MODELLING MODE CHOICE IN SHORT TRIPS - SHIFTING FROM CAR TO BICYCLE

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ABSTRACT
This paper investigates the mode choice behaviour of Danish population from the Greater Copenhagen Area when travelling short trips. Data from the Danish National Transport Survey identify the travel behaviour of the Danish population through interviews collecting travel diaries and socio-economic variables of a representative sample of the population. The investigated sample includes 11,072 observations.

The model considers five alternatives (i.e., car driver, car passenger, public transport, walk and obviously bike), for which level of service variables are calculated through assignment procedures available for each period of the day in which the trip was conducted. The present study estimates a mixed logit model able to capture taste variations and differentiates travel time parameters across modes. The mixed logit model allows investigating the effect of level of service variables, individual characteristics of the travellers, purpose of the trips and environmental conditions.

Results suggest heterogeneity among cyclists in the sensitivity to travel time, temperature and hilliness. The cost parameter is not significant, probably because of difficulties in the calculation, but possibly because of lower relevance of the cost for short trips. Expectedly, the selection of bicycle as mode for short trips is positively related to owning a bicycle and negatively linked to owning one or more cars. Urban density has also positive correlation with the selection of sustainable transport modes.

1. INTRODUCTION

Over the years demand for faster and more flexible transport has grown, as production, income, number of trips and travel distances have increased. Consequently, the use of motorized private modes has steadily increased in Denmark as all over the world. As a result, road congestion has become a major problem, especially in the Greater Copenhagen Area. Methods are necessary to decrease the congestion and to solve the related health problems through the promotion of sustainable transport modes, with particular emphasis on the shifting from private transport to bicycling.

In Europe, many projects have addressed this issue. Two large EU-financed projects, WALCYNG (Hydén, et al., 1999) and ADONIS (Forward, 1998), both studied the differences in the share of walking and cycling in different selected European cities, on the basis of which they have tried to find ways to increase walking and cycling instead of shorter car trips.

Various studies have been conducted in Denmark where applied methods are implemented to promote cycling (Troelsen, et al., 2004; Jensen, 2001, 2004). The traffic group at Aalborg University (Trafikforskningsgruppen Aalborg Universitet, 2001) made a bicycle and a free bus pass available to car drivers during a test period to see whether they would switch to more sustainable transport modes when travelling to work. Egetoft, et al. (2002) aimed to motivate people to plan their trips better to increase their possibilities to cycle. Finally, a Danish study based on Danish National Travel Survey (Jensen and Thost, 1999) shows that the hilliness and the size of the city (the latter only applies to cities with less than 10,000 inhabitants) are important for the share of people cycling. Furthermore, the size of the city is also important for the length of the cycling trip, and the share of people working in their own municipality.

A number of studies have been carried out according to the same concept presented in this study. Vågana (2006) presents a data analysis, based on the Norwegian transport survey study, describing walking and bicycling trips, whereas Vågana (2007) investigates whether it is possible to transfer short car trips to walking and bicycling. By means of logistic regression it is shown that gender, age, size of the city, season, length of trip chain and certain purposes are significant for the choice of transport mode. Rodríguez and Joo (2004) analyse the importance of the physical surroundings such as sidewalk availability, bicycle path, topology, etc. The results show that especially topology and sidewalk availability are important for the choice of transport mode. Wardman et al. (2007) combine a revealed preference- and a stated preference data to study the effect of a various policy tools intended to increase the bicycling share in commuting trips. Results show that segregated cycleway and payment for cycling to work were found to be highly effective on the bicycle share.

Nankervis (1999) and Bergström and Magnusson (2003) study the significance of the weather on bicycle commuting, where the main focus is on the maintenance of bicycle paths during winter. Rietveld and Daniel (2004) analyse to what extent municipality policies matter, and show that the most important factors for the choice of bicycling are the physical aspects such as altitude difference and city size, and the share of youngsters in the population. In addition, results conclude that difference in ethnic compositions is also important, as well as policy-related variables such as the number of stops per km on the route and the risk of accidents are important. Hunt and Abraham (2007) show that time spent cycling in mixed traffic is more onerous than time spent cycling on bike lanes or bike paths. Parkin et al. (2008) present a logistic regression model based on aggregate data that shows that the quality of main roads and the annual rainfall as well as the temperature are important. Also, segregate cycleway have significant relation with bicycle share, even though the elasticity is low. This is in contrast to a paper by Wardman et al. (2007) that illustrates that segregate cycleway and cycle lanes have a very high effect on share of bicycle mode in commuting trips. Vandenbulcke et al. (2011) aim to explain the spatial variation of the bicycle use for commuting to work in different Belgian municipalities. The main findings of the study are that much of the inter-municipality variation in bicycle use is related to environmental aspects such as the relief, traffic volumes and cycling accidents. In addition, town size, travel distance and demographic aspects also have some effect. Sener, et al. (2009) concludes that the perceptions of the quality of bicycle facilities and safety from traffic crashes show significant variation based on bicyclists' demographic and work characteristics, and bicycle amenities/facilities on the commute route and at the work place.

The Department of Transport at the Technical University of Denmark, in collaboration with the Danish Road Directorate, investigated short trips by car and examined whether it is possible to make car drivers shift to biking or walking. The study presents an MNL model investigating trips shorter than 22 km based on data from the Danish National Travel Survey and demonstrated how three types of conditions influence the choice of transport mode:

- Conditions concerning the purpose of the trip and the road user, where car ownership and number of children in the family are the most important factors.
- Conditions concerning the environment of the trip, where differences of hilliness and temperature have proved to be greatly relevant.
- Conditions concerning the travelling circumstances where the project describes the effect of speed for car drivers and cyclists, the parking conditions as well as a general effort to promote biking.

The study shows that cycling policies would reduce the short trips by car in favour of bicycling. 90% of short car trips would be transferred to bicycle, in the case where travellers would transfer to sustainable transport modes.

This paper aims to extend the previous choice model with a fresh and up-to-date perspective. Public transport was not considered in the MNL model of the previous study because of the lack of data about the level of service of the public transport service. The present study includes public transport in the choice model, since the evaluation of the transfer from car to bicycle could be biased by the exclusion of public transport as possible option. In addition, the MNL model of the previous study did not allow considering heteroscedasticity across alternatives and heterogeneity across travellers. To be able to capture taste variations through a specification that expresses randomly distributed parameters and differentiates the travel time parameters across modes to express different values of time for different modes, the present study estimates a mixed logit model.

The data used in the study, about short trips in the Greater Copenhagen Area, are available from the Danish National Travel Survey. The survey identifies the travel behaviour of a representative sample of the Danish population through interviews collecting travel diaries and socio-economic variables. For model estimation 11,072 observations constitute the sample of short trips in the Greater Copenhagen Area. Five alternatives are considered (i.e., car driver, car passenger, public transport, walk and bicycle), and level of service variables are calculated through assignment procedures available for each period of the day in which the trip was conducted.

The remainder of the paper is structured as follows. Section 2 describes the data used in the study. Section 3 describes the methods applied to measure and model the behaviour of travellers. Section 4 presents the results of a mixed logit model. Section 5 summarizes the major findings of this study.

2. DATA

The Danish National Travel Survey (also called TU-survey) identifies the travel behaviour of a representative sample of the Danish population. DTU Transport conducts the TU-survey on behalf of the Ministry of Transport and several other government departments, and the research firm Synovate assists with collecting the data for the study (DTU Transport, 2010).

The TU-survey investigates the trips during the day before the interview of Danes between the age of 10 and 84. Interviewees are selected by conducting random extraction from the Danish Civil Registration System (Det Centrale Personregister, CPR), administered by The Danish National Board of Health (Sundhedsstyrelsen). The response rate is on average approximately 62%, which is considered quite satisfactory for a study of this type. The investigation has mainly been conducted as telephone interviews, approximately 80% of the data, while self-reported internet interviews are approximately 20% of the data (Christiansen, 2009).

DTU Transport and Synovate have permission from the Danish Data Protection Agency (Datatilsynet) to process and store sensitive personal information such as name, coordinates, and precise address information. Approximately 95% of all locations (trip points, home addresses, workplaces, etc.) are geographically coded directly by the respondent in “search and select” in the questionnaire. In the remaining cases, the respondent completes a description of the site as a free text. These locations are coded afterwards parallel to the other locations. The addresses are treated to a level where 98% can be localized at the coordinate level, and 99.9% at the zone level. This information is confidential and may not be used outside DTU Transport and only with special permission (Christiansen, 2009).

The respondents are asked about why they travel and what means of transport the individuals use during the day in question. In addition, the individuals are asked about the trips, when and where they take place, for how long, etc. All trips are important for the study. In order to describe travel habits for selected groups, the interviewees are also asked about their age, gender, income, education, car availability, etc. The survey must reflect the diversity of the population travel behaviour (DTU Transport, 2010).

Data are collected each day throughout the year, thus the TU-data characterize the differences in transport behaviour across seasons, days of the week, etc. The study is the only large Danish study combining actual transport behaviour with a wide range of background variables. Asking the interviewees about their travel behaviour on a single day gives a good description of the average behaviour of each person. However, the disadvantage is that the distribution around the average cannot be described as accurately. Also, by only asking individuals about their personal travel behaviour, the family travel pattern is not represented by the data set. That would require that the same people would be interviewed about their behaviour over a longer period, the economy does not provide opportunities for that (Jensen, 2009).

2.1 Hilliness, parking and weather

Terrain ratio is calculated as the average gradient of all journeys undertaken within a radius of 5 km from the respondent's home. Hence, it indicates how hilly it is in the area and thus how difficult it is to cycle. The average parking is calculated within a radius of 5 km from the person's destination. It describes therefore how difficult it is to park in the area. The temperature is obtained from Danmarks Meteorologiske Institut (DMI). All three variables are implemented as continuous variables in the model specification.

3. METHODOLOGY

3.1 Mode choice attributes

To analyse current travel behaviour, or to forecast future travel behaviour, observed choices and alternatives composing the choice set of each traveller are necessary. The TU-survey collects the current travel behaviour, i.e. the observed choices. Route choice models and simulation methods are used to calculate the attributes of the alternatives within the choice set of each traveller. Five alternatives are considered, i.e. car driver, car passenger, public transport, walk and bicycle.

The level of service variables for car driver, car passenger and public transport are calculated through assignment procedures available for each period of the day in which the trip was conducted. The calculation of level of service variable allows considering congestion conditions similar in average to the ones encountered by the travellers. The car travel time includes free flow travel time plus the added travel time due to congestion. The public travel time includes waiting time, access- and egress time, walking time and in vehicle time. The cost for public transport is estimated from the TU-survey as an average cost per km travelled, limited to the minimum- and maximum cost for the public transport as it is set in the Danish public transport prizing system. The cost for car driver is calculated with values from the Danish Transportation Economic Unit prices (Modelcenter, 2010).

There is not any available information on travel speed on different parts of either the Danish bicycle network or the Danish pedestrian network. Therefore the travel speed for the two modes is estimated as an average travel speed. The travel time is thus dependent on the travel distance. The travel distance is calculated with a shortest path simulation method. The cost for bicycle is also calculated with values from the Danish Transportation Economic Unit prices. It is assumed that the travel cost for walk is zero.

3.2 Model specification

The present study estimates a mixed logit model (for a detailed discussion see Train, 2003).

The mixed logit probability can be derived from utility-maximizing behaviour based on random coefficients. The decision maker has a choice set of *J* alternatives. The utility of decision maker *n* from alternative *j* is specified as:

$$U_{nj} = \beta'_n x_{nj} + \varepsilon_{nj}, \tag{3.1}$$

where x_{nj} are observed variables that associate to the alternative and decision maker, β_n is a vector of coefficients of these variables for decision maker *n* representing the individual´s preferences, and ε_{nj} is a random term that is *iid* extreme value distributed over alternatives and decision makers. The coefficients vary over decision makers with density $f(\beta)$, which is a function of its parameters θ (e.g., mean and covariance of the β´*s* in the population). In the standard logit the β is fixed, while in the mixed logit the β varies over decision makers.

The researcher can only observe the x_{nj}´*s* but not β_n or the ε_{nj} ´*s*. If the β_n would be observed by the researcher then the choice probability would be standard logit, given that the ε_{nj} ´*s* are *iid* extreme value. Then the probability restricted on β_n is:

$$P_{ni}(\beta) = \frac{\exp(\beta'_n x_{ni})}{\sum_j \exp(\beta'_n x_{nj})}. \tag{3.2}$$

However, the researcher cannot condition on β, since the β_n is unknown. The unrestricted choice probability, which is the mixed logit probability, is therefore the integral of $P_{ni}(\beta_n)$ over all possible variables of β_n:

$$P_{ni}(\beta) = \int \frac{\exp(\beta'_n x_{ni})}{\sum_j \exp(\beta'_n x_{nj})} f(\beta)\, d\beta, \tag{3.3}$$

The present study specifies lognormal distribution, where $ln\beta \sim N(b,W)$, with parameters *b* and *W* that are estimated, for time variables that are supposed to be negative, and normal distribution for variables that are not expected to have a specific sign.

4. RESULTS

4.1 Data analysis

The data analysis in this paper focuses on trip chains shorter than 22 km. Cases were excluded because respondents opted not to provide information or because other relevant information was missing for the analysis. Given the restrictions the sample includes 7,966 individuals and 11,072 trip chains. Given the extensive data collected from the survey, only selected results are presented here.

Table 1 presents the category variables for personal characteristics and
Table **2** presents the category variables for trip characteristics Personal characterises variables include socio-economical variables: age, gender, main occupation, and whether the respondent has driving license or not. There are also personal and household economical variables. These are the number of cars owned, whether the respondent owns a bicycle, and number of children in the household. The trip characteristics variables include: mode choice, urban characteristics, and trip purpose.

The share of respondents using each mode is with 11% walking, 28% cycling, 47% driving, 6% being driven and 8% taking public transport. The dataset has 3,752 male (47%) and the average age is 48. The main occupation category homemaker only had two observations, so they were not included in the estimation.

Table 1: Category variables for personal characteristics.

Variable	**Total (*N = 7,966*), *N(%)***
Personal characteristics	
Age group	
16 - 17	140 (2)
18 - 24	536 (7)
25 - 34	1,210 (15)
35 - 44	1,696 (21)
45 - 54	1,515 (19)
55 - 64	1,407 (18)
65 - 74	979 (12)
75 and older	483 (6)
Gender	
Male	3,752 (47)
Female	4,214 (53)
Main occupation	
Student	768 (10)
Welfare	1,857 (23)
Un-employed	241 (3)
Employed	4733 (59)
Self-Employed	365 (5)
Respondent has a driving licence	
No	1,373 (17)
Yes	6,593 (83)
Respondent has a bicycle	
No	1,744 (22)
Yes	6,222 (78)
Vehicle availability	
Zero car	2,125 (27)
One car	4,396 (55)
Two cars	1,311 (16)
Many cars	134 (2)
Household category – Number of children	
No children between the age 0-4	6,983 (88)
Children between the age 0-4	983 (12)
No children between the age 5-9	6,823 (86)
Children between the age 5-9	1,143 (14)
No children between the age 10-15	6,605 (83)
Children between the age 10-15	1,361 (17)

Table 2: Category variables for trip characteristics.

Variable	**Total (*N = 11,072*), *N(%)***
Trip characteristics	
Mode choice	
Walk	1,173 (11)
Bicycle	3,092 (28)
Car driver	5,243 (47)
Car passenger	715 (6)
Public transport	849 (8)
Urban characteristics	
Copenhagen centre	3,834 (35)
Greater Copenhagen area	4,651 (42)
Minor town	1,311 (12)
Village	1,016 (9)
Rural area	260 (2)
Trip purpose	
Business	206 (2)
Work	1,768 (16)
Combination of work and other	886 (8)
Leisure	3,386 (31)
Shopping	3,526 (32)
Escorting	1,300 (12)

Table 3 presents the continuous variables. The personal characteristics variable is the respondents' income. The primary trip characteristic variables are the travel time. Other trip characteristics are travel distance and other time variables.

Table 3: Continuous variables.

Variable	*N*	Mean	Std. dev.	Min	Max
Personal characteristics					
Income DKK/1,000	7,966	267.6	185.6	0.0	1,500.0
Trip characteristics					
Walk					
Travel time [min]	1,173	23.4	23.4	0.1	186.9
Travel distance [km]	1,173	1.9	1.9	0.0	15.0
Bicycle					
Travel time [min]	3,092	22.4	19.1	0.1	88.0
Travel distance [km]	3,092	5.6	4.8	0.0	22.0
Car driver					
Travel time [min]	5,243	11.4	8.4	0.0	50.3
Travel distance [km]	5,243	8.4	6.4	0.0	40.6
Car passenger					
Travel time [min]	715	10.9	8.2	0.0	39.1
Travel distance [km]	715	7.7	6.2	0.0	29.4
Public transport					
Waiting time [min]	849	16.8	17.4	1.5	197.7
Access/egress time [min]	849	21.4	10.8	0.8	70.7
In vehicle time [min]	849	22.8	17.0	0.0	82.3
Travel distance [km]	849	11.2	8.2	0.8	61.5

4.2 Model estimates

The summary statistics from the model estimation are presented in Table 4. Table 5 summarizes the results from the mixed multinomial logit model estimated.

The asymptotic t-test is primarily used to test whether a specific parameter in a model differs from a known constant, often zero. Not all coefficient variables, obtained in the survey, proved to be statistically significant at 95% level. In addition, some variables that are considered interesting preference indicators cannot be included in the estimations because they are correlated with other more important variables. According to these considerations, some variables are deleted to increase the reliability of the model. The final model is constituted by 11,072 observations, where there are 7,966 individuals and 65 estimated parameters. These items are listed in the order in which they were estimated, except for the deleted variables. The alternative specific constant (ASC) for walk is fixed to zero for identification purposes.

Table 4: Summary statistics for the mixed multinomial logit model.

Summary statistics	
Number of observations:	11,072
Number of individuals:	7,966
Null log-likelihood:	-17,294.122
Final log-likelihood:	-9,580.599
Likelihood ratio test:	15,427.046
Rho-square:	0.446
Adjusted rho-square:	0.442

Table 5: The results from the mixed multinomial logit model estimates.

Name	Value	t-test	
Constant - Walk	0.000		
Constant - Bicycle	-4.640	-14.44	***
Constant - Car driver	-5.520	-16.35	***
Constant - Car passenger	-1.990	-7.39	***
Constant - Public transport	-2.120	-6.78	***
Travel cost	-0.002	-0.70	
Travel time - Walk	-2.830	-38.85	***
Travel time - Walk sigma	0.372	6.52	***
Travel time - Bicycle	-3.030	-43.90	***
Travel time - Bicycle sigma	0.232	6.34	***
Travel time - Car driver	-0.053	-6.70	***
Travel time - Car passenger	-0.063	-7.22	***
Waiting time - Public transport	-0.011	-3.94	***
In vehicle time - Public transport	-0.005	-0.90	
Access/egress time - Public transport	-0.038	-7.82	***
Transfers - Public transport	-0.161	-2.18	**
Bicycle	4.000	19.76	***
Male - Bicycle	0.076	0.86	
Male - Car driver	0.481	5.49	***
Male - Car passenger	-1.080	-8.75	***
Male - Public transport	-0.133	-1.19	
Temperature - Walk	-0.025	-3.06	***
Temperature - Walk sigma	0.058	4.16	***
Temperature - Bicycle	0.026	5.67	***
Temperature - Bicycle sigma	0.045	4.08	***
Temperature - Public transport	-0.016	-2.66	***
Trip purpose: Work - Bicycle	0.119	0.93	
Trip purpose: Work - Car driver	-0.540	-4.36	***
Trip purpose: Work - Car passenger	-0.576	-3.71	***
Trip purpose: Work & other - Car driver	-0.695	-4.69	***

Trip purpose: Work & other - Car passenger	-1.090	-5.16	***
Trip purpose: Leisure - Bicycle	-0.904	-8.11	***
Trip purpose: Leisure - Car driver	-0.450	-5.73	***
Trip purpose: Leisure - Public transport	-0.434	-4.02	***
Trip purpose: Shopping - Bicycle	-0.596	-5.57	***
Trip purpose: Escorting - Car driver	0.955	8.01	***
Urban: Copenhagen centre - Bicycle	0.179	1.83	*
Urban: Copenhagen centre - Car driver	-0.416	-3.85	***
Urban: Copenhagen centre - Car passenger	-0.776	-6.47	***
Urban: Copenhagen centre - Public transport	0.257	2.14	**
Hilliness - Bicycle	-0.015	-1.81	*
Hilliness - Bicycle sigma	0.036	1.84	*
Car parking	2.010	8.78	***
Car ownership - One car	2.850	25.23	***
Car ownership - Two cars	3.530	26.36	***
Car ownership - Three cars or more	3.840	13.93	***
Children in household: Ages of 5 to 9 - Car driver	0.204	2.53	***
Children in household: Ages of 10 to 15 - Car driver	0.155	2.09	**
Income - Car driver	0.001	3.95	***
Income - Public transport	-0.001	-2.09	**
Main occupation: Student - Bicycle	1.210	5.10	***
Main occupation: Student - Car driver	1.420	5.43	***
Main occupation: Student - Car passenger	0.908	3.09	***
Main occupation: Student - Public transport	1.230	3.93	***
Main occupation: Welfare - Bicycle	0.404	1.92	**
Main occupation: Welfare - Car driver	0.562	2.61	***
Main occupation: Welfare - Car passenger	-0.038	-0.15	
Main occupation: Welfare - Public transport	0.779	2.75	***
Main occupation: Employed - Bicycle	0.772	3.79	***
Main occupation: Employed - Car driver	1.140	5.41	***
Main occupation: Employed - Car passenger	0.427	1.68	*
Main occupation: Employed - Public transport	0.664	2.37	**
Main occupation: Self-employed - Bicycle	0.168	0.58	
Main occupation: Self-employed - Car driver	0.867	3.12	***
Main occupation: Self-employed - Car passenger	-0.281	-0.68	
Main occupation: Self-employed - Public transport	0.343	0.88	

* Significant at a 90% level.
****** Significant at a 95% level.
******* Significant at a 99% level.

4.2.1 Time variables

The travel time variables are important trip characteristics that are considered as a good indicator of individuals preferences. Wardman et al. (2007) have documented that travel time while cycling is considered to be three times more unpleasant than travel time by other transport modes. With an increase in the travel time the perceived convenience of a bicycle trip and a walking trip declines, this is not the case for other modes of transport (Noland and Kunreuther, 1995). Studies have also shown that experienced cyclists have a preference to short travel times (Stinson and Bhat, 2005; Hunt and Abraham, 2007). However, some cyclists may prefer slightly longer commuting distances, increasing the travel time, because of health and fitness reasons.

The model shows that the coefficients for the travel time variables are consistently negative for all transport modes except for public transport. The in vehicle time is not statistically significant, while the waiting time and the access/egress time for public transport mode are significant and have the expected negative sign. Walk travel time and bicycle travel time are log-normally, where both mean and standard deviation are significant. If this non-homogeneous effect is overlooked in the estimation, the model could compensate by making the public- and car transport modes more attractive. After all, it can be assumed that individuals use public transport and car more for the long distance travels than the short.

4.2.2 Personal characteristics

Table 5 shows that certain attributes of the personal characteristics are related to mode choice. The coefficient variable for describing a bicycle ownership has a high positive value. Logically, owning a bicycle increases the probability of individuals cycling. In central Copenhagen there is a bicycle sharing program, called Copenhagen City Bikes. The program was launched in 1995 with 1,000 bicycles and was the world's first large-scale urban bicycle sharing program (Bycyklen København, 2011?). Since 1965, interest in bicycle haring has grown on five continents: Europe, North America, South America, Asia, and Australia. There are approximately 100 bicycle sharing programs operating today in approximately 125 cities, with more than 139,300 bicycles (Shaheen, 2010).

Most research concludes that females cycle less than males (Howard and Burns, 2001; Dickinson et al., 2003; Rodríguez and Joo, 2004; Moudon et al., 2005; Plaut, 2005; Stinson and Bhat, 2005; Dill and Voros, 2007). The coefficient variable for gender also concludes that males cycle more than females, however it is not statistically significant. The models results also show that males are more likely to drive a car, while females are more likely to be car passengers, and that females are more likely to use public transport, however the results are not statistically significant.

The coefficient variable for income is not statistically significant for bicycle and is thus not included in the final model. Presumably, at an aggregate level, having a high income would result in less cycling (Pucher et al., 1999; Pucher and Buehler, 2006). Witlox and Tindemans (2004), Plaut (2005) and Guo et al. (2007) document a negative connection between cycling and income. However, Dill and Voros (2007) conclude that income has a positive effect on commuting by bicycle. Parkin et al. (2008) conclude that there is a connection between lower incomes and a lower bicycle share for commuting trips, in England and Wales. Dill and Carr (2003) conclude that income has no significant effect on bicycle share.

The coefficient variable for income is significant for car driver and public transport. The variable for car driver is positive indicating that the higher the individual's income is, the more individuals are willing to drive. The variable for public transport is however negative, which indicates that the higher the individual's income is, the less individuals are willing to travel by public transport. The coefficient variable for income is not statistically significant for car passenger and is thus excluded.

Another important indicator of personal preferences is the main occupation. Unemployed is used as a reference variable. The coefficient variable for students is positive for all transport modes indicating that the higher the value is, the more individuals are willing to travel by each mode. Students are most likely to travel as car drivers followed by public transport and bicycle. The coefficient variable for welfare is positive for car driver, public transport and bicycle. The model shows that individuals on welfare or more likely to use public transport than to travel with other transport modes. The coefficient variable for welfare is not significant for car passenger. The employed coefficient variable is positive for all transport modes. Self-employed is positive and significant at a 99% level of confidence for car driver. However, it is not significant for other transport modes.

The coefficient variables for the age categories are correlated with the main occupation variables. The main occupation variable is considered a better indicator of who people are with respect to age, and to avoid multicollinearity the age variables are not considered in the final model.

Mode choice behaviour is also strongly linked to household characteristics. Having a car in the household has a strong negative effect on share of bicycles as a mode choice (Cervero and Radisch, 1996; Stinson and Bhat, 2004, 2005; Plaut, 2005; Pucher and Buehler, 2006; Dill and Voros, 2007; Guo et al., 2007; Parkin et al., 2008) and that having fewer cars in the household increases bicycle use (Stinson and Bhat, 2004). This is consistent with the findings of the present paper. The coefficient variables describing car availability at the household is positive for all three categories (i.e., one car, two cars, three or more cars). The higher the number of cars in the household is, the more likely individuals are to drive a car. The coefficient variable for having a driving license is positive but not significant, and hence it is not presented in the final model.

The results show that individuals with children are more likely to be a car driver when compared to other transport modes. The coefficient variable for children in household, associated with the car driver transport mode, is positive for children between the ages of 5 to 9 and for children between the ages of 10 to 15.

4.2.3 Trip characteristics

The primary trip characteristics are the time variables. The estimation results show that other attributes describing the trip characteristics are also related to mode choice.

Hilliness is normally distributed for bikers. The presence of slopes has a negative impact on cycling, but the standard deviation is also significant and suggests that some cyclists do not mind to ride their bike up- hill. Various studies conclude that the presence of slopes has a negative effect on cycling frequency, e.g. Rietveld and Daniel (2004), Rodríguez and Joo (2004), Timperio et al. (2006) and Parkin et al. (2008).

Parkin et al. (2008) find that an increase in temperature results in higher cycling frequency. Studies have also shown that temperature influences cyclists more than other commuters (Bergström and Magnussen, 2003; Brandenburg et al., 2004). One reason for this could be that some commuters are dependent on travelling by bicycle, thus they cycle regardless of the temperature level. The model results show that temperature is normally distributed for walking and bicycle. The results show that individuals are more likely to bicycle and walk with increasing temperature, but the significant standard deviation suggests that some walkers and cyclists do not mind lower temperatures. The results indicate that individuals are less likely to travel by public transport with increasing temperature. For car users temperature change would not appear to be very important factors, thus it is not included in the model estimates.

Trip purpose is also a good indicator of personal preferences. The business category is used as a reference variable. There is a tendency to travel by bicycle when travelling to work, however the results are not statistical significant. The results show that individuals are less likely to use car to work and in work trips combination with other trip purposes. The results show that individuals are less likely to cycle, drive a car or use public transport in leisure trip. Also, individuals are less likely to use a bicycle when shopping. When travellers are escorting someone, they are more likely to drive a car.

Parkin et al. (2008), Pucher and Buehler (2006), Zahran et al. (2008) and Guo et al. (2007) conclude that residential densities have a large influence on mode choice. These studies conclude that higher densities lead to a higher share of bicycling. The model results show that urban characteristics also affect mode choice. In central Copenhagen individuals are more likely to choose sustainable transport modes, being the estimate positive for cycling and public transport. The coefficient variables for car driver and car passenger are negative and likely reflect the difficulty of accessing and finding parking in the city centre. The coefficient variable for the minimum level of car parking at the destination has a positive relation to driving a car.

The coefficient variable describing the number of transfer in public transport has negative sign. This indicates that the higher the numbers of changes individuals have to take, the less individuals are willing to travel by public transport.

One reason why commuters choose to cycle is because it is relatively low-cost (Bergström and Magnussen, 2003). The cost of other transport modes is also important when choosing a type of mode (Noland and Kunreuther, 1995; Rietveld and Daniel, 2004; Rodríguez and Joo, 2004; Pucher and Buehler, 2006). The coefficient variable for travel cost is problematic. The results are consistently negative; however the variable is not statistically significant.

5. DISCUSSION AND CONCLUSIONS

This paper analyzed the mode choice behaviour in trips shorter than 22 km, in the Greater Copenhagen Area, on the basis of data from the Danish National Travel Survey. The survey is being conducted by DTU Transport on behalf of the Ministry of Transport and other governmental departments. The sample for model estimation included 7,966 individuals and 11,072 trip chains.

Route choice models and simulation methods were used to calculate the alternatives attributes within the choice set of each traveller. Five alternatives were considered, i.e. car driver, car passenger, public transport, walk and bicycle. The level of service variables for car and public transport were calculated through assignment procedures available for each period of the day in which the trip was conducted. The travel attributes for walk and bicycle were calculated with a shortest path simulation method. A mixed logit model was estimated. The results help identifying important factors that affect the mode choice; e.g. the effect of level of service variables, individual characteristics of the travellers, purpose of the trips, environmental conditions, etc.

Firstly, the paper shows that travel time is important for cyclists, as other transport modes. The coefficients for the travel time variables are consistently negative and significant, for all transport modes except for public transport. Thus, travellers aim to minimize the travel time for all transport modes. While the in vehicle time for public transport is not significant, the waiting- and access/egress time for public transport mode are. This could indicate the travellers are more sensitive to the waiting time and the connection time then the in vehicle time. The results also show that travellers prefer not to transfer between public transports modes. Walk- and bicycle travel times are log-normally distributed, and significant standard deviation indicates that individuals have heterogeneous preference for travel time of non-motorized modes, and more homogeneous preference for travel time of motorized modes.

Secondly, certain attributes of the personal characteristics are related to the mode choice. The study concludes that even though males cycle more than females, it is not significant. The study also shows that men are more likely to drive a car than women, while women were more likely to be car passengers.

The results illustrate that income has no significant effect on bicycle share in mode choice. However, the variable for car driver and public transport is significant. The results indicate that the higher the individual's income is, the more individuals are willing to travel as car drivers and the less willing to travel by public transport. Although income has no significant effect on bicycle share, main occupation has, as well as on other transport modes. This could indicate that the level of income has some effect on bicycle shares.

The study shows that mode choice behaviour was also strongly linked to household characteristics. Bicycle ownership has positive influence on bicycle share, and the higher the number of cars in a household is, the more likely individuals are to drive a car. This could indicate that there is a negative effect on share of bicycles as a mode if there is a car in the household and that having fewer cars could increase cycling frequency. The study concludes that individuals with children were more likely to be a car driver, when compared to other transport modes.

Finally, the study shows that attributes describing the trip characteristics are also related to the mode choice. Hilliness is normally distributed for bikers and the presence of slopes has in average a significant negative impact on cycling. The results show also that individuals are in average more likely to bicycle and walk with increasing temperature and that individuals are less likely to travel by public transport with increasing temperature. The study concludes that individuals are less likely to use car to work and in work trips combination with other trip purposes. However, they are more likely to drive a car when escorting. Individuals are less likely to cycle, drive a car or use public transport in leisure trips. Also, individuals are less likely to use a bicycle when shopping. In central Copenhagen individuals are more likely to choose sustainable transport modes and the minimum level of car parking at the destination is positively related to drive a car.

This study helps uncovering factors that are able to make cycling more attractive, for example improving accessibility, enhancing infrastructures, addressing specific population groups for specific trip purposes. As the objective is the promotion of bicycle use with emphasis on everyday cycling, modelling the choice of transport modes in short trips allows understanding which policies might be effective in influencing the choice of sustainable transport modes in order to reduce car traffic.

The model presented in this paper is a work in progress. The model suggests that further heterogeneity investigation, possibly with a latent class approach, might uncover whether different population groups exhibit different preference structures. Also, estimates are not statistically significant for travel cost, and this suggests that further investigation in the cost calculation is needed. Last, scenario simulations would allow further evaluation of the effects of possible policy instruments intending to convert short car trips to cycling or walking.

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