Journal of Transport and Land Use 2 (1) [Winter 2009] pp. 29–46
Available at http://jtlu.org

Mode Choice of Older People Before and After Shopping

A Study with London Data

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Abstract: With the population aging in many countries, the travel habits of older people are receiving more attention in the transportation literature. However, our understanding of factors influencing their mode choices is still limited. This research focuses on mode choice for shopping trips, as these are the most frequent trips of older people. The study is not limited to trips to retail locations, but investigates the combined mode choice of trips to and from shops in order to understand which factors influence mode changes. Two types of models, multinomial logit (MNL) and nested logit (NL), are fitted to data from the London Area Travel Survey. The nesting structure is used to test the correlation in mode choice before and after shopping. A particular focus of the models is on the importance of accessibility variables such as bus and rail stop density and service quality for specific areas of London. The results show that mode choice combinations such as "walk to shop and take the bus back" are not as frequent as sometimes thought, and that bus stop density is more important to older people than attributes describing the quality of bus service, such as service frequency.

Keywords: Shopping tours; Mode choice; Older people

1 Introduction

Most industrialized nations are currently experiencing a shift in population demographics: a significant increase in both the number of older persons and in the percentage of older persons in the population. In the United Kingdom, the percentage of people over the state pension age (60 for women and 65 for men) increased from 16 percent in 1971 to 19 percent in 2004, and is projected to rise to 23 percent by 2031. The population group defined as the "oldest old" (age 85 and over) is growing particularly rapidly; this group grew by 84 percent between 1981 and 2004, to more than 1.1 million persons (Office for National Statistics 2005). This increase in the older population gives new impetus to the need to better understand the travel behavior of the "oldest old" and of the increasingly mobile group of recent retirees.

The increasing economic importance of older people is recognized also through a growing literature on the mobility of older people. The retail industry increasingly emphasizes accessi-

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bility issues (Ibrahim and McGoldrick 2003). However, analyses of travel behavior have traditionally focused on work trips as this behavior is easier to understand due to the more regular nature of the trips and the stricter time constraints that govern it. Further, shopping trips of employed individuals are often connected to work trips in trip chains.

The travel of older people, however, often does not follow the same patterns as that of younger people, and travel for purposes of leisure and shopping is becoming more important. According to the 2001 London Area Travel Survey (LATS) (for Transport 2001a) 46 percent all trips from home are for shopping purposes. This paper examines in particular older people's mode choice for shopping travel and allows for the fact that mode choice is often not determined by a single trip but by a trip chain. Therefore, mode choice for shopping tours (and not single trips) is the focus of this paper. The analysis attempts to answer questions such as to what extent high bus stop density encourages older people to use public transport before or after shopping. A further focus is on understanding which socioeconomic characteristics drive mode choice.

The paper is structured as follows. The following section reviews the existing literature; several studies have examined older people's travel behavior, but some have not distinguished trip purposes and therefore overlooked specific characteristics of shopping trips, and accessibility attributes have often been neglected. Section 3 explains the available data for this study and Section 4 presents some descriptive analysis. Sections 5 and 6 explain and describe the regression analysis. Section 7 concludes by summarizing the findings of this research.

2 Literature Review

Mode choices of shopping travel are diverse, and car driving is, in general, found to be the most frequently used mode (Gould *et al.* 1998). In the UK, for example, although some shopping trips are made by foot, by mass transit, or by bicycle, the car accounts for more than 64 percent of shopping trips (Department for Transport 2005). Trips for shopping are one of the major uses of the household vehicle. The Department for Transport 2001b further reports that 12 percent of all mileage and 20 percent of all car journeys in the UK are undertaken for shopping. These statistics should, however, be interpreted with care. Shopping trips are often combined with other types of travel, like the trip home from work (Bhat 1997). In some travel statistics, trips within journeys with multiple purposes are not cross-classified. For example, if a traveler visited a multi-purpose building containing shopping facilities, the trip may only be recorded as one shopping trip or a "personal business" trip rather than as a trip with two purposes or as two trips. Secondly, many shopping trips involve multiple stops, and there is some confusion as to whether these should be categorized as separate shopping trips.

Barber (1995) and Giuliano *et al.* (2003) define a shopping trip as a trip to any retail center, irrespective of the size and type of the store or shop and of whether or not a purchase is made; this is also the definition used in this analysis. Shopping travel is different from other kinds of travel for several reasons: Firstly, it does not have strict time constraints as long as it is within the time window of shop opening hours and can satisfy the maintenance requirements; secondly, after shopping, generally there is a load to carry, which increases travelers' difficulties. Both of these factors may influence mode choice and encourage a mid-journey change in transport mode. This is the main argument for looking at "combined mode choice" as done in this paper.

Several socio-economic variables—including sex, employment status, and age— have been found to influence shopping mode choice. Handy (1996) compared shopping mode choice between men and women, and between women from different household types; she found that socio-demographic variables have more significant effects on mode choice of shopping than sex. Bhat (1998) found that employed individuals are more likely to drive alone to a shopping place than those unemployed. Alsnih and Hensher (2003) further suggested that it is often useful to divide older people into the "younger old" (age 65–74) and the "older old" (75+) because declines in health often limit feasible activities around the age of 75. Schmöcker *et al.* (2008) noted that people aged 60–65 are also more likely to drive alone for shopping, but that this trend reverses sharply for those over 65, who are more likely to walk or use public transport; however, this research did not separately examine mode choice for trips from retail locations. Chen *et al.* (2004) and Schmöcker *et al.* (2008), using data from the United States and London respectively, further showed that disability is one of the key elements determining mode choice. Interestingly, wheelchair users are not always the least mobile; those with "some walking difficulties" but who do not use wheelchairs often make fewer trips (Schmöcker *et al.* 2005).

Previous findings also show that vehicle ownership is one of the most important factors determining mode choice. Chen *et al.* (2004) found that besides the above mentioned sociodemographic variables it is primarily car availability and public transport fare which affect mode choice between private and special transport services. The demand for special transport services has emerged as a particularly strong determinant of mode choice in studies of older people. Various projects funded by the European Union, as well as projects in Japan, Australia and the United States, have examined the uptake of special transport services among older people and specific user needs (see Enoch *et al.* 2004, for a summary). Most of these studies looking at mode choice and special transport services discuss only those with severe disability problems, which is not representative of the retired population. Alsnih and Hensher (2003) pointed out that the over-60 age group is one of the most diverse population groups.

In addition to socio-demographic variables, other factors such as land-use variables have significant effects on trip chaining and mode choice. Studies carried out by Krizek (2003) and Wallace *et al.* (1999) indicated that households living in areas with higher density of service facilities complete more tours and make fewer stops per tour. Limanond and Niemeier (2004) also used U.S. data from several traditional neighborhood areas in Washington State and similarly found that households residing in areas with greater accessibility tend to make more one-stop shopping tours, while households with poorer accessibility tend to make fewer one-stop shopping tours and compensate for their location deficiency by combining shopping trips with trips for other purposes into either two-or-more-stop shopping tours, multi-purpose shopping tours or work-related shopping tours, which are more likely to be made by car.

Whether a neighborhood will be attractive for walking trips will further depend on other factors not related to density, such as familiarity with local geography or perceived safety. Su (2007), for example, pointed out that older people from areas with more crime are less likely to walk. Besides these rather "large scale" parameters, "microscale" parameters often influence tour complexity and mode choice. Currently, the discourse on accessible and universal design in developed countries shows that factors such as curb height near bus stops or the availability of parking places near a destination often determine whether a tour can be made with a specific mode. Bromley *et al.* (2007) investigated the result of accessibility planning in the U.K. and found some positive effects, but also concluded that significant efforts still have to be made to make city centers fully accessible for wheelchair users. Similarly, in the case of public transport, recently introduced low-floor buses are more likely to be usable by people with mobility impairments, but other factors may influence the service uptake as much. Ibrahim and McGoldrick (2003) reported that, for older shoppers, the attributes "absence of waiting time" and "shortness of walking distance" are of particular importance where shoppers have a choice between private and public transport options. Nitta (1998) further showed that public transport becomes significantly less attractive to older people when they have to transfer between vehicles or routes to complete a single journey.

The importance of mobility to older people's quality of life (Metz 2000) and the role of accessibility to transport services is today widely accepted. Suen and Mitchell (1999) noted that "Accessible transportation is the passport to independent living for everyone." However, defining "good" and "accessible" for older people is a more difficult task. The literature not specifically focusing on shopping trips provides some findings regarding the importance of accessibility for older people. Wilds and Talley (1984) concluded that, in the United States, older passengers' perception of service reliability and the accessibility of bus transit are primary factors that affect mode choice for both work-related and shopping trips. Alsnih and Hensher (2003) explored the role of conventional and specialized public transport as an alternative to the automobile in meeting the mobility and accessibility needs of older people. Mainstream public transport operators may well find that the market for flexible public transport catering for seniors is large enough to move the emphasis away from the much-maligned community transport provider to become a core business component of mainstream operators. Kim and Ulfarsson (2004) examined not only the effects of neighborhood and trip characteristics but also personal and household characteristics on the mode choice of older people, using data from the United States. They found that the elderly are more likely to use transit if they live within five blocks of a bus stop. Older people are further more likely to share a ride with others when chaining trips, going on errands, or going to a medical appointment, and are less likely to use transit when going shopping or on errands. With this background, the following analysis using London data investigates the importance of public transport accessibility and sociodemographic variables on mode choice for trips to and from retail locations.

3 Data

The analysis in this paper is based on data from the 2001 London Area Travel Survey (LATS), provided by Transport for London (TfL). LATS collected data on 67,252 individuals in 29,973 households based on home interviews throughout the Greater London Authority and some neighboring districts.[1] The survey includes four main datasets for each individual: household information, personal information, details on vehicles owned by the household, and trip details of all trips undertaken on one weekday. All interviews were carried out in person and respondents were asked to complete a one-day travel diary. In total, 176,453 trips were made by respondents. LATS data only includes trips in and around London, and does not include holiday trips leaving the region. All tours made by persons aged 65 or older (9,109 tour records made by 6,251 individuals) were extracted from the interim LATS dataset records. From these records, only complete home-based tours were used in the analysis, which means only older

[1] The Greater London Authority includes the 33 London Boroughs.

people whose first trip is from home and last trip is to home on the day are included. Since this analysis is for shopping travel, only tours with at least one shopping trip were considered. Records with missing data were also excluded. This reduced the dataset to 4,513 shopping trips by 4,186 individuals.

Postcode-specific information on public transport service quality was provided by TfL. This additional dataset could be matched with the three-digit post code in the LATS data, making it possible to specify bus stop density (defined as bus stops per kilometer of road length) and Underground stop density.

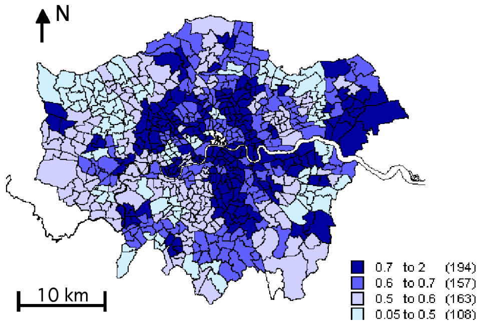
Because the literature shows that older people associate a very high cost with having to change buses (Nitta 1998) we further analyzed how many bus stops outside each subject's own postcode district can be reached directly without transfers as a proxy for bus service quality. However, no correlation between this variable and higher bus usage was found, so that variable was dropped in the analysis described below. As a second proxy for bus service quality we included bus headway, defined as the average waiting time between two buses arriving at the same bus stop. This was intended to test the hypothesis that higher service frequency at stops near a respondent's home might encourage the use of buses. Although at some stops in Central London this hypothesis might be difficult to justify (as more frequent buses are an index of more congestion on the buses, which could actually discourage older people from using them), it was assumed that capacity had not yet been reached at the majority of bus stops.

The limitation of these variables for specifying relative accessibility is based on the rather large spatial units of three-digit postcodes, which can contain several thousand households. Therefore, significant microscale local variability in accessibility is missed. As pointed out by Hensher (2007), local accessibility factors (down to the height of curb stones, etc.) are very important for older people. He argues that roads and pavements should be better adapted to the needs of the elderly, including larger signage containing only crucial information, among other changes.

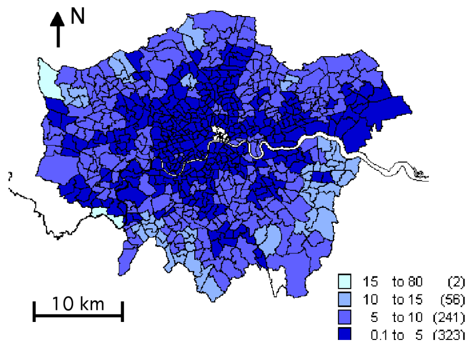
Figures 1 (a) and 1 (b) show the differences in bus frequency and bus stop density distribution throughout Greater London (east-west diameter approximately 55 km). The figures illustrate significant differences between different parts of London, and show that there is (unsurprisingly) a clear focus of services around the city center. Figures 1 (c) and 1 (d) map the distribution of the older population within London and show which areas have higher proportions of older people is higher. The proportion of older people is clearly higher in the outer regions of London than in central areas. A significant correlation between place of residence and bus stop density cannot be found (Pearson correlation $r=0.05$, $p=0.262$), suggesting that the choice of residence and location are independent. However, whether this finding still holds when the distance to a single bus stop from the person's residence is considered cannot be concluded from this dataset. The following analysis will focus on whether service quality has an impact on the likelihood of using public transport.

4 Descriptive statistics

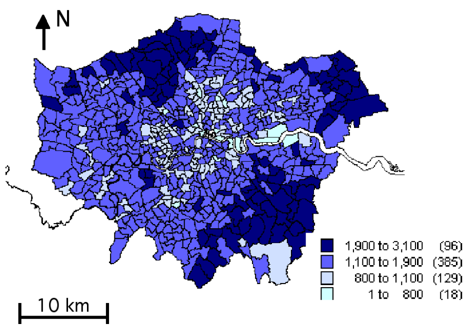
Interestingly, car usage and public transit have received much more attention than walking in previous research, even though walking is the most important mode for shopping trips. According to London data considering the whole population, around 79 percent of shopping trips are shorter than 3.5 km (for Transport 2001a). As shown in Figure 2, the average length of trips by



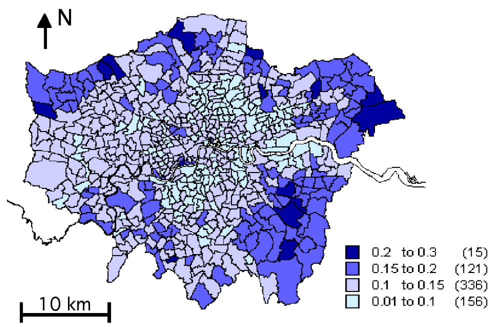
(a) Bus stop density in London (in stops/road-km).



(b) Bus headway distribution in London (in 60-min/number of buses serving a stop per hour.



(c) Distribution of older population in London (total population)



(d) London areas with high proportion of older people (pop. older than 65 / total population)

Figure 1: Bus service and population distribution in London.

older people is slightly less, as nearly 90 percent of trips are shorter than 3.5 km. Figure 2 shows the trip distance of walking trips analyzed in this study; nearly all are shorter than 500 m.

Figure 3 shows the modal split for different life-cycle stages; approximately 42 percent of shopping trips by older people are made on foot. Those aged 35–54 (often in full-time employment and with dependent children) use public transport least and drive most. Those aged 55–64 (often without dependent children but still in full-time employment) drive significantly less for shopping trips. It is notable that the "younger old" are more likely to be car passengers than the "older old." Taxi usage among all population groups is low, but highest among the older old (0.51% of shopping trips). The modal share of walking stays fairly constant between the different age groups. The tube and underground usage for shopping purposes is low for all population groups, but in particular for those over the age of 75.

Because people may use different modes when traveling to and from their shopping destinations, there are a total of 11 possible mode-choice combinations, as shown in Table 1. The table indicates that most trips before and after shopping are made by the same transport mode, with walking being the most frequent alternative for older people, followed by public transport. Walking is combined with a motorized transport mode in 32.6 percent of trips. As expected, walking is more often used before shopping than after shopping; however, the difference is not

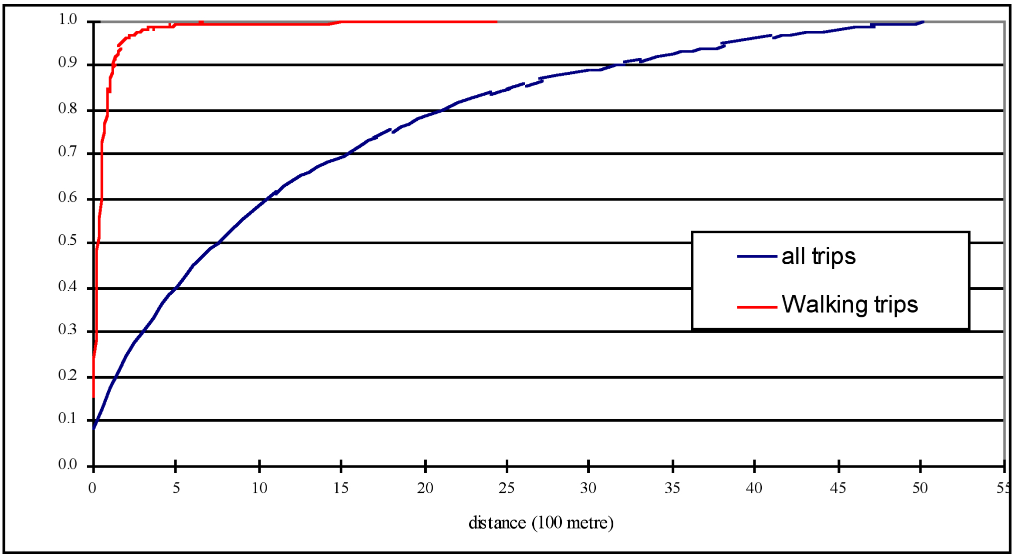


Figure 2: Trip distance of shopping trips

as large as might have been expected (+1.2%). Combinations of "drive and walk" or "car passenger and walk" are rare, occurring only when the shopper leaves their car at a car park and then walks to more than one shop before returning to the car. In Table 2, simple tours (home-shop-home) are extracted in order to remove the effects of trip chaining or visiting two shops close to each other before returning home. This reduces the number of mode combinations taken from 11 to six, with mode changes occurring only in 3.79 percent of all home-shop-home tours.

Table 1: Combined mode choice to and from shopping for all tours.

Mode choice label	Mode choice of shopping travel	Mode choice of travel after shopping	Percentage
1	car driving	car driving	16.41
2	public transport	public transport	18.78
3	car passenger	car passenger	9.57
4	walk	walk	29.39
5	car driving	walk	1.80
6	public transport	walk	8.02
7	car passenger	walk	1.54
8	walk	car driving	1.85
9	walk	public transport	9.33
10	walk	car passenger	1.41
11	other	other	1.89

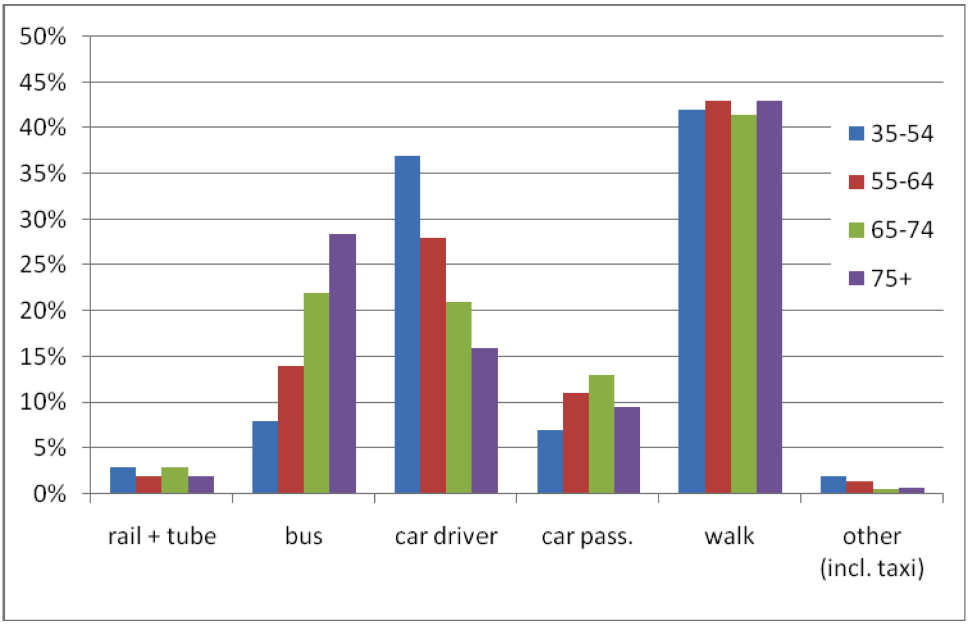


Figure 3: Modal share across population sections for shopping trips

5 Regression Analysis

5.1 Discrete choice analysis

In order to separate the various factors potentially influencing mode choice, discrete choice models are applied to the LATS dataset. The following material describes the application of multinomial logit (MNL) and nested logit (NL) models in order to capture correlation between alternatives. Mixed logit models were also considered, but initial tests did not lead to new findings nor to significantly improved model fit; this is probably due in part to the fact that the dataset does not contain a sufficient number of repeated observations of the same individuals. The underlying assumptions and the model formulation of MNL and NL have been extensively described (e.g. Ben-Akiva and Lerman 1985) and are omitted here. The estimation

Table 2: Combined mode choice to and from shopping for simple tours.

Mode choice label	Mode choice of shopping travel	Mode choice of travel after shopping	Number	Percentage
1	car driving	car driving	450	19.16
2	public transport	public transport	653	27.80
3	car passenger	car passenger	267	11.37
4	walk	walk	890	37.89
5	public transport	walk	28	1.19
6	walk	public transport	61	2.60
7	other	other	0	0.00

software BIOGEME (Bierlaire 2003) was used to calibrate the various models discussed herein. This estimation tool can be used for all types of closed-form as well as mixed GEV model structures. Furthermore, the program can accommodate non-linear utility functions.

5.2 Model attributes

The combined mode choice of trips before and after shopping is the dependent variable. There are five main sets of independent variables included in the model estimation: travel cost (GBP) and travel time (minutes) of the trips before and after shopping; tour type characteristics, formulated in terms of number of stops, travel purpose, etc.; public transport accessibility variables; individual variables; and household socio-economic variables.

From the extracted data, trips made by driving a car, riding on public transport, riding in a car as a passenger, and walking are taken separately in order to estimate linear regression models of travel time for all transport modes (Table 3). These regression models are used to estimate the travel time for all unchosen alternatives in the MNL and NL models. This is necessary because revealed-preference datasets (such as LATS) do not include information on the actual or perceived travel time if the trip would have been made with another mode.

Table 3: Calculated travel time for different modes (t-statistics in parentheses).

Travel time (min)	=	constant	+	coefficient	×	travel distance (100m)
car driving (R^2=0.364)	=	10.96 (45.79)	+	1.35 (36.61)	×	travel distance
public transport (R^2=0.041)	=	29.49 (81.10)	+	0.40 (11.09)	×	travel distance
car passenger (R^2=0.451)	=	12.12 (33.77)	+	1.45 (33.72)	×	travel distance
walk (R^2=0.090)	=	0.00	+	6.70 (19.88)	×	travel distance

The travel costs of these unchosen alternatives are estimated using the procedures described below, which follow assumptions made by Schmöcker *et al.* (2008) in regression models using the same LATS data:

Driving The marginal car costs are estimated at 7.4 pence per kilometer (12p/mile) plus associated parking costs. LATS contains data on the nature of parking for chosen trips. For all the missing car trips and for the unchosen alternatives, the charge for parking in both Inner and Outer London is estimated at £3 and £1 respectively. In summary, the total cost for driving is estimated as: 7.4 pence × travel distance (km) + parking cost.

Passenger It is assumed that car passenger costs are free since by testing various models it is found that this is better assumption than assuming costs similar to “Driving.”

Public transport When the respondent possesses a freedom pass, the trip cost is assumed to be 0; otherwise, the public transport cost is taken as £1. The Freedom Pass allows free travel on London’s public transport for people aged 60 or over and for people with certain disabilities who live permanently in a London borough. A single fare on public transport is 80p for bus and

£1.5 for Underground. In the following models, bus and Underground are not distinguished, so a public transport cost of £1 is assumed.

Walking No cost.

Trip characteristics included in the model are *travel purpose after shopping* (going home or not), *travel purpose in a tour* (shop only or not), and *tour complexity* (simple tour or not). The number of tours on the day surveyed was included in an earlier model, but the results were not statistically significant.

The variables describing public transport service quality have been described above and are only included in mode choices involving public transport. Household and individual socioeconomic variables included in model estimation are *age*, *travel disability*, *household income*, *household location* (Inner London or not), *sex* (male or female), and *household vehicle access*. Models with different age group specifications have been fitted; distinguishing the "younger old" (60–74) and the "older old" (75+), following findings by Alsnih and Hensher (2003), was found to give the best model fit. Models with more detailed income levels were also fitted, but a simple dummy variable distinguishing households with an annual income over £25,000 was found to be most effective, as additional income levels did not prove to be statistically significant nor to improve model fit.

5.3 Multinomial logit model results (simple tours)

Table 4 presents the estimation results of fitting an MNL model to the data on simple (home-shop-home) tours. Because there were only a few observations for simple tours with mode changes (3.79%, as shown in Table 2), only tours without mode changes are considered here. Trips made by driving are the reference category for the socioeconomic variables in Table 4, except for *car in household* which is related to driving and to being a passenger. It is interesting to note that very few of the socioeconomic variables are statistically significant.

Various other models have also been fitted. In particular, the interaction between socioeconomic variables has been tested but not found to be significant nor to improve model fit. The model suggests that, for a very basic choice model that does not distinguish the different public transportation modes, a small number of parameters can explain mode choice fairly well (the log likelihood ratio is 0.46). Travel cost, the availability of a car in the household, and bus stop density are statistically significant. All else being equal, travelers in London areas with higher bus stop densities are more likely to use public transport. Travel cost for driving is highly significant, with the expected negative sign. Travel time for driving and walking, however, have positive signs. This suggests that (all else being equal) older people enjoy the drive or walk to the shopping center, and that the positive effect of driving is more pronounced than the effect of walking. Being a passenger and using public transport have the "normal" negative signs. In general, these findings support findings in the literature suggesting that older people are sensitive to costs but that travel time is not as important. The statistically significant positive sign even suggests a similarity to findings reported by Mokhtarian and Salomon (2001), who point out that, in some cases, longer trips may be preferred by travelers because the journey is not necessarily only a by-product of the activity but might be enjoyable in itself. These results suggest that this theory may also hold true for older people when they are driving or walking. Obviously, especially for walking, this will only be true up to a certain trip distance, a fact considered in our model through the exclusion of walking as an option for longer trips.

Table 4: Multinomial logit for simple trips.

	Mode-specific variables			
	Drive	Public transport	Passenger	Walk
Constants	Reference	0.273	−2.496	−0.244
Travel time (min)	0.376**	−0.007**	0.012**	0.006**
Travel cost (GBP)	−6.536**	0.121		
Socioeconomic variables				
Age (65–74=1)	Reference	−0.278	−0.0259	0.08
Travel disability (with=1)	Reference	0.654	1.809*	1.784*
Sex (Male=1)	Reference	0.048	−1.398**	0.639
Car in household	2.467		2.146**	
Income (annual, over 25k=1)	Reference	−0.723	−0.569	−0.112
Accessibility variables				
Bus service headway		−0.041**		
Bus stops per km of road length		1.23**		
Rail stops per km of road length		0.367		
Number of individuals	2237			
Number of observations	2349			
log-likelihood at convergence	-1329.83			
Number of parameters	26			
Log likelihood ratio index	0.46			

To better illustrate the results, Table 5 shows the probabilities of making a trip with a specific mode for a reference case and the results of changes to one model parameter compared to this reference case. In the reference case consisting of a trip with a straight-line distance of 700 m (the average trip distance in Figure 2), car is the most likely choice,and it becomes even more likely as trip length increases. However, due to the cost sensitivity shown in the model results, this model predicts that the car will not be considered for short trips with high parking costs. Although bus stop density was found to be statistically significant, Table 5 suggests that even a doubling of the number of bus stops within London would only increase the market share by four percent for trips of the reference type. The last column in Table 5 shows the log-sum of utility for all choices, which can be interpreted as a measure of accessibility (e.g. Ben-Akiva and Lerman 1985)—in this case, as accessibility to modes rather than to destinations. The results show the decrease in accessibility once a private car is not an option.

5.4 Nested logit model results (complex tours)

All shopping tours were analyzed, regardless of the tour complexity. In this case, other mode choice combinations (such as drive to the shop and walk to the next shop) are possible, as shown in Table 1. To account for the potential existence of hidden correlations between some of the alternatives, several nested logit models were estimated; the framework of the model with best fit is shown in Figure 4. Two nests are included to account for correlations if a subject walked to

Table 5: Mode choice probabilities and log sum utility for different scenarios.

	Pr(drive)	Pr(PT)	Pr(pass)	Pr(walk)	logsum utility
Reference Case: dist=0.7km; parking cost=GBP 1; bus headway: 8; bus access 0.6 stops/km; tube access 0; male; age 60–74; no disability; veh in hh; not high income	0.89	0.04	0.03	0.04	3.41
(straight-line) trip distance: 1.5km	1	0	0	0	6.98
parking cost=GBP 3	0	0.36	0.28	0.36	1.18
age: 75+	0.88	0.05	0.03	0.04	3.42
disabled	0.65	0.05	0.13	0.17	3.73
female	0.88	0.04	0.01	0.07	3.42
no car in household	0	0.48	0.04	0.48	0.89
high income	0.93	0.02	0.02	0.04	3.37
100% increase in bus stop density: 1.2 stops/km	0.86	0.08	0.03	0.04	3.45

or from a shop and changed mode after their trip to the shop. Tours without any modal change are considered as separate options.

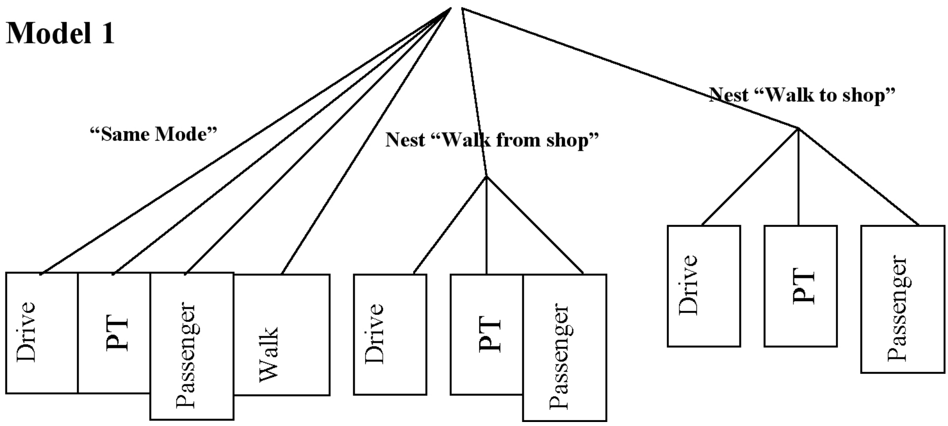


Figure 4: Frameworks of the nested logit model

The nesting parameters take values of 0.72 and 0.69 (both statistically significantly different from 1 according to the t-test 2.20 and 2.64), implying a correlation between the unobserved utilities around 0.49 and 0.52. The results shown in Table 6 suggest models that assume older people first choose whether to only walk one way to the shopping center before deciding on specific mode combinations are reasonable. In terms of model fit, the reported NL is similar to the MNL model fit, even though in this case 10 alternatives are considered and simple as well as complex tours are included.

Table 6: Estimation result of nested logit model 1.

	Drive	Drive + Walk	Walk + Drive	Passenger	Pass. + Walk	Walk + Pass.	Walk	PT	PT + Walk	Walk + PT
Constant	reference	−1.81**	−2.86**	−2.71**	−3.47**	−4.68**	−0.92**	−0.96**	−1.1**	−2.29**
Travel time before shopping					**0.005****					
Travel time after shopping					0.001					
Travel cost before shopping					**-1.21****					
Travel cost after shopping					**-1.61****					
Travel purpose after shopping (home=1)	reference	−3.97**	1.05**	0.005	−3.75**	1.22**	−0.64**	−0.39	−2.09**	1.56**
Tour Purpose (shop only=1)	reference	0.88**	0.72**	−0.39	1.1**	0.97**	0.49**	−0.34	0.63**	0.81**
Tour Type (simple=1)	reference	−1.32	−4.98**	0.54**	0.11	−3.96**	0.34	1.2**	−1.09**	−3.09**
Socioeconomic variables										
Age(65-74=1)	reference	0.13	0.31	0.09	0.39	0.38	0.29*	−0.06	0.06	0.4**
Travel disability(with=1)	reference	0.53	0.99**	0.48**	0.7*	0.87**	0.7**	−0.39*	0.41	0.52**
Gender (Male=1)	reference	−0.13	0.001	−1.85**	−1.63**	−1.16**	0.15	−0.44**	−0.46*	−0.2
Car in household	2.24**	2.24**	2.24**	2.24**	2.24**	2.24**	–	–	–	–
Income (annual over 25k=1)	reference	−0.33	−0.22	−0.44*	−0.4	−0.61*	−0.04	−0.65**	−0.22	−0.68**
Household location (Inner London=1)	reference	−0.95**	−1.17**	−2.96**	−3.2**	−3.19**	−2.03**	−1.93**	−1.82**	−2.52**
Accessibility variables										
Bus service headway								−0.03**	−0.03**	−0.03**
Bus stops per km of road length								0.58**	0.58**	0.58**
Rail stops per km of road length								−1.96	−1.96	−1.96

Number of individuals: 4186 — Number of observations: 4513 — Number of parameters: 91
log likelihood at convergence: -4190 — log likelihood ratio index: 0.44
Nest "walk from shop" (1/Lambda): 1.38** — Nest "walk to shop" (1/Lambda): 1.44 **

The results regarding the accessibility variables are similar to the MNL model. In particular rail stop density (includes tube) is not significant which might be because of less usage of this mode due to often low provision for those with walking disabilities. The income effect is still not very significant, though the model does show that those with high income are less likely to use public transport. Interestingly however whether the household is in Inner or Outer London is statistically significant. Those livening in Central London are more likely to drive even after having accounted for car availability and income effects. Reasons might be the less frequent "corner shops" and supermarkets in the very city center. Some of the socio-economic variables that were not statistically significant in the MNL model have now become more significant. Those with physical disabilities are more likely to use mode combinations. Persons under the age of 75 are more likely to walk and use public transport on the return than those over 75. This supports findings in the literature showing that there is a difference between the more mobile "younger old" and the "older old."

All mode-specific constants are negative, which means that (all else being equal) making the whole journey by driving is the preferred mode. This also supports findings emphasizing that independence is important for the quality of life for older people. In order to better understand the results of the MNL suggesting a positive travel time coefficient in these models, travel times and costs before and after shopping are distinguished—even though there is clearly some correlation between travel times and costs before and after shopping for simple home-to-home tours. However, as complex tours are also included, it is possible to distinguish them and obtain a statistically insignificant correlation. Traveling before shopping is perceived more positively than traveling after shopping, which may also be explained by the fact that an additional load of purchased goods must be carried after shopping. Further, the model suggests that older people are more sensitive to travel costs after shopping. In summary, these models suggest that people might enjoy traveling to a retail location, but after shopping are concerned with returning by the cheapest route possible. Other models (not shown) have been estimated including mode-specific travel costs and travel time but the differences between modes were not found to be significant nor do the models show significant improvements in terms of model fit.

If the traveler went home after shopping (possibly after visiting multiple shops but not combining their shopping trip with travel for any other purpose), then walking to the shop and returning by a motorized mode is more likely. This agrees with initial expectations, but the model also suggests that more complex mode choice combinations only occur for more complex shopping tours. In other words, in simple shopping tours where travelers only leave their homes to visit one shop before returning home, mode choice combinations are rare; but if several shops are visited, mode choice combinations are considered. Interestingly, however, if a tour is made for other purposes in addition to shopping, mode choice combinations are less likely. Further, if the tour is simple, older people are more likely to use public transport. These might, however, be mainly tours where the main purpose is combined with shopping.

6 Conclusions

This article looked at mode choice of older people to and from retail locations. The analysis shows that mode changes (such as walking to the shop and taking the bus back home) are not very frequent. The findings concerning mode choice of older people in trip chains could also have wider implications. It was argued that the pattern of the shopping tour has significant effects on mode choice. It was found that for more complex shopping tours more complex mode choice combinations were chosen. Further research should show whether this argument also holds the other way round: if better private and public transport services are provided, will older people be more likely to engage in more trips with multiple shopping stops? The proportion of older people driving is continuously increasing; those driving seem to be more likely to engage in tours with multiple purposes such as leisure trips combined with shopping. Therefore, in the future, older people may prove more likely to engage in complex tours.

The analysis undertaken in this research provides additional evidence that independent shopping travel by car is of high importance to older people, as not having a car available results in a sharp decrease in accessibility (measured here as the log-sum of the utility of all available modes). Any transport policy initiative supporting special transport services would be well advised to take these positive effects of independent travel into account. Further a positive coefficient for travel time was found consistently in all models. The MNL analysis shows that this is true for walking and in particular for driving, whereas traveling on buses is perceived to be burdensome. The results of the NL analysis further suggest that it is particularly the trip *to* rather than *from* the retail location that is enjoyable, possibly because of the extra physical burden imposed by carrying the fruits of a shopping expedition. Mokhtarian and Salomon (2001) propose that, more often than commonly thought, the trip destination is ancillary because of positive travel effects. In the case of older people's shopping trips it is generally thought that it is rather the trip frequency that is flexible (i.e. several short shopping trips with small shopping loads) but the increasing mobility of the younger old in particular might also lead to a preference for longer trips, especially by car. This finding will have implications for local retail areas, and lends support to the development of more out-of-town shopping centers.

The analysis presented in this paper suggests that the accessibility of bus services does significantly influence mode choice. As previously pointed out in Schmöcker *et al.* (2008), it is primarily bus stop density that encourages older people to use public transport more frequently. Results in this paper further show, however, that providing more bus stops does not necessarily lead to a significant increase in bus usage. This is in line with the literature on accessibility planning suggesting that small details are often what determine whether or not a trip can be made. In this article we further point out that bus service frequency does not appear to be of the same significance though this might be due to insufficient data accuracy. The primary attraction to public transport appears to be the relatively low fare and (through Freedom Pass) often free public transport as we find that direct costs (such as parking) are the main deterrent from car usage. Though parking in central London is often difficult to find and expensive, we further find (contrary to our initial expectations) that a central London residence seems to deter older people from walking, using public transport and rather encourage car usage. This might seem surprising at first glance, but further research could confirm whether this is due to more accessible food shopping facilities in the neighborhood for those living in the less-central boroughs of London.

Besides these findings, the models used in this research confirm several findings of other studies (mainly carried out in the United States) described in the literature review, such as the importance of car availability, that older people with high income are less likely to use public transport, and the influence of gender on public transport usage. The dataset used for this analysis clearly does not take into account a number of factors that might influence mode choice significantly. The advantage of using LATS is the large sample size, leading to relatively robust results; but a specific survey to investigate mode choice could include parameters such as better descriptions of the respondents' neighborhoods, available shopping options, and actual (and perceived) public transport service quality around subjects' homes. Further, a detailed analysis of the impact of shopping loads on destination and mode choice of older people is largely absent from the existing literature.

Acknowledgments

The authors would like to thank David Levinson and two anonymous reviewers for their helpful comments to improve the manuscript.

References

Alsnih, R. and D. Hensher (2003). The mobility and accessibility expectations of seniors in an aging population. *Transportation Research A*, 37(10): 903–916. doi:10.1016/S0965-8564(03)00073-9.

Barber, G. (1995). Aggregate characteristics of urban travel. In: S. Hanson, ed., *The Geography of Urban Transportation*, pp. 81–99. The Guilford Press, New York.

Ben-Akiva, M. and S. Lerman (1985). *Discrete Choice Analysis: Theory and Applications to Travel Demand*. MIT Press, London.

Bhat, C. (1997). Work travel mode choice and number of non-work commute stops. *Transportation Research B*, 31: 41–54. doi:10.1016/S0191-2615(96)00016-1.

—— (1998). Analysis of travel mode and departure time choice for urban shopping trips. *Transportation Research B*, 32(1): 361–371. doi:10.1016/S0191-2615(98)00004-6.

Bierlaire, M. (2003). Biogeme: A free package for the estimation of discrete choice models. In: *Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland*.

Bromley, R., D. Matthews, and C. Thomas (2007). City centre accessibility for wheelchair users: The consumer perspective and the planning implications. *Cities*, 3: 229–241. doi:10.1016/j.cities.2007.01.009.

Chen, I., F. Gross, K. Becheux, and P. Jovanis (2004). Estimating model preference between its-enhanced and existing paratransit services. In: *Transportation Research Board 83rd Annual Meeting, Washington, D.C.*

Department for Transport (2005). Transport statistics: National Travel Survey. Web page. URL http://www.dft.gov.uk/162259/162469/221412/221531/223955/223958/coll_nationaltravelsurvey2005/nationaltravelsurvey2005a. Accessed April 2007.

Enoch, M., S. Potter, G. Parkhurst, and M. Smith (2004). *INTERMODE: Innovations in Demand Responsive Transport*. Technical report, Department for Transport and Greater Manchester Passenger Transport Executive. URL http://www.dft.gov.uk/pgr/regional/policy/intermodeinnovationsindemand3722.

for Transport, D. (2001a). *LATS – An introductory report*. Technical report, Department for Transport. URL http://www.dft.gov.uk/pgr/inclusion/older/olderpeopletheirtransportnee3260.

—— (2001b). *Older people: Their transport needs and requirements – Main report*. Technical report, Department for Transport. URL http://www.dft.gov.uk/pgr/inclusion/older/olderpeopletheirtransportnee3260.

Giuliano, G., H. Hu, and K. Lee (2003). *Travel patterns of the elderly: the role for land use*. Technical report, METRANS Project 00-8. URL http://www.metrans.org/research/final/00-08_Final.pdf.

Gould, J., T. Golob, and P. Barwise (1998). Why do people drive to shop? future travel and telecommunications tradeoffs. Paper UCI-ITS-AS-WP-98-1, posted at the eScholarship Repository, Center for Activity Systems Analysis, University of California. URL http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1035&context=itsirvine/casa.

Handy, S. (1996). Non-work travel of women: patterns, perceptions, and preferences. In: *The Women's Travel Issues Second National Conference*.

Hensher, D. (2007). Some insights into the key influences on trip-chaining activity and public transport use of seniors and the elderly. *International Journal of Sustainable Transportation*, 1(1): 53–68.

Ibrahim, M. and P. McGoldrick (2003). *Shopping choices with public transport options: an agenda for the 21st century*. Ashgate, Hampshire UK.

Kim, S. and G. Ulfarsson (2004). The travel mode choice of the elderly: Effects of personal, household, neighborhood, and trip characteristics. In: *Paper presented at the 2004 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Krizek, K. (2003). Neighborhood services, trip purpose, and tour-based travel. *Transportation*, 30(4): 387–410. doi:10.1023/A:1024768007730.

Limanond, T. and D. Niemeier (2004). Effect of land use on decisions of shopping tour generation. *Transportation*, 31(2): 153–181. doi:10.1023/B:PORT.0000016578.21486.af.

Metz, D. H. (2000). Mobility of older people and their quality of life. *Transport Policy*, 7: 149–152. doi:10.1016/S0967-070X(00)00004-4.

Mokhtarian, P. and I. Salomon (2001). How derived is the demand for travel? some conceptual and measurement considerations. *Transportation Research A*, 35: 695–719. doi:10.1016/S0965-8564(00)00013-6.

Nitta, Y. (1998). Transportation mode change model to special bus incorporating generalized time. In: *Proceedings of the 8th international conference on transport and mobility for elderly and disabled people (TRANSED), Perth, Western Australia*.

Office for National Statistics (2005). URL. URL http://www.statistics.gov.uk/cci/nugget.asp?id=94. Accessed June 2007.

Schmöcker, J.-D., M. Quddus, R. Noland, and M. Bell (2005). Estimating trip generation of elderly and disabled people: An analysis of London data. *Transportation Research Record*, 1924: 9–18. doi:10.3141/1924-02.

—— (2008). Mode choice of older and disabled people: A case study of shopping trips in London. *Journal of Transport Geography*, 16(4): 257–267. doi:10.1016/j.jtrangeo.2007.07.002.

Su, F. (2007). *Understanding and satisfying older people's travel demand*. Ph.D. thesis, Imperial College, London.

Suen, S. and C. Mitchell (1999). *Accessible transportation and mobility*. Technical report, Committee on Accessible Transportation and Mobility. URL http://www.agilistics.com.au/newsletter/accessibletransport.pdf.

Wallace, B., J. Barnes, and S. Rutherford (1999). Evaluating the effects of traveler and trip characteristics on trip chaining, with implications for transportation demand management strategies. *Transportation Research Record*, 1718: 97–106. doi:10.3141/1718-13.

Wilds, M. and W. Talley (1984). Dial-a-Ride and bus transit services: A mode-choice analysis. *Transportation Research Record*, 984.