CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of Economic Studies

Bachelor Thesis

2020 **Michaela Preclíková**

CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of Economic Studies

Michaela Preclíková

Factors influencing the transport mode decision - case of the Czech Republic

Bachelor thesis

Prague 2020

Author: Michaela Preclíková
Supervisor: Mgr. Milan Ščasný, Ph.D.

Academic Year: 2019/2020

Bibliographic note

PRECLÍKOVÁ, Michaela. *Factors influencing the transport mode decision – case of the Czech Republic*. 42 p. Bachelor thesis. Charles University, Faculty of Social Sciences, Institute of Economic Studies. Supervisor Mgr. Milan Ščasný, Ph.D.

Abstract

The thesis describes shares of use of transport modes to reach different activities and analyses influence of socio-demographic variables on a choice of transport mode for commuting to work in the Czech Republic. Data from the INHERIT survey are used for the analysis. Factors which influence the transport mode decision were identified using the multinomial logit model. Results show that men, people with higher income and households with at least one child are significantly more likely to commute to work by car than women, people who earn less money and households without children. Living in large cities decreases the likelihood of using car for work trips and increases likelihood of travelling by public transport.

Abstrakt

Tato práce popisuje používání dopravních prostředků k dosažení různých destinací a analyzuje vliv socio-demografických proměnných na volbu způsobu dopravy pro dojíždění do práce v České republice. Pro analýzu jsou použita data z dotazníku INHERIT. Faktory, které ovlivňují rozhodnutí o dopravním prostředku, byly určeny s pomocí multinomiálního logistického modelu. Zjišťujeme, že muži, lidé s většími příjmy a domácnosti s alespoň jedním dítětem mají signifikantně větší pravděpodobnost dojíždět do práce autem než ženy, lidé, kteří vydělávají méně peněz a domácnosti bez dětí. Život ve velkých městech snižuje pravděpodobnost jezdit autem do práce a zvyšuje pravděpodobnost používat hromadnou dopravu.

Keywords

transport modes, socio-demographic variables, commuting to work, multinomial logit model, Czech Republic

Klíčová slova

způsoby dopravy, socio-demografické proměnné, dojíždění do práce, multinomiální logitový model, Česká republika

Range of thesis: 75 140

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague, May 6, 2020

Michaela Preclíková

Acknowledgments

I would like to express my gratitude to my supervisor Mgr. Milan Ščasný, Ph.D. for his continuous patience, enthusiasm and helpful critique and suggestions and for his willingness to answer all my questions and help me, especially while working with the data and modelling. I would also like to thank JUDr. et Mgr. Vojtěch Máca, Ph.D for his valuable comments and suggestions which helped me to improve my thesis. The support by the H2020-MSCA-RISE project GEMCLIME-2020, GA no. 681228 is very appreciated.

Institute of Economic Studies
Bachelor thesis proposal

Author's name and surname: Michaela Preclíková

E-mail: michaela.preclikova@centrum.cz

Phone: +420 608 227 697

Supervisor's name: Mgr. Milan Ščasný PhD.

Supervisor's email: milan.scasny@czp.cuni.cz

Notes: Please enter the information from the proposal to the Student Information System (SIS) and submit the proposal signed by yourself and by the supervisor to the Academic Director ("garant") of the undergraduate program.

Proposed Topic:

Factors influencing the transport mode decision – case of the Czech Republic

Preliminary scope of work:

Research question and motivation

People use transportation daily and there are many factors that have an impact on modal choice. My bachelor thesis aims at modal choice for commuting during working days and plans to answer the following questions: (i) which transport mode is chosen by people more frequently; (ii) how frequency of using different transport modes differ during usual day; and (iii) which household segments are more likely to use particular transport mode, focusing on socio-demographic characteristics (income, education, age, gender), housing and structural variables (a place of living, car ownership, etc.), and attitudinal variables (environmental concern, attitudes, norms). The outcome of my thesis should provide an answer to how each transport mode is used for daily commuting by various groups in the Czech Republic.

My intention is to answer the following questions: Do high-income people use their car since they can afford to own a car or just simply because the rich are strongly in favour of car use? How frequently is the public transport used across different age groups? Which transport mode is most often used by more frequent and less frequent commuters? Most of these questions have been already answered in various contexts and in many countries, see a comprehensive review by Meixell and Norbis (2008), Bury et al. (2017), ...
The car usage seems to prevail across all income levels (Taylor, 2009). According to a study conducted in Ontario and Quebec (Mercado, 2012) women tend to drive less to work compared to men and people with lower education travel to work by car less often than the high-educated ones.

Contribution

Despite the literature on modal choice and effect of various determinants on modal choice is huge, research on this subject in the Czech Republic is very limited, covering very narrow topics such as car ownership (Ščasný and Urban, 2011), fuel use in a car (Ščasný, 2012), or preferences for alternative-fueled vehicles (Scasny et al., 2018). A study by Braun Kohlova (2012) is one of a few studies conducted in the Czech Republic that aimed primarily at modal choice in cities.

Therefore, I would like to contribute to the research aiming specifically at frequency use of various transport modes in the Czech Republic. Most of the previous papers find a mutual consensus on the fact that car is the most used mean of transport. In my research I intend to analyse usage of various transport modes by carless population and households that own a passenger car and whether decision of automobile population differs for those who use (or intend to buy) a used car compared to those who use (or intend to buy) a new car.

This work will explain which groups of people decide for various transport modes. The results can be then very useful while promoting policies connected with transportation. Moreover, we will identify

groups of population which should be targeted when trying to change people's behaviour regarding the decisions about means of transport.

Methodology

The data used in this thesis were collected within the SUPREM survey (and will be provided by the supervisor). The survey was carried out in 2017 in the Czech Republic within that almost 3000 people were interviewed (sampled from general population, with a plan to buy a new car, and with a plan to buy a used car). Although, this survey collected primarily data about electric vehicles and car purchase decisions, it also gather data on frequency of use different transportation modes.

Frequency of use eight different modes (walking, driving, bus, tram, metro, rail, bicycle, motorbike) during a typical day will be analysed. The frequency is measured in a continuous scale from one to ten, including no use and usage larger than ten. At first, I will analyse which segments of population never used a particular mode (freq=0), estimating a univariate logit (=1 if frequency is not zero). Since decisions on various modes may be correlated, I will also use an appropriate model that allow to model the binary choice simultaneously (multivariate logit). Depending on the data, I will analyse the frequency estimating OLS or using a model that is suitable for the count data (like Poisson, negative binomial). In the literature review I will also pay my attention for the selectivity, i.e. treatment of not choosing particular mode when frequency of use is modelled.

Outline

Abstract

1. Introduction:
   - motivation
   - contribution
2. Literature review:
   - modelling modal choice behaviour
   - frequency of use different modes
   - determinants affecting usage of urban transportation modes
3. Methodology and data
   - econometric model to analyse a binary decision and frequency of use
   - data description

Results:

- binary choice (not using particular mode)
- analysing the frequency of use
- interpretation of the results
- comparison with existing literature

Conclusion

List of academic literature:

Bibliography

BUEHLER, Ralph. Determinants of transport mode choice: a comparison of Germany and the USA. *Journal of transport geography*, 2011, 19.4: 644-657.

CLARK, Ben; CHATTERJEE, Kiron; MELIA, Steve. Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice*, 2016, 89: 89-105.

HEINEN, Eva; CHATTERJEE, Kiron. The same mode again? An exploration of mode choice variability in Great Britain using the National Travel Survey. *Transportation Research Part A: Policy and Practice*, 2015, 78: 266-282.

KOHLOVÁ, Markéta Braun. *Cesty městem: o racionalitě každodenního cestování*. Sociologické nakladatelství (SLON), 2012.

MEIXELL, Mary J.; NORBIS, Mario. A review of the transportation mode choice and carrier selection literature. *The International Journal of Logistics Management*, 2008, 19.2: 183-211.

MERCADO, Ruben G., et al. Explaining transport mode use of low-income persons for journey to work in urban areas: a case study of Ontario and Quebec. Transportmetrica, 2012, 8.3: 157-179

PULIKANTI, Shashank; HABIB, Khandker Nurul. Investigating the Choice Making Behaviour of Transport Users: The Role of Psychology and Choice Contexts in Commuting Mode Choice Process. 2016

ŠČASNÝ, Milan, Zvěřinová, Iva, Rajchlová, Zuzana, Kyselá, Eva. Elektromobil: nejdříve do vesmíru, do Česka až po slevě. IDEA 16/2018 (prosinec 2018). Národohospodářský ústav Akademie věd ČR, v.v.i., Praha, ISBN: 978-80-7344-479-2.

ŠČASNÝ, Milan. Passenger Road Transport During Transition and Post-transition Period: Residential Fuel Consumption and Fuel Taxation in the Czech Republic. In: *Cars and Carbon*. Springer, Dordrecht, 2012. p. 221-246.

ŠČASNÝ, Milan.; URBAN, Jan. Passenger car ownership in the Czech Republic. In: Loster, T., Pavelka, T. International Days of Statistics and Economics. International Conference on International Days of Statistics and Economics. SEP 22-23, 2011, Prague, Czech Republic. 978-80-86175-77-5. pp. 555-70.

TAYLOR, Jean, et al. The travel choices and needs of low income households: The role of the car. The National Centre for Social Research, 2009

Table of Contents

Introduction

Recently, one of the most important aspects why we need to change or regulate travel behaviour are the climate problems (Steg, 2003; Transport Research and Innovation Portal, 2013). Despite large uncertainty in today's and primarily in future's world, International Transport Forum presents a publication called ITF Transport Outlook (2019) which tries to predict possible schemes in transportation sector until 2050. Based on its rather optimistic predictions, the emissions from passenger transport are expected to shrink by 19% by 2050 as a result of already existing policies aiming on urban transport[1], yet ITF argues that it is necessary to manage transportation policies in a sustainable way to achieve climate targets, because the number of CO_2 emissions from transportation is a substantial problem and will remain a problem also in the future.

A vast majority of studies and researches concludes that car is the most used transportation mode for passenger transport (*e.g.* Clark, Melia, & Chatterjee, 2016; Jensen, 1999; Steg, 2003; Taylor, *et al.*, 2009). Moreover, the number of cars and the car use itself is increasing which causes not only environmental, but also economic and social problems (Beirão & Cabral, 2007; Steg 2003). These results are also supported by ITF (2019) which predicts that the demand for passenger mobility will continue to grow rapidly[2], mainly because of overall population growth and because of increasing demand for mobility. It also states that car will stay the most dominant transport mode worldwide. Nevertheless, we might experience a shift from car use to public transport or shared mobility in cities.

The transportation system is a very complex one with many approaches how to solve transportation issues. However, the main targets of transportation policies are reducing the number of CO_2 emissions, decreasing the usage of cars and at the same time increasing the use of public transport and shared mobility (Ahern, *et al*., 2013; Anable, 2005). Now we know which targets we want to reach but the problem is the way how we can reach them. In order to propose specific transport policies, relevant data about passenger mobility need to be collected and policymakers need to be informed about people's needs and demands. Furthermore, understanding their behavioural and travel patterns, decision-

[1] Even though the number should shrink in passenger mobility, the CO2 emissions from non-passenger and international transport will probably increase by 60%.

[2] From 44 trillion to 122 trillion passenger-kilometres.

making process, attitudes and norms is of great importance in determining the appropriate policies (Ahern, *et al*., 2013; Pulikanti & Habib, 2016; Steg, 2003).

Majority of publications concerning transportation aims at either explaining travel patterns with the use of socio-demographic variables (*e.g.* gender, age, education, etc.) or the studies focus on people's behaviour, opinions and decision-making process. There exist many studies analysing the effect of various determinants on use of transport modes in different countries. However, research regarding this topic in the Czech Republic is very poor. There are studies covering topics such as car ownership (Ščasný & Urban, 2011), fuel use in a car (Ščasný, 2012), public transport efficiency (Fitzová, Matulová & Tomeš, 2018) or transport accessibility (Horák, Šeděnková & Ivan, 2008). Studies analysing the topic of use of different transport modes in the Czech Republic use only descriptive statistics (Pucher, 1999; Ivan & Horák, 2015). Except the publication by Bran Kohlová (2012) and recent survey called Česko v pohybu (2020), there are, to my best knowledge, no studies describing how the decision regarding transport mode is influenced by the individual's characteristics or another factors, like availability of transport infrastructure, quality and price of particular mode.

The objective of my thesis is to firstly, inform about share of use of transport modes in different countries and compare these statistics to the situation in the Czech Republic. Secondly, I will analyse which groups of people are using particular modes for commuting to work based mainly on socio-demographic variables. The effect of these determinants will be analysed using a multinomial logit model.

Data from the INHERIT survey are used for the analysis. The majority of results confirms previous studies. There are groups of people who are more likely to commute to work by car such as men, elderly, married or people with children. On the other hand, people from large cities are more likely to use public transport when commuting to work. Unfortunately, not all of the effects were found out to be significant.

The thesis is structured as follows. Section 1 focuses on reviewing literature regarding shares of use of transport modes, determinants which affect transport mode decision and methods used for modelling modal choice. Section 2 describes data and variables used for the analysis and in Section 3 methodology is presented. Results are interpreted and discussed in Section 4. The last chapter concludes and gives ideas for further research.

1 Literature review

This chapter reviews important and interesting literature about the use of different transport modes. First section provides information about shares of these modes in various countries for a better insight into the problematics. The second section shows an overview of specific determinants affecting the transport mode decision. The last part discusses the most frequent methods used for modelling modal choice.

1.1 Share of use of different transport modes

The share of use of transport modes varies across publications due to differences in research methods or differences in collected data. Some researchers use household surveys asking for example about main transport mode, mode used for commuting, modes used in a normal week, etc. On the other hand, others use variables such as passenger-kilometres[3] or the development of new purchased cars. Therefore, the interpretation and comparison of results has to be careful. Despite all dissimilarities, overwhelming majority of papers agree on car being the most used transportation mode (Clark, Melia, & Chatterjee, 2016; Jensen, 1999; Steg, 2003; Taylor, *et al.*, 2009). In the next sections, I compare studies from all over the world and then I focus only on the European countries.

1.1.1 Worldwide

Based on the data collected in the US, 86% of workers commuted by car in 2017 from which a majority was driving alone and only 9% were car-poolers (Davis & Boundy, 2020). 5% of commuters chose public transport and 2.7% walked. Bhat (1997) also analyses transport mode for journey to work in Boston. 77% of the respondents chose solo-auto (one traveller in the car), 11% of them were shared ridders and almost the same share uses public transport. These two studies report very similar results for drivers and car-poolers: over 85% of the respondents commute to work by car (either as a driver or car-pooler). Other study presented by Bassett *et al.* (2008) shows that using modes such

[3] A **passenger-kilometre**, abbreviated as **pkm**, is the unit of measurement representing the transport of one passenger by a defined mode of transport (road, rail, air, sea, inland waterways etc.) over one kilometre. (Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Passenger-kilometre)

as public transport, walking and cycling is much more common in Europe than in the US, Canada or Australia.

1.1.2 Europe

The following part presents different researches about the distribution of transport modes in European countries. They confirm the previous statement that active modes and public transport are more common in Europe. Apart from that, lower share of car usage and higher share of public transport usage is observed compared to the US.

A lot of European countries regularly collect national travel surveys in order to determine and understand travel patterns which help with promoting efficient transport policies (Ahern, et al., 2013). The surveys indicate that car is the dominant transport mode for all countries. Walking and cycling usually account together for approximately 25% and public transport accounts for 10%. However, these shares differ from country to country and the results are also influenced by differences in survey methods.

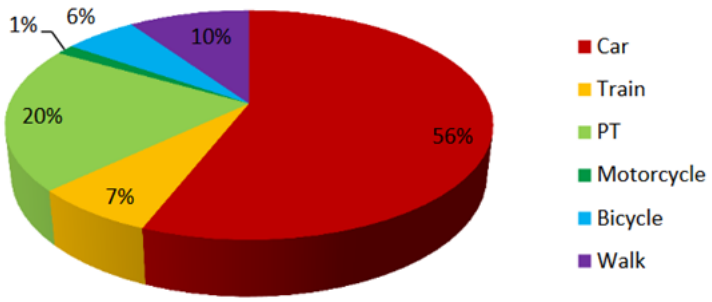
Survey conducted in the UK by Clark, Chatterjee & Melia (2016) shows that car is the dominant transport mode (64% of respondents) used for commuting to work. Both drivers and car poolers are considered in this group. Walking accounts for a 10% share, bus/coach for 5.4%, train 4.5% and bike uses 3.6% of respondents. Johansson, Heldt & Johansson (2006) conducted a survey in Sweden asking about transport mode used for commuting between Stockholm and Uppsala. As expected, car use prevails over other travel modes (54% of respondents) followed by train (31%) and bus (9%). Compared to the previous survey, there is a large increase in the share of use of train. The reason is that the distance between Stockholm and Uppsala is approximately 70 km. Therefore, it is very comfortable for people to commute by train. Other study, by De Palma & Rochat (2000), shows that 75% of respondents in Geneva use car to journey to work while the rest uses public transport.

Based on these studies, car is undoubtedly the most preferred transport mode while the share of other modes differs. Therefore, I also present summary results for the whole EU.

Fiorello *et al.* (2015) conducted a survey in the EU asking people about their preference for their main transport mode regarding the most frequent trip (work, school, etc.). The results are presented in Figure 1. Based on the answers, car is being the most common mode for the majority of people (56%), followed by 20% of respondents using the public

transport (bus, coach, tram, metro). Train is used only by 7% of respondents. Walking records a surprising success – 10% of respondents considers walking being their main transport mode.

Figure 1: Main transport mode used for the most frequent trip in the EU

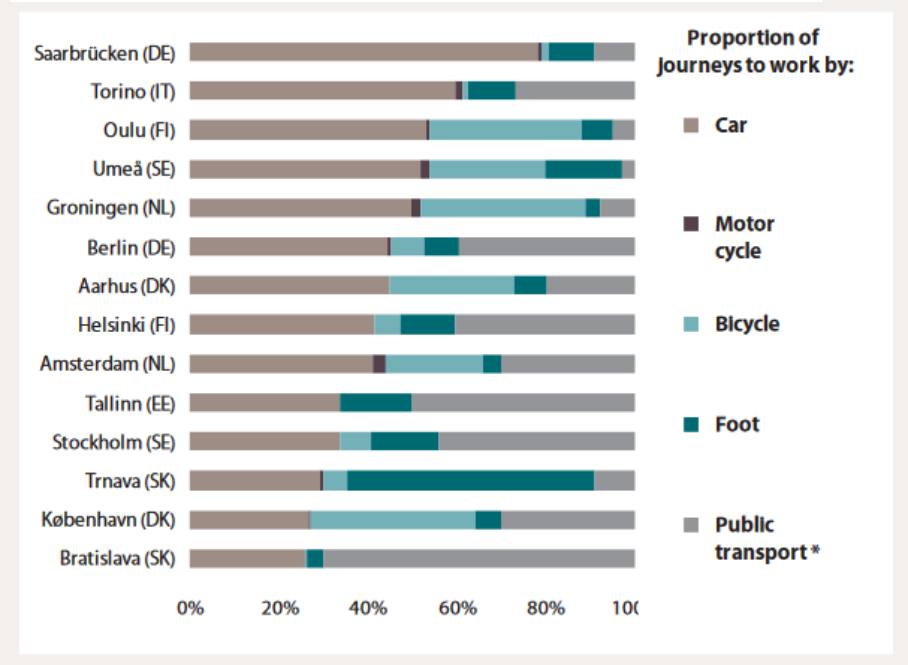


Source: Fiorello *et al.* (2015)

Eurostat (2019) provides statistics about modal split in the EU countries for year 2016. The data are measured by the number of passenger-kilometres made by each mode. Car is obviously the most dominant with the share of 83%, buses/coaches and trains accounts for 9% and 8%, respectively.

European Commission (2009) shows passenger transport by mode based on passenger-kilometres performed in the EU. In 2006, passenger car accounted for 74% of the modal share, followed by plane (10%), bus/coach (8%), railway (6%) and tram and metro (1%). European Commission also presents distribution by modes used for journey to work in selected cities, shown in Figure 2. Public transport includes rail, metro, bus and train. The share of modes differs not only across countries, but also across cities, which is also confirmed by this figure. For that reason, policymakers really need to understand what's behind these statistics before they implement transport policy.

Figure 2: Distribution of journeys to work, selected EU cities



Source: European Commission (2009)

I noticed that there are quite remarkable differences in results between studies using data from household surveys or interviews and studies measuring the number of passenger-kilometres. The reason is that household surveys usually ask about the main transport mode or about mode used for commuting to work. Thus, we do not know which modes they use for other purposes. Therefore, studies based on household surveys usually report lower share of car use and higher share of other modes. On the other hand, studies based on a passenger-kilometres measure mostly shows a higher percentage of car use, because people usually travel further by car than for example by metro or tram. Generally, I conclude that the majority of people in the EU uses car as the dominant transport mode, followed by bus/coach and railway.

1.1.3 The Czech Republic

Last part of the overview describes results for the Czech Republic. Fiorello *et al.* (2015) also provide information about share of transport modes for the Czech Republic. The share of car use is below 40% (average use of car in the EU is 56%), train uses nearly 10% and walking chooses less than 10% of respondents. Surprisingly, public transport is used by approximately 35% of respondents which is high share compared to EU average being 20%.

Directorate-General for Mobility and Transport (2019) provides report a in which main transport issues and transport situation for each country are described. Results for the Czech Republic about transport mode show that 67% of trips in 2016 were made by car (the EU average was 81%). Buses and coaches accounted for 15% (the EU average 9%), trains for 8% (the EU average is almost the same) and metro and tram for 10% (the EU average 2%). The results differ from those by Fiorello *et al.* (2015) because this study calculated modal splits based on passenger-kilometres and Fiorello *et al.* (2015) use survey about the most frequent trip.

Česko v pohybu (2020) is the most recent and unique survey analysing travel behaviour in the Czech Republic. Respondents were asked to fill a one-day travel diary and report all journeys made during that day. The most frequent mode is walking with share over 35%, followed by driving a car which accounts for almost 30%. Public transport, including also bus and train, accounts for 20.2% of all journeys, travelling by car as a passenger for 10% and cycling accounts for 4.5%. Surprisingly high share of walking can be caused by including very young respondents (6 years and older) who cannot use other modes.

To summarize, Czech citizens use public transport very often which could be effect of the public transport service and its quality, frequency and very high density of rail network (even the highest in the world). Apart from that, car is the most dominant transport mode, but the share of car usage is lower in the Czech Republic in comparison to other countries.

1.2 Determinants affecting the use of transport modes

As national authorities try to introduce some transport policies, there are factors which need to be considered since they have an impact on the transport mode people choose. It is of a great importance to determine and understand these factors in order to influence or change people's behaviour and their decision-making process.

These determinants can be divided into 3 groups. First category contains background information about the respondent (age, income, education, etc.). This category, usually referred to as "socio-demographic variables", shows us basic information, so that we can create a general picture and divide people into corresponding groups for a better overview.

Second category includes information about housing, transport infrastructure and mode characteristics and everything which relates to it. Here we can find questions about

housing structure, transport attributes, car ownership, public transport availability or trip information such as trip duration, trip length or trip purpose (Ahern, *et al*., 2013)

Last category informs about respondent's subjective factors which are linked to the behaviour, norms and attitudes. These can include questions about habit formation, behaviour (Johansson, Heldt & Johansson, 2006) or past behaviour, perception of transport modes (Jensen, 1999), importance and attractiveness of transport (Steg, 2003) as well as non-transport opinions.

The following sections take a closer look into each of these groups.

1.2.1 Socio-demographic variables

Socio-demographic variables have a great impact on people's decision-making process about transport modes (Clark, Chatterjee & Melia, 2016; Pulikanti & Habib, 2016), therefore, it is crucial to have a lot of information about people's background.

There are some studies which focus on differences in the use of transport modes between **men and women**. Buehler (2011) finds out that men perform trips more often than women. Mensah (1995) carried out a research about low-income people with the result that women with low income are much more dependent on public transport than low income men. Again, focusing only on low-income people commuting to work, women use private car transport less than men and at the same time women are more likely to commute by public transport than men (Mercado *et al*., 2012). Johansson, Heldt & Johansson (2006) confirm previous results stating that women, as opposed to men, travel by car less than by bus or train. On the contrary, Clark, Chatterjee & Melia (2016) discover a greater likelihood of commuting by car for women than men since women face "caring and housing responsibilities" more often.

Other important factor is **age**. Working-age population and the elderly seem to be strongly dependent on private car use (Mercado & Paez, 2009; Newbold *et al*., 2005; Paez *et al*., 2007; Pucher & Renne, 2005). Mercado *et al.* (2012) conclude that the age is "positively linked to the likelihood of driving a car to work". However, this study focuses only on low-income population, therefore the effect of age should not be generalized. Compared to older age groups, young people travel by car less (Steg, 2003). Rouwendal & Rietveld (1994) found out that commuting time decreases with higher age because older employees may not be willing to commute for longer time anymore.

Next determinant which drives people motivation about the transport mode is **income**. People with higher income tend to travel by car more often than lower income groups (Johansson, Heldt & Johansson, 2006; Steg 2003). However, Clark, Chatterjee & Melia (2016) find out quite surprising facts. According to them, there is a link between having higher income and reduced likelihood of using a car. They conclude that one reason can be that "higher status jobs" are located in in metropolitan and large urban areas which are difficult to be accessed by car. McQuaid & Chen (2012) find out that low income people living in the UK (mainly in large cities) commute longer since they can't afford to live in the city centre.

The effect of **education** seems to differ across studies. Some of them show that higher educated people are more likely to commute by car and people with lower education use train more in comparison to the higher educated ones (De Witte *et al*., 2008; Mercado *et al*., 2012). On the contrary, Schwanen, Dieleman, & Dijst (2001) show that more educated people are more likely to use public transport than less educated people and Clark, Chatterjee & Melia (2016) conclude that having higher education decreases the likelihood of commuting to work by car.

Marital status also affects a decision about transport mode. Mercado *et al.* (2012) and Steg (2003) find out that being single decreases the likelihood of car commuting to work compared to married people.

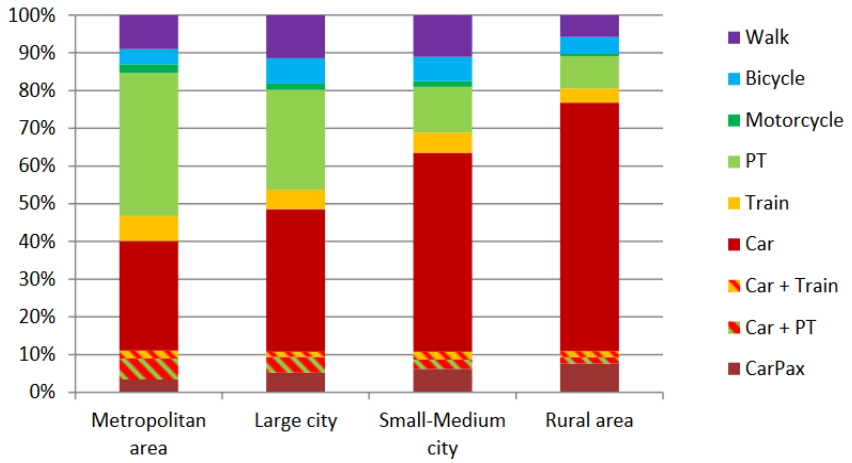
Employed people travel by car more frequently compared to unemployed ones. Moreover, employed adults in a household with children are more likely to drive (Buehler, 2011). People with higher employment status such as managers have lower likelihood of walking, cycling or travelling by public transport for work trips (Commins & Nolan, 2011).

Family background and number of children play a crucial role while deciding about transport mode. Commuting to work by car is more likely when people have children (Clark, Chatterjee & Melia, 2016; Steg, 2003). Mothers commute the least as opposed to fathers who commute the furthest, because after the birth of children, the transport mode use and its frequency usually start to differ between men and women which is caused by women usually taking care of children and household responsibilities (Lanzendorf, 2003; McQuaid & Chen, 2012).

1.2.2 Housing, transport infrastructure and mode characteristics

The use of transport modes differs according to a **size of a city** people live in. The results from Fiorello *et al.* (2015), shown in Figure 3, indicate that car use in the EU is much lower in large cities compared to rural areas due to well serving public transport. Accordingly, the use of public transport in metropolitan areas is much higher in comparison to rural locations. People living in rural or metropolitan areas use active transport modes (cycling and walking) less than people from large or medium cities which is in line with findings of Clark, Chatterjee & Melia (2016) who came to the same conclusion. The distance of public transport from household also affects the decision. Households living closer to public transport are more likely to make trips by public transport and less likely by car (Buehler, 2011). Most of the respondents in the EU (82%) claim that the location they live in is well served or relatively well served by public transport (Fiorello *et al.*, 2015). This statement mainly depends on the fact whether they live in metropolitan or rural area since the public transport is usually better served in larger cities.

Figure 3: Main transport mode used for the most frequent trip by living area in the EU



Source: Fiorello *et al.* (2015)
PT: public transport, CarPax: car-passenger

A **car ownership** is on average 1.4 cars per household with a majority of people having a driving license (Fiorello, *et al.*, 2015). The average number of cars increases in rural areas because of insufficient public transport service. More than 70% of households own a car based on a study from France and the UK (Fol, Dupuy & Coutard, 2007).

When deciding about transport mode, people also take **attributes** of particular mode into account, such as travel time, reliability or comfort. Important factor influencing the modal choice is also cost, which includes fixed capital costs, operational and fuel costs, cost of ticket or subscriptions. Car is preferred over other modes because of safety, flexibility, reliability, comfort and control (Beirão & Cabral, 2007; Taylor, *et al.*, 2009; Steg, 2005). It also saves time and people can use it when they want or need. On the other hand, car is valued negatively because of its high costs, parking problems, stress while driving and health and environmental impact. Positive features of public transport are affordability, easy access, regularity and less pollution. Moreover, public transport helps people to avoid parking problems, stress while driving and congestions. Oppositely, people reported negative attitudes toward public transport because it is often too crowded, dirty, less comfortable and less safe. Other reasons why many people refuse to use public transport are lack of direct connections, long travel time and unreliability (Beirão & Cabral, 2007).

Costs regarding individual modes can be influenced by policy instruments (directly or indirectly) such as imposing a fuel tax, user fee charges or tolls. Policymakers can also improve transport infrastructure and provide new roads, bus lines or bike paths. Apart from that, it is possible to provide subsidies and purchase new technologies or support transport alternatives, such as public transport or car-sharing. All these actions can motivate people and make them switch to other, more sustainable way of travelling.

A **purpose of a trip** also influences the chosen transport mode. There is a list of activities which appear in the travel surveys asking about a purpose of the trip (mainly based on Ahern, *et al.*, 2013): home, commute, work, education, business (work related travel), shopping/groceries, leisure, accompanying other persons, visiting friends or relatives, picking up or driving a third party (escorting), services (bank or medical), culture. Zvěřinová, Ščasný & Máca (2018) present which travel modes are used for travelling to different activities in 5 European countries. The results show that car is the most used mode for shopping trips and commuting from and to work. When it comes to sport and leisure activities, walking is the most dominant mode. Taking public transport is typical for commuting to school or university. Pucher & Renne (2005) and Buehler (2011) also confirm car being the dominant mode for trips to work.

1.2.3 Subjective variables

Even though my work focuses on the influence of socio-demographic variables on a chosen transport mode, people's attitudes, preferences, habits, social factors and behaviour are very important determinants in a decision-making process (Beirão & Cabral, 2007; Clark, Chatterjee & Melia, 2016; Clifton & Handy, 2001; Johansson, Heldt & Johansson, 2006; Pulikanti & Habib, 2016;). Therefore, I find it meaningful to inform about the importance of these variables.

One of the most used theories about decision-making process in transport researches is the **Theory of Planned Behaviour** (Clark, Chatterjee & Melia, 2016; Pulikanti & Habib, 2016; Steg, 2003) which was developed by Ajzen (1991). Theory of Planned Behaviour says that people behave based on the information they have. According to this theory, there are 6 concepts which form people's behaviour: attitudes, behavioural intention, subjective norms, social norms, perceived power and perceived behavioural control.

The decision-making process is also influenced by **habits** and their formation. People create some travel pattern which is repeated after a period of time. For example, because people commute daily to work or to school, they create a habit which is repeated every day. Once people get used to some habitual process, it is difficult for them to break it. This problem arises when policymakers try to influence people to switch from cars to public transport (or active modes) and people are not willing to do it due to the habit (Clark, Chatterjee & Melia, 2016; Pulikanti & Habib, 2016). Introducing a cheaper or somehow interesting offer for habitual commuters convinces some of them switch to another mean of transport (Fujii & Kitamura, 2003).

"**Attitudes** are positive or negative evaluations or beliefs held about something that in turn may affect one's behaviour" (Nairne, 2003). Parkany, Gallagher & Viveiros, (2004) conclude that attitudes are important in travel behaviour and can be sometimes even more significant than socio-demographic variables. Taylor *et al.* (2009) find out that car seems to play a central role in people's lives, because it allows them to access the necessary locations when they want or need. However, in last years, car is not seen just as a mode of transport (Steg, 2005). People drive and own car also because of expressing themselves, their social position, emotions and needs (Steg, 2003).

1.3 Modelling modal choice

Modelling modal choice varies across researches because of differences in research questions and especially because of differences in used data. I present which models are used based on the type of the dependent variable.

The family of discrete choice models occur most frequently in publications dealing with transport mode. **Discrete choice models** are usually used for modelling consumer choice behaviour, so this method is also typical for modelling modal choice (Chen, 2017; Koppelman & Pas, 1980). The reason is that researchers are usually not interested in calculating the quantities of some outcome, but it is examined if some event occurred or not (Greene, 2003).

The **binary choice** is used as dependent variable when the respondent chooses from 2 options. The outcome is either 0 or 1 which explains as "no" and "yes". Binary choice model is used, for example, for answering questions about using public or private transport or about deciding whether to commute by car or not. De Palma & Rochat (2000) examine decisions of either taking car to work or using public transport with the use of binary choice.

If an individual can choose from more than two alternatives, we speak about **multinomial choice** which can be further divided into unordered or ordered choice. Because of the nature of data used later, I will pay attention only to the unordered type. The most used models for multinomial discrete choice are logit-based such as logit, multinomial logit, nested logit, conditional logit, mixed logit, etc.

Multinomial logit model (MNL) is commonly used model if there is a group of mutually exclusive possible choices from which an individual can choose and the data include individual-specific characteristics (Greene, 2003). In other words, this model focuses on explaining the outcome based on the individual's attributes such as gender, income, education, etc. The MNL model is useful for examining the main travel mode, destination choice or which mode people use for commuting to work (Hensher, 1991). For example, Koppelman & Pas (1980) use the MNL model for estimating people's transport choice based on their perception, feelings and preferences. Mitra & Buliung (2015) analyse travel mode choice of children and youth to school in Toronto with the use of the MNL model. Usually both qualitative and quantitative independent variables are combined in

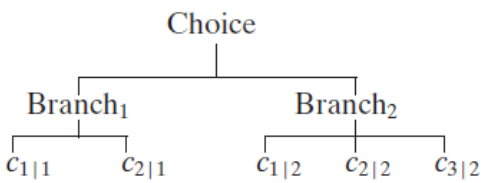
the multinomial logit. The MNL model is favoured for its relatively easy estimation and interpretation.

For estimating a model which focuses on choice-specific attributes, we use **conditional logit model** (McFadden, 1974)**.** This model is appropriate for explaining the individual's decision based on features of each alternative (e.g. cost, comfort, etc.) rather than on the characteristics of the individual. For example, Amoh-Gyimah & Aidoo (2013) analyse the influence of the characteristics of both individual and alternative on the choice of mode for journeys to work in Ghana using the conditional logit model. Study by McFadden (1974) uses conditional logit model to examine shopping transport mode and destination choice.

Nevertheless, a limitation of both conditional logit model and MNL model are the assumption of independent and identically distributed error terms and the assumption of independence from irrelevant alternatives (the IIA explained in more detail in Section 3) which restricts an individual's behaviour (Wooldridge, 2002). It is possible to verify the IIA assumption by performing a Hausman's specification test, but in the case of failing the test, another alternative model needs to be chosen.

Frequently used option which relaxes the IIA assumption is **nested (multinomial) logit model**. This model divides all alternatives into several groups and subgroups. so-called "nests". An example of a choice an individual is facing is shown in Figure 4. The nested logit model manages choice problems when the alternatives in each "nest" are correlated (Koppelman & Wen, 1998). There are numerous researches using nested logit model for studying travel mode choice such as Palma & Rochat (2000) who study travel mode choice for work trips in Geneva using nested logit or Train (1980) and Thobani (1984) who both use the nested logit model for analysing car ownership and mode choice to work.

Figure 4: Structure of choices for nested logit model



Source: Greene (2003)

Mixed multinomial logit model (MMNL) is used when we are interested in studying characteristics of both individual and selected option (Hoffman & Duncan, 1988). The MMNL structure can combine observed as well as unobserved factors which influence the individual's decision. The parameter for each variable is allowed to differentiate across all individuals (Audibert, He & Mathonnat, 2013). McFadden & Train (2000) show application of the MMNL on the demand for alternative vehicles.

Latent class logit model analyses individual behaviour which is dependent on observable characteristics and latent heterogeneity which is allowed to vary with unobservable variables. Data are divided into different classes and each class has their own parameter values. Latent class model is semi-parametric and the assumptions about individual heterogeneity are not needed. This model is usually used for count data, but Greene & Hensher (2002) analyse model with discrete choice. They compare latent class logit and mixed logit models on a survey about preferences for road environments.

Ben-Akiva *et al*. (2002) propose **hybrid choice models** which is an extension of discrete choice models and random utility model. Hybrid choice model is a flexible tool used for analysing complex choice behaviour which is strongly influenced by factors such as attitudes, motivation or latent constructs which all impact a decision-making process.

2 Data description

2.1 INHERIT survey

The data I aim to use are cross-sectional data from INHERIT survey. The dataset is provided by the supervisor who collected this survey with his colleagues.

The INHERIT survey studies "attitudes, preferences and behaviours of inhabitants of five European countries related to consuming, moving and living". The authors' ambition was to find out if various policies can affect people's lifestyles and behaviour to be healthier and more sustainable. This questionnaire survey was carried out in 2018 in the Czech Republic, Latvia, Portugal, Spain and the United Kingdom. Authors excluded incomplete observations and speeders. The survey gathered 10 288 web-based questionnaires from participants whose age was between 18 and 65 years.

The data about transport modes follow binary distribution – 1 if the respondents assigned that they use a particular mode for the particular activity or 0 if they do not use this mode. Respondents could choose from these travel modes and activities:

ACTIVITY	TRANSPORT MODE
	Taxi or other similar service
Work	Own car
Taking child/children to school	Car-pooling
Going to school or university	Walk
Social activities /entertainment	Public transport
Shopping/ Groceries	Bicycle
Sport/ Leisure activities	Bicycle-sharing
	Other/none

In this section, the distribution of travel mode choices to reach typical activities is reported, because it is of a great importance have a general overview of transport mode usage. Results for all 5 countries together are reported together with modal shares only for the Czech Republic, to compare the differences. Just those modes whose share is

meaningful or interesting are presented. Participants could choose from more transport modes because some of them use different modes when travelling to and from the particular activity. Therefore, totals over different modes may exceed 100%. All results are showed in Figure 5 below.

For all countries, 55% of respondents **commute to work** by car, 27% of them walk, the same share uses public transport and almost 8% use bicycle. The results are very similar for the Czech Republic, but Czech respondents use public transport and active modes more. Half of the respondents uses car for commuting to work. Public transport accounts for 34% and walking for 31%. Bike is used by 13% of respondents.

Half of the participants who commute to **school or university** uses public transport. Presumably because it's cheap and younger students usually do not own car yet. The second most used mode is walking. A majority of Czech respondents, who commute to school or university, uses public transport (78%), over 40% walks and only 21% uses car.

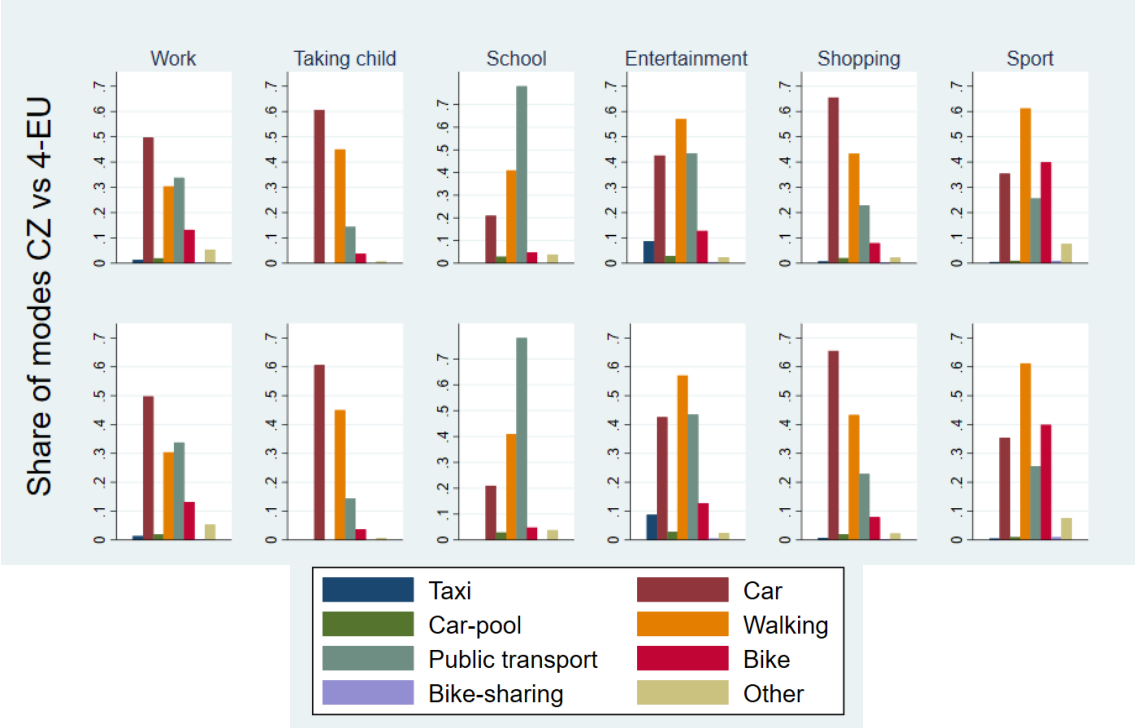
Speaking about **social activities or entertainment** such as going to cinema, restaurant or a pub, over a half of the participants uses car. However, the shares of individual modes are higher than for other activities, because category "entertainment" covers a variety of activities and people choose different modes whether they go to cinema, or a pub. Car accounts for 53%, walking accounts for 51%, public transport for 33%, bike for 9%, taxi for 8% and car-pooling for 7%. Walking to reach social activities or entertainment is also very common in the Czech Republic. 57% of the respondents reported that they walk, 44% travel by public transport, 43% by car and 13% use bike.

Car is the dominant mode for **shopping/groceries** with 64%, followed by walking (42%). Public transport accounts for 16%. I believe the reason for high share of using a car is due its convenience for grocery shopping than for example public transport. It is very likely that walking experienced high share because supermarkets are usually placed close to people's residences. The two most dominant modes for shopping in the Czech Republic are also car (66%) and walking (43%).

To reach **sport or leisure activities**, almost 60% of the participants choose walking, 41% car, 25% bicycle and 18% public transport. I assume that active modes account for high share, because these modes are in this case also part of the sport activity and not only a mean of transport. Active modes are dominant for sport and leisure activities also for Czech inhabitants. Waking accounts for 61% and bike for 40%.

Generally said, the results and often also particular shares are very similar. However, Czech respondents usually recorded higher share of public transport and active modes (walking, cycling) compared to other countries. A significant difference can be observed in commuting to school/university and social activities.

Figure 5: Distribution of modes to reach typical activities



Source: Author's computations based on data from the INHERIT survey
4-EU: Latvia, Portugal, Spain, UK

2.2 Variables and hypotheses

Dependent variables

For modelling the transport mode decision, I have decided to analyse which transport mode is used for commuting to work in the Czech Republic, because *work* is the most frequent performed activity during a typical week. As dependent variable I use data about travel mode choices for a journey to work.

As already stated before, the data about transport modes follow binary distribution – 1 if the respondents assigned that they use a particular mode for a particular activity or 0 if they do not use this mode.

Independent variables

The variables which inform about socio-demographics and housing structure are of my interest and they are shown in Table 1. My purpose is to show how these variables influence the travel mode people use. The base categories for binary and dummy variables are *male*, *small city*, *18-34 years*, *no retired*, *no children*, *primary & lower secondary*, *married* and *full-time*.

Table 1: Description of independent variables

Variable	Description
female	binary variable for gender *0 for male | 1 for female*
hincCZ	household net monthly income (in CZ)
hincmiss	binary variable for number of missings in household net monthly income
town	dummy variable for a size of the town according to a number of citizens *small city (up to 4 999) | medium city (5000 – 99 999) | large city (100 000 – 999 999) | over 1 million*
agecat	dummy variable for age category *18-34 years | 35-49 years | 50-65 years*
adult_HH	number of adults in the household (retired not included)

retired_HH	binary variable for number of retired people in the household *0 for no retired in a household* | *1 for at least one retired*
children_HH	dummy variable for number of children in the household *no children* | *one child* | *more children*
educat	dummy variable for the level of education *primary & lower secondary* | *upper secondary* | *tertiary*
marit	dummy variable for the marital status *married* | *civil partnership* | *separated (but legally still married)* | *divorced* | *widowed* | *single* | *not married couple (but they live together)* | *other*
employ	dummy variable for employment status *full-time* | *part-time* | *self-employed* | *students* | *looking after home* | *maternity or paternity* | *retired* | *unemployed* | *unable to work* | *other*

Hypotheses

Hypothesis 1

The choice of transport mode for commuting to work is related to socio-demographic variables and it confirms studies mentioned in the literature review. Men, older, married and employed people are more likely to commute to work by car while women, younger generation and single people are more likely to use public transport for trips to work. The effect of education is ambiguous.

Hypothesis 2

Household structure influences transport mode decision for journeys to work in a way that having a child or a retired person in a household increases the likelihood of commuting to work by car.

Hypothesis 3

People living in urban areas with high population density are less likely to use car as a mean of transport for work trips.

Hypothesis 4

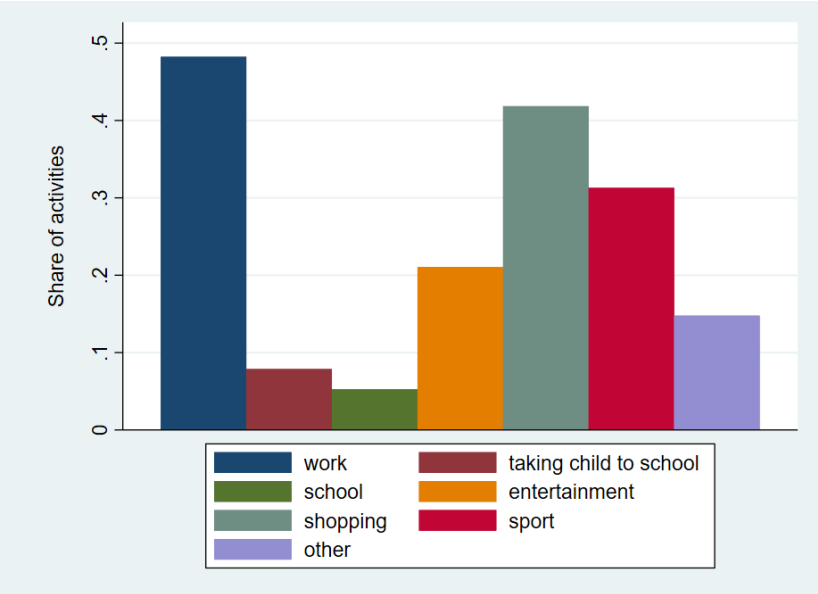
People with higher income are more likely to commute to work by car compared to people who earn less money.

2.3 Excluding observations

Before running the model, some observations were excluded, and I work with truncated sample. Therefore, I expect some bias in the results. In this section, the process of truncating the sample is presented.

Firstly, I excluded observations from non-Czech countries, so the sample contains 2 019 observations. The reason is that my work aims at studying the transport mode decision in the Czech Republic. Then different activities performed during a typical week were analysed. Since the respondents could choose more than one activity, the total exceeds 100%. Work is a typical activity for 48% of respondents, followed by shopping or doing groceries (42%), sport or leisure activities (31%), social activities or entertainment (21%), other activities (15%), taking child or children (8%) and lastly school or university (5%).

Figure 6: Distribution of modes to reach typical activities



Source: Author's computations based on data from the INHERIT survey

Since I am interested in commuting to work, the respondents which do not use commute to work during a typical week are excluded. From 2 019 respondents, 966 of them reported commuting to work during a typical week. There are differences in the distributions for many variables and the new sample cannot be described as a representative sample of the population anymore. Later, it is important to take a special

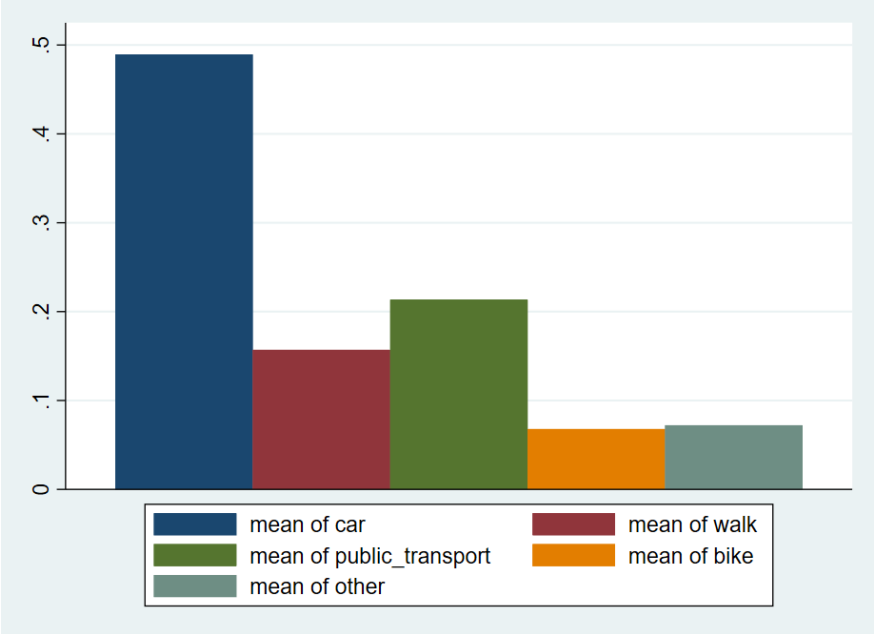
attention while interpreting the results, especially when it comes to variables *educat* and *employ*.

The last adjustment is about the number of transport modes used. Respondents assigned which transport modes they use for commuting to work, but they could choose more than one mode since some of them use different modes for journeys to and from work. I have decided to work just with observations which use only one transport mode, for it is the most frequent choice. From 966 observations (only Czech respondents who use at least one transport mode to work), 73% reported that they use one mode for commuting to work and 27% uses more than one mode. Logit models were also performed for commuters vs non-commuters and for multi-mode vs single mode. The results are in Appendix A.

2.4 Descriptive statistics

Final number of observations is 707. Modes with only few observations (*taxi, car-pooling* and *bicycle sharing*) were grouped together to category *other*. Figure 7 shows the distribution of the dependent variable, i.e. use of different transport modes in the final sample. Almost 49% of the respondents commute to work by car, 21.4 % commute by public transport, 15.7% walk to work, almost 7% use bike and the rest of them commutes differently. Comparing this graph to the survey conducted by Fiorello *et al.* (2015), the frequency of use of individual modes is very similar. Both results show that car is the dominant transport mode followed by public transport and then walking. This graph also confirms findings from surveys and studies mentioned in the literature review. Even though car is the most used transport mode, its share is much lower compared to the European and especially worldwide average. Shares of modes for other countries from the INHERIT survey are showed in Appendix B. Results from Česko v pohybu (2020) indicate that 44% of the respondents commute to work by car, 24% use public transport, 20% walks, 7% uses car as a passenger and 4.5% commutes by bike. These results are almost the same as those which I present.

Figure 7: Distribution of modes for commuting to work



Source: Author's computations based on data from the INHERIT survey

The descriptive statistics for independent variables is specified in Table 2. Men account for 53.6% of the sample and women for 46.4%. Average household net monthly income is almost 30 000 CZK. The majority of respondents lives in small or medium cities – both around 40% of the sample. Youngest age group (18-34 years) represents a share of 25% of the sample, middle age group (35 – 49 years) has the highest share of the sample with 44% and the oldest age group accounts for 31%. Average number of adults in a household is 2 persons and over 60% of the households do not have children. 21% of the households have one child and 16.5% reported having more children. The respondents usually reported living with no retired person in the household (84% of the sample). People with primary and lower secondary education account for 42% of the sample, followed by upper secondary education with a share of 37% and tertiary education with over 20%. When it comes to marital status, almost 45% of respondents reported being married. Another large category is *not married but living together* which accounts for 25%. The third largest group are single people with the share of 15%. Almost 70% of the participants work full-time.

Table 2: Descriptive statistics

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
gender				
male	0.536	0.499	0	1
female	0.464	0.499	0	1
income				
hincCZ	34 544	14 643	0	77500
hincmiss	0.137	0.344	0	1
town				
small city	0.390	0.488	0	1
medium city	0.403	0.491	0	1
large city	0.096	0.295	0	1
over 1 million	0.110	0.314	0	1
agecat				
18-34 years	0.253	0.435	0	1
35-49 years	0.438	0.497	0	1
50-65 years	0.308	0.462	0	1
adult_HH	2.013	0.852	0	5

retired_HH				
no retired	0.844	0.363	0	1
at least one retired	0.156	0.363	0	1
children_HH				
no children	0.622	0.485	0	1
one child	0.212	0.409	0	1
more children	0.165	0.372	0	1
educat				
primary & lower secondary	0.424	0.495	0	1
upper secondary	0.366	0.482	0	1
tertiary	0.209	0.407	0	1
marit				
married	0.451	0.498	0	1
partnership	0.004	0.065	0	1
separated	0.007	0.084	0	1
divorced	0.117	0.322	0	1
widowed	0.013	0.113	0	1
single	0.151	0.359	0	1
not married couple	0.257	0.437	0	1
other	0.006	0.075	0	1
employ				
full-time	0.687	0.464	0	1
part-time	0.045	0.208	0	1
self-employed	0.074	0.261	0	1
student	0.051	0.220	0	1
home	0.008	0.092	0	1
maternity	0.037	0.188	0	1
retired	0.042	0.202	0	1
unemployed	0.008	0.092	0	1
unable to work	0.041	0.198	0	1
other	0.006	0.075	0	1

Source: Author's computations based on data from the INHERIT survey

3 Theoretical concept and methodology

3.1 Random Utility Model

Random utility model is frequently used as a theoretical framework for discrete choice models (Ben-Akiva & Bierlaire, 1999). Since transportation systems are affected by consumer's behaviour and the decisions are based on consumer's preferences, random utility approach is commonly used in travel behavioural studies. The decisions made are influenced by both observable and unobservable characteristics (Greene, 2003). In a random utility model, U_a and U_b stand for an individual's utility of the two options (for example U_a is a utility of commuting by car and U_b is a utility of commuting by public transport). It is assumed that the individual chooses the option with the highest utility.

A linear random utility model is formulated as

$$U_a = \boldsymbol{w'\beta_a} + \boldsymbol{z_a'\gamma_a} + \varepsilon_a \text{ and } U_b = \boldsymbol{w'\beta_b} + \boldsymbol{z_b'\gamma_b} + \varepsilon_b \quad (1)$$

in which **w** denotes the observable characteristics of an individual such as age or education and $\mathbf{z_a}$ and $\mathbf{z_b}$ represent attributes of the options such as price or comfort. ε_a and ε_b represent random components. It is also assumed that an analyst is not able to observe these random components and they are only known by the individual and we need to count with some uncertainty.

3.2 Multinomial logit model

Unordered multinomial response is an extension of binary response, i.e. the response has more than two options. Multinomial logit model shows relationship between the multinomial response and independent variables. I have chosen this model, because it is frequently used for modelling transport mode choice and generally, this model is used when the individual chooses one alternative from more options. Apart from that, this model is favoured for its easy estimation.

The multinomial logit is used for estimating the probability that a respondent *i* decides for an option *j* conditioning on some particular characteristics. In other words, we try to find out what effect have changes in vector x_i on the response probabilities $P(y_i = 1|x_i)$, $j = 0, 1, 2, \dots, J$.

The multinomial logit is defined as

$$P(y_i = j|x_i) = P_{ij} = \frac{\exp(x_i'\beta_j)}{\sum_{j=1}^{J}\exp(x_i'\beta_j)}, \qquad j = 0, \dots, J \tag{2}$$

where y_i stands for a random variable describing the choice made, x_i is a vector indicating characteristics specific to the decision-maker and β_j is a vector of regression coefficients which are specific to the *j*th alternative (Greene, 2003).

The probability P_{ij} needs to satisfy 2 conditions: $0 < P_{ij} < 1$ and $\sum_{j=1}^{J} P_{ij} = 1$.

Thanks to these conditions, we do not have to specify the probability for the *J*th alternative, because it can be derived from the rest of the calculated probabilities. Afterwards, this excluded alternative will be used as a reference situation which will work as a comparison with the observed situation (Aloulou, 2018). Therefore, the multinomial logit model has response probabilities

$$P(y_i = j|x_i) = P_{ij} = \frac{\exp(x_i'\beta_j)}{1+\sum_{j=1}^{J}\exp(x_i'\beta_k)}, \qquad j = 0, \dots, J. \tag{3}$$

It is quite complicated to interpret the results for this model. The partial effects of the characteristics are

$$\frac{\partial P_{ij}}{\partial x_k} = P_{ij}\left[\beta_{jk} - \left(\sum_{k=0}^{J} P_{ik}\beta_{hk}\right)\right], \tag{4}$$

where β_{hk} is the *k*th element of β_h.

It is possible to calculate the ratio between the probabilities of choosing different alternatives. The log-odds ratio can be derived as

$$log\left[\frac{P_{ij}}{P_{ik}}\right] = x_i'(\beta_j - \beta_k) \tag{5}$$

and they are independent of other choices thanks to the independence of disturbances.

For estimating this model, the maximum likelihood estimation (MLE) is used. For each individual, we need to define d_{ij} which equals 1 if the individual *i* chooses an alternative *j* and 0 otherwise. The log-likelihood function then looks like this:

$$\ln L = \sum_{i=1}^{N}\sum_{j=1}^{J} d_{ij} \ln P(y_i = j|w_i). \tag{6}$$

The multinomial logit model is based on an assumption that the odds ratios are independent of the other alternatives. This property, called independence from irrelevant alternatives (IIA), implies that regardless the number of alternatives, the individual will always choose the same option, so the ratio will remain unchanged even if we add or remove some of the alternatives. However, there is a lot of criticism about this assumption. Famous example is Red Bus/Blue Bus example by McFadden (1974). It is supposed a consumer chooses between two options with equal probability (0.5) – car and red bus. Now we add blue bus as a third option. We assume that consumers are indifferent about the colour of the bus. So, they choose between car and bus with the same probability, 0.5, and the probability of each type of bus is 0.25. Nevertheless, the IIA assumption says that the blue bus would take the same share of the probability as car and red bus and the new probabilities are the same for all options (0.33) (Wooldridge, 2002). As already stated in the literature review, some researchers prefer using other models because of this restrictive assumption.

4 Results

This chapter presents results from the data estimation. Based on the reasons already stated in the literature review and methodology, the multinomial logit model was selected. The STATA software was used for the analysis.

For choosing the best fitted model, likelihood-ratio (LR) tests and Wald tests were used for comparing several models with different variables. The LR test uses restricted and unrestricted models and measures the difference in the log-likelihood functions for both models. This is the LR statistic with $\mathcal{L}_{UR}$ being the log-likelihood value for unrestricted model and $\mathcal{L}_R$ being the log-likelihood value for restricted model:

$$LR = 2(\mathcal{L}_{UR} - \mathcal{L}_R).$$

If the log-likelihood decreases significantly after dropping a variable, we know that this variable is significant for the model. The difference between the two models is multiplied by 2, so that the LR has an approximate chi-square distribution under the H_0.

Wald test approximates the LR test, but there is only one estimated model needed for performing the Wald test. This test also shows us if restricting some of the parameters significantly reduce the fit of the model. It is done by setting a set of the parameters simultaneously equal to zero or to some value. If the null hypothesis is not rejected, then excluding the tested variables should not reduce the fit of the model. It is argued that both tests should come to the same conclusion.

For measuring the explanatory power of the variables, pseudo R-squared suggested by McFadden (1974) is commonly used. The pseudo R-squared is computed as $1 - \frac{\mathcal{L}_{UR}}{\mathcal{L}_0}$, where $\mathcal{L}_{UR}$ is the log-likelihood function for the unrestricted model and $\mathcal{L}_0$ is the log-likelihood function of the model with only an intercept.

After running LR and Wald tests, which are presented in Appendix C, many of the variables were found out to be statistically insignificant. Nevertheless, I have decided to keep these variables in the model, because even if their estimates will not be significant, the direction of those parameters can be observed. The IIA assumption is verified by Hausman and also by Small-Hsiao tests (results shown in Apendix C).

The following model is used for estimating effect of different variables on a transport mode choice:

$$P(mode_i = 1|x_i) = \beta_0 + \beta_1 female_i + \beta_2 ln\_hincCZ_i + \beta_3 hincmiss + \beta_4 town_i + \beta_5 agecat_i + \beta_6 adult\_HH_i + \beta_7 children\_HH_i + \beta_8 retired\_HH_i + \beta_9 educat_i + \beta_{10} marit_i + \beta_{11} employ_i$$

Commuting to work by car is set as a base outcome. The estimated coefficients from the multinomial logistic regression are interpreted using two approaches. Firstly, relative risk ratios (RRR) are used to see which groups of people are more likely to commute by each transport mode. The relative risk ratios are derived by exponentiating the estimated coefficients. The estimated parameters are relative to a referent group which is in this case *car*. This type of interpretation is useful for comparing which groups of people are more likely to use one transport mode relative to the other one. If the RRR > 1, the outcome is more likely for the comparison group. If the RRR < 1, the outcome is more likely for the referent group. Secondly, marginal effects are computed to interpret and compare average probabilities of using a particular mode. Results from running the model, for relative risk ratios and for marginal effects are in Appendix D. For all interpretations, I assume that other variables are held constant.

Hypotheses

Hypothesis 1

The choice of transport mode for commuting to work is related to socio-demographic variables and it confirms studies mentioned in the literature review. Men, older, married and employed people are more likely to commute to work by car while women, younger generation and single people are more likely to use public transport for trips to work. The effect of education is ambiguous.

Looking at the estimates for gender, women are more likely to commute by public transport to work than by car relative to men. The relative risk ratio (RRR) is 1.82 and it is significant at the 5% significance level. Marginal effects show that being a woman decreases the average probability of commuting to work by car over 10 percentage points and at the same time being a woman increases the average probability of commuting to work by public transport by 5.5 percentage points.

With increasing age, people are more likely to commute by car compared to the youngest age group. However, the results are not statistically significant. Being in the age group 50-65 years increases the average probability of commuting to work by car by 3.4 percentage points and decreases the probability of using public transport on average by almost 6 percentage points in comparison to the age group 18-34 years. The difference between the youngest and middle age group is very small.

Even though not all estimates for levels of education are statistically significant, the coefficients show interesting tendency. Having primary and lower secondary or tertiary education results in the same average probability for commuting to work by car, around 0.45. However, having higher secondary education increases the average probability of commuting by car to work by 11 percentage points compared to primary and lower secondary education category. Same trend is observed for travelling by public transport, but the differences between categories are smaller.

Being married people increases the likelihood of commuting to work by car compared to being single, but the effect is not statistically significant. The difference in average probabilities between married and single for commuting by car is quite small, but looking at public transport, single people have higher average probability by 5.6 percentage points compared to married.

Speaking about employment status, part-time workers, students and those on maternity exhibit a lower average probability of commuting to work by car than full-time workers or self-employed. Moreover, being self-employed decreases the average probability of using public transport for work trips. Nevertheless, the differences are not statistically significant.

To summarize, women are more likely to travel by public transport and less likely to travel by car compared to men. Older people commute more by car and less by public transport in comparison to younger people. People who have the lowest or the highest education level are less likely to commute by car compared to people with the middle education level, so we cannot directly say that having higher or lower education leads to some result. Single people are more likely to use public transport and less likely to use car than married people. Full-time workers and self-employed commute to work by car more than other groups.

The hypothesis regarding gender is supported by the dats, while hypothesis on age, education, marital status and employment status is not supported due to insignificance.

Hypothesis 2

Household structure influences transport mode decision for journeys to work in a way that having a child or a retired person in a household increases the likelihood of commuting to work by car.

Having one child in the household compared to having no children decreases the relative probability of commuting by public transport rather than by car significantly at the 10% significance level by over 43%. People with one child are more likely to commute by car and less likely to use public transport for work trips than people without children. The same effect is observed if we compare households with no children and households with more than one child. However, in comparison to households with only one child, the results indicate that having more children does not necessarily mean that they are more likely to car and less likely to use public transport.[4]

Households with at least one retired person have higher likelihood of commuting by car and lower likelihood of using public transport for work trips than households with no retired person, though, the results are not statistically significant.

To sum it up, households with at least one child commute more by car than by public transport, in comparison to households with no children. The same effect is observed for retired people. The hypothesis is supported for children in the household, but it is not supported for retired.

Hypothesis 3

People living in urban areas with high population density are less likely to use car as a mean of transport for work trips.

The relative risk ratio of using public transport rather than car is increasing with the size of the city people live in. The RRR of preferring public transport to car is 3.6 for medium

[4] Having more than one child increases the relative probability of preferring car to public transport in comparison to households with one child. However, the marginal effects show the opposite. People with more children have higher average probability of commuting by public transport and lower average probability of driving a car to work than people with only one child.

cities, almost 8 for large cities and 21.4 for cities with over one million inhabitants compared to living in a small city and all of them are significant at the 1% significance level. Looking at the marginal effects, the average probability of commuting to work by car is decreasing with the increasing size of the city and opposite effect is observed for public transport. Living in small cities increases the average probability of driving to work by 30 percentage points and decreases the average probability of using public transport by over 61 percentage points, compared to living in a city with over one million people. The results are reasonable, because larger cities are better served with public transport and people living in smaller cities are often dependent on their car.

The results are in line with mentioned studies and the hypothesis is supported.

Hypothesis 4

People with higher income are more likely to commute to work by car compared to people who earn less money.

The results show that having higher income decreases the likelihood of commuting by public transport compared to using a car. Increasing income by 10% decreases the log-odds for preferring public transport to car by 0.12. The effect is significant at the 1% significance level and the hypothesis is supported.

Other results

My hypotheses are based on studies from literature review, which mostly focus on commuting by car or public transport. Apart from testing hypotheses, I would like to also report interesting results for active modes, walking and cycling.

Walking

The relative risk ratio for preferring walking to commuting to work by car is 1.82 for women relative to men. The ratio is statistically significant at the 5% significance level. Thus, women are more likely to prefer walking over driving a car to work than men. People with higher income are less likely to walk to work in comparison to drive a car. The RRR of walking rather than commuting by car to work is higher for people with primary and lower secondary education compared to other groups. People with no children have higher probability of walking to work compared to households with children, however, the differences are not statistically significant. If I compare results to full-time workers, all other types of employment status are more likely to walk to work

than to drive a car, especially self-employed and students. Moreover, their coefficients are statistically significant.

Cycling

Women have higher average probability of commuting by bike to work than men, but the difference is only 1.8 percentage points. People living in small cities are less likely to commute to work by bike than those who live in larger cities. One of the reasons may be long distance between the destinations. For people with higher secondary education relative to those with primary or lower secondary education, the relative risk ratio is 0.61 for preferring cycling to car. However, comparing the most educated people with the lowest educated ones, the relative risk ratio is 1.22 for preferring cycling to driving, but both ratios are not statistically significant. The average probability of cycling to work increase with increasing age, but older people usually do not cycle more than younger age groups. The reason may be small number of observations for bike use.

Conclusion

It is important to change transportation system to reach more sustainable solutions. Therefore, we need to understand people's decision-making process about transport modes and which factors drive their choice. Apart from other factors, the decision is influenced by socio-demographic variables, transport attributes and subjective variables. If policymakers know which groups of people choose particular modes, it is easier to promote some effective transport policies.

The purpose of this thesis was to describe share of use of different transport modes for reaching typical activities with the main focus on commuting to work and then analyse which factors influence the transport mode decision for work journeys in the Czech Republic. The study was motivated by Fiorello *et al*. (2015) who present comprehensive statistics about transportation in Europe and by similar studies such as Clark, Chatterjee & Melia (2016) and Mercado *et al.* (2012). The thesis was aiming at filling the gap in research of this topic in the Czech Republic using data from the INHERIT survey.

Looking at the transport modes used for commuting to work, car was the dominant mode used by almost half of the respondents. Public transport accounted for over 20%, walking for almost 16% and bike was used by 7% of the respondents. The results are in line with the expectations and mentioned studies, because car prevails across all modes in most cases. The only difference is that the shares of public transport and walking are much higher compared to other countries.

For analysing the effect of the determinants, which may possibly influence the transport mode decision, the multinomial logit model was used. Even though some coefficients were not statistically significant, I would conclude that men, older age groups, married and employed are more likely to commute to work by car while women, young people and single are more likely to choose public transport for work trips. Higher income increases the probability of commuting to work by car. The same effect is observed if there are children or retired people in the household. People who live in smaller cities are more likely to commute to work by car than by public transport and the opposite holds for people from larger cities.

There are two suggestions for further research. The socio-demographic variables are a good predictor of transport mode decision, but only to some extent. There is a lot of

factors influencing the decision such as habits, attitudes or even factors known by only the individual, so I would suggest analysing subjective variables to understand the motivation behind. Apart from that, I plan to examine the effect of socio-demographic variables on a transport mode decision, but with the use of nested logit model. The data will be divided into the following groups: whether the respondents commutes or not, if they use single or multi-mode and then which travel modes they use.

Bibliography

Ahern, A., Weyman, G., Redelbach, M., Schulz, A., Akkermans, L., Vannacci, L., . . . van Grinsven, A. (2013). *Analysis of National Travel Statistics in Europe OPTIMISM WP2: Harmonisation of national travel statistics in Europe.* Publications Office of the European Union. doi:10.2788/59474

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational behavior and human decision processes, 50*(2), 179-211.

Aloulou, F. (2018). The Application of Discrete Choice Models in Transport. In *Statistics: Growing Data Sets and Growing Demand for Statistics.*

Amoh-Gyimah, R., & Aidoo, E. N. (2013). Mode of transport to work by government employees in the Kumasi metropolis, Ghana. *Journal of Transport Geography, 31*, 35-43.

Anable, J. (2005). 'Complacent Car Addicts' or 'Aspiring Environmentalists'? Identifying travel behaviour segments using attitude theory. *Transport Policy, 12*(1), 65-78.

Audibert, M., He, Y., & Mathonnat, J. (2013). Multinomial and Mixed Logit Modeling in the Presence of Heterogeneity: A Two-Period Comparison of Healthcare Provider Choice in Rural China.

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D. L., & Crouter, S. E. (2008). Walking, Cycling, and Obesity Rates in Europe, North America, and Australia. *Journal of Physical Activity and Health, 5*(6), 795–814.

Beirão, G., & Cabral, J. S. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy, 14*(6), 478-489.

Ben-Akiva, M., & Bierlaire, M. (1999). Discrete Choice Methods and their Applications to Short Term Travel Decisions. In *Handbook of Transportation Science* (pp. 5-33). Springer, Boston, MA.

Ben-Akiva, M., Mcfadden, D., Train, K., Walker, J., Bhat, C., Bierlaire, M., . . . Munizaga, M. A. (2002). Hybrid Choice Models: Progress and Challenges. *Marketing Letters, 13*(3), 163–175.

Bhat, C. R. (1997). Work travel mode choice and number of non-work commute stops. *Transportation Research Part B: Methodological, 31*(1), 41-54.

Boruta, T., & Ivan, I. (2010). Public transport in rural areas of the Czech Republic – case study of the Jeseník region. *Moravian Geographical Reports, 18*(2).

Braun Kohlová, M. (2012). *Cesty městem: o racionalitě každodenního cestování.* Sociologické nakladatelství (SLON).

Buehler, R. (2011). Determinants of transport mode choice: a comparison of Germany and the USA. *Journal of Transport Geography, 19*(4), 644-657.

Centrum dopravního výzkumu. (2020). *Česko v pohybu*. Retrieved from https://www.ceskovpohybu.cz/

Clark, B., Chatterjee, K., & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice, 89*, 89-105.

Commins, N., & Nolan, A. (2011). The determinants of mode of transport to work in the Greater Dublin Area. *Transport Policy, 18*(1), 259-268.

Davis, S. C., & Boundy, R. G. (2020). *Transportation energy data book.* Oak Ridge National Laboratory.

De Palma, A., & Rochat, D. (2000). Mode choices for trips to work in Geneva: an empirical analysis. *Journal of Transport Geography, 8*(1), Pages 43-51.

De Witte, A., Macharis, C., & Mairesse, O. (2008). How persuasive is 'free' public transport? A survey among commuters in the Brussels Capital Region. *Transport Policy, 15*(4), 216-224.

Directorate-General for Mobility and Transport. (2019). *Transport in the European Union: current trends and issues.* Brussels: European Commission.

European Commission. (2009). *Panorama of transport.*

Eurostat. (2019). *Passenger transport.*

Evans, A., Kelly, A., & Slocombe, M. (2019). *National Travel Survey: England 2018.*

Fiorello, D., Zani, L., Christidis, P., & Navajas Cawood, E. (2015). *EU Survey on issues related to transport and mobility.* Publications Office of the European Union.

Fitzová, H., Matulová, M., & Tomeš, Z. (2018). Determinants of urban public transport efficiency: case study of the Czech Republic. *European Transport Research Review*(10).

Fol, S., Dupuy, G., & Coutard, O. (2007). Transport Policy and the Car Divide in the UK, the US and France: Beyond the Environmental Debate. *International Journal of Urban and Regional Research, 31*(4), 802-818.

Fujii, S., & Kitamura, R. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation, 30*(1), 81–95.

Greene, W. H. (2012). *Econometric Analysis* (7th ed.). Pearson Education.

Greene, W. H., & Hensher, D. A. (2002). A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological, 37*(8), 681-698.

Handy, S. L., & Clifton, K. J. (2001). Local shopping as a strategy for reducing automobile travel. *Transportation, 28*(4), 317–346.

Hensher, D. A. (1991). Efficient estimation of hierarchical logit mode choice models. *Doboku Gakkai Ronbunshu, 1991*(425), 17-28 .

Hoffman, S. D., & Duncan, G. J. (1988). Multinomial and conditional logit discrete-choice models in demography. *Demography, 25*(3), 415–427.

Horák, J., Šeděnková, M., & Ivan, I. (2008). *Modelling of public transport accessibility for municipalities in the Czech republic.* Ostrava.

Chen, T., & McQuaid, R. W. (2012). Commuting times – The role of gender, children and part-time work. *Research in Transportation Economics, 34*(1), 66-73.

ITF. (2019). *ITF Transport Outlook 2019.* Paris: OECD Publishing.

Ivan, I., & Horák, J. (2014). Demand and Supply of Transport Connections for Commuting in the Czech Republic. In *Geoinformatics for Intelligent Transportation* (pp. 137-147). Cham Springer.

Jensen, M. (1999). Passion and heart in transport — a sociological analysis on transport behaviour. *Transport Policy, 6*(1), 19-33.

Johansson, M. V., Heldt, T., & Johansson, P. (2006). The effects of attitudes and personality traits on mode choice. *Transportation Research Part A: Policy and Practice, 40*(6), 507-525.

Koppelman, F. S., & Pas, E. I. (1980). Travel-choice behavior: Models of perceptions, feelings, preference, and choice. *Transportation Research Record*(765), 26-33.

Koppelman, F. S., & Wen, C.-H. (1998). Alternative nested logit models: structure, properties and estimation. *Transportation Research Part B: Methodological, 32*(5), 289-298.

Lanzendorf, M. (2003). Mobility biographies : A new perspective for understanding travel behaviour. *10th International Conference on Travel Behaviour Research.* Lucerne.

Lenz, B., Nobis, C., Köhler, K., Mehlin, M., Follmer, R., Gruschwitz, D., . . . Quandt, S. (2010). *Mobilität in Deutschland 2008.*

McFadden, D. L. (1974). Conditional logit analysis of qualitative choice behavior. In *Frontiers in econometrics* (pp. 105-142). New York.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of applied Econometrics, 15*(5), 447-470.

Mensah, J. (1995). Journey to work and job search characteristics of the urban poor. *Transportation, 22*(1), 1-19.

Mercado, R. G., Paez, A., Farber, S., Roorda, M. J., & Morency, C. (2012). Explaining transport mode use of low-income persons for journey to work in urban areas: a case study of Ontario and Quebec. *Transportmetrica, 8*(3), 157-179.

Mercado, R., & Páez, A. (2009). Determinants of distance traveled with a focus on the elderly: a multilevel analysis in the Hamilton CMA, Canada. *Journal of Transport Geography, 17*(1), 65-76.

Mitra, R., & Buliung, R. N. (2015). Exploring differences in school travel mode choice behaviour between children and youth. *Transport Policy, 42*, 4-11.

Nairne, J. S. (2003). Sensory and working memory. In *Handbook of psychology* (pp. 423-444).

Newbold, K. B., Scott, D. M., Spinney, J. E., Kanaroglou, P., & Páez, A. (2005). Travel behavior within Canada's older population: a cohort analysis. *Journal of Transport Geography, 13*(4), 340-351.

Paez, A., Scott, D., Potoglou, D., Kanaroglou, P., & Newbold, K. B. (2007). Elderly Mobility: Demographic and Spatial Analysis of Trip Making in the Hamilton CMA, Canada . *Urban Studies, 44*(1), 123-146.

Parkany, E., Gallagher, R., & Viveiros, P. (2004). Are Attitudes Important in Travel Choice? . *Transportation Research Record, 1894*(1), 127-139.

Pucher, J. (1999). The transformation of urban transport in the Czech Republic, 1988–1998. *Transport Policy, 6*(4), 225-236.

Pucher, J., & Renne, J. L. (2005). Rural mobility and mode choice: Evidence from the 2001 National Household Travel Survey. *Transportation , 32*, 165–186.

Pulikanti, S., & Habib, K. N. (2016). Investigating the Choice Making Behaviour of Transport Users: The Role of Psychology and Choice Contexts in Commuting Mode Choice Process.

Rouwendal, J., & Rietveld, P. (1994). Changes in Commuting Distances of Dutch Households . *Urban Studies, 31*(9), 1545–1557.

Schwanen, T., Dieleman, F. M., & Dijst, M. (2001). Travel behaviour in Dutch monocentric and policentric urban systems. *Journal of Transport Geography, 9*(3), 173-186.

Steg, L. (2003). Can public transport compete with the private car? *IATSS Research*, 27-35.

Steg, L. (2005). Car use: lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A: Policy and Practice, 39*(2), 147-162.

Ščasný, M. (2011). Passenger Road Transport During Transition and Post-transition Period: Residential Fuel Consumption and Fuel Taxation in the Czech Republic. In *Zachariadis T. (eds) Cars and Carbon* (pp. 221-246). Dordrecht Springer.

Ščasný, M., & Urban, J. (2011). Passenger car ownership in the Czech Republic. *International Days of Statistics and Economics.* Prague.

Taylor, J., Barnard, M., Neil, H., & Creegan, C. (2009). The Travel Choices and Needs of Low Income Households: the Role of the Car. *The National Centre for Social Research*.

Thobani, M. (1984). A nested logit model of travel mode to work and auto ownership. *Journal of Urban Economics, 15*(3), 287-301.

Train, K. (1980). A Structured Logit Model of Auto Ownership and Mode Choice. *The Review of Economic Studies, 47*(2), 357-370.

Transport Research and Innovation Portal. (2013). *Passenger transport: Thematic Research Summary.*

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data.* MIT Press.

Zvěřinová, I., Ščasný, M., & Máca, V. (2018). *INHERIT: Barriers and Potential for Adopting Healthier, More Equitable and Environmentally Friendly Solutions Identified in a Five-Country Survey.* Prague.

List of Appendices

Appendices

Appendix A

logit 1: dependent variable non-commuters (0) vs commuters (1)

logit 2: dependent variable single mode (0) or multi-mode (1)

Table A.1: Logit models

variable	**logit 1**	**logit 2**
	coef. (std.err.)	coef. (std.err.)
female		
female	-0.0048 (0.11)	-0.0482 (0.18)
ln_hincCZ	0.0566 (0.13)	0.0898 (0.21)
hincmiss	1.2616 (2.61)	1.5738 (4.25)
town		
medium city	0.0204 (0.11)	0.3292* (0.19)
large city	0.1054 (0.17)	0.835*** (0.26)
over 1 million	0.2477 (0.17)	0.8754*** (0.26)
agecat		
35-49 years	0.331** (0.15)	0.1087 (0.23)
50-65 years	0.2586 (0.18)	-0.1353 (0.3)
adult_HH	-0.0235 (0.06)	0.2913*** (0.1)
retired_HH		
at least one retired	-0.1142 (0.15)	0.299 (0.24)
educat		
upper secondary	0.0655 (0.11)	0.0957 (0.18)
tertiary	0.2373* (0.14)	0.2535 (0.22)
children_HH		
one child	0.0361 (0.13)	0.0751 (0.2)

more children	0.0588	0.1193
	(0.15)	(0.24)
marit		
partnership	0.2455	1.7082*
	(0.67)	(0.94)
separated	-0.4285	0.5325
	(0.51)	(0.88)
divorced	-0.0222	0.3631
	(0.17)	(0.29)
widowed	0.4029	0
	(0.53)	0
single	0.1797	0.4666*
	(0.17)	(0.27)
not married couple	0.1836	0.3765*
	(0.14)	(0.21)
other	0.5091	1.1377
	(0.55)	(0.7)
employ		
part-time	-0.3393	-0.1621
	(0.24)	(0.38)
self-employed	-0.1726	0.1851
	(0.19)	(0.28)
student	-0.7425***	0.5192
	(0.21)	(0.32)
home	-1.0713**	0
	(0.51)	0
maternity	-1.8697***	-0.4658
	(0.23)	(0.47)
retired	-1.3429***	-0.5988
	(0.26)	(0.6)
unemployed	-1.975***	0.1871
	(0.4)	(0.84)
unable to work	-1.5733***	-0.0824
	(0.21)	(0.43)
other	-0.9411*	0.588
	(0.52)	(0.91)
_cons	-0.5498	-3.3008
	(1.31)	(2.14)

Appendix B

Figure B.1: Share of modes in each country from the INHERIT survey

Appendix C

Results from testing the models

Model1 mode = female + ln_hincCZ + town

Model2 mode = female + ln_hincCZ + town + agecat

Model3 mode = female + ln_hincCZ + town + adult_HH

Model4 mode = female + ln_hincCZ + town + adult_HH + children_HH

Model5 mode = female + ln_hincCZ + town + adult_HH + children_HH + retired_HH

Model6 mode = female + ln_hincCZ + town + adult_HH + children_HH + retired_HH + employ

Model7 mode = female + ln_hincCZ + town + adult_HH + children_HH + retired_HH + employ + marit

Table C.1: Likelihood ratio tests

Likelihood-ratio test	LR chi2 = 5.95
(Assumption: Model1 nested in Model2)	Prob > chi2 = 0.6528
Likelihood-ratio test	LR chi2 = 0.44
(Assumption: Model3 nested in Model2)	Prob > chi2 = 0.9792
Likelihood-ratio test	LR chi2 = 15.83
(Assumption: Model3 nested in Model4)	Prob > chi2 = 0.0449
Likelihood-ratio test	LR chi2 = 4.51
(Assumption: Model4 nested in Model5)	Prob > chi2 = 0.3416
Likelihood-ratio test	LR chi2 = 52.05
(Assumption: Model5 nested in Model6)	Prob > chi2 = 0.0407
Likelihood-ratio test	LR chi2 = 57.13
(Assumption: Model6 nested in Model7)	Prob > chi2 = 0.0386

Table C.2: Wald tests for independent variables

Ho: All coefficients associated with given variable(s) are 0

variable	chi2	df	P>chi2
0b.female	.	0	.
1o.female	8.857	4	0.065
1b.town	.	0	.
2o.town	24.26	4	0
3o.town	32.756	4	0
4o.town	65.495	4	0
1b.agecat	.	0	.

2o.agecat	0.706	4	0.951
3o.agecat	4.188	4	0.381
0b.childre~H	.	0	.
1o.childre~H	10.361	4	0.035
2o.childre~H	2.216	4	0.696
0b.retired~H	.	0	.
1o.retired~H	3.654	4	0.455
1b.educat	.	0	.
2o.educat	7.9	4	0.095
3o.educat	1.754	4	0.781
1b.marit	.	0	.
2o.marit	0.74	4	0.946
3o.marit	0.243	4	0.993
4o.marit	7.471	4	0.113
5o.marit	3.431	4	0.488
6o.marit	3.852	4	0.426
7o.marit	0.347	4	0.987
8o.marit	0.884	4	0.927
1b.employ	.	0	.
2o.employ	3.265	4	0.514
3o.employ	8.77	4	0.067
4o.employ	5.537	4	0.236
5o.employ	0.388	4	0.983
6o.employ	8.926	4	0.063
7o.employ	5.059	4	0.281
8o.employ	5.174	4	0.27
9o.employ	8.493	4	0.075
10o.employ	0.673	4	0.955
ln_hincCZ	15.95	.	0.0031
adult_HH	4.90	.	0.2975

Table C.3: Hausman tests of IIA assumption

Ho: Odds (Outcome-J vs Outcome-K) are independent of other alternatives.

Omitted	chi2	df	P>chi2	evidence
walk	16.072	24	0.885	for Ho
public_t	2.66	35	1	for Ho
bike	-0.567	24	---	---
other	-0.048	24	---	---
car	22.764	35	0.945	for Ho

Table C.4: Small-Hsiao tests of IIA assumption

Ho: Odds (Outcome-J vs Outcome-K) are independent of other alternatives.

Omitted	lnL(full)	lnL(omit)	chi2	df	P>chi2	evidence
walk	-282.381	-269.384	25.993	36	0.891	for Ho
public_t	-292.905	-274.633	36.545	36	0.443	for Ho
bike	-342.808	-330.948	23.721	36	0.942	for Ho
other	-359.681	-344.136	31.091	36	0.701	for Ho
car	-213.037	-200.066	25.942	36	0.892	for Ho

Appendix D

Table D.1: Results from the MNL model

variable	**WALK**	**PT**	**BIKE**	**OTHER**
	coef. (std. err.)	*coef.* (std. err.)	*coef.* (std. err.)	*coef.* (std. err.)
female				
female	0.5959** (0.27)	0.5982** (0.28)	0.4818 (0.37)	-0.104 (0.37)
ln_hincCZ	-0.6301* (0.32)	-1.2081*** (0.33)	0.2311 (0.48)	-0.5049 (0.44)
hincmiss	13.1881** (6.61)	24.7863*** (6.72)	4.3253 (9.94)	-10.0361 (8.88)
town				
medium city	0.9472*** (0.27)	1.2716*** (0.32)	0.3252 (0.35)	-0.0525 (0.37)
large city	-0.0128 (0.51)	2.078*** (0.39)	-0.0632 (0.68)	0.0334 (0.6)
over 1 million	-0.3679 (0.68)	3.0626*** (0.42)	-15.8114 (1744.95)	-0.1873 (0.7)
agecat				
35-49 years	0.1453 (0.39)	-0.0651 (0.36)	0.3255 (0.58)	-0.1753 (0.48)
50-65 years	-0.0968 (0.47)	-0.4914 (0.46)	0.8414 (0.66)	-0.643 (0.63)
adult_HH	0.2774* (0.16)	0.3071* (0.17)	0.1646 (0.22)	0.1047 (0.22)
children_HH				
one child	-0.5483* (0.32)	-0.8351** (0.33)	-0.8678* (0.51)	-0.7376 (0.49)
more children	-0.3337 (0.38)	-0.4454 (0.39)	-0.3624 (0.53)	0.1122 (0.5)
retired_HH				
at least one retired	-0.0148 (0.38)	-0.1276 (0.41)	-0.4004 (0.55)	0.7042 (0.45)
educat				
upper secondary	-0.6161** (0.27)	-0.3333 (0.28)	-0.4933 (0.38)	-0.6668* (0.38)

tertiary	-0.2094	0.3059	0.1973	0.0445
	(0.35)	(0.34)	(0.44)	(0.45)
marit				
partnership	1.1552	-14.5706	-15.7543	-15.5466
	(1.34)	(4131.5)	(6647.93)	(6578.97)
separated	0.313	0.5833	-16.1234	-14.9461
	(1.21)	(1.24)	(4931.55)	(4888.39)
divorced	0.6459	0.1408	-0.5476	1.1434**
	(0.41)	(0.43)	(0.69)	(0.54)
widowed	-0.3961	-2.2039*	-17.1962	-15.7606
	(0.88)	(1.19)	(3643.99)	(3727.14)
single	-0.0464	-0.3936	0.2484	0.8299
	(0.45)	(0.43)	(0.61)	(0.56)
not married couple	-0.0386	-0.1062	-0.1225	0.1612
	(0.33)	(0.34)	(0.46)	(0.45)
other	-16.3181	-0.3304	-16.002	1.0303
	(3244.13)	(1.13)	(5244.84)	(1.38)
employ				
part-time	0.7562	0.52	-0.7044	-0.2785
	(0.57)	(0.52)	(1.09)	(1.1)
self-employed	0.8716**	-0.7456	-0.7306	0.0727
	(0.4)	(0.6)	(0.77)	(0.67)
student	1.2335**	0.8441	-0.4465	-0.0118
	(0.62)	(0.58)	(1.2)	(0.92)
home	0.6191	0.0259	-16.0417	-15.5382
	(1.05)	(1.29)	(4609.39)	(4349.48)
maternity	1.1104*	-0.2772	-15.3515	1.7858**
	(0.64)	(0.7)	(2426.52)	(0.71)
retired	0.8719	0.8598	0.0234	1.4543**
	(0.69)	(0.72)	(0.94)	(0.74)
unemployed	2.685**	2.4842*	-15.9198	-15.414
	(1.22)	(1.29)	(6396.11)	(6214.7)
unable to work	0.8201	0.0383	-0.1042	1.6886***
	(0.57)	(0.64)	(0.82)	(0.65)
other	0.8996	-16.6544	-17.6292	-16.7022
	(1.1)	(4762.57)	(8266.58)	(6973.05)
_cons	4.1787	9.9637***	-4.7918	3.0208

	(3.32)	(3.34)	(5.01)	(4.49)
Observations			707	
Log-likelihood			-793.71916	
Pseudo R^2			0.1637	
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table D.2: Relative risks ratios

variable	**WALK**	**PT**	**BIKE**	**OTHER**
	RRR	*RRR*	*RRR*	*RRR*
	(std. err.)	(std. err.)	(std. err.)	(std. err.)
female				
female	1.8147**	1.8189**	1.619	0.9012
	(0.49)	(0.52)	(0.6)	(0.52)
ln_hincCZ	0.5325*	0.2988***	1.26	0.6035
	(0.17)	(0.1)	(0.61)	(0.1)
hincmiss	0**	0**	75.589	0
	(0)	(0)	(751.33)	(0)
town				
medium city	2.5786***	3.5667***	1.3843	0.9488
	(0.7)	(1.13)	(0.48)	(1.13)
large city	0.9873	7.9882***	0.9388	1.0339
	(0.5)	(3.1)	(0.63)	(3.1)
over 1 million	0.6922	21.3841***	0	0.8292
	(0.47)	(8.89)	(0)	(8.89)
agecat				
35-49 years	1.1564	0.9369	1.3848	0.8392
	(0.46)	(0.34)	(0.81)	(0.34)
50-65 years	0.9078	0.6118	2.3196	0.5257
	(0.42)	(0.28)	(1.54)	(0.28)
adult_HH	1.3197*	1.3595*	1.179*	1.1104
	(0.21)	(0.23)	(0.26)	(0.23)
retired_HH				
at least one retired	0.9853	0.8802	0.6701	2.0223
	(0.38)	(0.37)	(0.37)	(0.37)
educat				
upper secondary	0.54**	0.7165	0.6106	0.5133*
	(0.15)	(0.2)	(0.23)	(0.2)

tertiary	0.8111	1.3578	1.2181	1.0455
	(0.28)	(0.46)	(0.53)	(0.46)
children_HH				
one child	0.578*	0.4338**	0.4199*	0.4782
	(0.18)	(0.14)	(0.21)	(0.14)
more children	0.7162	0.6406	0.696	1.1187
	(0.27)	(0.25)	(0.37)	(0.25)
marit				
partnership	3.1747	0	0	0
	(4.26)	(0)	(0)	(0)
separated	1.3675	1.792	0	0
	(1.65)	(2.22)	(0)	(2.22)
divorced	1.9076	1.1512	0.5783	3.1375**
	(0.78)	(0.5)	(0.4)	(0.5)
widowed	0.6729	0.1104*	0	0
	(0.6)	(0.13)	(0)	(0.13)
single	0.9547	0.6746	1.2819	2.2931
	(0.42)	(0.29)	(0.78)	(0.29)
not married couple	0.9621	0.8992	0.8847	1.1749
	(0.32)	(0.3)	(0.41)	(0.3)
other	0	0.7186	0	2.8018
	(0)	(0.81)	(0)	(0.81)
employ				
part-time	2.1302	1.6819	0.4944	0.7569
	(1.21)	(0.87)	(0.54)	(0.87)
self-employed	2.3907**	0.4745	0.4816	1.0754
	(0.96)	(0.29)	(0.37)	(0.29)
student	3.4334**	2.3259	0.6399	0.9883
	(2.14)	(1.34)	(0.77)	(1.34)
home	1.8573	1.0262	0	0
	(1.96)	(1.32)	(0)	(1.32)
maternity	3.0355*	0.7579	0	5.9644**
	(1.96)	(0.53)	(0)	(0.53)
retired	2.3915	2.3627	1.0237	4.2815
	(1.64)	(1.7)	(0.96)	(1.7)
unemployed	14.6588**	11.9919*	0	0

	(17.85)	(15.46)	(0)	(0)
unable to work	2.2706	1.039	0.901	5.4121***
	(1.29)	(0.66)	(0.74)	(0.66)
other	2.4586	0	0	0
	(2.7)	(0)	(0)	(0)
_cons	65.2809	21240.25	0.0083	20.5071
	(216.42)	(70888.5)	(0.04)	(70888.5)
Observations	707			
Log-likelihood	-793.71916			
Pseudo R^2	0.1637			
Note:	*p<0.1; **p<0.05; ***p<0.01			

Table D.3: Marginal effects

variable	**CAR**	**WALK**	**PT**	**BIKE**	**OTHER**
	coef.	*coef.*	*coef.*	*coef.*	*coef.*
	(std. err.)	(std. err.)	(std. err.)	(std. err.)	(std. err.)
female					
male	0.5341	0.135	0.1847	0.062	0.0838
	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)
female	0.4324	0.1876	0.2393	0.0795	0.0607
	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
town					
small city	0.6082	0.1373	0.0801	0.0784	0.0955
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
medium city	0.4432	0.2318	0.1831	0.0779	0.0636
	(0.03)	(0.03)	(0.02)	(0.02)	(0.01)
large city	0.4284	0.0864	0.3688	0.0502	0.066
	(0.06)	(0.03)	(0.06)	(0.03)	(0.03)
over 1 million	0.3078	0.0415	0.6144	0	0.0363
	(0.06)	(0.02)	(0.06)	(0)	(0.02)
agecat					
18-34 years	0.4823	0.1481	0.2355	0.0414	0.0924
	(0.05)	(0.04)	(0.04)	(0.02)	(0.03)
35-49 years	0.4756	0.1677	0.2226	0.056	0.0776
	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)

50-65 years	0.5167	0.1488	0.1784	0.0996	0.0556
	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)
retired_HH					
no retired	0.4906	0.1578	0.2168	0.0721	0.062
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
at least one retired	0.4849	0.1532	0.195	0.0484	0.1181
	(0.05)	(0.04)	(0.04)	(0.02)	(0.03)
children_HH					
no children	0.4455	0.1684	0.2349	0.0761	0.0744
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
one child	0.6015	0.1396	0.1643	0.0434	0.0508
	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)
more children	0.5101	0.1426	0.1907	0.0609	0.095
	(0.05)	(0.03)	(0.04)	(0.02)	(0.03)
educat					
primary & lower secondary	0.4529	0.183	0.209	0.0716	0.083
	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)
upper secondary	0.5629	0.1294	0.1968	0.0549	0.0556
	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)
tertiary	0.436	0.1442	0.2522	0.0836	0.0833
	(0.04)	(0.03)	(0.03)	(0.02)	(0.03)
marit					
married	0.4906	0.1485	0.2323	0.074	0.0537
	(0.03)	(0.02)	(0.03)	(0.01)	(0.01)
partnership	0.5397	0.4603	0	0	0
	(0.28)	(0.28)	(0)	(0)	(0)
separated	0.4819	0.1892	0.3289	0	0
	(0.19)	(0.16)	(0.19)	(0)	(0)
divorced	0.4031	0.2182	0.2168	0.0356	0.126
	(0.05)	(0.05)	(0.04)	(0.02)	(0.04)
widowed	0.7648	0.1686	0.0666	0	0
	(0.12)	(0.11)	(0.06)	(0)	(0)

single	0.4779	0.1399	0.1761	0.091	0.114
	(0.06)	(0.04)	(0.03)	(0.04)	(0.04)
not married couple	0.5014	0.1468	0.22	0.0671	0.0639
	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)
other	0.6056	0	0.2225	0	0.1719
	(0.19)	(0)	(0.13)	(0)	(0.16)
employ					
full-time	0.5216	0.1227	0.2137	0.0807	0.0602
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
part-time	0.4478	0.2114	0.2676	0.0345	0.0383
	(0.09)	(0.08)	(0.06)	(0.03)	(0.04)
self-employed	0.5086	0.2708	0.1203	0.0371	0.0627
	(0.07)	(0.06)	(0.05)	(0.03)	(0.04)
student	0.3687	0.2683	0.286	0.0363	0.0403
	(0.09)	(0.1)	(0.07)	(0.04)	(0.03)
home	0.5478	0.231	0.2213	0	0
	(0.19)	(0.16)	(0.15)	(0)	(0)
maternity	0.3823	0.2523	0.1313	0	0.2341
	(0.1)	(0.1)	(0.06)	(0)	(0.1)
retired	0.3407	0.1774	0.275	0.0537	0.1525
	(0.09)	(0.08)	(0.1)	(0.04)	(0.08)
unemployed	0.1535	0.4092	0.4373	0	0
	(0.13)	(0.18)	(0.17)	(0)	(0)
unable to work	0.3778	0.1902	0.1668	0.052	0.2125
	(0.09)	(0.07)	(0.06)	(0.04)	(0.09)
other	0.6483	0.3517	0	0	0
	(0.22)	(0.22)	(0)	(0)	(0)

Table D.4: Differences in marginal effects

variable	**CAR**	**WALK**	**PT**	**BIKE**	**OTHER**
	coef.	*coef.*	*coef.*	*coef.*	*coef.*
	(std. err.)	(std. err.)	(std. err.)	(std. err.)	(std. err.)
female					
female	-0.1017**	0.0526*	0.0546	0.0177	-0.0231
	(0.04)	(0.05)	(0.03)	(0.02)	(0.02)
town					
medium city	-0.1649***	0.0945***	0.103***	-0.0007	-0.0319
	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)
large city	-0.1798***	-0.051	0.2887***	-0.0284	-0.0295
	(0.06)	(0.04)	(0.06)	(0.03)	(0.04)
over 1 million	-0.3004***	-0.0958***	0.5343***	-0.0789***	-0.0592**
	(0.07)	(0.03)	(0.06)	(0.02)	(0.03)
agecat					
35-49 years	-0.0067	0.0196	-0.0128	0.0147	-0.0147
	(0.06)	(0.04)	(0.05)	(0.02)	(0.03)
50-65 years	0.0344	0.0007	-0.0571	0.0587	-0.0367
	(0.07)	(0.05)	(0.05)	(0.04)	(0.04)
children_HH					
one child	0.1561***	-0.0288	-0.0706**	-0.033	-0.0236
	(0.05)	(0.04)	(0.04)	(0.02)	(0.02)
more children	0.0646	-0.0258	-0.0442	-0.0153	0.0206
	(0.06)	(0.04)	(0.04)	(0.03)	(0.04)
retired_HH					
at least one retired	-0.0057	-0.0047	-0.0218	-0.0239	0.0561
	(0.06)	(0.04)	(0.05)	(0.03)	(0.04)
educat					
upper secondary	0.11***	-0.0536*	-0.0122	-0.0168	-0.0274
	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)
tertiary	-0.017	-0.0387	0.0432	0.0121	0.0004
	(0.05)	(0.04)	(0.04)	(0.03)	(0.03)
marit					
partnership	0.049	0.3118	-0.2323***	-0.0748***	-0.0537***
	(0.29)	(0.28)	(0.03)	(0.01)	(0.01)
separated	-0.0088	0.0407	0.0966	-0.0748***	-0.0537***
	(0.19)	(0.16)	(0.19)	(0.01)	(0.01)

divorced	-0.0876 (0.06)	0.0696 (0.05)	-0.0155 (0.05)	-0.0388 (0.03)	0.0723 (0.04)
widowed	0.2742** (0.12)	0.02 (0.11)	-0.1657*** (0.06)	-0.0748*** (0.01)	-0.0537*** (0.01)
single	-0.0128 (0.07)	-0.0086 (0.05)	-0.0562 (0.04)	0.0173 (0.04)	0.0603 (0.04)
not married couple	0.0108 (0.05)	-0.0017 (0.04)	-0.0124 (0.04)	-0.0069 (0.03)	0.0102 (0.02)
other	0.1149 (0.2)	-0.1485*** (0.02)	-0.0098 (0.13)	-0.0748*** (0.01)	0.1182 (0.16)
employ					
part-time	-0.0738 (0.09)	0.0886 (0.08)	0.0538 (0.07)	-0.0468 (0.04)	-0.0219 (0.04)
self-employed	-0.013 (0.07)	0.1481** (0.07)	-0.0934* (0.05)	-0.0441 (0.03)	0.0025 (0.04)
student	-0.1529 (0.1)	(0.1) (0.16)	0.0723 (0.08)	-0.0451 (0.04)	-0.02 (0.03)
home	0.0262 (0.2)	0.1082 (0.1)	0.0075 (0.15)	-0.0817*** (0.01)	-0.0602*** (0.01)
maternity	-0.1393 (0.1)	0.1296 (0.09)	-0.0824 (0.06)	-0.0817*** (0.01)	0.1739* (0.1)
retired	-0.1809* (0.1)	0.0547 (0.05)	0.0613 (0.1)	-0.0274 (0.05)	0.0923 (0.08)
unemployed	-0.368*** (0.13)	0.2865 (0.18)	0.2235 (0.17)	-0.0817*** (0.01)	-0.0602*** (0.01)
unable to work	-0.1437 (0.09)	0.0674 (0.07)	-0.0469 (0.06)	-0.0291 (0.04)	0.1523* (0.09)
other	0.1268 (0.22)	0.2289 (0.22)	-0.2137*** (0.02)	-0.0817*** (0.01)	-0.0602*** (0.01)
Note:		*p<0.1; **p<0.05; ***p<0.01			