cohorts can be explored (e.g. Dargay, 2007).

Table 1 describes the demographic and income breakdown of the survey sample according to the key socially vulnerable population segments. It is important to note for the purposes of this paper that the income distribution shows that all the socially disadvantaged segments (later explained in more detail) in the sample are concentrated within the lowest income bands (see Stokes and Lucas, 2011 for an in-depth analysis of this).

Single parents, people with mobility difficulties (physical disability), and the elderly (65 plus years) have the largest proportion of their population in the lowest income band, whilst non-whites and people living in rural areas have slightly higher representation in the higher income bands, although this is still significantly below the average. The vast majority of single parents are women and 75% of the economically inactive population are also female (mostly carers of young children). Nearly half of single parents are carless and the unemployed/economically inactive, elderly and people with mobility difficulties also have very low car ownership rates when compared to the whole sample. However, more single parents do hold a driving license and more than half have regular access to a car, whilst most non-whites do not.

**Table 1: Socio-economic characteristics of socially disadvantaged segments**

| | Single parents | Non-White | Elderly | Rural | Mobility Diff. | Un-employed | Whole Sample |
|---|---|---|---|---|---|---|---|
| Age (years) | | | | | | | |
| Mean | 35.2 | 28.6 | 74.3 | 42.1 | 64.5 | 33.1 | 39.3 |
| **Age distribution (%)** | | | | | | | |
| 0-16 years | 0 | 31.2 | 0 | 19.0 | 0 | 4.1 | 20.7 |
| 17-64 years | 99.6 | 62.3 | 0 | 59.2 | 44.4 | 95.3 | 60.0 |
| 65+ years | 0.4 | 6.5 | 100 | 21.8 | 55.6 | 0.6 | 19.3 |
| **Household annual income level (%)** | | | | | | | |
| Less than £25K | 88.6 | 52.1 | 79.5 | 39.0 | 77.5 | 70.7 | 46.0 |
| £25-50K | 10.1 | 29.5 | 16.0 | 35.2 | 17.1 | 20.6 | 33.3 |
| £50K or more | 1.3 | 18.4 | 4.5 | 25.8 | 5.4 | 8.7 | 20.7 |
| **Employment Status (only adults) (%)** | | | | | | | |
| Full time | 25.5 | 42.8 | 2.4 | 44.4 | 8.6 | 0 | 44.0 |
| Part time | 25.5 | 12.7 | 4.6 | 16.1 | 4.8 | 0 | 14.5 |
| Student | 3.4 | 11.6 | 0 | 2.7 | 0.8 | 0 | 4.0 |
| Econ. Inactive | 41.0 | 25.2 | 3.4 | 8.6 | 7.5 | 100.0 | 10.4 |
| Retired | 4.8 | 7.7 | 89.5 | 28.3 | 78.3 | 0 | 27.1 |
| **Indicators of Car ownership** | | | | | | | |
| No car (%) | 47.6 | 28.6 | 33.4 | 6.4 | 39.0 | 38.9 | 18.5 |
| No license (%) | 25.1 | 52.3 | 41.2 | 29.4 | 46.5 | 34.7 | 38.6 |
| Cars per HH | 0.54 | 0.95 | 0.77 | 1.53 | 0.81 | 1.05 | 1.13 |
| **Gender (%)** | | | | | | | |
| Female | 93.0 | 51.6 | 54.9 | 50.7 | 58.3 | 39.9 | 51.7 |
| **Sample** | | | | | | | |
| % of sample | 2.0 | 9.7 | 16.6 | 14.9 | 11.3 | 1.9 | 100.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| No. of cases | 3,992 | 18,925 | 32,341 | 29,095 | 22,042 | 3,726 | 195,018 |

(Source: National Travel Survey 2002-2010)

The different travel behaviours of these socially disadvantaged population segments are also identified in table 2, which was used to validate our model outputs. Single parents make the most trips, the majority of which are by car, over relatively short distances, for escort purposes. Non-whites make the least and shortest trips in terms of distance but the longest trips in terms of trip duration. This is a modal effect as nearly a third of their trips are either by public transport (bus) or non-motorized modes.

The largest mode share for walking and cycling is seen amongst the unemployed and single parents. In the case of cycling, the unemployed have the biggest share at 3 trips per week, double the overall sample mean. In the case of weekly trip frequency, single parents and rural populations make the most trips overall. However, there is an income bias in the case of rural populations, caused by the fact that they are relatively better off financially. Although only 6.4% of them have no access to a car, this could also be due to necessity as public transport options are extremely limited in most rural areas of the UK.

Considering trip distances, single parents and the unemployed have the shortest trip distances. This may be either because they have less need to travel further (e.g. in the case of the unemployed) or because they are unable to travel further due to cost constraints and/or because of their familial responsibilities and time use constraints (e.g. in the case of the single parents).

**Table 2: Travel behaviour measures of socially disadvantaged segments**

| | Single parents | Non-White | Elderly | Rural | Mobility Diff. | Un-employed | Whole Sample |
|---|---|---|---|---|---|---|---|
| **Trip Frequency (trips per week)** | | | | | | | |
| Mean | 16.2 | 10.5 | 11.5 | 15.1 | 10.2 | 12.2 | 14.0 |
| **Trip Distance (miles per trip)** | | | | | | | |
| Mean | 5.7 | 6.6 | 7.0 | 10.8 | 5.3 | 6.5 | 8.1 |
| Median | (2.5) | (4.3) | (3.0) | (8.6) | (2.9) | (3.0) | (3.0) |
| **Travel time (minutes per trip)** | | | | | | | |
| Mean | 23.3 | 28.8 | 24.8 | 25.4 | 23.7 | 27.4 | 25.1 |
| **Modal Split (%)** | | | | | | | |
| Walk | 15.8 | 13.1 | 11.0 | 7.1 | 8.0 | 20.9 | 11.3 |
| Cycle | 1.7 | 1.0 | 1.0 | 1.4 | 0.8 | 3.0 | 1.7 |
| Car - Driver | 47.9 | 33.0 | 48.4 | 57.1 | 46.6 | 39.1 | 47.9 |
| Car - Pass. | 26.6 | 26.9 | 24.0 | 27.6 | 27.1 | 17.2 | 26.6 |
| Bus | 7.2 | 17.3 | 11.1 | 3.1 | 10.8 | 14.0 | 7.2 |
| Rail | 2.7 | 6.4 | 1.2 | 1.1 | 0.7 | 3.2 | 2.7 |
| Taxi | 1.2 | 1.2 | 1.5 | 0.6 | 3.0 | 1.7 | 1.2 |
| Other | 1.5 | 1.5 | 1.7 | 2.0 | 3.2 | 0.9 | 1.5 |
| **Trip Purpose (%)** | | | | | | | |
| Work | 10.7 | 18.5 | 2.4 | 14.7 | 5.7 | 4.1 | 16.3 |
| Shopping & Personal Business | 22.2 | 22.4 | 47.8 | 23.7 | 44.5 | 32.5 | 23.9 |
| Social | 9.6 | 10.2 | 20.8 | 16.6 | 15.3 | 17.4 | 15.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VFR | 10.4 | 9.7 | 10.5 | 8.4 | 11.2 | 14.6 | 9.5 |
| Escort and Ed. | 26.7 | 25.9 | 6.1 | 16.8 | 10.3 | 18.1 | 17.6 |
| Employers Business | 2.6 | 2.9 | 1.0 | 5.2 | 1.5 | 1.2 | 3.9 |
| Other | 17.9 | 10.4 | 11.5 | 14.7 | 12 | 12.1 | 13.5 |
| **Stages** | | | | | | | |
| Stages per trip | 1.03 | 1.08 | 1.03 | 1.03 | 1.03 | 1.05 | 1.04 |
| **N** | | | | | | | |
| Total Trips | 64,750 | 198,435 | 373,371 | 438,093 | 223,977 | 45,427 | 2,737,087 |

(Source: National Travel Survey 2002-2012)

### *3.2 Identifying indicators*

The first stage of model building involved identifying some key indicators of a) travel behaviour and b) social disadvantage based on descriptive analysis of the data. Only directly quantifiable (by the NTS) indicators were included and we also attempted to eradicate evident overlaps between the independent and dependent variables. Table 3 identifies the original list of optimal indicators based upon an overview of the literature. The data that was actually available within the NTS dataset is highlighted in bold, and in italics where there was proxy data available.

**Table 3: Indicators of travel behaviour and social status**

| **TRAVEL BEHAVIOUR** | **SOCIAL DISADVANTAGE[1]** |
|---|---|
| • **Number of trips**<br>• **Journey distance**<br>• **Journey duration**<br>• **Mode of travel**<br>• **Trip purposes**<br>• **Vehicle ownership**<br>• **Driver licence**<br>• **Public transport availability**<br>• *Cost of travel* (public transport only)<br>• Levels of exposure to traffic | • **Household income**<br>• *Personal income* (issues with public release)<br>• **Employment status**<br>• Socio-economic group (SEG)<br>• **Gender, age,** *ethnicity* (only non-white)<br>• *Disability (physical* & cognitive) (mobility difficulty)<br>• General health and wellbeing<br>• *Educational attainment*(head of household only)<br>• *Housing security*(tenure)<br>• Financial security |

**In bold = available; in italic = proxy measure available; plain text = not available.**

Table 3 identifies that more data is available within the NTS for the travel behaviour indicators than for the indicators of social disadvantage, which is perhaps not surprising given that it is a bespoke travel survey. Additionally, some important data for assessing travel disadvantage (e.g. transport affordability is also only partially collected - for public transport but not car journeys). As such, it would require considerable effort to construct a measureable unit of analysis for total weekly travel spend (cost of travel). Although the available data for populating indices of social disadvantage are sparse, disaggregation by some key independent variables such as income, employment status and demographic groupings is clearly possible.

[1] It should be noted that the definitions for social disadvantage are taken from the policy documentation, in particular the Social Exclusion Unit study, 2003.

In deciding the modelling approach, we opted for an enhanced trip-based travel demand model for two key reasons. First, from a practical point of view, the existing national and local datasets that were available to us were not geographically specific enough for meaningful spatial modelling, as explained above. Second, a key aim of the study is to improve the social equity decision-making powers of policymakers. Most national and local policymakers in the UK and elsewhere tend to rely on traditional (if enhanced) 4-stage models of travel demand and standard travel survey data. This suggests enhancement of the existing models is a useful starting point for the purposes of practical decision-making.

To keep the models as simple as possible for the ease of their interpretation, we selected only two dependent (Y) variables of travel behaviour: i) number of trips per week and ii) average length (miles) per journey (with a logarithmic transformation)[2]. By contrast, the UK NTEM model (WSP, 2002; 2009) relates to trip frequency only and not to journey distance. However, in this instance while income might have only a marginal effect on *how often* people travel, it is likely to have a much greater impact on *how far* they go, due to the cost and affordability constraints of the additional travel. As such, there was an argument for also modelling average weekly journey distances as well.

### *3.3 Modelling approach*

The NTEM models trip rates for 8 home-based purposes and 7 non-home-based purposes as a function of the status of the individual (gender together with a six-way distinction between children, over 65s, and for adults of working age, students, full-time employed, part-time employed, non-working) and household structure (number of adults), car ownership, and area type. As such, the baseline models each have the following general form, where the $\delta$ variables are "dummies" (0,1) indicating the presence of a particular characteristic, and the N variables are positive integer numbers:

$$Y = \alpha_{\text{person-type}} + \beta_{\text{fem}}.\delta_{\text{fem}} + \sum_{\text{area-type}}\beta_{\text{area-type}}.\delta_{\text{area-type}} + \beta_{\text{adults}}.(N_{\text{adults}}-1) + \beta_{\text{cars}}.\ N_{\text{cars}}$$

These baseline models for trip making were expanded to identify the *additional* effects of the inclusion of an extended 23 bands variable for household income[3].

Seven key categories of social disadvantaged populations were identified from the literature (Social Exclusion Unit, 2003): single parents (family structure), non-whites (ethnicity), people with mobility difficulties (physical and cognitive disability), elderly (age), and unemployed (actively seeking work). Most of these categories are not independent and so it is possible for an individual to be represented in more than one segment. The economically inactive are independent from the unemployed: the first category includes home-workers and people unable to work due to health issues, while the unemployed category only considers those not working but still actively seeking work. Socio-economic characteristics such as gender, household income and

[2] Initially journey duration was also included within the model but was seen to be highly correlated with journey distance and was removed.

[3] Household income was used because the Office for National Statistics will not release the data for personal income at the more detailed 23 bands that are available for household income. It is recognised that the effects of personal income may be different.

employment status were also analysed as they represent personal and household features of socially disadvantaged segments.

The analysis of categorical data presents certain difficulties in exposition. If there is only one categorical variable, then there are two possibilities for model specification, either (i) to include a regression constant and, after defining a base for the categorical variable, include all the other levels as dummies, or (ii) to drop the constant, and include all the levels as dummies. In the first case, the coefficients are the increments to the base, and in the second they are the absolute values for each level. When there is more than one category variable then the choice between methods (i) and (ii) remains for one of the category variables (which can be arbitrarily selected) but for each of the remaining variables we have to select a base level and drop the associated dummy from the list of the regression variables.

Our approach has been to use method (ii) and to select the person-type variables (represented by $\alpha_{\text{person-type}}$ in the Equation given earlier) as the category for which the absolute values will be estimated for all levels. For all other categories, the base level will be explicitly stated. It should be noted that these are arbitrary conventions, which do not affect the results (model fit) but have some relevance for the interpretation.

Although the dataset covers a nine-year period, for the sake of simplicity, we have modelled and present it here as a pooled cross-section. We also compared the pooled model with the individual year specification models but found no evidence that the *overall trends* we present in the following section significantly vary year on year, although there were some uplifts in the overall levels of trips over time. Thus, we present the results for the pooled model.

However, the relative insignificance of time across the nine-year period of the dataset is in itself an interesting finding, especially given that the real income of the lowest households remained static or was even reduced over this same period (Hills et al, 2010). Car ownership levels also increased 28-50% in 10 years 2005-2011 for this lowest income quintile (Stokes and Lucas, 2011). This would seem to suggest that the commonly accepted relationship between increased income and car ownership has broken down in the case of lowest income households, who are acquiring private vehicles *despite* a non-increase in their (real) incomes. One explanation for this might be the increased inadequacy of public transport for meeting everyday travel needs even within constrained income scenarios. We discuss the policy implications of this finding further in the conclusions section of the paper.

## 4. DISCUSSION OF RESULTS

Table 4 presents the outputs from the two models (i) trip frequency and ii) trip log-distance[4], considering the baseline variables as well as the addition of the other social disadvantage variables. As can be seen in the table, the vast majority of the additional coefficients are highly significant, while both the "NTEM" and the "extended" models have reasonably good adjusted $R^2$ values. In particular, it is clear that there are important effects on travel behaviours due to

[4] Note that the units for the trip frequency models are in trips per week, while, due to the logarithmic transform, the units for the log-distance models can be interpreted as the proportional change relative to the mean.

household income, the presence of children, being non-white and having a mobility difficulty. The most important finding within the extended model was the effect of household income on trip making patterns at the lower end of the income distribution. The significance of this relationship held even after including additional indicators of social disadvantage. We next discuss the results of these models, focusing first on the effects of adding variables of social disadvantage and secondly on adding a variable for household income[5].

[5] It can be noted that this variable was also adjusted to take account of inflation effects over the ten year period of the NTS dataset, i.e. from 2002-2010 the change in price of goods and services over time in the UK, based on the Retail Price index (RPI) and the Consumer Price Index (CPI).based upon figures provided by the UK Office for National Statistics http://calculateinflation.com/uk/

## Table 4: Trip Frequency and Trip Distance Models

| | | Trip frequency | | | | Log-distance | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NTEM | | EXTENDED | | NTEM | | EXTENDED | |
| | | B | t | B | t | B | t | B | t |
| ORIGINAL NTEM VARIABLES | London | -1.25 | *-16.4* | -1.27 | *-16.8* | 0.07 | *9.1* | 0.03 | *4.1* |
| | Metropol. (Ref.) | **Ref.** | | **Ref.** | | **Ref.** | | **Ref.** | |
| | Urban (over 250K) | 0.18 | *2.3* | 0.01 | *0.1* | 0.03 | *4.3* | 0.02 | *3.0* |
| | Urban (100-250K) | 0.17 | *2.0* | 0.00 | *-0.1* | 0.03 | *4.2* | 0.03 | *3.3* |
| | Urban (25-100K) | 0.23 | *3.0* | -0.04 | *-0.6* | 0.07 | *9.6* | 0.06 | *8.8* |
| | Urban (3-25K) | -0.11 | *-1.5* | -0.47 | *-6.4* | 0.22 | *30.3* | 0.21 | *29.6* |
| | Rural (Ref.) | -0.39 | *-4.8* | -0.77 | *-9.9* | 0.38 | *50.0* | 0.36 | *48.2* |
| | Child | 12.07 | *147.7* | 9.74 | *30.8* | 1.09 | *140.4* | 1.22 | *39.9* |
| | Full-time Worker | 16.59 | *211.3* | 11.30 | *35.7* | 1.88 | *252.2* | 1.82 | *59.5* |
| | Part-time Worker | 18.07 | *179.7* | 12.93 | *40.2* | 1.52 | *159.8* | 1.53 | *49.0* |
| | Student | 13.57 | *99.5* | 10.27 | *31.3* | 1.34 | *103.5* | 1.36 | *42.9* |
| | Non-worker | 14.10 | *159.4* | 10.47 | *33.1* | 1.55 | *185.0* | 1.58 | *51.5* |
| | Retired | 12.14 | *147.5* | 9.78 | *30.9* | 1.59 | *203.7* | 1.57 | *51.1* |
| | Female | 0.20 | *4.6* | 0.50 | *11.7* | -0.11 | *-26.0* | -0.10 | *-24.1* |
| | N of adults in HH | -1.39 | *-37.4* | -1.17 | *-29.9* | -0.10 | *-27.0* | -0.12 | *-30.6* |
| | N of cars in HH | 2.47 | *92.6* | 1.45 | *49.4* | 0.13 | *49.6* | 0.08 | *29.2* |
| EXTENDED HOUSEHOLD INCOME BANDS | Under £1,000 | | | **Ref.** | | | | **Ref.** | |
| | £1,000- £1,999 | | | 0.94 | *2.3* | | | 0.07 | *1.8* |
| | £2,000- £2,999 | | | 0.19 | *0.5* | | | 0.11 | *2.9* |
| | £3,000- £3,999 | | | 0.06 | *0.2* | | | 0.02 | *0.5* |
| | £4,000- £4,999 | | | -0.24 | *-0.7* | | | 0.05 | *1.4* |
| | £5,000- £5,999 | | | 0.00 | *0.0* | | | 0.01 | *0.4* |
| | £6,000- £6,999 | | | -0.21 | *-0.6* | | | 0.03 | *1.0* |
| | £7,000- £7,999 | | | 0.36 | *1.1* | | | 0.05 | *1.5* |
| | £8,000- £8,999 | | | 0.63 | *1.9* | | | 0.05 | *1.5* |
| | £9,000- £9,999 | | | 0.27 | *0.8* | | | 0.03 | *0.9* |
| | £10,000- £12,499 | | | 1.24 | *3.9* | | | 0.01 | *0.4* |
| | £12,500- £14,999 | | | 1.20 | *3.8* | | | 0.05 | *1.6* |
| | £15,000- £17,499 | | | 1.38 | *4.3* | | | 0.05 | *1.8* |
| | £17,500- £19,999 | | | 1.65 | *5.2* | | | 0.07 | *2.2* |
| | £20,000- £24,999 | | | 1.88 | *6.0* | | | 0.09 | *3.0* |
| | £25,000- £29,999 | | | 1.99 | *6.3* | | | 0.09 | *2.9* |
| | £30,000- £34,999 | | | 2.08 | *6.6* | | | 0.12 | *3.9* |
| | £35,000- £39,999 | | | 2.27 | *7.2* | | | 0.12 | *4.0* |
| | £40,000- £49,999 | | | 2.41 | *7.6* | | | 0.18 | *6.1* |
| | £50,000- £59,999 | | | 2.23 | *7.0* | | | 0.20 | *6.6* |
| | £60,000- £69,999 | | | 2.60 | *8.0* | | | 0.22 | *7.0* |
| | £70,000- £74,999 | | | 3.38 | *8.0* | | | 0.24 | *5.9* |
| | Over £75,000 | | | 2.10 | *6.6* | | | 0.29 | *9.3* |
| EXTENDED VARIABLES | Presence of children | | | 2.05 | *38.3* | | | -0.16 | *-31.5* |
| | Driver licence | | | 4.61 | *72.8* | | | 0.07 | *12.2* |
| | Non-white | | | -1.74 | *-23.3* | | | 0.00 | *0.1* |
| | Mobility difficulty | | | -1.93 | *-25.7* | | | -0.07 | *-9.7* |
| | Single Parent | | | 0.88 | *5.4* | | | -0.18 | *-11.6* |
| **SSR (residual sum of squares)** | | 9,672,475 | | 9,244,723 | | 90,052 | | 88,933 | |
| **SST (total sum of squares about mean)** | | 47,206,872 | | 47,917,219 | | 506,966 | | 508,695 | |
| **no. of parameters** | | 15 | | 42 | | 15 | | 42 | |
| **Adjusted $R^2$** | | 0.80 | | 0.81 | | 0.82 | | 0.83 | |
| **No. of Obs.** | | 166,361 | | 166,361 | | 166,361 | | 166,361 | |

### *4.1 Effects of social disadvantage*

***Presence of children:*** The variable used is a dummy variable indicating the presence of at least one child in the household. The general effect is to increase trip frequency (by 2 trips per week), while reducing average journey distance by 16%, suggesting a more localised pattern of travel.

***Driving licence:*** This is a dummy variable with the value 1 if the individual has a licence. There is some interaction with the number of cars and the effects are similar. Trip frequency increases strongly (by 4.6 per week in addition to the household car ownership effect) for those who also have a licence, while average journey distance increases by 7%. This confirms that transport disadvantage can occur for some individuals even if they are living within households that do have access to a car.

***Non-white:*** The variable is an NTS-based recoding of a more detailed question on ethnicity, and is a dummy variable with the value 1 if the individual is "non-white". While no significant effect was found for average distance, the number of trips per week was reduced on average by 1.7. Although we did not model the use of different modes, it is evident from our background analysis of the NTS data that this is an effect connected with greater use of public transport and much more locally based travel patterns by the non-white population.

***Mobility difficulties:*** This variable is based on two questions in the NTS, one of which investigates general travel difficulties and one that relates specifically to difficulties with walking. Only those who registered difficulties in both questions were represented by a dummy variable with the value 1. Significant negative effects were found for all three dependent variables: people with mobility differences made on average 2 fewer trips per week, the average distance was 7% shorter. This decrease in trip frequency and travel distance is consistent with other similar studies conducted in the UK (Schmöcker et al., 2005) and in Canada (Farber and Paez, 2010).

***Single parent:*** This is a dummy variable indicating that the person comes from a household with one adult and at least one child. On average, single parents make an additional 0.9 trips per week, with a lower average journey distance by 18%. This does not take into account the interaction effects between presence of a child in the household, household income and gender. Given that 97% of all single parent households are female and that single parent households are more likely to be car owning, these interaction effects are significant. These findings are consistent with previous studies of the trip making patterns of single parents (e.g. Roorda et al, 2010).

### *4.2 Effects of income (household)*

***Income:*** Our original models used a log-linear function of annual gross household income, which was highly significant for both dependent variables (as an illustration, those on £50,000 made 1.2 more trips, with an average trip length of 2.8 miles more compared with those on £5,000). However, although the log-linear form for income had a better fit than a linear form, it did not capture the non-linear effect of income on trip frequency very well. Quite a different picture is given when the extended 23 income bands from the NTS is represented in terms of dummy variables, and estimate a coefficient for each band (after choosing one as the base, in this case < £1000 p.a.), as demonstrated in Figure 1.

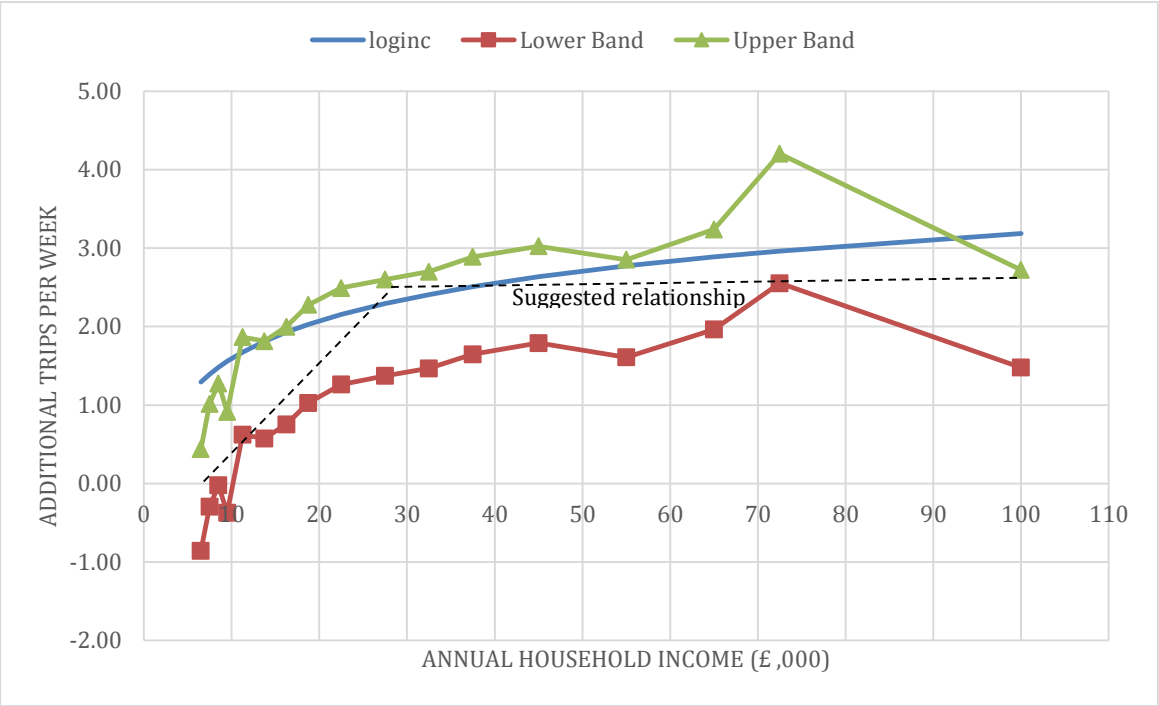


**Figure 1: Effect of household income on the number of trips**

The solid blue line indicates the effect of income on trip frequency for the fitted model when assuming a functional form relating to $\log_{10}$(income). In this form, it is implied that there will be an equivalent rise in trip making for a given proportional increase in household income. It can be seen that relative to the base (< £1000 p.a.), a person from a household with £25,000 p.a. makes around 2 more trips per week, while a person with income > £75,000 makes 2.5 additional trips. Compared with this, we have plotted the 95% confidence intervals (upper and lower bounds) for the coefficients for each band (since the sample size for each band is relatively low). It can be seen that there is a tendency for trip rates to fall as we move from the lowest income up to the £6000-7000 p.a. band. However, it is reasonable to treat these lowest bands as anomalous, since they are well below the poverty line, and are probably households who have little or no regular income, but nonetheless have access to other sources of finance (see e.g. Hills, 2010 on this).

If we therefore ignore these lowest bands, then a very consistent pattern emerges. It is evident that there is a steep and more or less linear rise in the number of trips between £7,000 per annum (which approximately equates with a single person household on welfare benefits) and about £27,000 (which is roughly the average household income level in the UK), with the increase over this range being about 2 trips, suggesting approximately an additional 0.1 trips per additional £1000 p.a. There appears to be no significant increase in trip making after this. It seems that below £25,000 per annum, which is close to the average income for a single person in the UK (Hills, 2010), people need to make a trade-off between travel and other essential items of household expenditure, such as food shopping, heating and other housing costs.

In the diagram, we have represented this by a piece-wise linear dashed function. It is clear that the shape differs from the logarithmic form, which is probably dominated by the pattern in the

range £7,000-27,000 and thereby gives a misleading impression of how the trip rate increases for the higher incomes. This is probably the most significant finding of the research in terms of its policy implications, which we will discuss further in the concluding section of the paper. The results suggested that from a policy decision-making perspective it would be useful to identify exactly what kinds of trips are being suppressed as a result of these income effects at the lower end of the distribution[6].

We next present the results of these further disaggregated models for trip generation and journey distance.

### *4.3 Effects of journey purposes*

Although economic status has already been accounted for within the results for the Extended NTEM models above, the effect of journey purpose is still an important consideration in understanding the lower trip making patterns of socially disadvantaged population groups. It is generally understood by policymakers that these groups do not need to travel as much because of their lower engagement in economic activities such as employment. This may not, in fact, necessarily be the case for all socially disadvantaged groups, as the next section of this paper shows.

#### 4.3.1 Number of trips

Annex 1 presents the results for number of trips considering the effects of journey purpose. It can be seen that in general mandatory activities (such as employment and personal business trips) show a higher fit than social trips. This suggests that socioeconomic variables are better at describing participation in mandatory rather than voluntary activities (see also Paez and Farber, 2010; 2012).

Income effects

The model demonstrates that higher income levels imply a greater propensity to undertake social and leisure trips that potentially incur an additional cost at the destination end, such as visits to the cinema and other paid leisure activities, which is consistent with previous findings (Van den Berg et al., 2011). As such, journey purposes such as "social" and "other" (which includes the categories of holiday, non-home-based business and other) have the most significant increase as income rises, even though in strictly nominal terms this change might not be so obviously high, as it only goes up by 1-1.5 trips.

However, if we consider that on average around 2 trips are performed for "social" activities and less than 4 for "other" activities, this is an important difference. It demonstrates that the social and leisure activities that potentially incur additional expenditures at the destination end rise *more than 50% above the average frequency* for the highest income quintile. On the other hand,

[6] We also note that the role of income may be different depending on the specific social disadvantaged groups (e.g. non-white in trip distances dues to social segregation, single parents and trip rates), but the low representativeness within the sample of these socio-demographic categories in certain income brackets prevented a more detailed analysis.

this variation is almost zero for all other journey purposes and an opposite effect occurs on business trips and visits to friends and relatives (VFR) (see Figure 2).

One possible explanation for these trends could be that low-income households perform more joint travel activities to reduce their overall household expenditures. A complementary hypothesis is that low-income groups have less flexibility in their residential location with respect to jobs, which could force them to travel longer distances to work and work longer hours, thus have less opportunity to perform social trips due to time and cost constraints.

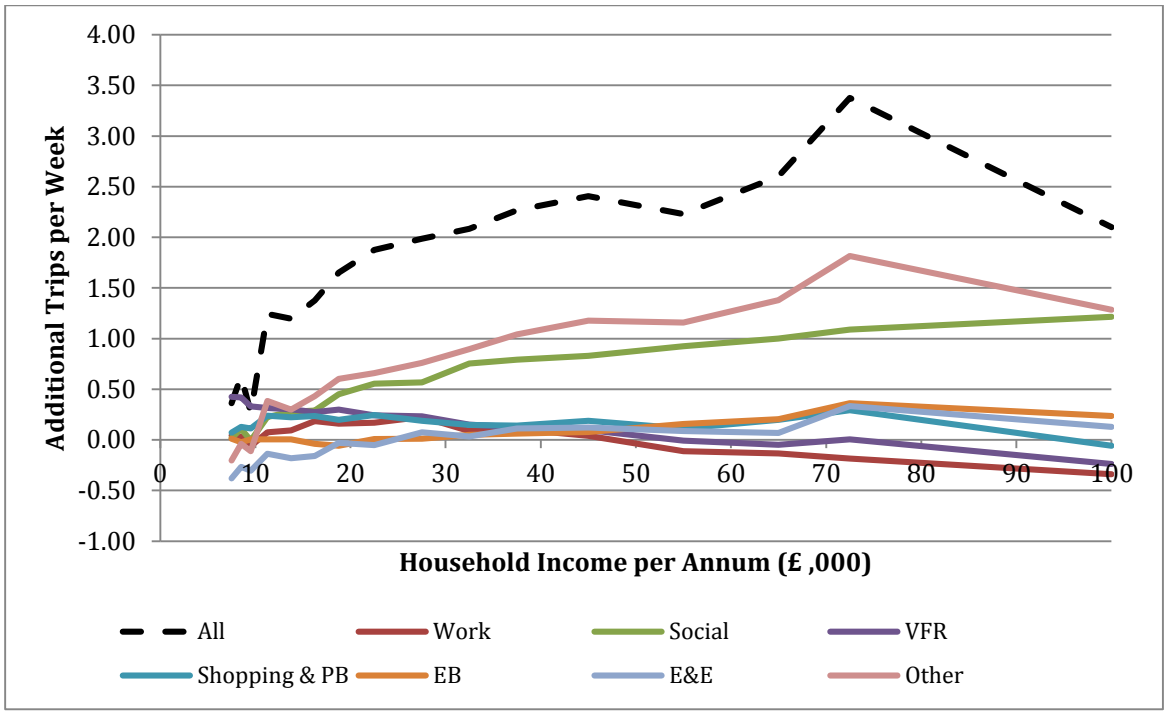


**Figure 2: Graph to demonstrate the effect of income on number of trips**

(VFR: Visiting Friends and Relatives, PB: Personal Business, EB: Employer's Business, E&E: Escort and Education

Source: National Travel Survey)

Effects of social disadvantage

Full-time workers have lower frequencies of social trips and VFR, while unemployed and retirees have higher frequencies of social and personal business trips. This suggests that non-mandatory trips increase as time constraints diminish or disappear (also confirmed by Van den Berg et al, 2011; Carrasco et al, 2008).

Being "non-white" involves more frequent "work" and less frequent "other" trips (as also found by Farber and Páez, 2012), but has a minor effect on personal business trips and VFR. This could correspond with a trade-off between work and leisure activities as mentioned above, as non-whites are over-represented in the lower income quintiles.

Disabled people have no significant differences in their trip trends to the reference group for most journey purposes, except for a significant negative trend in social trips (as also demonstrated by Schmöcker et al., 2005). This may be because of the lack of accessible social

activities within their local areas, or because they are also over-represented in the lower income quintiles and so constrained by income effects.

The presence of children in the household implies a negative effect on trip generation for all journey purposes, social and work trips being the most affected. In addition, there is a reduction in all out-of-home activities and for work trips (this could be the impact of the children carer status of some individuals in these households).

Single parents have decreased trip frequencies for virtually all journey purposes except education and escort trips and a slight increase in their trips for VFR. This is intuitive given their responsibility as the sole carers of children. In the case of commuting, the reduced trip-making effect can be explained by the occupational status of single parents, with fewer in full-time employment and a higher percentage of unemployed or economically inactive individuals. With regard to travel to reduced leisure trips, there may be both financial and time constraints. The increase in VFR trips could be explained by their increased reliance on friends and family for their social support networks.

#### 4.3.2 Journey distances

Annex 2 presents the results for journey distance by purpose. The results from the log-distance linear regression models show consistent findings with the empirical evidence elsewhere, especially for journey purposes such as "social" trips (Van den Berg et al., 2011) and "work" (Maoh and Tang, 2012; Farber and Páez, 2010).

As expected, the highest coefficients (i.e. longer journey distances) are associated with areas with lower population density, which is most notable in the case of VFR and personal business trips.

Income effects

Trip distance is particularly affected by income levels for "employers business", "work" and "VFR" (see Figure 3). The pattern of activity indicates that longer commute distances are possible when income constraints are relaxed. This could be the influence of residential location choice, where higher income groups chose to relocate from areas of dense employment to dormer suburbs and the rural hinterland. Modal effects will also account for this, as higher income is generally related to shorter trip durations over longer distances.

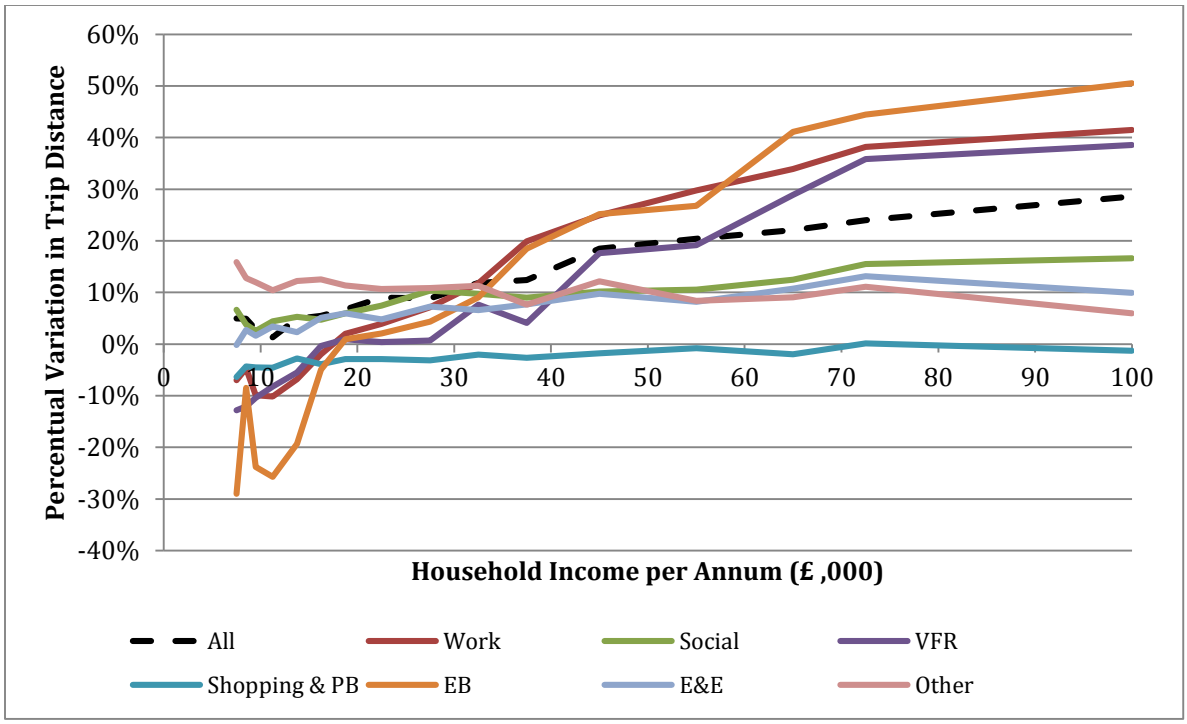


**Figure 3: Graph to demonstrate the effect of income on trip distance**

(VFR: Visiting Friends and Relatives, PB: Personal Business, EB: Employer's Business, E&E: Escort and Education. Source: National Travel Survey)

Effects of social disadvantage

These effects reveal few surprises, being largely in line with the findings of other studies (e.g. Farber and Páez, 2010 and Maoh and Tang, 2012 for employment purposes and Van den Berg *et al*., 2011 for social purposes). The number of adults in a household implies decays in journey distances, especially for VFR. The presence of children in a household implies more localized activity patterns. Associated with their home-based responsibilities, women show more localised travel activity patterns to employment. Full-time workers travel the furthest for social activities, which may be related to their higher financial budgets. Non-whites present lower trip distances for almost all trip purposes, except work, a result that is also consistent with the findings of Maoh and Tang (2012).

## 5. CONCLUDING REMARKS AND NEXT STEPS

Although our research uses standard modelling approaches and datasets, we believe our findings are of considerable interest for the readership of this journal, since it pushes forward state-of-the-art transport policy and practice in the area of transport equity analysis. Our research clearly demonstrates that low-income and other variables of social disadvantage do have a significant effect on people's travel behaviours even after controlling for other proxy measures. This has long been the claim of qualitative studies of these social groups, but until now has not been the specific finding of any modelled analysis based on the use of standard trip-end models and publicly available national datasets.

In fact, by using just two key indicators of travel behaviours, namely weekly trip frequency and average weekly trip distance, we have been able to identify that low income and other indicators of social disadvantage are important predictors of travel behaviour even when controlling for other social characteristics such as age, gender household size, area type and employment status. One of the most important findings is that low income can have a significant effect in supressing the number of weekly trips made for some groups but that single parents tend to make more than the average number of weekly trips than other low-income groups.

Our findings are particularly relevant for UK policy context at a time when the Department for Transport is seeking to update its NTEM suite of models and is currently seeking consultation on which national travel trends these updates should consider. As stated previously, while the current UK models already take account of demographic changes within the population, economic factors and changes in land uses, they do not consider the specific effects of income on vehicle ownership or travel trends. Our research implies that this oversight could have significant implications for the reliability of the modelled predictions of future trends because the travel behaviours of lower-income groups are changing. Specifically, low-income groups are displaying higher levels of car ownership but are not behaving consistently with the commonly associated higher levels of trip frequencies and journey distances. This is important because the national model is used to cascade predictions down to the local level of planning when deciding whether new roads, railways and other transport services are needed. As others such as Goodwin (2012) have suggested, the current model may not be a good predictor of local travel trends amongst the many changes that are occurring in people's travel behaviours within the UK. These consequences are also applicable in other regions of the developed world with similar contexts.

More broadly than this, however, it is important that local planners and policymakers understand differences in the behaviours of different income and social groups when thinking about potential changes in local services provision. Local transport authorities can easily and cheaply replicate the simple methods we have demonstrated in this paper using models that they are familiar with and the data that are already available to them. In other words, there is little excuse for them *not to* do assess the social equity of their policy decisions as a standard element of the planning process. At a time when resources for transport services are tight and cutbacks in services are almost inevitable, even simple disaggregation models can help transport professionals to predict the influence of different transport decisions on the most low-income sections of the population, who may be most reliant on these services for their livelihoods.

The findings we have highlighted in this paper are not only relevant for the developed world, but also for several developing countries, where similar NTS data and NTEM modelling techniques are standard practice for assessing transport policies (SECTRA, 1998; Guevara and Thomas, 2007). Similarly, the potential to demonstrate the social equity of transport decision-making is also often missed because key indicators of social disadvantage are simply not considered within the analysis. The income categories that are generally included within these models are too few (e.g. low, medium, high) to be able to capture suppressed travel demand from these factors.

This is not to suggest that our analysis does not have caveats. For example, it is clear that there are difficulties with the interpretation of the modelled results in terms of their directionality. Simply put, people may be travelling more because they want to (as evidenced by the income effect) or because they are obliged to (as evidenced by the presence of children in a household). Hence, a lower number of trips per week can be an ambiguous indicator of transport disadvantage. Similar remarks apply to average journey distances whereby people may elect to travel further (e.g. to access better quality destinations) or may be obliged to, because of a lack of nearby services. As such, one of the future challenges for our research is to better understand the direction of causation and other exogenous interaction effects, such as the supply of transport and land use activities.

For this, more complex accessibility and destination choices models are needed, as well as fine granular geographical data. These approaches therefore pose problems for datasets such as the NTS because they are not geo-coded. There are some proxy variables that could be included within the NTEM to partly account for these effects (for example ward density, public transport availability and frequency, as well as the perceived accessibility of essential services such as doctors, post office etc.). Even so, there are other local contextual factors such the timing and availability of transport services and perceptions of personal safety, which will affect people's willingness and ability to travel and are only associated with specific locations. These avenues of enquiry will be pursued in our further analyses.

The cost of travel is also an important factor in the travel behaviours of low-income groups, which is also difficult to adequately capture using NTS data. Although there is data collected within the NTS travel diary on the cost of public transport fares, the cost of car trips is not recorded. This could potentially be calculated based on the vehicle type and mileage, but would require complex additional analysis. It also would not reveal anything about the affordability of the travel expenditure in relation to household incomes and other weekly expenditures. As such, in our future research we plan to undertake analysis of the UK Living Costs and Food Survey, which includes detailed data on transport expenditures as part of the weekly household budget and in relation to household incomes. It can be released at a local area level to also allow area-based socio-demographic, economic, transport and land use factors to be considered. It is thus a potentially fruitful line of enquiry in understanding the travel behaviours of low-income and socially disadvantaged groups.

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## Annex 1: Models for Trip Frequency by Purpose

| | ALL | | WORK | | SOCIAL | | VFR | | SHOPPING AND PB | | EB | | E&E. | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | t | B | t | B | t | B | t | B | t | B | t | B | t | B | t |
| London | -1.27 | -16.8 | 0.00 | 0.0 | -0.05 | -1.6 | -0.28 | -14.0 | -0.42 | -13.5 | 0.00 | -0.2 | -0.25 | -6.7 | -0.51 | -9.9 |
| Metropol. (Ref.) | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 |
| Urban (over 250K) | 0.01 | 0.1 | -0.03 | -1.0 | 0.15 | 5.0 | -0.08 | -3.9 | -0.05 | -1.6 | -0.02 | -0.7 | 0.03 | 0.7 | 0.04 | 0.7 |
| Urban (100-250K) | 0.00 | -0.1 | 0.02 | 0.5 | 0.05 | 1.6 | -0.13 | -6.2 | 0.00 | 0.1 | -0.02 | -0.6 | 0.11 | 2.7 | 0.07 | 1.4 |
| Urban (25-100K) | -0.04 | -0.6 | 0.02 | 0.6 | 0.13 | 4.3 | -0.09 | -4.7 | -0.01 | -0.5 | -0.03 | -1.5 | 0.10 | 2.6 | -0.04 | -0.8 |
| Urban (3-25K) | -0.47 | -6.4 | -0.05 | -1.7 | 0.24 | 8.4 | -0.15 | -7.7 | -0.15 | -4.9 | 0.02 | 1.1 | -0.14 | -3.8 | -0.39 | -7.7 |
| Rural (Ref.) | -0.77 | -9.9 | -0.26 | -8.9 | 0.14 | 4.6 | -0.35 | -16.9 | -0.22 | -6.8 | 0.16 | 6.7 | -0.14 | -3.6 | -0.24 | -4.5 |
| Child | 9.74 | 30.8 | 0.33 | 2.8 | 2.23 | 18.0 | 1.78 | 21.1 | 1.54 | 11.7 | 0.05 | 0.5 | 2.70 | 17.4 | 3.81 | 17.6 |
| Full-time Worker | 11.30 | 35.7 | 6.30 | 53.9 | 1.14 | 9.1 | 0.96 | 11.3 | 1.83 | 13.9 | 1.29 | 13.5 | -0.92 | -5.9 | -0.21 | -1.0 |
| Part-time Worker | 12.93 | 40.2 | 4.04 | 33.9 | 1.84 | 14.5 | 1.21 | 14.1 | 2.89 | 21.6 | 0.83 | 8.5 | 0.82 | 5.2 | 2.13 | 9.7 |
| Student | 10.27 | 31.3 | 0.56 | 4.6 | 2.22 | 17.2 | 1.50 | 17.1 | 1.70 | 12.5 | 0.22 | 2.3 | 2.74 | 17.0 | 4.06 | 18.1 |
| Non-worker | 10.47 | 33.1 | 0.30 | 2.6 | 2.31 | 18.6 | 1.69 | 20.0 | 4.58 | 34.8 | 0.15 | 1.5 | 0.50 | 3.2 | 1.44 | 6.7 |
| Retired | 9.78 | 30.9 | 0.35 | 3.0 | 2.42 | 19.4 | 1.04 | 12.3 | 5.39 | 40.9 | 0.13 | 1.4 | -0.15 | -0.9 | 0.45 | 2.1 |
| Female | 0.50 | 11.7 | -0.21 | -13.3 | -0.28 | -16.6 | 0.15 | 12.7 | 0.34 | 19.3 | -0.21 | -16.3 | 0.17 | 8.0 | 0.71 | 24.4 |
| N of adults in HH | -1.17 | -29.9 | 0.28 | 19.4 | -0.34 | -21.9 | -0.23 | -21.9 | -0.11 | -6.8 | -0.20 | -17.1 | 0.11 | 5.8 | -0.58 | -21.5 |
| N of cars in HH | 1.45 | 49.4 | -0.02 | -1.7 | 0.30 | 25.6 | 0.21 | 27.2 | 0.22 | 18.2 | 0.16 | 18.5 | 0.24 | 16.9 | 0.57 | 28.6 |
| Less than £1.000 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 | 0b | 0.0 |
| £1.000- £1.999 | 0.94 | 2.3 | 0.12 | 0.8 | 0.08 | 0.5 | 0.30 | 2.7 | -0.13 | -0.8 | 0.01 | 0.1 | 0.16 | 0.8 | 0.56 | 2.0 |
| £2.000- £2.999 | 0.19 | 0.5 | -0.07 | -0.5 | 0.15 | 1.0 | 0.45 | 4.4 | -0.07 | -0.4 | 0.01 | 0.1 | -0.56 | -3.0 | -0.27 | -1.0 |
| £3.000- £3.999 | 0.06 | 0.2 | 0.09 | 0.7 | 0.12 | 0.8 | 0.36 | 3.8 | -0.21 | -1.4 | -0.03 | -0.3 | -0.37 | -2.1 | -0.27 | -1.1 |
| £4.000- £4.999 | -0.24 | -0.7 | 0.07 | 0.6 | 0.02 | 0.2 | 0.43 | 4.7 | -0.30 | -2.1 | 0.01 | 0.1 | -0.41 | -2.5 | -0.47 | -2.0 |
| £5.000- £5.999 | 0.00 | 0.0 | 0.12 | 1.0 | 0.00 | 0.0 | 0.40 | 4.6 | -0.07 | -0.5 | 0.04 | 0.5 | -0.45 | -2.8 | -0.51 | -2.3 |
| £6.000- £6.999 | -0.21 | -0.6 | 0.07 | 0.6 | 0.01 | 0.1 | 0.31 | 3.5 | -0.14 | -1.0 | 0.03 | 0.3 | -0.49 | -3.0 | -0.49 | -2.1 |
| £7.000- £7.999 | 0.36 | 1.1 | 0.04 | 0.3 | 0.02 | 0.1 | 0.42 | 4.8 | 0.07 | 0.5 | 0.01 | 0.1 | -0.38 | -2.3 | -0.20 | -0.9 |
| £8.000- £8.999 | 0.63 | 1.9 | 0.03 | 0.3 | 0.11 | 0.9 | 0.42 | 4.7 | 0.13 | 0.9 | -0.02 | -0.2 | -0.27 | -1.6 | -0.04 | -0.2 |

| | ALL | | WORK | | SOCIAL | | VFR | | SHOPPING AND PB | | EB | | E&E. | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | t | B | t | B | t | B | t | B | t | B | t | B | t | B | t |
| £9.000- £9.999 | 0.27 | 0.8 | -0.06 | -0.5 | -0.01 | -0.1 | 0.33 | 3.8 | 0.11 | 0.8 | 0.01 | 0.1 | -0.30 | -1.9 | -0.11 | -0.5 |
| £10.000- £12.499 | 1.24 | 3.9 | 0.07 | 0.6 | 0.23 | 1.8 | 0.32 | 3.7 | 0.24 | 1.8 | 0.01 | 0.1 | -0.14 | -0.9 | 0.38 | 1.8 |
| £12.500- £14.999 | 1.20 | 3.8 | 0.09 | 0.8 | 0.28 | 2.2 | 0.30 | 3.6 | 0.22 | 1.7 | 0.00 | 0.0 | -0.18 | -1.2 | 0.30 | 1.4 |
| £15.000- £17.499 | 1.38 | 4.3 | 0.19 | 1.6 | 0.29 | 2.3 | 0.27 | 3.2 | 0.23 | 1.8 | -0.04 | -0.4 | -0.16 | -1.0 | 0.43 | 2.0 |
| £17.500- £19.999 | 1.65 | 5.2 | 0.16 | 1.4 | 0.45 | 3.6 | 0.30 | 3.5 | 0.20 | 1.5 | -0.06 | -0.6 | -0.03 | -0.2 | 0.60 | 2.8 |
| £20.000- £24.999 | 1.88 | 6.0 | 0.17 | 1.5 | 0.55 | 4.5 | 0.24 | 2.9 | 0.25 | 1.9 | 0.01 | 0.1 | -0.05 | -0.3 | 0.66 | 3.1 |
| £25.000- £29.999 | 1.99 | 6.3 | 0.23 | 2.0 | 0.57 | 4.6 | 0.23 | 2.8 | 0.19 | 1.4 | 0.01 | 0.1 | 0.07 | 0.5 | 0.76 | 3.6 |
| £30.000- £34.999 | 2.08 | 6.6 | 0.09 | 0.8 | 0.76 | 6.1 | 0.15 | 1.8 | 0.15 | 1.1 | 0.05 | 0.5 | 0.03 | 0.2 | 0.89 | 4.2 |
| £35.000- £39.999 | 2.27 | 7.2 | 0.11 | 0.9 | 0.79 | 6.3 | 0.13 | 1.5 | 0.14 | 1.1 | 0.06 | 0.7 | 0.11 | 0.7 | 1.04 | 4.8 |
| £40.000- £49.999 | 2.41 | 7.6 | 0.04 | 0.3 | 0.83 | 6.7 | 0.10 | 1.1 | 0.19 | 1.4 | 0.08 | 0.8 | 0.12 | 0.8 | 1.18 | 5.5 |
| £50.000- £59.999 | 2.23 | 7.0 | -0.11 | -1.0 | 0.93 | 7.4 | -0.01 | -0.1 | 0.11 | 0.9 | 0.16 | 1.6 | 0.09 | 0.6 | 1.16 | 5.3 |
| £60.000- £69.999 | 2.60 | 8.0 | -0.13 | -1.1 | 1.00 | 7.8 | -0.05 | -0.6 | 0.20 | 1.5 | 0.21 | 2.1 | 0.07 | 0.4 | 1.38 | 6.2 |
| £70.000- £74.999 | 3.38 | 8.0 | -0.18 | -1.2 | 1.09 | 6.6 | 0.00 | 0.0 | 0.29 | 1.7 | 0.36 | 2.8 | 0.33 | 1.6 | 1.82 | 6.3 |
| £75.000 or more | 2.10 | 6.6 | -0.34 | -2.9 | 1.21 | 9.7 | -0.24 | -2.8 | -0.06 | -0.5 | 0.24 | 2.5 | 0.13 | 0.8 | 1.29 | 5.9 |
| Presence of child. | 2.05 | 38.3 | -0.50 | -25.0 | -0.34 | -16.0 | -0.07 | -5.2 | -0.08 | -3.6 | -0.02 | -1.0 | 2.63 | 99.5 | 3.06 | 83.2 |
| Car License own. | 4.61 | 72.8 | -0.02 | -0.9 | 0.67 | 27.1 | 0.35 | 21.0 | 1.17 | 44.3 | 0.16 | 8.6 | 1.28 | 41.0 | 2.27 | 52.4 |
| Non-white | -1.74 | -23.3 | 0.19 | 7.0 | -0.82 | -27.8 | -0.22 | -11.0 | -0.12 | -3.7 | -0.05 | -2.3 | -0.12 | -3.2 | -0.73 | -14.3 |
| Mobility diff. | -1.93 | -25.7 | -0.36 | -13.0 | -0.89 | -30.1 | -0.26 | -13.2 | -0.13 | -4.0 | -0.04 | -1.9 | -0.01 | -0.4 | -0.25 | -4.8 |
| Single Parent | 0.88 | 5.4 | -0.11 | -1.9 | -0.24 | -3.7 | 0.06 | 1.3 | -0.28 | -4.2 | -0.13 | -2.6 | 1.15 | 14.4 | 1.59 | 14.2 |
| **Sum of squares** | | | | | | | | | | | | | | | | |
| Residual | 9,244,723 | | 1,004,594 | | 689,222 | | 283,908 | | 1,181,697 | | 135,113 | | 1,199,401 | | 2,689,647 | |
| Total | 47,917,219 | | 2,797,331 | | 1,127,425 | | 434,890 | | 2,927,612 | | 155,305 | | 2,116,288 | | 5,394,039 | |
| **DoF** | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | |
| **Adjusted $R^2$** | 0.81 | | 0.64 | | 0.39 | | 0.35 | | 0.60 | | 0.13 | | 0.43 | | 0.50 | |
| **No. of Obs.** | 166,361 | | 166,361 | | 166,361 | | 166,361 | | 166,361 | | 166,361 | | 166,361 | | 166,361 | |

(VFR: Visiting Friends and Relatives. PB: Personal Business. EB: Employer's Business. E&E: Escort and Education. Source: National Travel Survey)

## Annex 2: Models for Log-Distance by Purpose

| | ALL | | WORK | | SOCIAL | | VFR | | SHOPPING AND PB | | EB | | E&E. | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | T | B | t | B | t | B | t | B | t | B | t | B | t | B | t |
| London | 0.03 | 4.1 | 0.10 | 8.2 | -0.01 | -1.3 | 0.17 | 12.0 | -0.03 | -4.5 | -0.20 | -6.6 | -0.05 | -6.9 | 0.01 | 0.9 |
| Metropolitan (Ref.) | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | |
| Urban (over 250K) | 0.02 | 3.0 | 0.00 | -0.3 | 0.03 | 2.9 | 0.05 | 3.9 | -0.01 | -1.4 | 0.06 | 2.0 | 0.00 | 0.6 | 0.00 | -0.2 |
| Urban (100-250K) | 0.03 | 3.3 | -0.03 | -2.3 | 0.03 | 2.4 | 0.08 | 5.9 | -0.02 | -2.2 | 0.06 | 1.9 | 0.01 | 1.8 | -0.01 | -0.9 |
| Urban (25-100K) | 0.06 | 8.8 | 0.04 | 3.0 | 0.05 | 5.1 | 0.07 | 5.2 | 0.03 | 3.8 | 0.14 | 4.5 | 0.03 | 3.7 | 0.00 | 0.3 |
| Urban (3-25K) | 0.21 | 29.6 | 0.16 | 13.0 | 0.15 | 14.6 | 0.17 | 12.8 | 0.27 | 41.7 | 0.22 | 7.3 | 0.07 | 9.2 | 0.03 | 2.6 |
| Rural (Ref.) | 0.36 | 48.2 | 0.34 | 26.6 | 0.30 | 28.5 | 0.46 | 33.0 | 0.53 | 76.6 | 0.23 | 7.8 | 0.17 | 21.9 | 0.10 | 7.7 |
| Child | 1.22 | 39.9 | 1.26 | 14.3 | 1.52 | 32.9 | 1.78 | 29.5 | 1.32 | 47.0 | 1.68 | 7.5 | 0.63 | 19.6 | 0.90 | 16.5 |
| Full-time Worker | 1.82 | 59.5 | 1.81 | 24.0 | 1.63 | 35.2 | 1.82 | 30.1 | 1.41 | 50.3 | 2.47 | 13.6 | -0.03 | -0.8 | 0.91 | 16.6 |
| Part-time Worker | 1.53 | 49.0 | 1.52 | 20.1 | 1.56 | 33.1 | 1.78 | 28.9 | 1.38 | 48.4 | 2.12 | 11.6 | 0.20 | 6.1 | 0.86 | 15.5 |
| Student | 1.36 | 42.9 | 1.59 | 20.1 | 1.60 | 33.5 | 1.86 | 29.7 | 1.40 | 47.6 | 2.32 | 11.5 | 0.73 | 21.8 | 0.82 | 14.7 |
| Non-worker | 1.58 | 51.5 | 1.69 | 21.3 | 1.56 | 33.7 | 1.80 | 29.7 | 1.39 | 49.7 | 2.29 | 12.4 | 0.11 | 3.3 | 1.06 | 19.3 |
| Retired | 1.57 | 51.1 | 1.57 | 20.0 | 1.57 | 33.8 | 1.85 | 30.4 | 1.35 | 48.3 | 2.19 | 11.8 | 0.02 | 0.7 | 0.92 | 16.8 |
| Female | -0.10 | -24.1 | -0.24 | -34.5 | -0.05 | -7.9 | -0.04 | -5.2 | 0.01 | 2.5 | -0.41 | -23.4 | 0.00 | -1.0 | 0.04 | 5.5 |
| N of adults in HH | -0.12 | -30.6 | -0.19 | -31.3 | -0.06 | -10.3 | -0.13 | -18.3 | 0.00 | -0.9 | -0.18 | -12.2 | 0.04 | 8.9 | -0.16 | -23.8 |
| N of cars in HH | 0.08 | 29.2 | 0.10 | 21.6 | 0.09 | 21.7 | 0.05 | 9.2 | 0.07 | 26.5 | 0.04 | 3.7 | 0.08 | 25.6 | 0.07 | 13.8 |
| Lessthan £1.000 | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | | Ref. | |
| £1.000- £1.999 | 0.07 | 1.8 | -0.02 | -0.2 | -0.05 | -0.7 | 0.05 | 0.6 | -0.10 | -2.7 | -0.24 | -1.0 | 0.01 | 0.3 | 0.17 | 2.4 |
| £2.000- £2.999 | 0.11 | 2.9 | 0.11 | 1.1 | 0.02 | 0.4 | 0.02 | 0.2 | -0.07 | -2.1 | 0.17 | 0.8 | 0.01 | 0.1 | 0.23 | 3.5 |
| £3.000- £3.999 | 0.02 | 0.5 | 0.01 | 0.2 | -0.07 | -1.3 | -0.07 | -1.1 | -0.07 | -2.2 | -0.13 | -0.6 | 0.00 | 0.0 | 0.17 | 2.7 |
| £4.000- £4.999 | 0.05 | 1.4 | 0.06 | 0.7 | -0.05 | -0.9 | -0.10 | -1.6 | -0.05 | -1.8 | 0.08 | 0.4 | -0.02 | -0.5 | 0.21 | 3.5 |
| £5.000- £5.999 | 0.01 | 0.4 | 0.01 | 0.1 | -0.04 | -0.8 | -0.17 | -2.8 | -0.09 | -3.1 | -0.10 | -0.5 | -0.02 | -0.7 | 0.15 | 2.7 |
| £6.000- £6.999 | 0.03 | 1.0 | 0.05 | 0.6 | 0.00 | 0.1 | -0.16 | -2.6 | -0.06 | -2.2 | 0.01 | 0.0 | -0.02 | -0.7 | 0.11 | 1.9 |
| £7.000- £7.999 | 0.05 | 1.5 | -0.07 | -0.8 | 0.07 | 1.4 | -0.13 | -2.0 | -0.06 | -2.2 | -0.29 | -1.4 | 0.00 | -0.1 | 0.16 | 2.7 |
| £8.000- £8.999 | 0.05 | 1.5 | -0.05 | -0.6 | 0.04 | 0.8 | -0.12 | -1.9 | -0.04 | -1.5 | -0.08 | -0.4 | 0.03 | 0.8 | 0.13 | 2.2 |

| | ALL | | WORK | | SOCIAL | | VFR | | SHOPPING & PB | | EB | | E&E. | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | T | B | t | B | t | B | t | B | t | B | t | B | t | B | t |
| £9.000- £9.999 | 0.03 | 0.9 | -0.10 | -1.2 | 0.03 | 0.5 | -0.10 | -1.7 | -0.05 | -1.6 | -0.24 | -1.2 | 0.02 | 0.5 | 0.12 | 2.1 |
| £10.000- £12.499 | 0.01 | 0.4 | -0.10 | -1.3 | 0.04 | 0.9 | -0.08 | -1.4 | -0.05 | -1.6 | -0.26 | -1.4 | 0.03 | 1.1 | 0.10 | 1.9 |
| £12.500- £14.999 | 0.05 | 1.6 | -0.07 | -0.9 | 0.05 | 1.1 | -0.06 | -0.9 | -0.03 | -1.0 | -0.19 | -1.1 | 0.02 | 0.7 | 0.12 | 2.2 |
| £15.000- £17.499 | 0.05 | 1.8 | -0.02 | -0.3 | 0.05 | 1.0 | 0.00 | -0.1 | -0.04 | -1.4 | -0.05 | -0.3 | 0.05 | 1.6 | 0.12 | 2.3 |
| £17.500- £19.999 | 0.07 | 2.2 | 0.02 | 0.3 | 0.06 | 1.3 | 0.01 | 0.2 | -0.03 | -1.0 | 0.01 | 0.1 | 0.06 | 1.8 | 0.11 | 2.1 |
| £20.000- £24.999 | 0.09 | 3.0 | 0.04 | 0.5 | 0.07 | 1.6 | 0.00 | 0.1 | -0.03 | -1.0 | 0.02 | 0.1 | 0.05 | 1.5 | 0.11 | 2.0 |
| £25.000- £29.999 | 0.09 | 2.9 | 0.07 | 1.0 | 0.10 | 2.3 | 0.01 | 0.1 | -0.03 | -1.1 | 0.04 | 0.2 | 0.07 | 2.3 | 0.11 | 2.0 |
| £30.000- £34.999 | 0.12 | 3.9 | 0.12 | 1.6 | 0.10 | 2.1 | 0.08 | 1.3 | -0.02 | -0.7 | 0.09 | 0.5 | 0.07 | 2.0 | 0.11 | 2.1 |
| £35.000- £39.999 | 0.12 | 4.0 | 0.20 | 2.6 | 0.09 | 2.0 | 0.04 | 0.7 | -0.03 | -0.9 | 0.18 | 1.0 | 0.08 | 2.4 | 0.08 | 1.4 |
| £40.000- £49.999 | 0.18 | 6.1 | 0.25 | 3.3 | 0.10 | 2.2 | 0.18 | 2.9 | -0.02 | -0.7 | 0.25 | 1.4 | 0.10 | 3.0 | 0.12 | 2.3 |
| £50.000- £59.999 | 0.20 | 6.6 | 0.30 | 4.0 | 0.11 | 2.3 | 0.19 | 3.1 | -0.01 | -0.3 | 0.27 | 1.5 | 0.08 | 2.5 | 0.08 | 1.5 |
| £60.000- £69.999 | 0.22 | 7.0 | 0.34 | 4.5 | 0.12 | 2.7 | 0.29 | 4.6 | -0.02 | -0.7 | 0.41 | 2.3 | 0.11 | 3.2 | 0.09 | 1.6 |
| £70.000- £74.999 | 0.24 | 5.9 | 0.38 | 4.5 | 0.16 | 2.7 | 0.36 | 4.4 | 0.00 | 0.0 | 0.44 | 2.3 | 0.13 | 3.1 | 0.11 | 1.6 |
| £75.000 or more | 0.29 | 9.3 | 0.41 | 5.5 | 0.17 | 3.6 | 0.39 | 6.3 | -0.01 | -0.4 | 0.51 | 2.8 | 0.10 | 3.1 | 0.06 | 1.1 |
| Presence of child. | -0.16 | -31.5 | 0.02 | 2.4 | -0.05 | -7.2 | -0.16 | -16.3 | -0.04 | -9.4 | 0.02 | 1.2 | 0.28 | 50.9 | -0.29 | -33.6 |
| Car License own. | 0.07 | 12.2 | 0.16 | 14.3 | 0.07 | 7.8 | 0.20 | 16.5 | 0.06 | 10.1 | 0.22 | 5.7 | 0.26 | 40.4 | 0.06 | 5.3 |
| Non-white | 0.00 | 0.1 | 0.06 | 4.6 | -0.01 | -0.7 | 0.04 | 3.1 | 0.02 | 2.3 | -0.02 | -0.5 | -0.02 | -3.3 | -0.05 | -3.7 |
| Mobility difficulties | -0.07 | -9.7 | 0.01 | 0.3 | -0.01 | -0.6 | -0.08 | -5.6 | -0.03 | -5.3 | -0.16 | -3.4 | -0.03 | -4.0 | -0.10 | -7.3 |
| Single Parent | -0.18 | -11.6 | -0.11 | -3.9 | -0.02 | -0.9 | -0.11 | -4.0 | -0.03 | -2.5 | -0.06 | -0.9 | 0.14 | 8.3 | -0.14 | -5.3 |
| **Sum of squares** | | | | | | | | | | | | | | | | |
| Residual | 88,933 | | 37,241 | | 59,788 | | 72,598 | | 45,724 | | 18,083 | | 54,413 | | 58,417 | |
| Total | 508,695 | | 256,000 | | 325,206 | | 324,553 | | 324,962 | | 128,513 | | 100,515 | | 93,444 | |
| **DoF** | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | | 42 | |
| **Adjusted $R^2$** | 0.83 | | 0.85 | | 0.82 | | 0.78 | | 0.86 | | 0.86 | | 0.46 | | 0.37 | |
| **No. of Obs.** | 166,361 | | 61,631 | | 97,822 | | 82,700 | | 127,522 | | 18,106 | | 166,361 | | 119,265 | |

(VFR: Visiting Friends and Relatives. PB: Personal Business. EB: Employer's Business. E&E: Escort and Education. Source: National Travel Survey)