The impact of personal ICTs on mobility behaviour

A study on the impact of personal ICTs on the amount of travel and mode choice using the first wave of the Dutch Mobility Panel.

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ABSTRACT

The potential of information and communication technologies (ICT) to change our society, including mobility is evident. Both empirical and statistical research on the relation between ICTs and the amount of travel and mode choice requires continuous attention because of the rapid innovations related to both spectrums of that relation. Quantitative research that considers state-of-the-art personal ICTs like high speed mobile Internet (4G) or smartphones and tablets in relation to mobility is limited. In this research an attempt is made to contribute to the understanding of the relation between personal ICTs and the amount of travel and mode choice for long-distance home-work trips with use of the first wave of the Dutch Mobility Panel. From the literature, current knowledge on the mobility aspects, modern day ICTs and understanding of the relations that might work between them are presented to provide context to the obtained results. Mechanisms like the fragmentation of activities, transport as a derived demand from activity patterns and travel time use are described because of their perceived importance in understanding the relation.

The variation in the amount of travel, calculated in the average amount of trips per day, average travel distance per day and average distance per trip, is analyzed over groups with low, medium and high Internet use and tele-working frequencies. For the total amount of travel, the average trips per day and average distance per trip are significantly different over the groups with low, medium and high Internet use with respectively 3.3, 3.1 and 2.8 trips per day and 10.92, 13.40 and 15.39 kilometers per trip. Furthermore, when analyzing the total amount of travel over profiles considering age, work situation and Internet use the variations go in opposite directions between different profiles. For students the number of trips is higher for the groups with higher Internet use, while for the unemployed group of respondents the amount of travel is much lower for the group with high Internet use. This trend is also observed when only leisure or shopping trips are considered but with smaller variations and only with significant differences in the amount of trips per day. Tele-working from home decreases the number of commuter trips significantly, which makes sense. When another indicator for tele-working (working over distance via the Internet independent of location) is used, only the average travel distance per trip varies significantly with an increase from around 17 to 26 kilometers respectively for the groups with incidental and daily use of the Internet for the purpose of working over distance.

Considering the relation between ICT and mode choice, the most comprehensive model in this research is able to explain 84.6% of the variation in mode choice between car and train for long distance home-work trips. The included ICT variables only explain 0.9% of the total variance. Furthermore, only tablet possession and interaction terms of age and Internet use and tablet possession and access to the Internet via 3G/4G LTE are showing significant effects. Owning a tablet increases the chance of a person choosing the car to complete long-distance home-work trips. Owning a tablet in combination with access to the Internet via 3G/4G increases the chance of a person choosing the train via the chosen method in this research.

Additional time and research is required to link the observed variation to specific mechanisms like the improved ability to use travel time efficiently or fragmentation of activities as a result of modern ICTs. Considering the context of the relations, the interweaving of the digital and physical world and limiting technological determinism are extremely important to consider as starting points for any research on the complex relation of ICT and mobility. The complexity of the future relation between personal ICTs and mobility is expected to grow exponentially.

SUMMARY

The desire and need to understand, explain and predict travel (choice) behaviour dates back centuries and is widely shared throughout society. The difficulty is however that human travel behaviour doesn't follow a fixed pattern but is continuously changing. Causes for these changes can be as simple as a broken car in the morning or as complex as changes in the growing possibilities for people to communicate or exchange information unrestricted by distance via various technologies. Because nowadays both information and communication technologies (ICTs) and mobility are extremely versatile by itself, (the complexity of) the interactions that might work between them are expected to have grown exponentially over the past decades and is expected to keep doing so in the decades to come. This perceived complexity of the relation between personal ICTs and mobility is confirmed in the presented qualitative and quantitative information in this research.

Because many of the most recent ICT related innovations like high speed mobile Internet or tablets have become available to the public only in the last few years, not only time to consider the new characteristics, possibilities and effects of ICTs in research, but also the time to collect comprehensive data, which is required for empirical and statistical analysis on the relation between ICT and mobility, is limited. With growing pressure on the planets resources, a growing population among other threats to (the freedom to) travel – and in fact society as a whole – the importance of understanding (future) changes is evident for a variety of purposes, including effective and efficient policy making.

From their role as internal knowledge institute for the Dutch Ministry of Infrastructure and Environment, their desire to keep evolving the understanding of travel (choice) behaviour and in a reaction to recent developments, the Netherlands institute for Transport Policy Analysis (KiM) initiated the Dutch mobility panel (MPN). Via this panel comprehensive disaggregated data is collected via a personal questionnaire, household questionnaire and three-day mobility diary over four consecutive years. In order to ensure a feasible research, a strict delineation on both the ICT and mobility side of the relation was required which resulted in the decision to focus on researching the impact of personal ICTs on travel amounts and mode choice for long-distance commuter trips by car or train for a variety of reasons, including the lack of recent scientific research on the described relations. Based on an initial exploration of the available MPN data, relevant literature and the delineation of the research, the objective of the research was to:

Contribute to the understanding of the relation between personal ICTs and mobility by providing empirical and statistical insights in observed and calculated variations of relevant variables and expected relations between those variables by using the first wave of the Dutch Mobility Panel dataset. In order to do so, the available data will be used mainly to determine and explore:

1. the variation in access to and use of Internet, possession of smartphones, tablets and the frequency of individuals to work over distance (tele-work).
2. the variation in aggregated travel amounts of homogeneous groups in context of their Internet use and tele-working frequencies.
3. the impact of Internet use, tele-working, smartphone possession and tablet possession on mode choice for long-distance home-work trips with use of a binary logit model.

Literature overview

The literature often describes four main effects of ICTs on transportation, which originated already in around 1986; 1. Substitution-effect: where ICT replaces (part of) a trip (for example Teleworking or Internet shopping); 2. Generation-effect: where ICT use leads to new travel (receiving a discount coupon via email initiating a trip to the store); 3. Modification-effect: where ICT use leads to an adjustment (change) in travel (for example departure time or mode choice) without stimulating or eliminating travel, or a; 4. Neutral-effect: where ICT use has no impact on travel. Despite the fact that ICT and transportation have developed drastically over the past decades, the described categorization of effects is still used often in research present-day.

It is however debatable whether this type of categorization is still sufficient to cover the interactions that might be present in the current complex landscape of personal ICTs and mobility. Possibly, the effects by itself can't be seen separately from one another. In literature this perceived complexity isn't often addressed or acknowledged, however some efforts to formulate important consideration related to this complexity when researching ICT and mobility can be found. In 2008 three starting points for research that considers the relation between ICT and mobility were formulated, being that; consideration of the interweaving of the 'real' and digital space-times should be put up front, technological determinism is to be avoided and that effects cannot be separated from the contexts in which they are situated.

ICT and the amount of travel

Important to consider here is that the demand for transport is derived, it is not and end in itself. People mostly travel in order to satisfy their needs at particular locations which can be related to various purposes (mandatory: work, or optional: shopping, leisure). Looking specifically at the impact of personal ICTs on the amount of travel, a large variety of qualitative research is available. In essence, research on the amount of travel is focussing on showing any possible significant reduction or increase in disaggregated or aggregated amounts of travel and determining the specific drivers behind the observed variations. The mechanisms that are considered as important explanations for the observed variation vary greatly. For example the relation between tele-working and the work related amount of travel is one relatively straight forward and direct relation that has been researched extensively. Obviously, when a person works at home one day, he or she might not have to travel to work, which could reduce the amount of daily travel. However, the amount of travel might as well increase when calculated over a different timeframe or not at the personal but household level. Also the effect of for example children using the car of their father when working from home, called the rebound effect, is acknowledged in literature.

Other complex mechanisms like the decoupling (or fragmentation) of activities in time and space, which is fuelled mostly by modern-day ICTs, so that daily activity patterns change drastically. This type of change could obviously have a major impact on for example the amount of trips or average distance per trip. Quantitative research on this subject that might provide additional insights in how these mechanisms are changing mobility patterns is still limited. The challenges for performing such research in the future are large considering the described complexity of the ICT and mobility landscape and the high quality and detailed data that is required for such research.

ICT and mode choice

The fact that travel demand, mode and route choice are all interconnected is well-known and commonly agreed upon in literature. As a result ICT might influence mode choice indirectly by the influence on travel demand or route choice. This is, for instance, the case if tele-working reduces the amount of commuter trips, so that an individual might decide to prefer to make the trips that are left by train instead of by car. Also the impact of ICTs on the fragmentation of activities might result in different modality preferences for individuals. Statistically researching the decision of individuals to travel by a particular mode as a separate aspect of mobility is however still common practice.

The factors that are traditionally considered when modelling mode choice may be classified into four groups; characteristics of the trip maker (e.g. age, income, household structure), characteristics of the trip (e.g. trip purpose, time of day, travel time, cost), built environment or spatial characteristics (e.g. land use diversity, infrastructure design, distance to transit) and personal preferences and attitudes (e.g. perception of travel comfort with public transport). A full mode choice model will include variables in all of the four categories, but often because of various limitations only variables from one, two or three of the categories are considered. Research that considers only ICT related variables to explain variation in mode choice or that includes a combination of traditional and ICT related variables in either one of those categories is extremely limited. Moreover, literature that considers ICT related variables that represent the current possibilities like access to high speed mobile Internet or the possession of a smartphone remains completely unknown to the author.

Data description and limitations

For this research, the first wave of the Dutch Mobility Panel (MPN) was available, which was collected in the autumn of 2013. In total the MPN data set contains 6126 respondents, 3572 households and around 40.000 registered trips. The mobility diary data set only contains the individuals that both completed the personal survey and the full three day mobility diary, which are 3996 individuals divided over 2475 households. Every year additional questions are added to the personal questionnaire about a special topic. In 2013 and 2015 this special topic will be the relation between ICT-use and travel behaviour, in 2014 and 2016 it will be attitudes and behaviour towards different transport modes.

For the main analysis, four samples were selected from the complete MPN dataset. The first sample (n=6126) is used to explore the variance of the ICT related variables in context of personal characteristics and includes only data which was collected via the personal and household questionnaire. The second sample (n=3904) is used to determine and analyse the variance in travel amounts in context of peoples Internet use for the total population for which both the questionnaire and mobility diary data was required. Sample three (n=1938) is then used to analyse the variance in work related travel amounts in context of working over distance (tele-working) including only the working population. The last sample, sample four (n=971) is used to analyse mode choice for long-distance home-work trips.

In these samples a variety of personal (gender, age, income, education level, work situation) household (household structure, number of cars in household, urban density at housing location), mobility (stated dominant and stated preferred modality for home-work trips and three day mobility information including distance, cost, purpose, mode choice) and ICT related (Internet access via LAN, WLAN, 3G/4G, Internet use measured in days per week and hours per day, frequency of working over distance via the Internet and smartphone and tablet possession) variables are used.

Unfortunately, no specific separation is made between fixed ('at-home') and mobile Internet use in the data. Furthermore, it is acknowledged that the definition of 'Internet use' is ambiguous and hard to measure or remember for respondents. Also the terminology smartphone and tablet aren't able to represent the variety of devices that is currently available. As in any qualitative research, it is important to interpret any results in context of these characteristic of the dataset, the limitations of specific variables and the chosen approach to process and manipulate the data.

Results and reflection

Internet access, Internet use, frequencies of working over distance via the Internet, smartphone possession and tablet possession are all varying strongly in context of an individual's personal characteristics. Age was expected and proves to be an important factor behind the variation in ICT use and possession. The variation is also noticeable when shown over a person's (work) occupation, highest completed education, household composition or urban density at housing location amongst other variables. The high variation in both ICT and other (for example socio-demographic) characteristics of individuals make it difficult to point out specific profiles of users. Nowadays, younger individuals and elderly, students and incapacitated individuals show both high and low amounts of Internet access, Internet use and smartphone and tablet possession. This makes it difficult to control for the context when researching the effect of ICT on mobility.

The amount of travel of the total population is significantly different (measured in the number of trips per day and distance per trip) when averaged and compared over groups with low, medium and high Internet use in hours per day. The group with high amounts of Internet use compared to the group with low use make on average 0.5 trips less per day, while the average distance per trip has increased just a bit less than 5 kilometres. The specific and complex character of the variation in the total amount of travel became clear when considering age and the work situation of respondents in combination with their Internet use. Looking specifically at the variation in leisure and shopping related travel, it was observed that only the average amount of trips per day is significantly different. The average travel distance per trip varies slightly but the means aren't significantly different. A possible explanation for the observed variation might be again that the use of ICTs allows individuals to travel less, for example because we become more efficient in combining activities.

Looking at the commuter amount of travel of the working population, considering two indicators of tele-working, it is shown that the direct relation of tele-working from home (first indicator of tele-working) and the amount of travel is clearly present and results in significant different average number of trips per day. This direct relation seems obvious and is confirmed in the results in this research. When travel amounts are calculated and compared in context of the second indicator of tele-working (working over distance via the Internet independent of location) the results vary. Not the number of trips but only the average distance per trip varies significantly over groups with incidental, weekly or daily use of the Internet for the purpose of working over distance.

Looking at the stated behavioural changes or preferences of individuals, it was expected that the impact of ICTs on mode choice for example via the possibility to work during a trip is minor. This is confirmed by the results of the estimated models. The most comprehensive model was able to explain 84.6% of the variation in mode choice between car and train for long-distance home-work trips. The included ICT related variables were only able to explain 0.9% of the variance in mode choice, which was determined by eliminating the ICT related variables from the full model and comparing their explanatory strengths. Among the other sub-models with specific blocks of explanatory variables; trip characteristics (distance, travel time and travel cost) and modality preferences are showing the most explanatory strength, which seems realistic when looking at conclusions from other literature.

Tablet possession is one ICT related explanatory variable that is significant in all models. Tablet possession increases the change of a person choosing the car if included as a single predictor variable, while increasing the change of a person choosing the train when combined with the access to 4G. Additional research is needed to extend the analysis presented in this research in-depth, for example to explore the inclusion of interaction terms in the full mode choice model or to explore varying (categorizations of) ICT related variables.

Conclusions and recommendations

The objective of contributing to the understanding of the relation between ICT and mobility is not entirely met. Because of the characteristics of the available data, the chosen approach and the limited amount of time for this research, the author is unable to formulate any hard evidence for specific impacts of ICT on the amount of travel and mode choice. The fact that ICT has the potential to change mobility patterns is however confirmed and empirical and statistical results provide support for future research on the matter. With the recent scientific literature being so limited on the described relations, insights from this research in the advantages and disadvantages of the used method suggest the importance of a strong delineation for any research on the relation between ICT and mobility in order to limit the complexity of both the considered framework of relations and the context the relations are located in.

The results have shown that strong variations in travel amounts are present when the number of trips per day and travel distance per trip are analysed over groups with similar Internet use and tele-working frequencies. On average the group of respondents with higher amounts of Internet use or frequencies of tele-working make less trips per day, but make those trips over a larger distance. This trend could be the result of many factors, including modern-day possibilities to change activity, travel and communication patterns through ICTs.

The impact of ICT on mode choice is researched statistically but showed to be weak when analysed via the method that is used in this research. Furthermore, it can be concluded that the relation between ICTs and mode choice can be very different for different type of people, which supports the expectation that the relation is not only very complex but also extremely diverse at the disaggregated level.

Finally it has to be said that researching the relation between ICT and mobility at the general level as was done in this research takes large amounts of time, effort and requires high quality, comprehensive and detailed data. Maybe, our scientific perception of the relation is a bit outdated and limited. It is debatable whether substitution, generation or modification effects can be seen separately from each other or that all these effects occur simultaneously and at random because the impacts of ICTs occur in much greater detail, with much higher levels of complexity and diversity and through key mechanisms like the decoupling of everyday activities, space and time. In the near future, we might be increasingly dependent on the support of information and communication technologies in order to fully and truly understand and comprehend the impact of those technologies on mobility and society as a whole.

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Wiebe

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CHAPTER 1. INTRODUCTION

This first chapter provides background information to the research followed by the motivation for performing this research and a strict delineation of mobility and ICT aspects. Then, the objective and main research question that contains the focus of this research is formulated. Sub-research questions are then introduced to operationalize the main research questions. Finally, a reading guide is provided which explains the structure of this document and helps the reader in finding specific parts that might be of particular interest.

1.1 BACKGROUND

The desire and need to understand, explain and predict travel (choice) behaviour dates back centuries and is widely shared throughout society. The difficulty is however that human travel behaviour doesn't follow a fixed pattern but is continuously changing. Causes for these changes can be found in various directions. Often they are the result of a certain change in someone's personal life (for example getting older or switching jobs) or the environment he or she is living in (for example a changing office location or increased fuel prices). The cause for a change in peoples choices related to travel can however also be as simple as a broken car in the morning that forces someone to travel via public transport (PT). The literature on changes that have (had) an impact on mobility patterns is extensive. An article from van Cranenburgh, Chorus, and van Wee (2012) provides one typology and overview of the literature related to substantial changes and their impact on mobility patterns. While in the paper from Cranenburgh et al, the authors focus mainly on global or national changes; it shows the diversity of possible changes in society clearly.

The birth of the twenty-first century was dominated by two powerful trends affecting most aspects of life and economic progress. The stronger trend is globalisation, supported and encouraged by the other trend, cheap and high-capacity telecommunications (Ortuzar & Willumsen, 2011). The combination of the two is changing the way we perceive and tackle many modern issues and as a result their influence in transport (planning) is evident.

The relationship between information and communications technologies (ICTs) and transportation has been discussed in the transportation literature for at least 40 years (Associates, 1983; Harkness, 1977; Memmott III, 1963). One of the first major ICT related developments (with a global impact) was the land-line phone. The relation between the land-line phone and transportation is also one of the first relations on the topic of ICTs and transportation that was being researched on a large scale. For a long time it was perceived (and hoped) by researchers and policy makers that ICTs like the landline phone would substitute for transportation completely and that it would solve pressing issues like congestion and the depletion of fossil fuels. In the past decades however, researchers found that the relation is much more complex (Mokhtarian, 1990, 2002; Oliver, 2014).

One of the main reasons that the relation between ICT and mobility has become even more complex is the rapid innovation of personal ICT related devices, services and applications in the past few years. The growing access to, quality and speed of (mobile) Internet, the growing range of devices like smartphone and tablets but also the numerous services and applications that have been developed are examples of the innovations that increase the possibility for individuals to use ICTs for whatever purpose is desired to fulfil at whatever location at any moment in time.

1.2 MOTIVATION

ICTs are expected to continuously have a noticeable impact on mobility patterns. With growing pressure on the planets resources, growing population among other threats to (the freedom to) travel, like congestion and hazardous emissions, the importance of understanding (future) changes is evident. Maybe now more than ever, information on the impact of the described changes is required for the development and implementation of effective and efficient policy, but also for the development of products and services that are vital to the survival of our planet, and society.

The fact that in recent years some major ICT related innovations were introduced to large shares of the (western) society, research on the current relation between characteristics of ICT use and their impact on mobility is limited. Not only the time to consider the new characteristics and possibilities of ICTs in research, but also the time to collect comprehensive data, which is required for empirical and statistical analysis on the subject has been limited. As a result, the knowledge on the impact of ICT on mobility is limited and the need for additional insights of high priority.

From their role as internal knowledge institute for the Dutch ministry of infrastructure and environment, their desire to keep evolving the understanding of travel (choice) behaviour and in a reaction to recent developments, the Netherlands institute for Transport Policy Analysis (KiM) initiated the Dutch mobility panel (MPN). This panel consists of a household survey, a personal survey and a three day mobility diary and contains the reaction of just above 6000 respondents in around 2000 households (with just under 4000 respondents with a complete personal survey, household survey and mobility diary), from which data will be collected in four consecutive years. The first data set, collected in the period from August to November 2013, is available for and will be used in this particular research.

1.3 DELINEATION OF THE RESEARCH

This research is about using disaggregated cross-section data collected via a personal and household survey and mobility diary to determine, analyse and assess the relation between and impact of ICTs on mobility. Both ICT and mobility in our current society are extremely versatile. Consequently, the relations that might work between them are extremely complex. In order to ensure that the research is feasible and with consideration of limited time and resources a strict delineation of the research is required in both the direction of mobility and ICT.

The general characteristics of the ICT related MPN data doesn't allow for specific mechanisms in the framework of ICT and mobility to be researched properly. The data is considered to suite a general exploration of possible relations best and therefore, this is the chosen approach for this research. This could results in a lack of direction and focus in this research and consequently a strict delineation is even more important. The delineation of the mobility and ICT side of the relation are presented next.

1.3.1 MOBILITY

On the mobility side of the relation, two important aspects of human travel that are of interest to not only researchers but also policy makers and certain businesses are the amount of travel and mode choice. The relevance of these aspects is obvious considering their strong link with land-use, environmental and economic impacts and the challenges our society currently faces. In this research, the focus is applied to analysing the impact of ICT on these two aspects of mobility. Despite the fact that there is also a relation present between route choice and mode choice, this relation isn't considered in this research. The relation between the amount of travel and mode doesn't take a central position in this research and is only considered briefly.

Two important factors that need to be taken into consideration when performing research related to modality decisions are the distance and purpose of a trip. Under the assumption that specific relations are present in the following trip segment, in order to limit the complexity of the research and in consideration of the limited time and resources, the decision is made to focus on long-distance home-work trips. Long-distance in this research means longer than 10 km, where the alternatives in the choice set for the analysis are the train and car. This type of trip is chosen mainly for the following reasons;

1. Scientific literature and knowledge on the impact of personal ICTs on the amount of travel and mode choice between car and train for long-distance commuter trips is limited.
2. With the selection of home-work trips over 10 km, the bicycle and urban public transport are (almost entirely) naturally eliminated from the choice set of alternative modalities for individuals.
3. The relation of ICT on mode choice is expected to be a relative complex one; therefore a simple mode choice set is preferred. The decision is made to focus on the decision between car and train to complete the selected long-distance trips because:
    a. the potential of ICT to change the utility of long-distance car and train trips.
    b. of the key role of Public Transport in transport policy, and
    c. the important role of the car in the Dutch national transport system.
4. Because of limited time and resources, other trip purposes than work (e.g. shopping, leisure) aren't considered in the analysis of mode choice. The decision to focus on trips for the purposes of work related activities is justified because of their important role in research, the (Dutch) transport system and their strong link with transport problems like (peak-hour) congestion.

1.3.2 ICT

The term 'information and communication technology' represents a wide variety of products and services. We can recognize and separate in-vehicle ICT, infrastructure related ICT and personal ICT but even these categories don't cover the full range of technologies. In this research the focus is on personal characteristics related to (the) ICT (use of individuals). This selection covers the most recent ICT related innovations like smartphones or high speed mobile Internet but doesn't include Intelligent Transport systems (including navigation systems) in this research.

Access to the Internet, Internet use, working over distance by using the Internet (tele-working), smartphone and tablet possession are mainly considered in this research. This delineation includes (stated) preferences and behavioural changes related to the selected ICT variables and mobility aspects. The decision to consider these specific variables is mainly related to the possibilities and limitations of the available data from the MPN dataset but also to an exploration of relevant literature prior to this research. How these variables represent the relevant factors on the ICT side of the relation exactly and how these factors are related to the amount of travel and mode choice is however unclear because the understanding (both empirically and statistically) of (the impact of) those factors is currently still limited.

1.4 OBJECTIVE

Based on an initial exploration of the data, relevant literature and the delineation of the research, the following research objective is defined:

Contribute to the understanding of the relation between personal ICTs and mobility by providing empirical and statistical insights in observed and calculated variations of relevant variables and expected relations between those variables by using the first wave of the Dutch Mobility Panel dataset.

In order to do so, the available data will be used mainly to determine and explore:

1. the variation in access to and use of Internet, possession of smartphones, tablets and the frequency of individuals to work over distance (tele-work).
2. the variation in aggregated travel amounts of homogeneous groups in context of their Internet use and tele-working frequencies.
3. the impact of Internet use, tele-working, smartphone possession and tablet possession on mode choice for long-distance home-work trips with use of a binary logit model.

1.5 RESEARCH QUESTIONS

For this research the following main research question is defined:

> *What is the net-effect of Internet use and tele-working on the amount of travel and what is the impact of Internet use, tele-working, smartphone and tablet possession on mode choice for long-distance home-work trips?*

In order to allow ourselves to find a satisfying answer in the limited available time and with the available resources, the main research question needs to be operationalized, which is done in the next section by formulating more specific sub-research questions (visualized in Figure 1.1).

1.5.1 SUB RESEARCH QUESTIONS

The following sub-research questions were formulated:

1. *How can we expect personal ICT use of individuals to influence the amount of travel and mode choice (for long-distance commuter trips) according to the available literature?*

First the relevant literature is explored, which provides critical information for this research for five specific reasons. The obtained information; (1) provides insight in the relevant relations between ICTs and the amount of travel and mode choice, (2) provides arguments for the selected ICT related variables, (3) helps to understand the limitations of those variables, (4) provides support for the way in which the relevant ICT related variables can be considered in the analysis, and (5) provides context for the interpretation of results from the analysis.

2. *What are the limitations of the used ICT variables from the MPN dataset for this research?*

After the selected samples from the MPN dataset are presented, the limitations of the selected ICT variables; *Internet access, Internet use, smartphone possession, tablet possession and tele-working,* for the purpose of the data analysis are elaborated on.

3. *How do Interne use, tele-working frequencies, smartphone possession and tablet possession differ in context of the socio-demographic, household and mobility characteristics of an individual?*

The selected ICT variables in the MPN data set are explored empirically in order to improve our understanding of their variation and possible relations that might work between them.

4. *How do the personal (socio-demographic, household and mobility) characteristics and the possession of a smartphone and/or tablet of individuals affect their amount of Internet use and frequency of tele-working?*

Regression analysis is used to explore, and improve our understanding of, the drivers behind the observed variation in Internet use and frequencies of tele-working.

5. *How does the total, shopping and leisure related amount of travel vary in context of Internet use and how does the commuting amount of travel of the working population vary in context of tele-working**?***

The variation in the averaged amount of travel is analysed over homogeneous groups with varying amounts of Internet use and tele-working frequencies. (Stated) behavioural changes variables related to ICT and travel amounts are used to provide context (for the interpretation of) (to) the results.

6. *What is the effect of Internet use, smartphone possession, tablet possession, and tele-working on mode choice decisions for long-distance home-work trips?*

The selected ICT variables are incorporated in a variety of discrete mode choice models (binomial logit) to analyse the decision of an individual between car and train to complete their long-distance home-work trips. (Stated) behavioural changes variables related to ICT and mode choice are used to provide context (for the interpretation of) (to) the results.

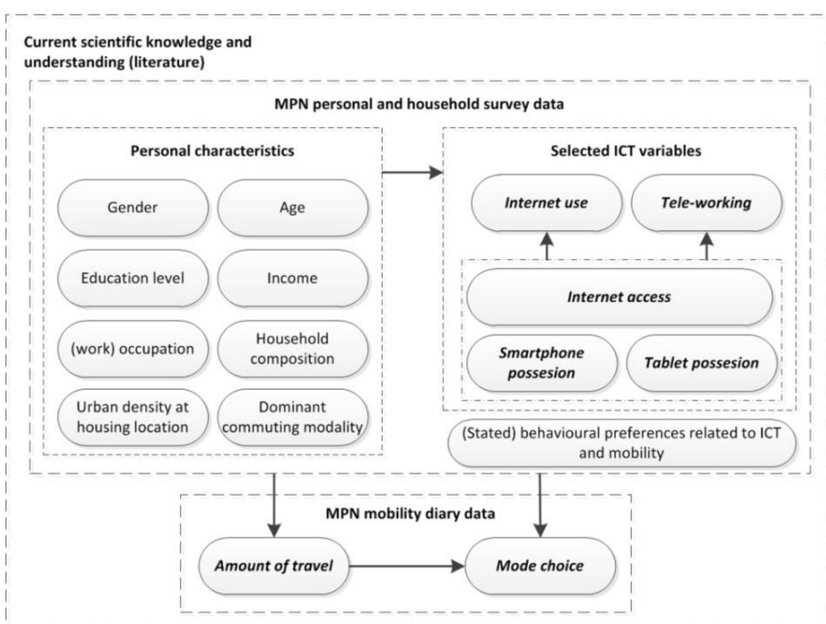


Figure 1.1: Visualization of the sub-research questions.

1.6 READING GUIDE

The thesis is divided in seven chapters with the final chapter containing the literature that is referred to and used in this research. The first chapter introduces the research and gives a description of the background of the research (section 1.1), motivation for the research (1.2), delineation of the mobility and ICT related aspects that are considered in this research (1.3), the objective of the research (1.4) and the main and sub-research questions (1.5).

Then in chapter 2 an overview of the current knowledge that is relevant to this research is provided. First travel demand is considered as a separate important aspect of mobility (2.1) with special attention for activity based approaches, the key position of work related trips (in trip tours) and a conceptual decision framework for urban travel and daily activity patterns. Then relevant information on mode choice from literature is presented (2.2), including an overview of factors influencing mode choice, a brief consideration of mode choice specifically for long-distance commuter trips after which a conceptual model for the factors influencing mode choice is presented. Theoretical and practical insights on information and communication technologies are presented next in order to provide the reader with an overview of modern-day characteristics of personal ICTs (2.3). In section 2.4, relevant information from literature on the relation between ICTs and mobility is presented with specific attention to the relation between ICT and the amount of travel (2.4.1) and ICT and mode choice (2.4.2). Finally, in section 2.5 a reflection on the presented theoretical information is provided and integrated with the relations of interest in this research.

In chapter 3 the data that was used to perform the empirical and statistical analysis in this research are presented. The MPN dataset is briefly introduced after which a description of the personal and household questionnaire is provided (3.1), the selected samples for various aspects of the analysis are introduced (3.2), limitations of the data are formulated (3.3), the required manner in which data is processed is elaborated on (3.4) including a brief introduction of the statistical methods that were used in this research (3.4.6).

Chapter 4 then gives the results of the performed analysis in four sections. At the end of all of the four sections a brief reflection on the results is provided. Also at section 4.3 and 4.4, first an insight is provided in stated behavioural changes by showing the answers of a selection of MPN respondents on specific questions related to both ICT and the amount of travel and ICT and mode choice.

Section 4.1 then presents the variation in ICT and personal characteristics of the dataset with special consideration of Internet access, Internet use, tele-working frequencies and smartphone and tablet possession. Then in section 4.2 the results of a simple logistic regression model with Internet use and tele-working frequencies as outcome variables are presented. This analysis aims to provide some insight in the explanatory variables of Internet use and tele-working frequencies so that further understanding of the drivers behind the variation can be obtained. In section 4.3 then the results of an analysis of the variation of travel amounts, measured in the number of trips per day, average travel distance per day and average distance per trip are shown in context of Internet use (4.3.1) and tele-working frequencies (4.3.2). First the total amount of travel is determined over low, medium and high internet use with an extension of the analysis over a combination of profiles with Internet use and age and Internet use and work situation of a person. Then the leisure and shopping related amount are analysed over Internet use. Finally the variation in the amount of work-related travel is shown over two different indicators of tele-working frequencies. The results of multiple binomial logistic models for the choice between car and train for long-distance home-work trips are presented. Both a full choice model, with consideration of numerous explanatory variables, sub-models with specific blocks of explanatory variables, sub-models for two age groups, a model with the amount of travel and three models with socio-demographic and ICT related interaction terms are provided.

Chapter 5 presents a discussion of the results in consideration of the presented literature in chapter 2. This chapter is an important part to read for researchers who are planning on attempts to research the relation of ICT and the amount of travel, ICT and mode choice or maybe even ICT and mobility in general. Subsequently, the variation in ICT access, possession and use (5.1), ICT and the amount of travel (5.2) and ICT and mode choice (5.3) are elaborated on.

In chapter 6 conclusions which aim to answer the research question are formulated after which a reflection on the limitations of this research, both related to ICT data (6.2.1) and the chosen method (6.2.2), finally in this chapter recommendations are formulated for both researchers (6.3.1) and policy makers (6.3.2). The figure below presents a visualisation of the thesis structure with the location where answers to the sub-research questions and the description of other aspects of the research like the MPN dataset or the selected samples can be found.

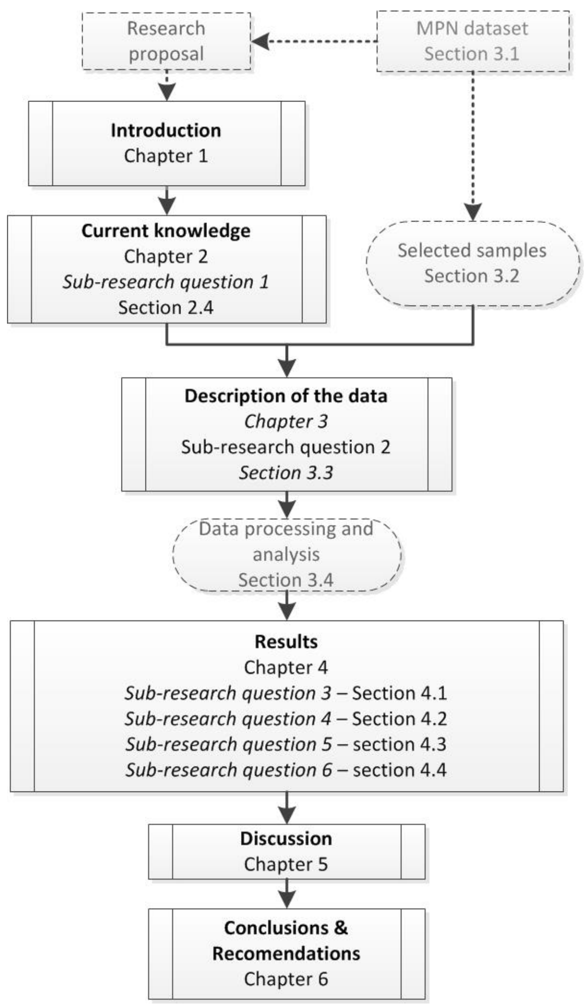


Figure 1.2: Visualization of the thesis build-up.

CHAPTER 2. CURRENT KNOWLEDGE FROM LITERATURE

Before considering the impact of ICTs on the amount of travel and mode choice, understanding of the separate aspects and the present relations and factors is required. In this chapter after the introduction of knowledge from literature on travel amounts (travel demand) and mode choice, an introduction of ICTs in our modern day society is presented. Then, the relevant knowledge from available literature on the possible relations of ICTs with the amount of travel and mode choice is presented.

2.1 TRAVEL DEMAND

The demand for transport is derived, it is not an end in itself (Ortuzar & Willumsen, 2011). People mostly travel in order to satisfy their needs at particular locations which can be related to various purposes (mandatory; work, or optional; shopping, leisure). In order to understand the demand for transport, we must understand the way in which these activities are distributed over space, where in this research the focus is on long-distance (mostly inter-urban) trips between activities.

2.1.1 TRIP-BASED APPROACH

One of the best known models in transportation modelling is the classic four-stage transport model (Ortuzar & Willumsen, 2011). This model uses a trip-based approach in which individual trips are used as the unit of analysis and usually includes four sequential steps; trip generation, trip distribution, modal split and assignment. The first, trip generation, step involves the estimation of the number of home-based and non-home based person-trips produced from, and attracted to, each zone in the study area. The second, trip distribution, step determines the number of trips from each zone to each other zone. The third, mode choice, step splits the person-trips between each pair of zones by travel mode obtaining both the number of vehicle trips and number of transit trips between zones. The fourth, assignment, step assigns the vehicle trips to the roadway network to obtain link volumes, travel distances and travel times and the person trips to the transit network.

As Bhat and Koppelman (2003) correctly point out, there are however major limitations to this aggregated approach. One limitation is the separate modelling of home-based and non-home based trips, without consideration of dependence among such trips. Other important limitations is the lack of considering trips as part of a tour (linked trips) nor the time of day a trip is completed. The behavioural inadequacy of the trip-based approach has led to the emergence of the activity-based approach to demand analysis.

2.1.2 ACTIVITY BASED APPROACH

Trips are in essence generated by the need or desire to participate in activities that are divided by space. Activity based travel demand models acknowledge travel as a derived demand. The conceptual appeal of this approach originates from the realization that the need and desire to participate in activities is more basic than the travel that some of these participations may entail. The activity based approach shares some similarities with the traditional four-step models – activities are generated, destinations for the activities are identified, travel modes are determined and, finally, the specific network facilities or routes used for each trip are predicted.

However, activity based models incorporate some significant advancements over four-step trip based models, such as the explicit representation of realistic constraints of time and space as well as the linkages amongst activities and travel both for an individual person as well as across multiple person in a household (Castiglione, Bradley, & Gliebe, 2014).

This approach also allows for further expansion of behavioural theories related to activity schedules. Ben-Akiva, Bowman, and Gopinath (1995) state that these behavioural theories of activity and travel patterns can be classified into two stages: (1) activity time allocation, and (2) activity distribution in time and space. In the first stage, an individual selects an activity program, i.e. an allocation of available time among feasible activities. In the second stage, an individual selects a specific path in time and space (an activity schedule) to perform the activity program. Household structure, temporal, spatial and institutional opportunities and constraints determine the feasible activity schedules.

The key factors affecting activity schedules and related travel patterns are (Ben-Akiva et al., 1995):

- Socio-economic characteristics of the individuals, including income, life cycle, household structure and role, occupation;
- Spatial opportunities including the variations of feasible activities over the time of the day; and
- Temporal opportunities including the variations of feasible activities over the time of the day; and
- Distribution of travel level of service characteristics among residential and employment locations by different modes of travel and times of day.

Related to the proposed importance to consider activity schedules in demand modelling is the inclusion of a timeframe. This is for example proposed in the article from Bowman (1995), who considers a daily timeframe of activity schedules for three reasons as is stated in the article;

- By extending the temporal scope of decision making beyond a trip or a tour, a daily representation can capture very important interactions which affect the choice of time of day, location and mode.
- It is a human experience to operate on a daily cycle with a daily return to a home place for an extended period of rest. Associated with this daily cycle or rest and activity, activities are often planned on a daily basis.
- Many activities, most notably the work activity, occur in a daily routine.

While modelling of such complex decision making processes related to travel remains imperfect, it provides a good qualitative base for understanding how travel is generated and decision are made within the patterns of daily travel.

2.1.3 THE KEY POSITION OF WORK RELATED TRIPS

Both in the trip-based approach and the activity-based approach it is acknowledged that the purpose of a trip is extremely important to take into account. Often a key distinction is made between choices related to work-trips and the choices of non-work travel patterns. In the trip-based approach this is reflected by an estimation of home-based non-work trips (HBO) and non-home-based trips (NHB) conditional on the outcome of work trip models.

Also in the more complex tour based models (Daly, van Zwam, & van der Valk, 1983; Gunn, A.I.J.M., & Daly, 1987), in which shorter trips may be explained as links in one longer tour, the importance of work related trips is acknowledged. The grouping of trips in this modelling approach is based on the view that all travel can be viewed in terms of round-trip journeys based at the home. Within the destinations that form a round-trip it is natural to assume some ranking of importance (Bowman, 1995).

With the behavioural hypotheses that travellers make choices about less important activities in a tour conditional on decisions about more important activities in the tour, Weisbrod and Daly (1979)and Antonisse, Daly, and Gunn (1986) examined the raking of destinations which led to an a priori recognition of the dominance of working as an activity. The primary destination is the destination highest in the following ranking:

1. Usual (fixed) workplace
2. Other work-related destinations; and
3. The non-work destination with the longest activity time.

2.1.4 DECISION FRAMEWORK AND DAILY ACTIVITY PATTERN

Figure 2.1 shows the overall framework of the decisions relevant to urban travel demand (on the left), depicting the important decision categories and their interaction (Ben-Akiva et al., 1995; Ben-Akiva & Lerman, 1985). The general steps can however also help to understand decisions making (and thereby the possible impact of ICTs) in a more regional context. Each category of individual or household choices falls into a distinct category of decision making. As for mobility and lifestyle decisions, such as residential location or car ownership, occur at irregular and infrequent intervals in a timeframe of years. Activity and travel scheduling is a planning function which occurs at more frequent and regular intervals such as days. Rescheduling occurs on the shortest timeframe, within the day, as activities are carried out, in response to information which prompts changes to the planned activity travel schedule. The left side of the figure below shows the conceptual design for the daily activity schedule with consideration of key components like the primary activity and primary and secondary tours (Bowman, 1995).

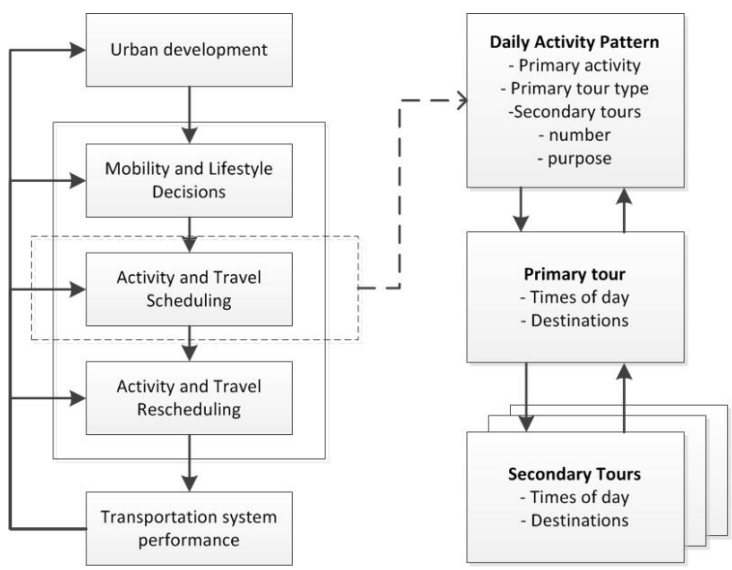


Figure 2.1: Decision framework and conceptual daily activity pattern

2.2 MODE CHOICE

The choice of transport mode is probably one of the most important classic model stages in transport planning because of the implications of particular modes on land use and the environment plus the key position of public transport in policy. Public transport is by far the most efficient in the use of road space besides producing fewer accidents and emissions than using a private car. On long-distance trips for the purpose of work, the tension between car and public transport takes a central position.

While mode choice is in reality strongly linked to trip generation (including considerations as the importance of tours in the previous section), trip distribution, route choice and other aspects of mobility, analysing mode choice as a stand-alone decision for single (one-way) trips for a particular purpose is very common practice.

2.2.1 FACTORS INFLUENCING MODE CHOICE

The factors that are traditionally considered when modelling mode choice may be classified into three groups (Ortuzar & Willumsen, 2011); characteristics of the trip maker, the trip and the built environment variables describing the characteristics of the spatial and transport infrastructure, e.g. grouped by the 5D's (5D's are density, design, diversity, distance to public transport and destination access - for an overview of transport (Ewing & Cervero, 2010)). More recently in literature the importance of another fourth category is acknowledged more and more, being the preferences and attitudes of an individual. Preferences and attitudes are defined as behavioural predispositions characterized by a certain travel mode or set of travel modes that an individual habitually uses (Vij, Carrel, & Walker, 2013).

1. Characteristics of the trip maker, for example;
    - Age, car availability/ownership or household structure.
2. Characteristics of the trip, for example;
    - The trip purpose, time of the day, travel time (in-vehicle, waiting time etc.), travel cost.
3. Built environment variables describing the characteristics of the spatial context;
    - Density, land use diversity, infrastructure design, destination accessibility and distance to transit.
4. Preferences and attitudes;
    - Related to the preferences, attitudes and habits of individuals.

All categories can be specified into great detail, but the fourth category is however in particular a difficult one because of the difficulty to measure preferences and attitudes and the many levels on which preferences, attitudes and habits can influence decisions both long-term (buying a car) or short term (mode choice). Jensen (2007) examines lifestyle from the social sciences perspective, and argues that it needs to be understood on four different levels, form a global to an individual lifestyle. The described variety in research is presented clearly in a recent article from Olde Kalter, Geurs, Hoogendoorn-Lanser, and Beek (2014). In this article a table is presented that contains per article both the considered trip purpose, the used (type of) data, the model specification and the specific variables that were considered. It becomes clear that the majority of researches don't consider variables in all of the four categories, not only but also because of including all four categories puts high demands on the collected data.

2.2.2 MODE CHOICE FOR LONG-DISTANCE COMMUTER TRIPS

In this research the mode choice experiment is limited to a trip set that considers only long distance commuter trips, being longer than 10 km. The distance component limits the set of alternative modalities that individuals can choose to complete their trips. In this research the selected alternatives are the car and train, which in the Netherlands are the dominant modalities to complete long-distance commuter trips (for more information on mobility in the Netherlands see: (Ministry of Infrastructure and the environment, 2013)).

The focus on commuting behaviour is present in a large share of the mode choice related literature. The common decision to focus on commuting behaviour is also recognized in the mentioned overview that Olde Kalter, Geurs, et al. (2014)presented in there article. Literature on the decision between car and train is also widely available, which is partly the result of the key position of public transport in policy making but also because of the transport related issues like congestion that are strongly linked to work related (peak) travel by car.

If the purpose and choice set of a trip changes, the characteristics of determinants of mode choice also change. If for example the decision between cycling and the bus (tram/metro) is analysed, it is considered important to include the quality of bicycle infrastructure as a variable, but if the decision between the car and train is analysed, the travel distance to a highway entrance is considered more important. This variation in characteristics of the included factors is different and important to consider per mode choice experiment.

2.2.3 CONCEPTUAL MODEL

The conceptual model below presents the four clusters of factors related to mode choice with examples of specific factors that are related to mode choice decisions.

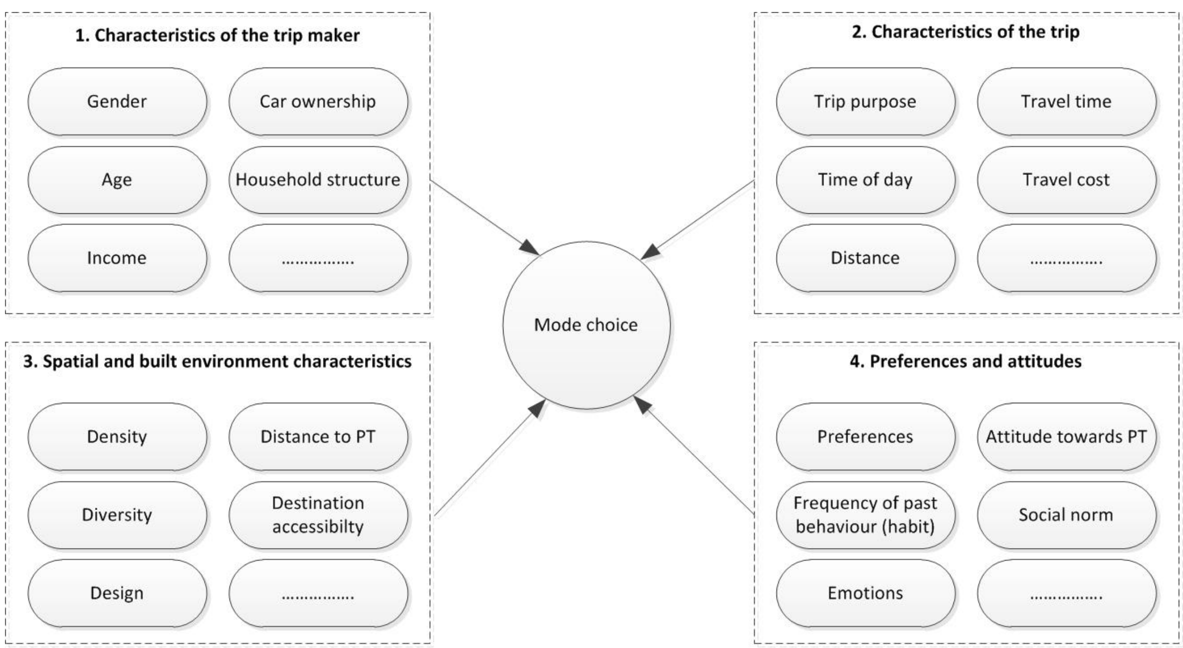


Figure 2.2: Conceptual model of mode choice and explanatory clusters.

2.3 INFORMATION AND COMMUNICATION TECHNOLOGY

The words, information and communication technology, represent the full range of integrated information technologies and telecommunications (telephone and wireless signals), computers as well as necessary software, middleware, storage and audio-visual systems, which enable users to access store, transmit and manipulate information. The products (devices) and services related to ICT have developed rapidly over the past decades. If we compare the possibilities of ten years ago to present day it often boggles believe how fast the sector has developed. In this section, as mentioned in the delineation of the research, the focus is on 'personal' ICTs.

In the authors perception two important trends of the past decades are the individualization of and increased mobile access to ICTs. These trends can easily be understood when comparing the land-line phone and the home-computer to the modern-day smartphone. Were in the past the land-line phone and the home-computer were available in the house of an individual and often used by all members of a household, smartphones are owned by individuals, often used only by themselves while the actual use has become (almost completely) unrestricted by time, space and purpose.

2.3.1 MOBILE ICTS; DEVICES AND SERVICES

The current range of devices that provide individuals with mobile access to ICT related services is rather extreme. Laptops, tablets, phablets and smartphones are available in all price categories, from under a hundred euro's to far over a thousand euro's. With the price obviously the quality changes, but nowadays even the cheapest products provide extensive possibilities and relatively high quality. In essence products are more and more designed for specific purposes, with larger screens so that work can be done more easily, with high computing powers so that people can play heavy games, or with as much computing power as possible in a small device so that people can carry that device around and use it every day.

Both fixed and mobile devices provide users with access to numerous services, from which the Internet is currently probably the most widely used. The Dutch institute 'Statistic Netherlands' measured in 2012 that 94% of the Dutch households had access to an Internet connection at home and that in 2011 87% of the Dutch Internet users went online (almost) every day, while in 2005 this was only 68%. Moreover, in 2011 already 60% of the Internet users had mobile access via a laptop (33%), smartphone (47%) or tablet (19%).

Internet can be used to access or share information amongst numerous other purposes but can also be used to improve the connectivity or possibilities of applications specifically designed for a designated purpose. Currently, mobile Internet is perhaps one of the few technologies that come close to emulating the success of the fixed Internet (Fuksa, 2013). Backed by the entire telecommunication industry, coupled with the fact that it combines two of the hottest innovations in recent times (mobile phone and the Internet), mobile Internet is poised in the past few years to succeed the fixed Internet as the next big thing (Jiang, 2009).

2.3.2 APPLICATIONS

With the improved quality of mobile devices and mobile services like the Internet, also the range of possible applications by using a particular combination of devices and services has increased dramatically and often unrestricted by time or place. More and more applications are being developed that can be used for a specific purpose on a specific device with a specific operating system. Without going into technical details, the enormous variety of applications that are most commonly accessed via mobile devices like smartphones or tablets via mobile Internet (either WiFi or 3G/4G) is easily understood if one considers the number of applications for the two dominant operating systems being, android and iOS with respectively 1.3 and 1.2 million available applications for downloading and personal use in their designated online markets (Statista, 2014).

Furthermore, individuals can use any combination of ICT related devices and services like a smartphone and mobile Internet for an extreme range of diverse applications. One application that is of particular interest to researchers in previous decades is tele-working. In literature different terms and definitions of tele-working are recognized, tele-working and e-working are the most common ones. The definitions are often differing in the inclusion or exclusion of work related activities at different locations. People can tele-work from home, but because of the state of the art ICTs are currently more and more possible to 'tele-work' independent of time and space.

Mokhtarian and Salomon (1996b) discuss various approaches in measuring the dependent variable in the context of teleworking. Such measurements can be binary: e.g. 'would/would not like to telework'; or 'does/does not telework'. However other research has adopted discrete measures using ordered data (e.g. (Popuri & Bhat, 2003; Walls, Safirova, & Jiang, 2006)) in which it is also stressed that information on telework frequency captured using a diary instrument and reference week is a more precise and therefore reliable measure of behaviour than that of asking people to recall amounts of teleworking retrospectively (e.g. for the last month).

2.3.3 ADAPTATION

In literature, if ICT is considered as a stand-alone phenomenon, the focus in recent years is often on the adaptation of specific state-of-the-art devices and services like the smartphone or mobile Internet (Bouwman, Carlsson, Molina-Castillo, & Walden, 2007; Fuksa, 2013; Shin, 2007; Verkasalo, López-Nicolás, Molina-Castillo, & Bouwman, 2010). Complex models like the UTAUT and UTAUT2 are used in the presented literature to assess the adaptation of technology in which determinants like performance and effort expectancy are described but also the importance of moderators of the key relationships are mentioned like age and gender.

2.4 ICT AND MOBILITY

Identifying the full range of possible relations between all of the aspects these terms represent is an enormous, maybe even impossible task. In an attempt to understand the impact of telecommunications on transportation, Mokhtarian (1990) described three forms of communication, which in the broadest sense; all require their own 'type of transportation':

- Transportation of people, to meet face-to-face (or within earshot);
- Transportation of objects, such as letters, books, newspapers, usb-sticks and so, and;
- Transportation of electronic impulses, either in the form of electrical current along copper wires, coaxial cable, or optical fibre, or in the form of radio waves through the air.

These three types of communications as well as their transportation modes are all partly interchangeable. The trend of autonomous growth is however also introduced by Mokhtarian (1990), which is important to consider. The trend of autonomous growth in essence means that digital communications might replace part of the 'face-to-face' and written communication but that in time the overall sum of the three types of communications will increase (Figure 2.3).

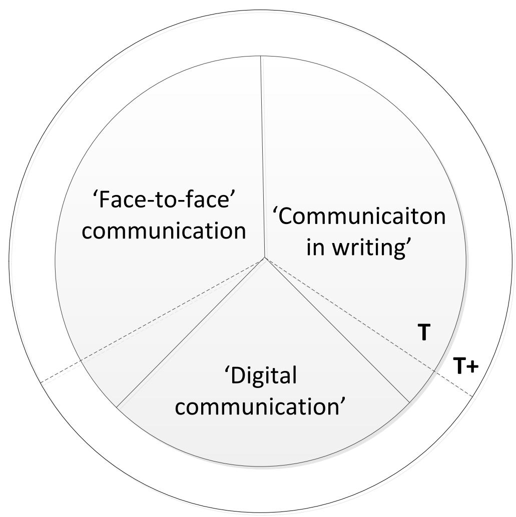


Figure 2.3: Autonomous growth of communication

Based on this interchange ability a number of relationships are possible between physical travel and telecommunications. The literature (Mokhtarian, 2002; Salomon, 1986) described four possible effects of telecommunications (from here under the term ICT) on transportation:

1. Substitution-effect: where ICT replaces (part of) a trip (for example Teleworking or Internet shopping);
2. Generation-effect: where ICT use leads to new travel (receiving a discount coupon via email initiating a trip to the store);
3. Modification-effect: where ICT use leads to an adjustment (change) in travel (for example departure time or mode choice) without stimulating or eliminating travel, or a;
4. Neutral-effect: where ICT use has no impact on travel.

Despite the fact that ICT and transportation have developed drastically over the past decades, the described categorization of effects is still relevant and used in research present-day (Mokhtarian, 2002; Oliver, 2014).

In addition, Schwanen, Dijst, and Kwan (2008) point out that in the literature, (Bouwman et al., 2007). This is, for instance, the case when tele-working is proposed as a solution that helps to lower road congestion. Without any meaning of negating substitution and generation mechanisms, it is pointed out in this article that attention to other sorts of interactions between the electronic and the physical world fades to the background.

Furthermore, in this article, three points of departure for understanding how ICTs mediate everyday life are presented;

- The interweaving of 'real' and digital space-times should be put up front,
- Technological determinism is to be avoided, and
- Effects cannot be separated from the contexts in which they are situated.

These nuances however don't mean that specific research isn't useful, it simply points out that research (results and conclusions) on interactions between the digital and physical world should be executed and interpreted with great caution.

2.4.1 ICT AND THE AMOUNT OF TRAVEL

The substitute and generation effect of ICT on transportation in essence mean that the amount of travel that is generated is reduced or increased. The net-difference over a certain period of time can be analysed at the aggregate level (Day, 1973; Graham & Marvin, 1996), or at the disaggregate (individual) level (Johansson, 1999; Zumkeller, 1996). In a disaggregated analysis, the changes in individual behaviour are analysed. In a aggregated analysis, groups of observations might be replaced with summary statistics based on those observations, for example when the average amount of travel is calculated of a particular group from the individual amount of travel of the respondents in that group are being used. The net-difference can then be the result of many different types of ICT use.

In consideration of the three points of departure as stated by Schwanen et al. (2008), beside the direct relation like between tele-working and commuter travel, also attention is given in this section to a more generalised understanding of the interaction between ICTs, activity schedules and as a result the amount of travel, often called the decoupling (or fragmentation) of activities in space and time.

2.4.1.1 TELE-WORKING AND THE AMOUNT OF TRAVEL

One specific ICT activity that has been linked to the amount of travel because of its direct implications is tele-working. Research on the impact of teleworking on the amount of travel are widely available and often consider elasticity's related to the trips per day, car trips per day for work, home and other purposes, total trips, total kilometres per week, total train trips per week et cetera. Examples are efforts from Pendayala, Konstandino et al. (1991), HGC 1992, Henderson and Mokhtarian (1996), Spittje (1999) and Hjorthol (2002). Martens, Korver, and Raspe (2002) for example predicted a small substitution effect by modelling estimations; between 0 and 5 per cent of the amount of kilometres is substituted by teleworking. A reduction in the kilometres travelled can be of significant influence because individuals with a large commuting distance are most likely to telework, as stated by (Ministerie van verkeer en waterstaat, 1992; van Reisen, 1997).

However, this effect is mitigated because of an increased amount of leisure and business trips. Consequently, the net effect is just 0.5 per cent maximum of the total amount of kilometres travelled. While this research calculated the net-effect per different periods of time, Pendyala, Konstandino, and Kitamura (1991) for example focused on the reduction in kilometres on teleworking days; conclusion were that the travelling in peak hours was reduced by 60 per cent, total travel distance reduced by 75 per cent and the amount of high way kilometres reduced by a whopping 90 per cent. Also in Martens et al. (2002) model estimations were used to assess the reduction in the number of trips, with similar results as for the substitution of kilometres travelled. van Reisen (1996) Found a reduction of 6 per cent of home-work trips but an increase in private trips of 4 per cent.

Beside the positive substitution effect of tele-working on mobility, a negative effect described in literature is that of the rebound effect (Frondel, Peters, & Vance, 2007): teleworking can lead to households moving to locations farther from work because the acceptation border of 45 minutes commuting travel time increases if the trip has to be made less frequent. Finally a mitigation effect to the effect of teleworking might is that teleworking is most popular with people who were already very mobile (AVV, 1997). Spittje (1999) confirms this by identifying that on an annual base teleworkers spend more time travelling then non-teleworkers and make on top of this 23 per cent more car kilometres in favour of holiday trips.

2.4.1.2 DECOUPLING OF EVERYDAY ACTIVITIES, SPACE AND TIME

As mentioned before, travel is seen as a derived demand from the participation in activities that are divided by space. It is commonly believed that, due to developments in ICTs, ''professional and social relations can be established and maintained almost equally easily over any distance across the globe'' as stated by Couclelis (1996). As a consequence, activities seem to be getting less firmly linked to fixed spatial locations and times which might be manifested in the fragmentation of activities into tasks that are widely distributed over space and across time (Couclelis, 2000; Dijst, 2004). This can obviously has its effects on not only the amount of travel, but all aspects of modern day mobility. This so-called 'activity-fragmentation' in space and time facilitates the blurring of the boundaries between previously separated life-domains of work, care and leisure.

In the manuscript of Hubers (2013) on spatial-temporal fragmentation of everyday life the lack of empirical support for the propositions is acknowledged. Another reason for the limited amount of support for the concept of fragmentation is that the concept is intuitively sensible but difficult to grasp theoretically, methodologically and empirically. Moreover, the collection of the required specific, high quality and detailed data to research the actual fragmentation of activities is difficult, costly and time-consuming.

In another article from (Alexander, Hubers, Schwanen, Dijst, and Ettema (2011)), an attempt is made to develop indicators to assess the spatial and temporal fragmentation of activities. The explanatory factors related to the ICT use of individuals that are taken into account in this article are the possession of a personal digital assistant (PDA; predecessor of the smartphone), possession of a laptop and general Internet use (in the amount of hours per week). The results show that the indicators differentiate between the multiple facets of activity fragmentation (such as the number, dispersion, and configuration of fragments). The preliminary analyses also suggest that, although the temporal fragmentation of activities appears to be or have become more common, spatial activity fragmentation is rather limited.

2.4.2 ICT AND MODE CHOICE

The fact that travel demand, mode and route choice are all interconnected is well-known. As a result ICT might influence mode choice indirectly by the influence on travel demand or route choice. This is, for instance, the case if tele-working reduces the amount of commuter trips, so that an individual might decide to prefer to make the trips that are left by train instead of by car. Also the impact of ICTs on the fragmentation of activities might result in different modality preferences for individuals (see for example (Lenz & Nobis, 2007)).

The focus in this research is on the impact of individual ICT use on mode choice. If we consider the conceptual model from section 2.2.3, Figure 2.2, we see a similarity in two clusters; the trip maker characteristics and preferences and attitudes, which are person-bounded instead of bounded to the actual trip, spatial or built environment context. The impact of ICT on the spatial and built environment characteristics or trip characteristics is located outside the scope of this research.

Research that considers ICT related variables as characteristics of individuals (either as fixed attributes or as preferences or attitudes) is extremely limited. Only an article of Olde Kalter, Geurs, et al. (2014) is known to the author, in which the MPN dataset is used to estimate an discrete choice model for home-based work trips while including factors related to ICT use amongst others. The considered ICT variables were weekly vs non-weekly use of Internet for the purpose of emailing, e-conferencing and tele-working. The choice set consisted of the car, train and bicycle. No significant effects of the ICT related variables were found.

Another impact of individual ICT use on mode choice might occur considering the increasing possibilities because of ICT related services and products to use travel time more efficiently. In this direction, the constant availability of up-to-date travel information to individuals independent of their location might also influence mode choice, for example because people perceive the required planning of train trips less of a drawback.

2.4.2.1 ICT AND TRAVEL TIME USE

Even before ICTs were available people were already looking to use their travel times as efficient as possible, for example by reading books. Modern-day technology like smartphone and wireless Internet simply allow people to increase the efficiency and pleasure of working on the move (Golob & Regan, 2001). This is especially relevant for long-distance travel, were it is evident that travelling by train is more suitable for performing secondary activities during the trip than travelling by car (or plane). This is acknowledged in a report from Thalys-International (2012) where a survey pointed out that 90% of the respondents valued the productivity potential of travel time by train as very good while only 6% said the same about air travel time.

Some studies however don’t find that ICT-enabled activities on the move has impact on modal choice (Line, Jain, & Lyons, 2011). In this qualitative study no discrete choice models are used to estimate the extent to which ICT related factors might influence mode choice. In the mentioned studies, in-vehicle travel time is considered, a consideration of other aspects of travel time, waiting time, walking time or transfer time, might however be relevant because of the ability of modern day ICTs to work even if an individual is waiting on a platform. In this direction, transfer time might become even more annoying (interrupting work during a trip) to individuals while waiting, walking and travel time might become less annoying.

2.5 REFLECTION – RELATIONS OF INTEREST

It is clear from literature that ICTs can have an impact on travel demand and mode choice via multiple complex mechanisms. Empirical and statistical research on travel amounts and mode choice that includes modern ICT technologies is however limited for a number of reasons. This research contributes to the scientific knowledge by determining and analysing differences in travel amounts over homogeneous groups in context of their Internet use and frequency of tele-working and aims to include ICT related variables in a mode choice experiment specifically for long-distance commuter trips.

It is important to consider that the conceptual model related to travel demand only presents the location of the relations of interest in the presented decision framework and conceptual daily activity pattern. The conceptual model related to mode choice shows the actual location of ICT related variables in the clusters of determinants that are considered in this research.

2.5.1 ICT AND THE AMOUNT OF TRAVEL

ICT is continuously changing the urban development (being it on a slow paste) but on the individual level also has the ability to influence; our activity schedules (because of fragmentation of activities or tele-working amongst other), the relocation (or rescheduling) of our activity schedules (because of up-to-date information like delays or changing dinner times), but also our long term mobility and lifestyle decisions (because of changing travel time efficiency and as a result buying a train subscription for the commuter trip).

In the figure below, the relations of interest for this research are presented. We are interested in the variation of total daily travel in context of Internet use and the variation of the commuter travel in context of tele-working.

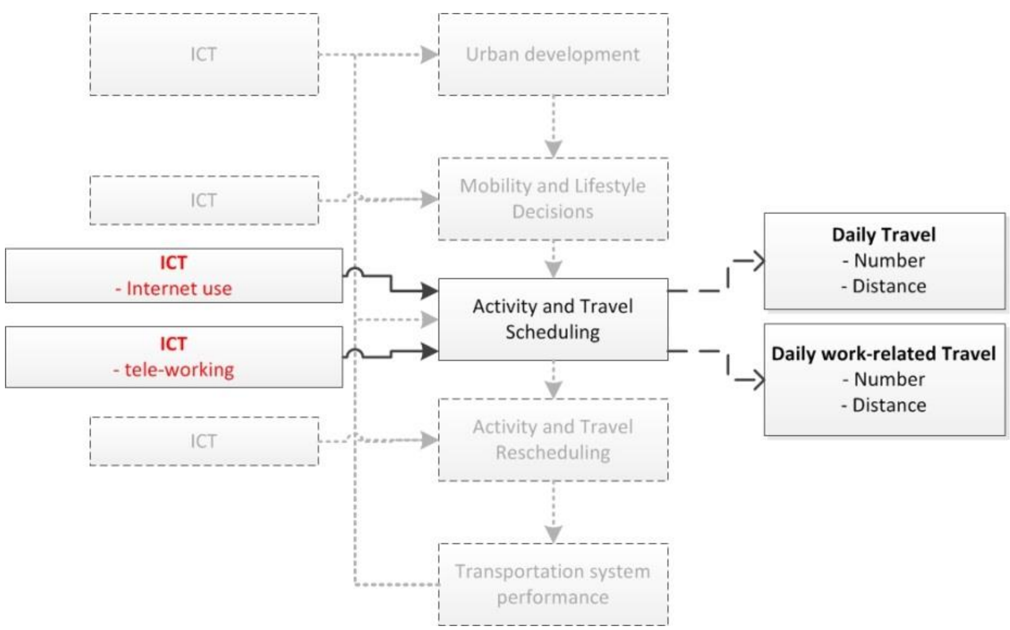


Figure 2.4: Conceptual model of relations between ICT and the amount of travel

2.5.2 ICT AND MODE CHOICE

As mentioned, literature that incorporates ICT related aspects of individuals in discrete mode choice experiments is limited. In this research the focus is on the impact of ICT use of individuals on mode choice. The relevant ICT characteristics of individuals that are available from the MPN data, in context of the presented theoretical knowledge, are incorporated in a variety of binomial logit models (alternatives car and train). Both a full mode choice model (including all four clusters), separate models (including only one or parts of the described block) and additional specific sub-models will be estimated to provide a full overview of the impact of ICT characteristics in discrete mode choice experiments.

Stated behavioural preferences related to ICT and mode choice can't unfortunately be included in the model because of sample size limitations (also see section 3.1 for more information on why sample size limitations are present in the MPN dataset).

Figure 2.5 presents the four clusters of explanatory variables that are commonly considered in literature; characteristics of the trip maker, characteristics of the trip, spatial and built environment characteristics and preferences and attitudes and the possible position of ICT in this conceptual model. As is shown in the figure, ICT aspects might be seen as a separate variable that falls under one of the four clusters of explanatory variables but also has the ability to influence the traditional explanatory variables. This view is best explained by a number of examples. In the examples below, specific aspects of ICTs are named specifically, being for example smartphone possession, internet use et cetera. Many other examples can be thought of, but for every cluster two variables are formulated;

- The possession of a smartphone can be seen as a characteristics of a trip maker
- The amount of Internet use might (indirectly) influence the highest completed education, because Internet might increase efficiency in learning and communication among students.
- The presence of free WiFi during a trip can be seen as a characteristic of a trip
- The possession of a smartphone and access to the Internet via 4G have the potential to decrease trip cost for example by finding discount tickets via the Internet just before a trip
- Real-time information screens alongside infrastructure can be seen as an ICT related built environment characteristics.
- ICT might influence the design of the built environment (on the longer-term)
- The preference of working during a trip via the Internet and a laptop can be seen as a personal preference
- ICT might influence the attitude towards public transport because the pleasure and efficiency of travelling might change.

In figure 2.5 also the impact of mode choice on personal characteristics and mode choice on preferences and attitudes is shown with a question mark. These arrows represent that possible impact of a particular mode choice on for example the possession of a tablet (characteristics of the trip maker) or the preference to work during a trip using the Internet (preferences and attitudes). These relations are important to consider because essentially it is unknown for example whether a person owns a tablet because he or she was always travelling by train a lot (mode choice -> ICT possession), or that he or she has decided to travel by train more often because she has bought a tablet with 4G Internet access (ICT -> mode choice).

In the available literature, almost no attempts are made to research any of the described relations, which are presented in the figure below.

In this research, ICT related variables are included in multiple binomial logit models; Internet use, frequency of tele-working, smartphone possession and tablet possession. These variables are seen as characteristics of the trip maker. So, the box under cluster 1; *ICT related characteristics* is considered in this research, which means that in essence the relation of ICT related characteristics of a trip maker on mode choice is assessed within the framework of the four traditionally considered explanatory variable clusters. The influence of ICT on all four clusters and as a characteristic of the trip, spatial and built environment, preference or attitude isn't considered. Also the possible impacts of mode choice on ICTs aren't considered in the mode choice experiment.

It is evident that the interweaving of ICT and mobility, in this mode choice, is complex and possibly impossible to explain or understand in detail. The efforts in literature that consider the growing expected impact of ICTs on mode choice is however limited and therefore a 'simple' consideration of ICTs like in this research might be very relevant.

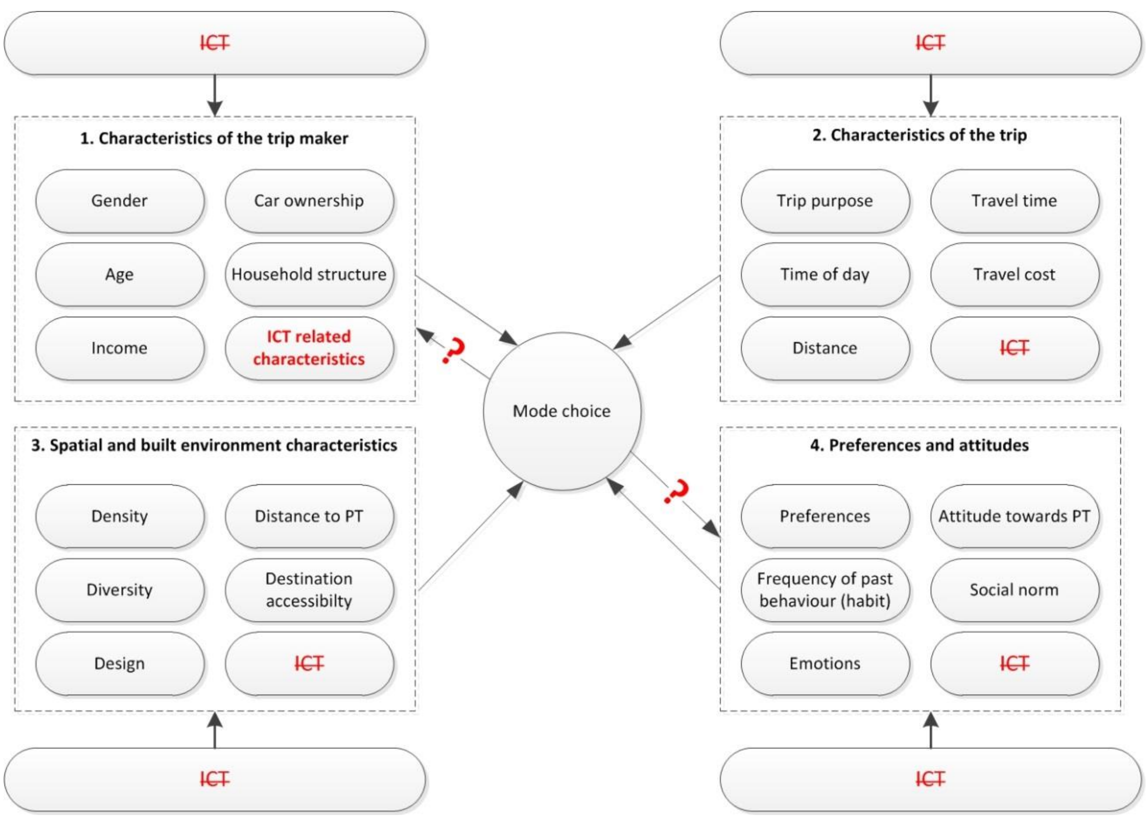


Figure 2.5: Conceptual model of relations between ICT and mode choice.

CHAPTER 3. DESCRIPTION OF THE DATA

For this research, the first wave of the Dutch Mobility Panel (MPN) is available, which was collected in the autumn of 2013. In total the MPN data set contains 6126 respondents, 3572 households and just over 40.000 registered trips. The mobility diary data set only contains the individuals that both completed the personal survey and the full three day mobility diary, which are 3996 individuals divided over 2475 households. The description of the selected sample for the analysis is described in the following sections.

Important characteristics of the MPN are:

- The MPN is a household panel, which means that every member aged 12 and more is asked to fill in a personal questionnaire and travel diary.
- In addition to the personal questionnaire, one household member (the head of the household) is asked to fill in a household questionnaire with questions related to characteristics of the household.
- The MPN diary is a multi-day diary. Respondents must record their travel behaviour for three successive days.
- Every year additional questions are added about a special topic. In 2013 and 2015 this special topic will be the relation between ICT-use and travel behaviour, in 2014 and 2016 it will be attitudes and behaviour towards different transport modes.

More information on the overall set-up, design and the philosophy behind the innovative design approach of the MPN web-based diary is described in an article from Hoogendoorn-Lanser, Schaap, and Olde Kalter (2014a). More information on the external validity of the data and additional insights in the characteristics of the dataset can be found in the article from Olde Kalter, Hoogendoorn-Lanser, and Geurs (2014).

3.1 STRUCTURE OF THE PERSONAL QUESTIONNAIRE

Important to consider is the chosen structure, or built-up of the personal questionnaire in the MPN. With very specific questions related to ICT use and the desire to obtain the highest possible quality of data, the decision is made to carefully select participants for specific questions. This means in essence that if a person doesn't use Internet, a question to that respondent related to Internet use is irrelevant and the threat of respondents answering at random present.

The exact selection criteria in the MPN personal questionnaire is to complex and extensive to explain here. In general, people are selected first based on their Internet use in days per week. If a person doesn't use Internet, no further questions related to Internet use are asked. Then, the frequency of Internet use for sixteen specific Internet activities is asked (varying from Internet banking to looking up information on the Internet of products). Most of these sixteen activities can be categorized under either work, shopping or leisure related activities. The frequency of use for any of the specific activities related to these three categories determines whether a respondent will be asked to answer an additional section on ICT and working, ICT and shopping or ICT and leisure. Then, respondents in the sections of ICT and working and ICT and shopping were asked whether they worked over distance (and on which location), or shopped over distance in the past three months. The answers to these questions then determine, which specific questions are finally asked to them. Via this selection procedure, only respondents who stated that they have used the Internet for tele-working over distance during a trip, get the specific question what the benefit of tele-working during a trip via the Internet for that person is.

3.2 DESCRIPTION OF THE SELECTED SAMPLES

In the section below the sample selection from the MPN dataset for this research are introduced. For the different aspects of the analysis, different information (variables) is required and as a result the sample size per sample varies. To obtain the results, presented in section 4.1 and 4.2, only data from the personal and household questionnaire were used. To obtain the results in section 4.3 and 4.4 the mobility diary trip data is linked to the personal and household data in order to calculate travel amounts and analyse mode choice. The use of the different samples and the related (sections with presented) results are shown below in Table 3-1. More detailed characteristics of the variables like specific categories and the percentage of respondents per category for all the four samples are presented in appendix A.

Included sections of the MPN dataset	Sample	Described in section	Results in section
Personal and household questionnaire	1	3.2.1	4.1 and 4.2
Personal questionnaire and trip mobility diary	2	3.2.2.2	4.3.1
Personal questionnaire and trip mobility diary	3	3.2.2.3	4.3.2
Personal, household questionnaire and trip mobility diary	4	3.2.3	4.4

Table 3-1: Overview of samples and related document sections.

3.2.1 SAMPLE 1 - THE EXPLORATION OF ICT USE

Sample 1 contains personal, household, mobility and ICT related variables of the personal and household questionnaire (N=6126). The variables that are included in the sample and used for the analysis are presented below in Table 3-2.

Variables	Notes
ICT related variables	
Internet use	Categorical: in days per week and hours per day
Working over distance with use of the Internet	Categorical: 1 day per quarter or none up to > 4 days per week
Smartphone possession	Binary: Yes or No
Tablet possession	Binary: Yes or No
Access to Internet via fixed connection (LAN)	Binary: Yes via desktop PC or laptop or No
Access to Internet via WiFi (WLAN)	Categorical: per (combination of) devices or no
Access to Internet via 3G/4G technology (LTE)	Categorical: per (combination of) devices or no
Personal and household variables	
Gender	Binary: Male or Female
Age	Categorical age variable is used
Personal monthly net income	Categorical: No income up to > €5.000
Highest completed education	Categorical: Dutch terminology of the Dutch educational system
(work) occupation	Categorical: Including student, incapacitated, combinations
Household composition	Categorical, one person hh, couple et cetera
Urban density at housing location	Categorical: Five categories [inhabitants/km2]
Mobility variables	
Dominant modality for work-related trips in the past twelve months	Categorical: Stated dominant modality

Table 3-2: Selection of ICT related variables

3.2.2 SAMPLE 2 & 3 - ICT AND THE AMOUNT OF TRAVEL

For the analysis related to the amount of travel, the trip mobility diary data (Number of respondents=3996) of the MPN is required in addition to the personal and household characteristics that were introduced in the previous section.

3.2.2.1 TRIP SELECTION

It is important to acknowledge that the following trip selection for the calculation of variations in travel amounts over groups with similar Internet and tele-working use is based on the primary objective of this research to determine the impact of ICTs on travel amounts. This means that it isn't priority to select trips in order to enable ourselves to calculate the best possible indicators for real-life travel amounts. Consequently can't the calculated travel amounts be used to draw conclusions on the number of completed trips or travel distances by a particular group, but are solely calculated for the purpose of comparing travel amounts of particular homogeneous groups.

Only 'regular' commuter, shopping or leisure trips are included in the calculation of travel amounts; holiday trips, trips abroad, freight trips and trips that are the result of jobs that include travel (for example travelling from client to client as a sales representative) are excluded for the calculation. Furthermore, reasons behind days of a respondent without any travel aren't taken into consideration. Being sick, being on holiday or heavy snow were stated as reasons for respectively 16.7, 5 and 7 percent of the total amount of days without travel (1965), which on the total amount of travel days (just below 12000 travel days) is less than 5 percent. Moreover, the most important argument for including the described days without is travel is that these days might also be influenced by ICTs, for example because people who are used to working over distance might call of work because of sickness or the weather more easily. Consequently, the number of trips is in reality higher and the travel distance per trip lower, if days on which people didn't travel because of sickness, being on holiday or the weather would be included.

Then, it is important to consider the structuring of the mobility diary data. Considering the fact that trip tours are represented as in reality, people might not make similar amounts of home-work and work-home, home-shopping and shopping-home, home-leisure and leisure-home trips. People might for example complete a trip from home to work, from work to the shop and from the shop home (1 commuter trip, 1 shopping trip, 1 trip home) instead of travelling from home to work, from work to home, from home to the shop and from the shop home (1 commuter trip, 1 shopping trip and 2 trips home). The purposes of trips home then are linked and similar to the purpose of the completed activity before going home.

The decision to include both trip towards the work, shopping or leisure related activity and the trip from that activity home is based on the desire to represent changing activity patterns. People might for example travel to a city centre farther away from home to complete multiple short trips in that city centre because such a complex tour can be planned ahead more easily because of ICTs instead of completing multiple short-distance trips from home to work, shopping or leisure activities closer to home, for example in their own neighbourhood. As a result, the amount of total trips might be reduced in particular because of the reduction in trips towards home. This is represented in the calculations by including trips in both directions for a particular purpose.

3.2.2.2 SAMPLE 2 – INTERNET USE AND THE GENERAL AMOUNT OF TRAVEL

Sample 2 contains the entire population of respondents for whom their age, (work) occupation, Internet use (in hours per day) and their travel behaviour (from the trip mobility diary) is known (N=3904). How the averaged travel amounts are calculated is explained in section 3.4.3. Below in Table 3-3 the average amount of travel of the population is presented and finally in Table 3-4, the number of respondents per categorized Internet use in hours per day is presented (more on the categorization of variables in section 3.4.1).

In addition, a limited amount of respondents were asked to state their opinion (yes/no) on benefits of using the Internet related to travel. The results from these statements are presented alongside the calculated results in chapter 5 and used to provide some context to the calculated and observed variation in travel amounts.

Calculated variables – average per person	Mean
Number of trips per day	3.1
Travel distance per trip	11.6 km

Table 3-3: Sample 2 - Calculated travel amounts of the total population.

Internet use in hours per day categorized	Count
Low internet use (<1)	631
Medium internet use (1-4)	2792
High internet use (>4)	481

Table 3-4: Sample 2 - Respondent count per category of Internet use.

3.2.2.3 SAMPLE 3 – TELE-WORKING AND THE WORK-RELATED AMOUNT TRAVEL

Sample 3 contains the working population of respondents for whom their (work) occupations is either entrepreneur, working in paid labour (inside and outside the government) or a combination of occupations including paid labour and their travel behaviour (from the trip mobility diary) is known (N=1938).

The MPN dataset contains multiple indicators related to working over distance (tele-working). The variable that was related to the frequency of using the Internet for working over distance was presented and used in sample 1 and will also be used in this section. However, one more variable related to tele-working is included in this sample and used in the analysis. This new variable represents the amount of working from home, measured in the amount of hours per week, in a recent and representative week (without being sick or any other abnormalities).

The decision to include another indicator in this section is made because; (1) it represents tele-working behaviour in a representative and recent week and as a result is more suitable to relate to the (recent) trip data from the mobility diary, (2) it is measured in hours per week which is more suitable for an analysis of travel amounts per day, (3) it is answered only by the working population, which is a selection criteria in this section.

On the next page in Table 3-5 the average amount of work-related travel of the working population is presented and finally on the next page in Table 3-6 and Table 3-7, the number of respondents per category of the two categorized tele-working variables is presented.

In addition, a limited amount of respondents were asked to state their opinion (likert-scale) on benefits of working from home related to travel. The results from these statements are presented in chapter 5 alongside the calculated results and used to provide some context to the calculated and observed variation in travel amounts.

Calculated variables – average per person	Mean
Number of commuter trips per day	1.05
Travel distance per commuter trip	20.22 km

Table 3-5: Sample 3 – Calculated travel amounts of the working population

Frequency of working over distance with use of the Internet	Count
Incidental (2 days per quarter or less)	1237
Weekly (1 to 3 days a month)	242
Daily (1 – 7 days per week)	459

Table 3-6: Sample 3 – Respondent count per category of working over distance.

Frequency of tele-working from home in recent representative week categorized	Count
No tele-working	1802
Part-time tele-working (12 to 25 hours per week)	89
Full-time tele-working (25 hours or more per week)	42

Table 3-7: Sample 3 – Respondent count per category of tele-working hours.

3.2.3 SAMPLE 4 - ICT AND MODE CHOICE

Sample 4 contains 971 trips made by car (N=831) or train (N=140) selected from the trip mobility diary data over a distance of 10 kilometres or longer with corresponding characteristics of the trip maker from the personal and household questionnaire. The sample however doesn't consist of only one trip per respondent. How the 971 trips were selected is elaborated on below.

3.2.3.1 TRIP SELECTION

If only one trip per person was selected, the number of trips by car or train over a distance of 10 kilometres or longer was too small when considering the large amount of explanatory variables and their often specific categories. Therefore, the decision is made to allow for multiple trips per person, but only if the arrival location is different so that identical home-work trips are not included but home-work trips with a different work location can be included[1].

Trips (and their trip makers) were only selected if all of the statements below were true:

- Trip completed from home to a work location (one directional) with the purpose of working at the arrival location
- Completed by car or train
- Over a distance of 10 kilometres or longer
- No identical person ID, departure location (PC4), arrival location (PC4) and modality
    - Filtering out all identical home-work trips of respondents (over different days)
- No identical person ID, departure location (PC4) and arrival location (PC4)
    - Filtering out all identical home-work trips of respondents with a different modality
- For which all the trip, spatial and trip maker related information (explanatory variables) is present

3.2.3.2 EXPLANATORY VARIABLES

Table 3-8 presents all the ICT related explanatory variables that are included in the mode choice experiment. An overview of all other personal characteristics, household characteristics and modality preferences that are included as explanatory variables are presented in appendix B.

Table 3-9 presents all the trip and spatial and built environment characteristics that are included in the mode choice experiment. The travel distance between postal codes (PC6 level) by car and train and the spatial characteristics of the departure location were supplied by the Dutch institute Netherlands Environmental Assessment Agency (PBL). The (peak-hour) travel times are obtained from the national transport model and delivered by another external party; Goudappel Coffeng. Included in the travel time by car is a consideration of common delays (for example because of congestion), so that in fact the peak-hour travel time is used. The trip costs by car and train needed to be calculated, which was possible with the available data. Included in the trip cost by car and train is a consideration of travel cost compensation. More information on the calculation of trip costs is presented in section 3.4.5.

[1] The risk of over-dispersion because of the violation of the assumed independence of errors that is common in logistic regression experiments is acknowledged but after testing proved not to be problematic to the intention of this research.

In addition, a limited amount of respondents in sample 4 were asked to state their opinion (likert-scale) on the impact of home-working on mode choice and the preferences of mode choice related to the possibility to work during a trip. The results from these statements are presented in chapter 4 alongside the estimated models and used to provide some context to the results of the mode choice experiment.

Variables	Category	Reference category	Total (N=971)	Car (N=831)	Train (N=140)
ICT characteristics			[% of total]	[% of group total]	
Internet use in hours per day	Low	X	12	87.5	12.5
	Medium		14	86.6	13.4
	High		74	78.7	21.1
Frequency of working over distance via the Internet	Incidental	X	54	86.6	13.4
	Weekly		16	83.9	16.1
	Daily		30	84.7	15.3
Owns a smartphone	Yes		77	85.1	14.9
	No	X	23	87.1	12.9
Owns a tablet	Yes		60	88.5	11.5
	No	X	40	81.1	18.9
Has access to the Internet via 3G/4G technology	Yes		65	84.3	15.7
	No	X	35	88.1	11.9

Table 3-8: ICT related explanatory variables of mode choice.

Variables		Mean	Minimum	Maximum
Trip characteristics				
Trip distance	[km]	35.1	10.0	208.0
Travel time by car (peak-hour)	[min]	36.2	9.0	174.0
Travel time by train	[min]	77.1	17.0	409.9
Trip cost by car (including compensation)	[€]	3.2	0.00	29.1
Trip cost by train (including compensation)	[€]	5.4	0.00	23.3
*Spatial characteristics**				
Measured from departure location				
Distance to highway entrance	[km]	3.5	.1	27.45
Distance to train station	[km]	3.4	.08	23.15
Distance to subway/metro stop	[km]	46.3	.04	167.9
Distance to bus stop	[km]	0.3	.01	2.47

Table 3-9: Trip and spatial characteristics.

3.3 LIMITATIONS OF THE DATA

The MPN dataset is a comprehensive and high quality dataset. The personal characteristics of individuals are (almost) all represented in such a manner that the information is perfectly structured and easy to use. Also the trip mobility diary data is rather comprehensive and structured in such a way that calculations are easy to perform and results can be interpreted with confidence.

However, no dataset is perfect; measuring reality in variables and attempts of representing this reality in models has its limits. We should not forget that models are a simplified representation of reality; the limitations of the data that was used to perform this research are elaborated on next. Not all considerations below limit the possibility to perform the research, some are only a comparison of the (characteristics of the) available data and the complex and diverse reality of ICTs. Only the most important limitations of the data are presented below.

3.3.1.1 ICT RELATED VARIABLES

Limitations related to Internet use:

- The fact that *no separation between mobile and fixed Internet use* is considered limits the possibility of separating the effect of those essentially different types of Internet. Knowing whether a person has access to mobile Internet (WiFI or 3G/4G) in combination with the amount of Internet use in days per week and Hours per day doesn't provide enough information to make the separation between mobile and fixed use.

- *The definition of Internet use is unclear and difficult to remember*. The amount of days per week that Internet is used is relatively clear under the assumption that 1 second of accessing the Internet on a given day is counted as using the Internet on that day. However, the amount of hours per day that Internet is used can be interpreted in multiple ways. This can possibly be best explained by asking yourself the following questions:
  - My phone is synchronising my email, agenda and social media activity 24 hours per day 7 days a week, do I count my Internet use when I am receiving an email on my phone, when I am reading the email on my phone or when I am answering the email on my phone?
  - I am reading my Facebook timeline for over 20 times a day for a number of minutes, checking the departure times of my train during the day for about 3 times a day to see if any delays might occur for a number of minutes, listening to music via the Internet (for example Spotify) for about 19 songs every day, to what amount do these activities sum up when asked to state my Internet use in hours per day?

- *Limited amount of context* related to Internet use of respondents. If people answered they use Internet for 6 hours per day or more, but whether this is the result of a job in web-developing or because he or she is a heavy online gamer remains unknown.
  - It is known for which frequencies Internet is used for 16 specific 'Internet activities', but because the categories are inconsistent with the categories of Internet use (days per week and hours per day versus x days per week, x days per month, x days per quarter), it is difficult to determine their link.

Limitations related to device possession:

- *The terminology 'smartphone' doesn't account for the variety of devices that are available.* The term smartphone represents a wide variety of devices with possibly very different characteristics and related possible impacts on mobility. A smartphone designed and built four years ago (say a HTC Evo 4G) can be very different (for example in user friendliness because of computing power and speed) from a smartphone that was designed and built last year (say an Iphone 6 plus), which isn't considered in the MPN data.

For the smartphone variable, the limitations become even more important when data is collected via the MPN over time. At this time, 'old' smartphone are relatively fast replaced by 'new' smartphones; however the 'old' smartphones are still available for a low price.

Limitations of the tele-working variables:

- The *two tele-working variables* that are used (working from home and working over distance via the Internet independent of location) were measured in *different categories* and as a result hard to compare. Furthermore, the 'working over distance via the Internet' variable isn't measured in hours (per day or week) but in a more varying manner presented in the previous sections. As a result, the impact on mobility might be different in comparison to the impact of other variables which were measured in hours per day or week.

Limitations related to preferences and attitudes:

- *The selection structure of the personal questionnaire* (see section 3.2) resulted for all of the MPN's preference and attitude ICT related variables in a relatively small sample size. The sample size of the already limited number of trips would become too small if only trips from respondents for whom the preference and attitude variables were present would have been selected. Consequently, the ICT related preferences and attitudes could only be used to provide context and are not included in the mode choice experiment

3.3.2 OTHER VARIABLES

Limitations of explanatory variables of mode choice:

- The number of respondents who are present in sample 4, for who their *income* remains unknown is too large (almost 15% of the selected sample) to include this variable in the mode choice experiment. The variable is replaced by the education variable, which is strongly correlated to a person's income.
- *Travel time* is only represented by one variable, without consideration of a separation between in-vehicle, waiting and transfer times.
- *Travel cost* by car and train is calculated under heavy assumptions under certain important restrictions (section 3.4.5).

3.4 DATA PROCESSING

The MPN data wasn't collected specifically for this research. Consequently, to improve the quality of the analysis some available variables needed to be changed (mostly categorized) or additional variables and obviously the results needed to be calculated. In the sections below, the processing of the data for different purposes is elaborated on.

3.4.1 CATEGORIZATION OF CATEGORICAL VARIABLES

Throughout the analysis of the data sometimes a different categorization is used for one variable. This is the case for the following variables presented below. For some variables the new categorization will explain itself, which is the case for age and access to the Internet via either WiFi or 3G/4G. Internet access is for example originally categorized in no access or access via one or a combination of devices, the new binary categorization simply considers access to the Internet via WiFi or 3G/4G (yes/no). Not all new categorizations are however self-explaining, additional information on the characteristics of the categorized variables and the original categories is presented in appendix C.

- Age
- Internet hours per day
- Working over distance using the Internet
- Tele-working from home
- Personal monthly net income
- Highest completed education
- (work) occupation
- Household composition
- Dominant modality for work related trips in the past twelve months
- Internet access via WiFi per device
- Internet access via 3G/4G per device

3.4.2 INTERNET USE IN HOURS PER DAY CATEGORICAL TO SCALE

For the use of Internet in hours per day a calculated average of use per group is used to analyse the variation. The presented values below in Table 3-10 were used to calculate the averages over the homogeneous groups. The value of 0.5 is chosen under the assumption that the use of all respondents that use Internet for less than 1 hour per day can be averaged to 0.5. The value 8 is chosen under the assumption that the use of all respondents that use Internet for more than 6 hours per day can be averaged between the minimum and assumed maximum of 10 hours Internet use per day.

Original	Less than one hour	1-2 hours	2-3 hours	3-4 hours	4-5 hours	5-6 hours	6 hours or more
Value	0.5	1.5	2.5	3.5	4.5	5.5	8

Table 3-10: Continuous values related to categories of Internet hours per day.

3.4.3 CALCULATING TRAVEL AMOUNTS

Important to consider is that only trips within the Netherlands are included in the calculation of travel amounts. The travel amounts per person were calculated before averaging the values over homogeneous groups in context of their ICT characteristics. For every person in the trip mobility diary, three travel days are completed. Multi-modal trips are included as one trip and selected based on their stated main purpose. The average amount of trips per day is then calculated by summing up the total amount of trips per person and dividing the outcome by three. The average amount of distance per day is then calculated by summing up the total amount of travel distance and dividing the outcome by three. The average distance per trip is calculated by dividing the total amount of travel distance by the total amount of trips.

3.4.4 ESTIMATED DISCRETE CHOICE MODELS

In order to determine the impact of ICTs on mode choice, different discrete choice models were estimated. Because two alternative of the outcome variable are present (the car and train) and the predictor variables are both continuous and discrete, a binomial logit model is used. All estimated models with a brief description are presented below in Table 3-11.

Model number	Description of the model
1	Full model with all explanatory variables
2	Including only trip characteristics
3	Including only spatial characteristics
4	Including only socio-demographic characteristics
5	Including only household characteristics
6	Including only mobility preferences
7	Including only ICT related variables
1.1	Full model excluding mobility preferences and number of cars in household
1.2	Full model excluding ICT related variables
7.1	Including only ICT related variables with a sample of only all respondents below the age of 35
7.2	Including only ICT related variables with a sample of only all respondents above the age of 34
8	Including calculated travel amounts
A	Including only an interaction term between age and Internet use in hours per day
B	Including only an interaction term between access to the Internet via 3G/4G and smartphone possession
C	Including both interaction terms of model B and C

Table 3-11: Estimated binomial logit models.

3.4.5 EXPLANATORY VARIABLES OF MODE CHOICE

Not all explanatory variables that are used in this research were present in the MPN dataset. The Dutch institute PBL delivered a large dataset with departure and arrival locations (PC6 level) with corresponding travel distances by car and train and all the spatial characteristics of the departure location so that the variables could be linked to the trips that were present in the trip diary dataset. The (peak hour) travel times were delivered by Goudappel Coffeng. However, not for all trips the characteristics in the dataset were present. If the information was missing, the stated distance by the respondents (from the MPN dataset) was used to calculate the travel times by car and train. This was done by multiplying the stated distance with a calculated ratio between distance and travel time by car and train, using the trips for which the information from the PBL and Goudappel Coffeng was available. The trip cost by car and train also needed to be calculated based on the distance of a trip.

3.4.5.1 TRIP COST BY CAR AND COMPENSATIONS

The distance of a trip is multiplied by an assumed cost per kilometres, for which five types of fuel are considered; (1) gasoline, (2) diesel, (3) LPG – gas, (4) electricity or hydrogen and (5) hybrid. For the cost per kilometres only fuel cost are considered, meaning no depreciation, insurance or any other costs. The assumed costs per kilometre for the four fuel types are (based on an middle weight – 1300kg car (Watkosteenauto.nl, 2013)):

1. Gasoline – 0.14 cents
2. Diesel – 0.08 cents
3. LPG - 0.07 cents
4. hybrid - 0.12 cents
5. Electricity or hydrogen - 0.04 cents

For every trip it is known whether the trip was made by a car using; (1) gasoline, diesel or LPG, or (2) Electricity, hydrogen or a hybrid. For all trips made with a car using electricity, hydrogen or a hybrid, the cost per kilometre are initially set to 0.04 cents, the cost per kilometre for all other trips are initially set to 0.14 cents. These values are however only used to ensure a full presence of kilometre costs for every trip. The binary separation by itself isn't representing fuel cost realistically because different types of fuel are found in a similar category.

Then in the second step, the fuel type of the (first) car that is owned by the household of the trip maker is used under the assumption that the majority of trips from a particular respondent are made by the car that is owned by his or her household. If the fuel type is unknown, the initial costs per kilometres of 0.04 and 0.14 cents remain.

Then for the compensations, businesses are often compensating employees for their travel costs. This can be done in many ways, which are represented in the MPN dataset by a specific variable. In this research only a full (100%), half (50%) or no compensation are considered based on the assumption that the mental barrier related to cost and mode choice is more important than the actual costs. For example a fuel pass is assumed to increases the feeling of 'free travelling', while a compensation at the end of the year, so that the fuel at the gas station needs to be paid with own many is assumed to reduce the feeling of 'free-travelling'. The included categories per level of compensation are presented on the next page in Table 3-12.

Compensation category	Included categories
No compensation	--
Half compensation	Fixed amount per kilometre (afterwards) Fixed amount per day/month/year considering the home-work travel distance (determined prior to considered period) Fixed amount per day/month/year (determined prior to period under different agreements) I travel with a lease car, company car.
Full compensation	Compensation of actual costs Fuel pass

Table 3-12: Categorisation of trip cost by car compensation.

3.4.5.2 TRIP COST BY TRAIN AND COMPENSATIONS

The Dutch railway company (NS) uses a unit (Dutch: tariefeenheden) system with corresponding unit rates for the calculation of train ticket prices (OVinNederland.nl, 2014). Over long distance trips the number of units is (almost) always equal to the amount of kilometres, but at the shorter distances these values tend to differ for multiple reasons including that the starting rate (€2.5) is similar for all trips covering 0 to 8 units. After 250 units, the cost of a train ticket remains equal (€27.5). Because in this research, the focus is on trips of 10 kilometres or longer, the amount of kilometres is assumed to be equal to the amount of unit rates allowing for a calculation of trips costs by train using the following formula:

For all trips longer than 8 kilometres: $Trip\ cost\ by\ train = 2{,}5 * (0{,}1 * Trip\ distance)$

For all trips longer than 250 kilometres: $Trip\ cost\ by\ train = 27.5$

Then for the compensations of travel cost by train also information from a specific variable from the MPN dataset is available and again three categories are considered; 100%, 40%, no. The decision to compensate for 40% instead of 50% of the cost is based on 40% being the most common discount that the Dutch railway company provides. The included categories per level of compensation are presented below in Table 3-13.

Compensation category	Included categories
No compensation	--
40% compensation	Partial compensation of public transport subscription Fixed amount per kilometre (afterwards) Fixed amount per day/month/year considering the home-work travel distance (determined prior to considered period) Fixed amount per day/month/year (determined prior to period under different agreements)
100% compensation	Full compensation of public transport subscription Compensation of actual costs

Table 3-13: Categorisation of trip cost by train compensation.

3.4.6 STATISTICAL METHODS

Multiple statistical techniques were used to obtain various results. The analysis of variance test (ANOVA), chi-square test, logistic regression and the utility theory and binary logit model are introduced and described briefly in the sections below. Only the most basic equations, mathematical techniques and assumptions that are relevant to this research are presented in the sections below. For additional theoretical information and application examples can be found in the book from Mister Field (2009).

3.4.6.1 ANALYSIS OF VARIANCE

Analysis of variance can be used to compare three or more means. It is preferred over the execution of multiple t-tests (in which two means are compared) because of a smaller chance of a type I error – the familywise error rate. ANOVA tests tell us whether three or more means are the same, so it tests the null hypotheses that all group means are equal. Extensive information on the theory and mathematics behind t-tests, one-way ANOVA, multivariate analysis of variance (MANOVA) can be found in the introduced book from Mister Field (2009).

Most important to consider for this research is that ANOVA is a test with limitations. It doesn't provide specific information about which groups were affected. Assuming an experiment with three different groups, it remains unknown via ANOVA tests whether the differences between all groups are significantly different or only for example the difference between group 1 and 2 or between group 2 and 3. The analysis of variance will be used to test whether the effect of the used ICT variables (internet use and tele-working) on the differences in the average mean travel amounts (measured in trips per day, distance per day and distance per trip) over groups is significant.

3.4.6.2 CHI-SQUARE TEST

The terminology 'chi-square test' can apply to any test statistic have a chi-square distribution. In this research it refers to the Pearson's Chi-square test of independence of two categorical variables. Essentially it tests whether two categorical variables forming a contingency table are associated. The test is based on the simple idea of comparing the frequencies you observe in certain categories to the frequencies you might expect to get in those categories by chance.

The Pearson's chi-square (X^2) is given by:

$$X^2 = \sum \frac{(observed_{ij} - model_{ij})^x}{model_{ij}}$$

In which *i* represents the rows in the contingency table and j represents the columns. The expected frequencies ($model_{ij}$) are then calculated for each cell of the table by using the column and row total. (Multiply row total *i* by column total *j* and dividing this number by the total number of observations). The Phi measure (for 2x2 contingency tables) and the Cramer's V (if one of the two categorical variables has more than 2 categories) can be used to assess the strength of association and are calculated by taking the chi-square value and dividing it by the sample size and then taking the square root of this value.

3.4.6.3 LOGISTIC REGRESSION

The essence of regression analysis is to fit a model to data, which can be sued to predict values of the dependent variable from one or more independent variables. Linear regression can be used if the dependent variable is continuous and logistic regression can be used if the dependent variable is discrete.

Logistic regression techniques share some of the assumptions of normal regression(Field, 2009):

1. Linearity: The assumption of linearity in logistic regression, assumes that there is a linear relationship between any continuous predictors and the logit of the outcome variable. This assumption can be tested by looking at whether the interaction term between the predictor and its log transformation is significant (Hosmer & Lemeshow, 1989).
2. Independence of errors: This assumption means that cases of data should not be related; for example, you cannot measure the same people at different points in time.
3. Multicollinearity: not so much an assumption but rather a problem that occurs if predictors are too highly correlated.

3.4.6.4 UTILITY THEORY AND THE BINARY LOGIT MODEL

Understanding and modelling the decision of individuals to travel by a particular mode is extremely difficult because of the complexity of the decision-making process, the large number and variety of factors that influence the decision-making process, the role of attitudes, preferences and habits, the dynamic nature of the choice-set and so on. Consequently, literature on the topic of mode-choice is vast and the complexity, goals and approach of research and used mathematical models vary greatly.

When individuals have to select an option from a finite set of alternatives, discrete choice modelling techniques are applicable. In this disaggregated method the following assumption takes a central position:

> *The probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option.*

To concept of utility is then used to represent the attractiveness of the alternatives that is derived by the characteristics of those alternatives (Lancaster, 1966). This utility theory is the most common theoretical framework for generating discrete choice models (Domenich & McFadden, 1975; Williams, 1977), which contains the following assumptions;

1. Individuals belong to a given homogeneous population, act rationally and possess perfect information, i.e. they always select that option which maximises their net personal utility.
2. There is certain set of available alternatives and a set of vectors of measured attributes of the individuals and their alternatives.
3. Assuming that the choice set have been pre-determined (which is true in this research); each option has associated a net utility for individuals. The modeller, who is an observer of the system, does not possess complete information about all the elements considered by the individual making a choice; therefore, the modeller assumes that the net utility can be represented by two components:
    - A measurable, systematic or representative part which is a function of the measured attributes, and
    - A random part which reflects the idiosyncrasies and particular tastes of each individual, together with any measurement or observational errors made by the modeller.

Over time, researchers have made numerous attempts to improve the modelling techniques, which have resulted in a large variety of discrete choice models on the base of the utility theory. Improving mode choice models is extremely important for example for developing high quality national transport models. However, when the purpose isn't to estimate a 'perfect' mode choice model, the described theory and set of assumptions can also be used for more explorative research.

The binomial logit model (or the multinomial logit model with the outcome variable consisting of more than 2 categories) is the simplest and most popular practical discrete choice models (Domenich & McFadden, 1975; Ortuzar & Willumsen, 2011). Binary logistic regression estimates the probability that a characteristic is present given the values of a number of explanatory variables.

The formula presented below represents the logistic function that can be used for a binary logistic regression experiment with one predictor variable. This formula is based on the formulation of the logistic function ($F(t)=1/1+e^{-t}$) where t is viewed as a linear function of explanatory variable x. F(x) in the formula below then represents the probability of F occurring, e is the base of natural logarithms, β_0 is a constant, X_1 is the predictor variable and β_1 is the coefficient (or weight) attached to that predictor variable.

$$F(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_{1i})}}$$

When there are more than one predictor variables, the equation can easily be extended to:

$$F(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_{1i}| + \beta_2 X_{2i} + \ldots + \beta_n X_{ni})}}$$

CHAPTER 4. RESULTS

This chapter presents the results from the analysis of the described samples. After every main section of results, brief reflections on the results are formulated. Section 4.1 presents an analysis of variation in ICT and personal characteristics. Section 4.2 presents the results from a simple logistic regression experiment with internet use and tele-working frequencies as outcome variable. Section 4.3 presents the results from an analysis of variations in travel amounts of homogeneous groups and finally section 4.4 presents the results of the binomial logit models that were estimated.

4.1 ICT AND PERSONAL CHARACTERISTICS

In the sections below the variation in Internet access (section 4.1.1), Internet use (4.1.2), frequencies of working over distance via the Internet (tele-working) (4.1.3), smartphone possession and tablet possession (4.1.4) is presented in context of personal (socio-demographic, household, mobility and ICT related) characteristics.

4.1.1 INTERNET ACCESS

In order to access the Internet people can use a fixed connection (LAN), a wireless connection (WLAN or WiFI) or mobile connections (mostly via long term evolution (LTE, 3G/4G) technologies) predominantly via Desktop PCs or laptops, smartphones or tablets. From the 6126 respondents who are 12 years or older, 75.6%, 84% and 47.7% stated that they are able to access the Internet respectively via LAN, WiFi or 3G/4G. Furthermore, of all respondents who can access the Internet via WiFi, this is mainly possible via only the desktop PC or laptop (14.6%), desktop PC or Laptop and smartphone (21.9%) or via the desktop PC or laptop, smartphone and tablet (27.2%). Of all respondents who can access the Internet via 3G/4G technologies, this is mainly possible via only the smartphone (80.3%), the tablet and smartphone (6.6%) or via the desktop PC or laptop, smartphone and tablet (2.6%). If age is an indicator of the adoption of innovations over time with elderly being 'old-fashioned' and younger individuals being 'modern users', Figure 4.1 presents what is to come (looking from right to left); a decrease of Internet access via LAN, and a strong increase of Internet access via WiFi and 3G/4G. A table with all percentages of access to WiFi and 3G/4G per (combination of) device(s) is presented in appendix D.

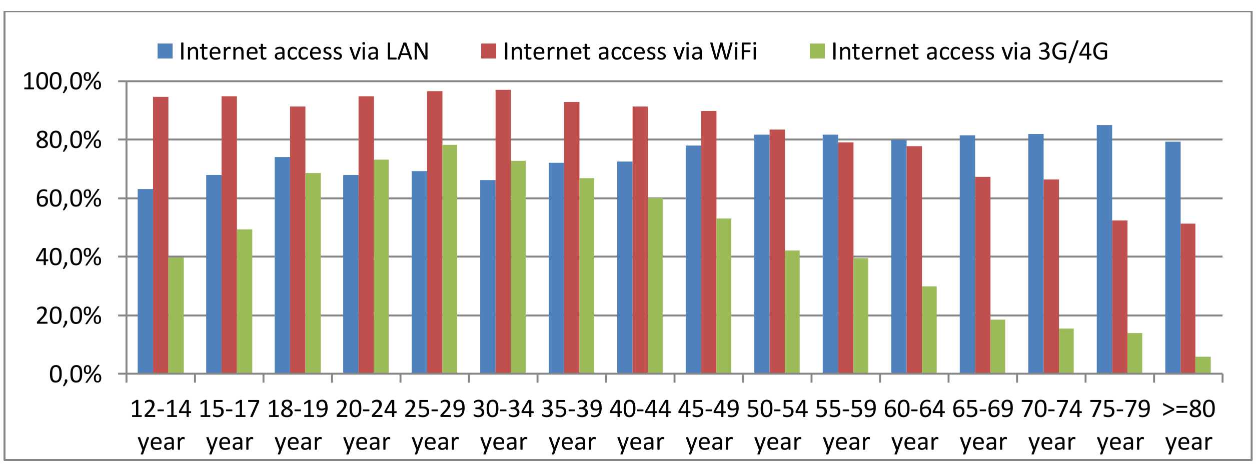
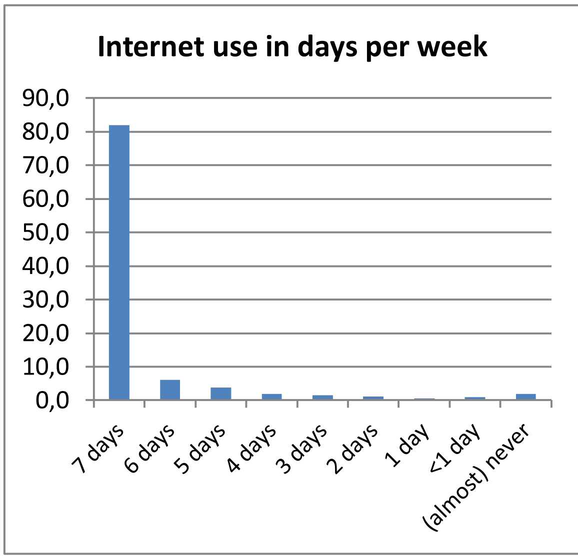


Figure 4.1: Internet access over age.

4.1.2 INTERNET USE

From the 6126, 98% state that they use Internet at least one day of the week (120 respondents answered they use Internet (almost) never). The largest group of individuals (82%) however state that they use Internet for all seven days of the week (Figure 4.2 on the left).

The amount of days that Internet is being used for isn't however a particularly good measure by itself, considering the fact that the actual use can range from one minute every day up to 24 hours every day. In Figure 4.2 on the right it is visualized that the highest percentage of respondents uses Internet for 1 to 2 hours every day (around 35%) and that more than 80% uses Internet between zero and four hours every day. Furthermore, Figure 4.3 shows the increasing amount of (average) Internet hours per day when the amount of Internet days per week increases.



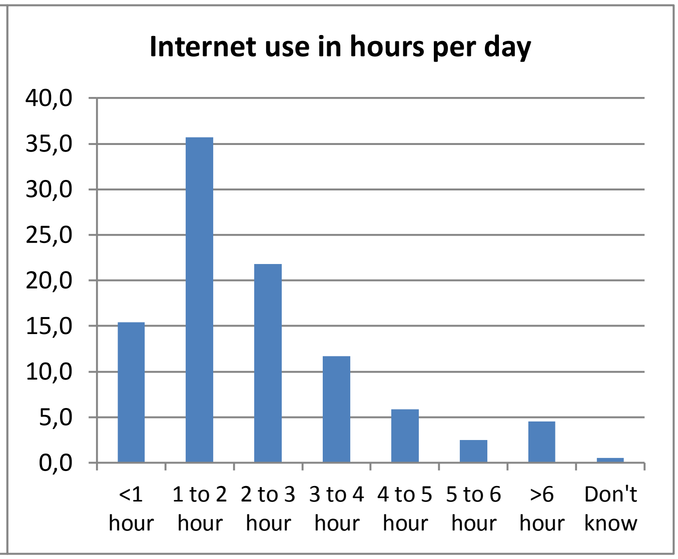


Figure 4.2: Internet use in days per week and hours per day.

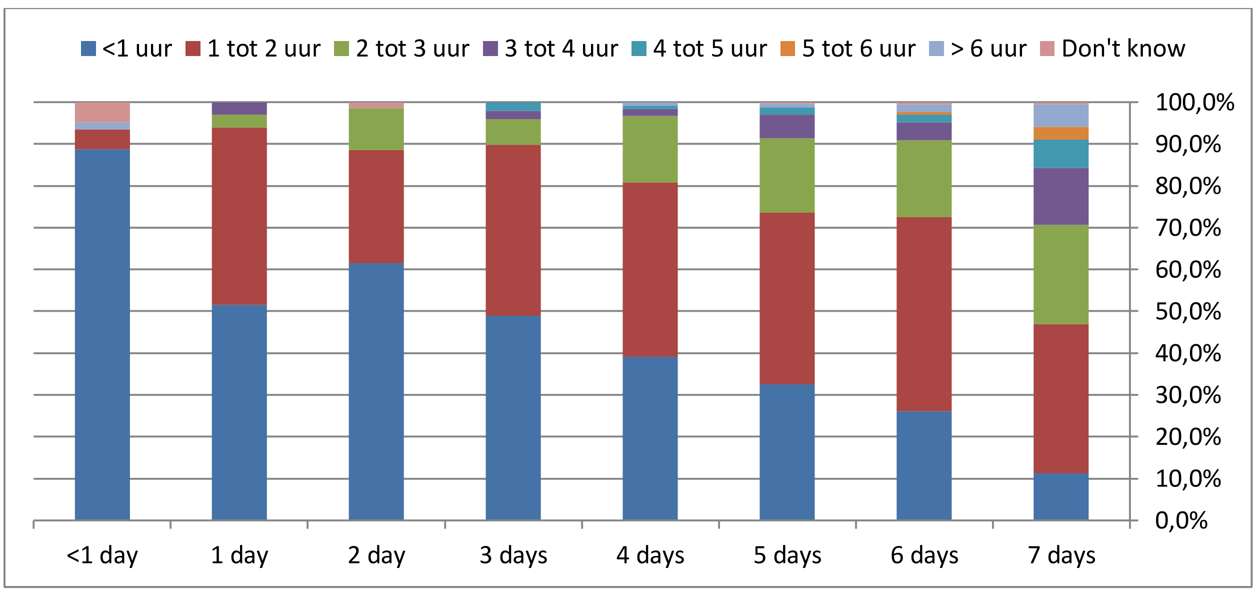


Figure 4.3: Internet days per week over Internet hours per week.

4.1.2.1 INTERNET USE IN DAYS PER WEEK

From the group of respondents that answered they (almost) never use Internet (120 respondents – which is 2% of the total population):

- 77.5% is older than 60 years,
- 50.8% is retired and 20.8% houseman/woman
- 82.5% has access to the Internet via LAN, but only 39.2% has access to the Internet via WiFi and only 3.3% via 3G/4G
- 97.5% doesn't own a smartphone and 91.7% doesn't own a tablet.

The percentage of daily users from the total population is 82%. If respondents are categorized in homogeneous groups based on their personal characteristics the percentage of daily users of those specific groups is different. With a fault margin of 10% from the average (82%) the groups that fall outside this range are identified. The variation can however sometimes be biased by a small amount of respondents in a particular group. Therefore, groups with less than 100 respondents are marked with a double ** and the groups with less than 50 respondents with a single *. A full table of the calculated percentages for all groups is presented in appendix E.

The groups with a lower percentage of daily Internet users than the 72% - 92% range are presented below in Table 4-1.

Variable	Value	Percentage of daily users
Age	75 - 79 years	68.9
	80 years and older	66.3
Highest completed education	LBO/VBO/VMBO (kader- en beroepsgerichte leerweg)	71.7
(Work) occupation	House man/woman	69.3
Internet access via WiFi	No	60.7
Person owns a smartphone	No	67.8

Table 4-1: Groups with percentage of daily Internet users below average.

The groups with a higher percentage of daily Internet users than the 72% - 92% range are presented below in Table 4-2.

Variable	Value	Percentage of daily users
Age	25 – 29 years	92.9
	30 – 34 years	93.9
	35 – 39 years	92.3
Personal monthly net income	€4.001 - €4.500*	95.2
Household composition	One parent household with children	92.3
	One parent household with children + other(s)*	93.3

Table 4-2: Groups with percentage of daily users above average.

This means that the groups with a particular gender, urban density at housing location, dominant modality for commuter trips in the past twelve months, Internet access via LAN (yes/no), Internet access via 3G/4G (yes/no) and tablet possession aren't showing any variation outside the margin. Interesting to point out is that the groups without access to Internet via 3G/4G and the group with access to Internet via 3G/4G are exactly on the limits of the 72% - 92% range, respectively with a percentage of daily users of 72.9% and 91.9%. Furthermore, the group of individuals who own a smartphone also show a percentage close to the set limit; 91%.

4.1.2.2 INTERNET USE IN HOURS PER DAY

The calculated average for all respondents is 2.4 hours of Internet use per day. We can see for example directly that the calculated average for men (2.48 hours) is a few percentages higher than the use of woman (2.32). The fault margin of ten percent (0.24 hours) is again used to find the outliers. Again, if the number of respondents is below 100 a double ** mark and below 50 a single *mark is presented. A full table of the calculated averages for all groups is presented in appendix F.

The groups with their Internet use in hours per day below the calculated average minus fault margin (below 2.16 hours) are presented below in Table 4-3.

Variable	Value	Average Internet use in hours per day
Age	60 – 64 years	2.06
	65-69 years	1.89
	70 – 74 years	1.90
	75-79 years	1.71
	80 years and older	1.83
(Work) occupation	Retired	1.91
	House man/woman	2.04
Internet access via WiFi	No	1.86
Internet access via 3G/4G	No	2.09
Person owns a smartphone	No	1.98

Table 4-3: Groups with below average Internet use in hours per day.

The groups with their Internet use in hours per day above the calculated average plus fault margin (above 2.64 hours) are presented below in Table 4-4.

Variable	Value	Average Internet use in hours per day
Age	15 – 17 years	2.99
	18 – 19 years	3.27
	20 – 24 years	3.31
	25 – 29 years	2.96
	30 – 34 years	2.68
Dominant modality for commuter trips	Train	2.87
	Walking**	2.68
(Work) occupation	Incapacitated	2.84
	Unemployed	2.86
	Student	2.96
	Multiple occupations including paid labor	3.02
Household composition	One parent household with children	2.71
Urban density at housing location	2500 or more inhabitants per km2	2.67
Internet access via 3G/4G	Yes	2.71
Person owns a smartphone	Yes	2.64

Table 4-4: Groups with above average Internet use in hours per day.

This means that the groups with a particular gender, personal monthly net income, highest completed education, access to Internet via LAN (yes/no) and whether a person owns a tablet (yes/no) aren't showing any variation outside the margin.

4.1.3 WORKING OVER DISTANCE WITH USE OF THE INTERNET

The available categories that respondents could choose to indicate their frequency of working over distance by using the Internet were; less than 1 day per quarter or not, 1 to 2 days per quarter, 1 to 3 days per month, 1 to 3 days per week and more than 4 days per week. A full representation of the frequencies of working over distance in context of the socio-demographic, household and mobility characteristics of individuals is presented in appendix G. The variation is visualized over age, in which the working population (18-65) is showing the highest use of Internet for the purpose of working over distance (Figure 4.4). The highest share of the population (over 50%) however stated that they (almost) never use Internet for the purpose of working over distance.

When the frequencies of working over distance via the Internet is categorized and the variation over Internet access via LAN, WLAN or 3G/4G and smartphone and tablet possession is shown, the differences between the groups become even more clear. Especially the differences between the groups with and without Internet access via WiFi and 3G/4G and the groups with and without the possession of a smartphone are noticeable (Figure 4.5).

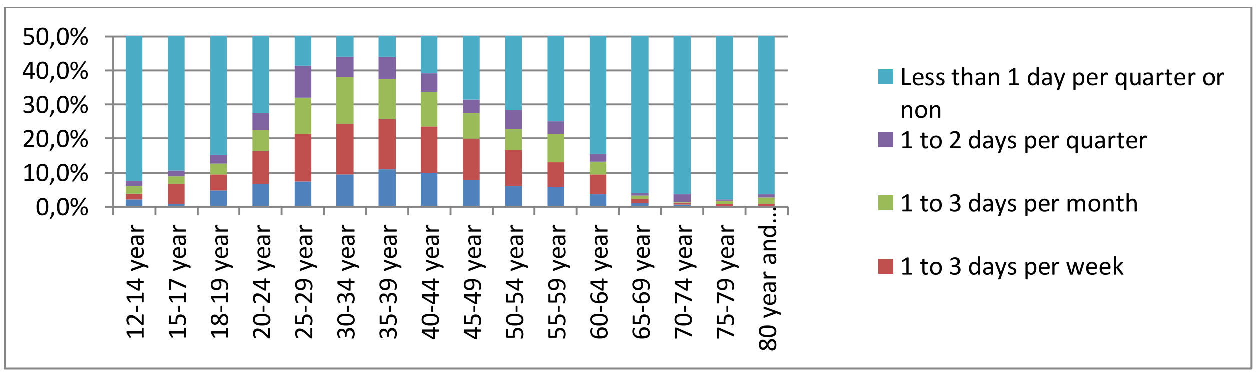


Figure 4.4: Frequency of working over distance over age.

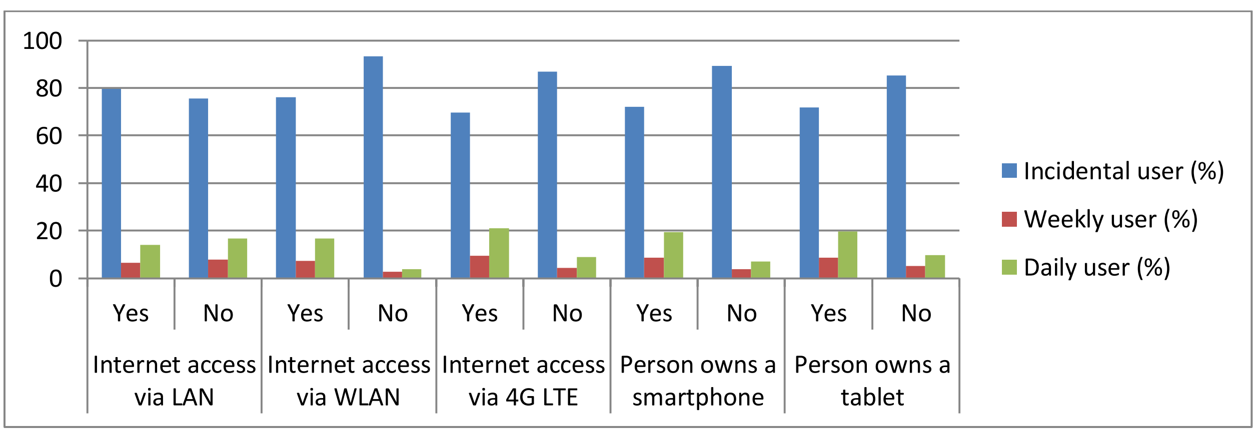


Figure 4.5: Frequency of working over distance over Internet access and device possession.

4.1.4 SMARTPHONE AND TABLET POSSESSION

Of the total population, 61.1% of the respondents own a smartphone and 49% owns a tablet. Figure 4.6, shown below, presents the variation in smartphone and tablet possession over Internet use and frequencies of working over distance with use of the Internet. Especially the variation in smartphone possession shows distinct variation over the presented categories with over 82.5% of the respondents owning a smartphone in the '5 to 6 hour group' and only 41.3% in the 'less than 1 hour' group. The variation in tablet possession is much less distinctive. Figure 4.7 presents the variation in smartphone and tablet possession over the frequencies of working over distance via the Internet, which shows a high representation of smartphone and tablet owners in the groups that tele-work for 1 to 3 or 4 or more days per week.

Furthermore, from the group of smartphone owners 97.7% also has access to the Internet via WiFi and 71.8% via 3G/4G. From the group of tablet owners 98.1% has access to the Internet via WiFI and 58.1% via 3G/4G. A full table of the variation in smartphone and tablet possession over the socio-demographic, household, mobility and ICT variables is presented in appendix H.

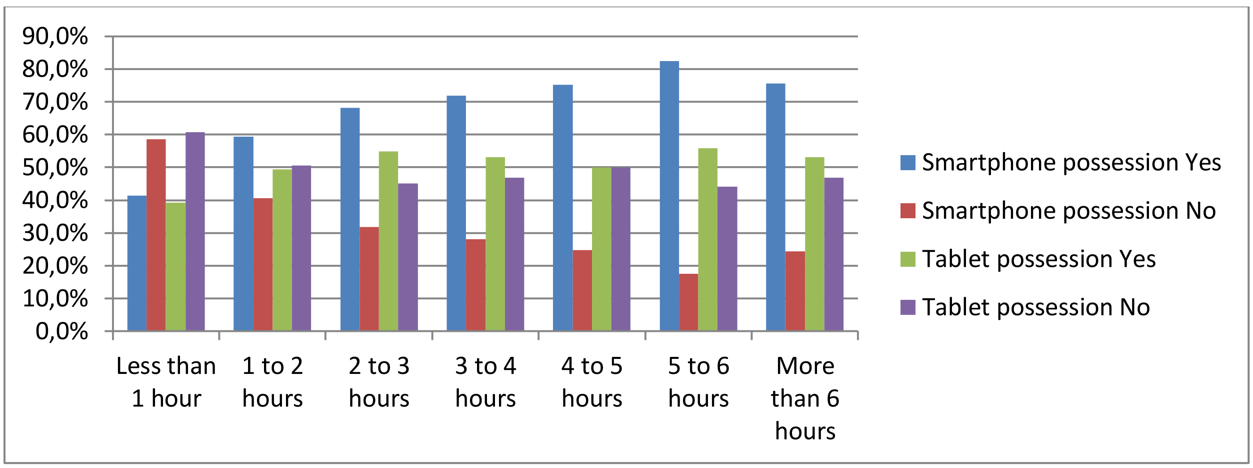


Figure 4.6: Smartphone and tablet possession over Internet use in hours per day.

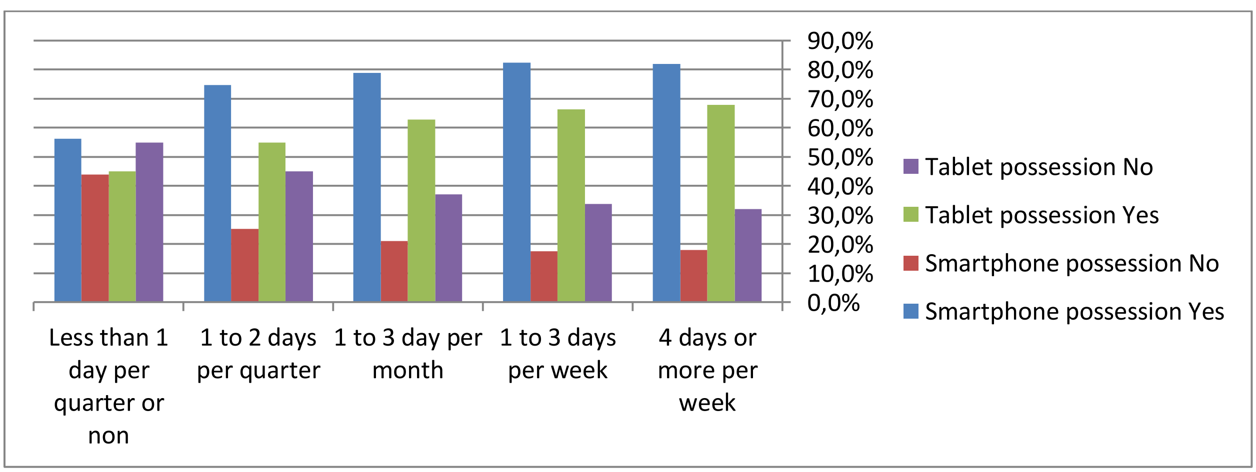


Figure 4.7: Smartphone and tablet possession over working over distance.

4.1.5 REFLECTION

Whether respondents have aaccess to the Internet via a fixed connection (LAN), wireless connection via a router (WiFi) or via a mobile connection (3G/4G) shows to vary strongly over age. The variation in access to the Internet via a fixed connection is less noticeable with percentages between 60 and 80 per cent for all age groups. It will be very interesting to compare the percentages of Internet access in the future to the second, third and fourth wave of the MPN dataset. By doing so, it becomes visible whether the older generations adapt to the new technologies which could result in for example higher percentages of respondents with access to the Internet via mobile technology (3G/4G).

Internet seems to be used every day by the largest share of the population (82%). On average, Internet is used for around 2.4 hours per day. Again, we see a clear distinction over age with much higher percentages of daily users among middle aged respondents (age 25-39) and lower percentages among elderly (75 and older). The amount of Internet hours per day is higher for the age group 15-34 years and lower for respondents who are 60 years or older. Whether a respondent has access to the Internet via 3G/4G also seems a strong determinant for the amount of hours Internet use per day with much lower amounts for respondents who don't have this access and much higher amounts for people who do have this access.

Working over distance via the Internet is logically mostly done by the working population with their age between 25 and 59. It is however interesting to see that the age group 20-24 and 55-59 show similar frequencies of working over distance. This fuels the hypotheses that this ICT related possibility to work over distance is fully adapted to by the older generations.

Smartphone and tablet possession is high and seems not to be related strongly to amounts of Internet use and frequencies of working over distance. The variation in tablet possession seems to be independent of age, with similar percentages in the younger and older categories. Smartphone possession is higher amongst the younger generations. In the perception of the author this seems logical with elderly being provided with tablets more often to increase their accessibility or possibilities to fill up time with fun digital activities. Smartphones however are less necessary for this age group because they were already able to send text messages and call with their land line phones or older mobile phones.

It is important here to acknowledge the extreme complexity and variety of personal and ICT related characteristics of individuals and the fact that decisions related to ICT use and for example urban density of the housing location can be made by individuals in different contexts and with different priorities; one person might buy a smartphone because it comes in handy when navigating through the busy city centre he or she is living in for the past years, but another person might choose to move to a city centre because he recently bought a smartphone and tablet with access to high-speed mobile Internet that limits the need to work at an office that is located in the rural area he or she lived in for the past years. The state-of-the-art ICTs that were introduced recently seem to be more easily adapted to by the younger generations. This might be a consequence of younger individuals being more able and willing to learn and adapt to 'new' technologies but could also be the result of higher social pressures on the younger generations to keep up with the latest technology. The adaptation of the current technologies, but also of new technologies that are to come is a research direction that requires extensive time and efforts by itself in order to improve our understanding of such mechanisms.

4.2 DETERMINANTS OF INTERNET USE AND TELE-WORKING

The outcome variables in the logistic regression analysis of which the results are presented in this section are the amount of hours Internet is used per day and the frequency that Internet is used for working over distance. The predictor variables that are included in the analysis are selected based on the information obtained from chi-square tests. If the strength of the relation is greater than 0.1 (Cramer's v) it is assumed that a 'relation' is present. Consequently, these variables are included in the logistic regression analysis. The full results of the estimated logistic regression models are presented in appendix J and K.

4.2.1 IDENTIFYING RELATIONS

In order to meet the most important precondition of chi-square tests (<20% of all cells with expected counts below 5) some variables needed to be categorized. These variables are: Income, Household composition and dominant modality. For the logistic regression analysis some variables were also categorized. These variables are: (work) occupation and highest completed education. Internet use and tele-working were also categorized for the logistic regression analysis. An overview of the characteristics of the categorization per variable is presented in appendix C.

The table below presents the chi-square test results if the Cramer's V statistic is higher than 0.1, so that the variable is selected as having a relation with Internet use or tele-working. Gender, urban density at housing location, household composition, dominant modality for commuting trips and access to Internet via a fixed connection (LAN) didn't show any correlations higher than 0.1. While the dominant modality didn't show any significant relation to Internet use, the categorized variable is still included in further analysis because of particular interest in the relation between ICT and mobility in this research.

Variables	Age	Income	Education	(Work) occupation	Smartphone possession	Tablet possession	Internet access via WiFi	Internet access via 4G
Internet use	0.128			0.112	0.279		0.240	0.248
Tele-working	0.174	0.166	0.177	0.201	0.274	.165	0.234	0.236

Table 4-5: Chi-square test results (Cramer's V).

4.2.2 TESTING FOR MULTICOLINNEARITY

Chi-square tests were executed with all combinations of the explanatory variables to detect any risks of multicollinearity. Any correlation coefficient (cramer's v) of the relation between any combinations of the explanatory variables below 0.600 is assumed to be low enough to include in this exploratory analysis, but the author stresses the importance of also using common sense. Furthermore, it is acknowledged that multicollinearity only provides a treat to the interpretation of individual predictor variables and not to the predictive strength of the entire model.

It is already known from previous results that Internet access via both WiFi and 3G/4G is highly dependent of whether an individual owns a smartphone or tablet. This is confirmed statistically with a Cramer's V of .469 and .605 for smartphone possession and access to Internet via respectively WiFi and 3G/4G and a Cramer's V of .378 and .205 for tablet possession and access to Internet via respectively WiFi and 3G/4G. Therefore, only smartphone and tablet possession (as assumed superior indicators of the possibility to use Internet or work over distance) are included in the logistic regression analysis.

As is often the case, Income and education also show a relatively strong correlation (Cramer's V = 0.383) and are also not included simultaneously in any regression model. The results of the chi-square test considering Age show a relatively high correlation to almost all explanatory variables, and are therefore also left out of the models. The full table with chi-square tests between the explanatory variables is shown in appendix I.

4.2.3 INTERNET HOURS

The dependent variable in model 1 and 2 in this section consists of three alternatives: Low (<1 hour per day), Medium (1-4) hours per day and high (>4 hours per day) Internet use, the reference category is medium (or average) users. The dominant modality for commuter trips was only asked to respondents who are working paid labour (limiting sample size). Consequently, dominant modality and work situation couldn't be included in one model.

Model 1: The log-likelihood change between the original model (no explanatory variables included) and the final model (all explanatory variables included) is significant, which tells us that the fit has improved and that some of the variation in Internet use can be explained by the included variables. The pseudo p^2-value (Nagelkerke) shows that 6.7 percent of the variation in Internet use can be explained by smartphone possession and work situation. With the Pearson and the Deviance statistic not being significant, believe that the model is a good fit has increased so no further tests are applied and the results accepted.

In short, when a person owns a smartphone, the Internet use of an individual has a significant change of being high relative to medium, as is for students and unemployed individuals relative to people who are working paid labour. However, whether an individual is retired increases the chance that he or she is using Internet for a low amount of hours per day relative to medium amount of hours per day when compared to people who are working paid labour.

Model 1 – Internet use (N=5964)	
Explanatory variables	Smartphone possession (Work) occupation categorized (Categories: Unemployed, student, entrepreneur, paid labour)
-2LL intercept only	434.873
-2LL final	105.403
Nagelkerke	.067

Table 4-6: Logistic regression model 1 – Internet use.

Model 2: The log-likelihood change between the original model (no explanatory variables included) and the final model (all explanatory variables included) is significant, which tells us again that the fit has improved. The pseudo p^2-value (Nagelkerke) shows that 3.9 percent of the variation in Internet use can be explained by smartphone possession and dominant modality. With the Pearson and the Deviance statistic not being significant, believe that the model is a good fit increase so no further tests are applied and the results accepted.

For this data the work situation is a better predictor of Internet use than dominant modality. Smartphone possession shows similar effects as in the previous model (1). The dominant modality for commuter trips doesn't show a significant effect, with exception of Public Transport users compared to people who are travelling to work with personal motorized transportation modalities.

When an individual is travelling to work predominantly by PT, the changes (significantly) increase of that person using Internet for a high amount of hours per day relative to medium use.

Model 2 – Internet use (N=3144)	
Explanatory variables	Smartphone possession Dominant commuter modality categorized (Categories: PMT, PT, NMT)
-2LL intercept only	165.900
-2LL final	68.129
Nagelkerke	.039

Table 4-7: Logistic regression model 2 – Internet use.

4.2.4 TELE-WORKING

Internet hours might as well be an important determinant for the frequency of Tele-working, not only because Internet is needed to tele-work. Education is included over income because of the limitations of the income variable related to sample size. Here the reference category ''incidental use of Internet for tele-working" is selected because of that group being the largest and interest towards the drivers behind Internet use for tele-working (weekly or daily in this case).

Model 1: The log-likelihood change between the original model (no explanatory variables included) and the final model (all explanatory variables included) is significant, which tells us that the fit has improved. The pseudo p^2-value (Nagelkerke) shows that 29 percent of the variation in Internet use can be explained by smartphone possession, tablet possession, education level and work situation. With the Pearson and the Deviance statistic not being significant (Significance level <.05), believe that the model is a good fit increases so no further tests are applied and the results accepted. All variables show significant effects with a confidence level of 95%.

In short, if an individual owns a smartphone, owns a tablet or has medium or high education (vs low or no education) the change of that person tele-working (being it daily or weekly) increases. If a person is a student, unemployed or retired, the chance that he or she is Internet daily or weekly for the purpose of tele-working decreases.

Model 1 – Tele-working (N=5989)	
Explanatory variables	Smartphone possession Tablet possession Highest completed education categorized (Categories: low, medium, high) (Work) situation categorized
-2LL intercept only	1765.834
-2LL final	342.517
Nagelkerke	.290

Table 4-8: Logistic regression model 1 - Tele-working.

Model 2: The log-likelihood change between the original model (no explanatory variables included) and the final model (all explanatory variables included) is significant, which tells us that the fit has improved. The pseudo p^2-value (Nagelkerke) shows that 30 percent of the variations in Internet use can be explained by smartphone possession, tablet possession, education level, work situation and the amount of Internet hours per day. Consequently, from these and previous results we can conclude that the amount of Internet hours per day is explaining only 1 percent of the variation in Internet use for Tele-working. With the Pearson and the Deviance statistic not being significant, believe that the model is a good fit increase so no further tests are applied and the results accepted. All variables show significant effects with a confidence level of 90%.

The parameters in model 2 show similar parameter values as in model 1. It is also observed that if a person is using Internet for High or Medium amounts compared to low amounts of hours per day, the chance of a person using Internet for tele-working daily or weekly increases.

Model 2 – Tele-working (N=5957)	
Explanatory variables	Smartphone possession Tablet possession Highest completed education categorized (Work) situation categorized Internet hours categorized
-2LL intercept only	2113.406
-2LL final	632.522
Nagelkerke	.302

Table 4-9: Logistic regression model 2 – Tele-working.

4.2.5 REFLECTION

In the above section an attempt is made to determine the strength of particular variables to explain the variation in Internet use and frequencies of working over distance via the Internet. While acknowledging in the previous section that the relation is much more complex than is represented in the models, the obtained results improve our understanding of the modelled relations. Also, the regression experiment obviously is limited when considering the lack of tests for any threats of violation of the stated assumptions; linearity of the logit, independence of errors and multi-collinearity.

The intention was however not to find a perfect fit, but to assess the relation of personal characteristics and ICT use in a particular direction. This is done and it can be concluded that the estimated models are able to explain at best 6.7% of the variation in Internet use and 30.2% of the variation in frequencies of working over distance via the Internet. The (work) situation of an individual (categorized in student, incapacitated, unemployed and working paid labour) is significantly predicting the amount of Internet use and frequency of tele-working of respondents. This confirms the empirically observed trend in sections 4.1.2 and 4.1.3. Furthermore, smartphone possession and tablet possession are relatively strong predictors of Internet use and tele-working frequencies.

4.3 ICT AND THE AMOUNT OF TRAVEL

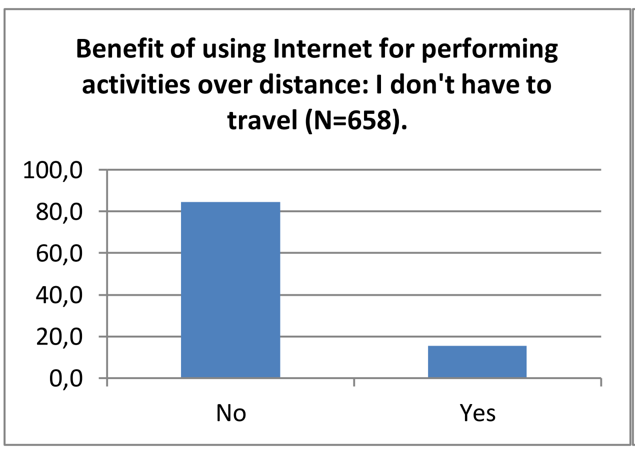
In this section the variation in the amount of travel, calculated in the average number of trips per day, average travel distance per day and average distance per trip, over Internet use (for the total population) and tele-working (for the working population) is analysed. Additional variations of travel amounts over specific profiles and specifically related to shopping and leisure travel are also presented next. Whether the calculated averages (means) of the three indicators of the amount of travel are significantly different is determined with use of a multivariate analysis of variance (MANOVA) as was described in section 3.4.6.1. The amount of * marks behind the indicator in all tables represent the level of significance in table 4-10, 4-11, 4-12, 4-13 and 4-14.

4.3.1 INTERNET USE

In the following section sample 2 is used, including the total population who both completed the questionnaire and trip mobility diary as was described in section 3.2.2.2. To provide additional context to the results, the variation in the amount of travel over gender, age, education level and (work) occupation, are presented in appendix L.

4.3.1.1 STATED BEHAVIOURAL CHANGES

16.5% of the respondents from the total population stated that a benefit of performing activities over distance by using the Internet is that they don't have to travel. This is an important statement considering not only the fact that Internet indeed has the ability to substitute for travel but also because it shows the derived demand and maybe even disutility of travel to many individuals. Another benefit is that people (17.3%) are more able to combine activities and appointments more effectively and efficiently by using the Internet, which obviously has its effect on daily activity patterns and the related amount of travel.



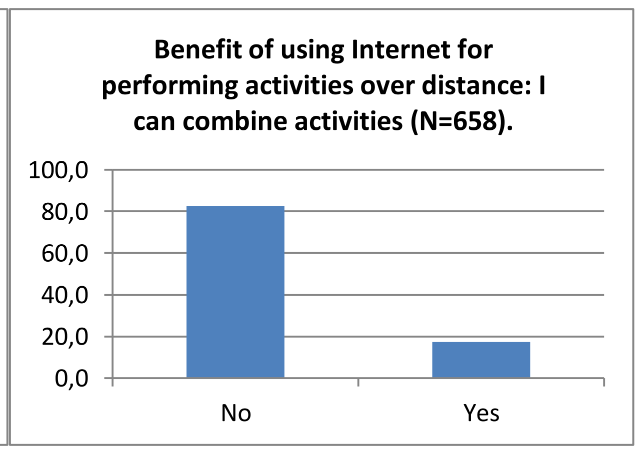


Figure 4.8: Stated benefits of Internet use related to travel.

4.3.1.2 THE AMOUNT OF TRAVEL

Both the average trips per day and the average travel distance per trip are significantly different ($\alpha<0.01$) over the three groups with low, medium and high Internet use. The average amount of trips per day is 0.5 trip lower per day for the group of respondents with high Internet use in hours per day (2.8 trips per day) compared to the group of respondents with low Internet use (3.3 trips per day). Also the travel distance per trip is higher for the group with high Internet use in hours per day compared to the other two groups (for low, medium and high Internet use respectively 10.92, 13.40 and 15.39 km per trip). The average amount of travel distance per day has increased for the group with high Internet use compared to the lower groups. So, people with higher Internet use make fewer trips, but make their trips over a greater distance on average, ICT might as well be one of the reasons for the observed variation. Because age and work situation of a person proved to be strongly linked to Internet use, profile of respondents with a combination of their age and Internet use and work situation and Internet use were created. The amount of travel over these profiles is shown in Figure 4.9.

Indicator (average per person) *=$\alpha<0.10$, **=$\alpha<0.05$, ***= $\alpha<0.001$	Group with low Internet use	Group with medium Internet use	Group with high Internet use
#Trips per day***	3,3	3,1	2,8
Travel distance per day*	32,88 km	35,87 km	38,81 km
Travel distance per trip***	10,92 km	13,40 km	15,39 km

Table 4-10: Calculated travel amounts over Internet use.

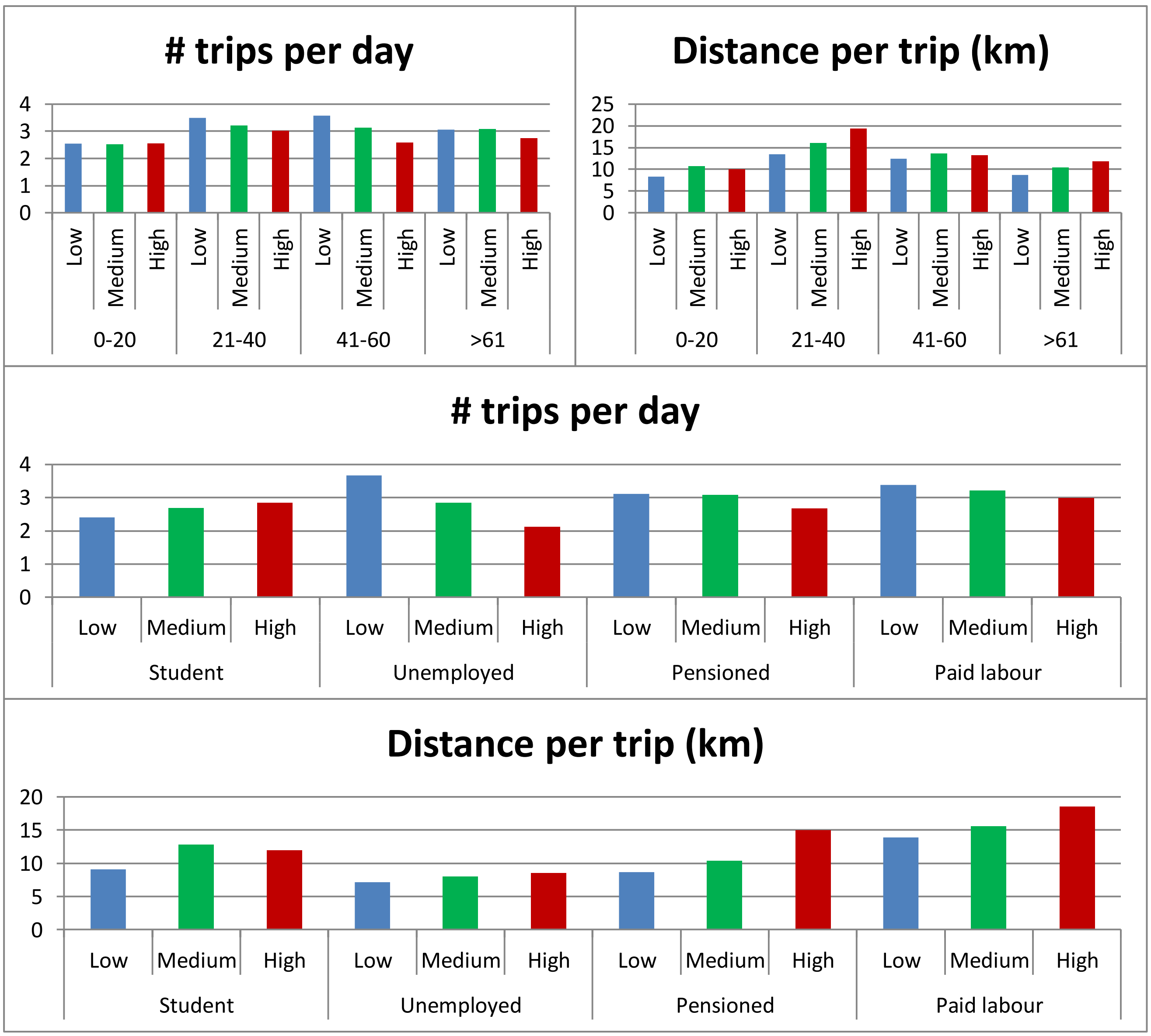


Figure 4.9: Calculated travel amounts over age, work situation and Internet use.

4.3.1.3 THE AMOUNT OF LEISURE-RELATED TRAVEL

Looking specifically at leisure related trips, additional insights related to Internet use and the amount of travel are obtained. Related to travel for leisure related purposes over 30% of 1783 respondents who answered this question in the MPN questionnaire stated that friends they met via the Internet live further away. 10-15% of 1161 respondents stated that they travelled further by car or train because they met people via the Internet who live further away.

Only the average leisure-related trips per day are significantly different (α<0.05) over the three groups with low, medium and high Internet use. The group with high Internet use make 0.66 leisure related trips per day on average compared to 0.80 trips of the group with low Internet use (Table 4-11). The travel distance increases by 2.55 kilometres on average when Internet use increases. This however results in an increase in the average amount of leisure related travel distance per day from 6.85 to 6.91 kilometres.

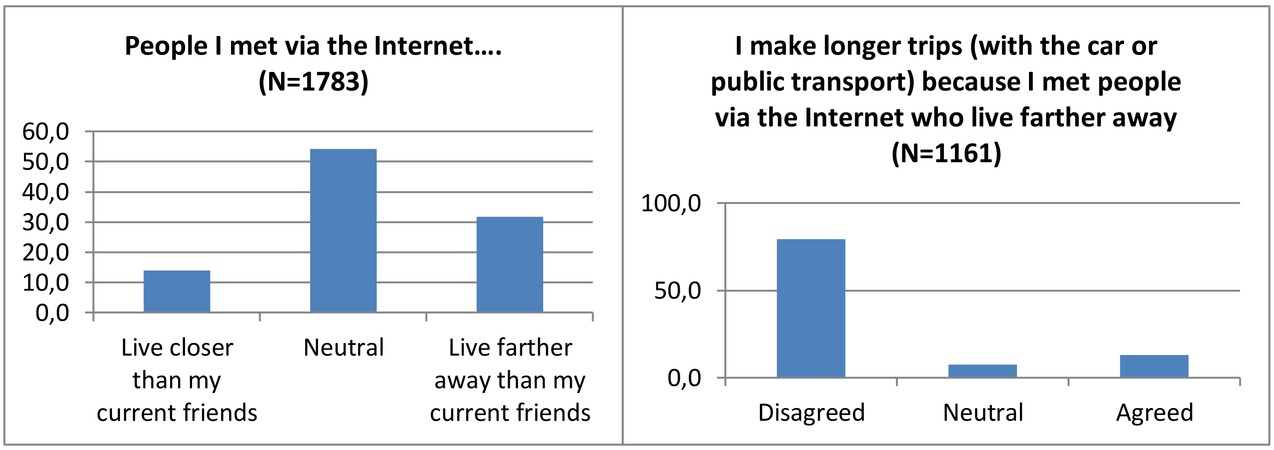


Figure 4.10: Stated behavioural changes related to Internet friends and travel.

Indicator (average per person for leisure related travel) **=α<0.10, **=α<0.05, ***= α<0.001*	Person with low Internet use	Person with medium Internet use	Person with high Internet use
#Trips per day**	0.80	0.74	0.66
Travel distance per day	6.85 km	7.59 km	6.91 km
Travel distance per trip	9.16 km	11.53 km	11.71 km

Table 4-11: Calculated leisure related travel over Internet use.

4.3.1.4 THE AMOUNT OF SHOPPING-RELATED TRAVEL

Looking specifically at shopping trips additional effects are observed. Over 65% of 1003 respondents stated that they shop less often because of the Internet. In addition, only around 17% of the same 1003 respondents who answered this question in the MPN questionnaire stated that they shop farther away because of the Internet. This suggests that the number of shopping trips on average per person per day decrease if Internet use increases, which is confirmed in the data (Table 4-12).

Only the average shopping-related trips per day are significantly different ($\alpha<0.01$) over the three groups with low, medium and high Internet use. The groups with low, medium and high Internet use in hours per day respectively make on average 0.98, 0.84 and 0.79 shopping trips per day. The average distance per shopping trip increases from 4.89 kilometres for the group with low Internet use to 5.49 kilometres for the group with high Internet use. In total the average shopping related travel distance per day for the low, medium and high group is respectively 4.56, 4.08 and 4.03 kilometres.

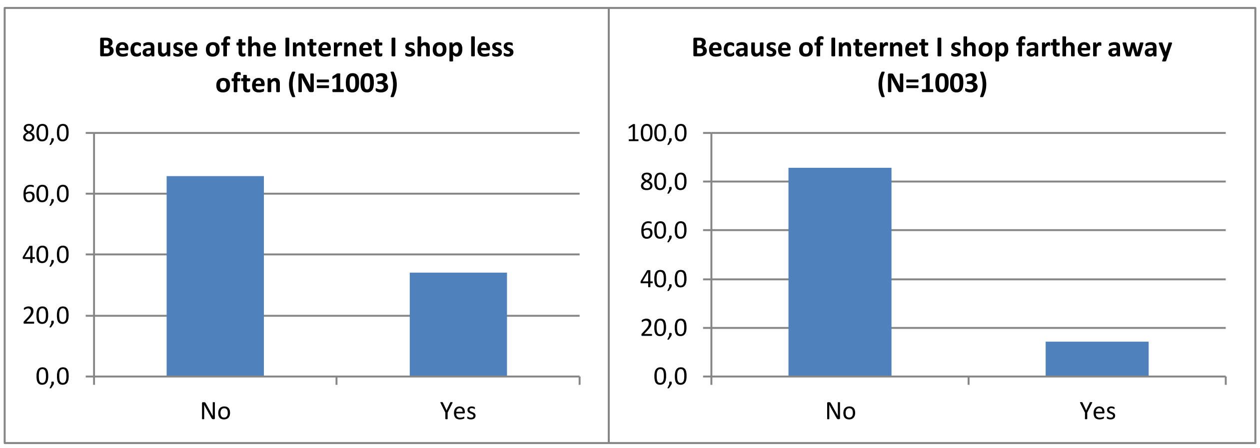


Figure 4.11: Stated behavioural changes related to Internet and shopping related travel.

Indicator (average per person for shopping related travel) *$*=\alpha<0.10$, $**=\alpha<0.05$, $***=\alpha<0.001$*	Person with low Internet use	Person with medium Internet use	Person with high Internet use
#Trips per day* **	0.98	0.84	0.79
Travel distance per day	4.56 km	4.08 km	4.03 km
Travel distance per trip	4.89 km	5.16 km	5.49 km

Table 4-12: Calculated shopping related travel over Internet use.

4.3.2 TELE-WORKING

In the following section sample 3 is used, consisting of the working population as was described in section 3.2.2.3.

4.3.2.1 STATED BEHAVIOURAL CHANGES

14.8% of the 467 respondents from the working population stated that a benefit of performing activities over distance by using the Internet is that they don't have to travel. Furthermore, 9.9% of 253 respondents from the working population where able to move away further from the work location because of the ability to work from home. When the same question but in a hypothetical manner was asked to respondents (N=314); working from home would enable (my entire household) to live further from work, 30.9% agreed to this statement.

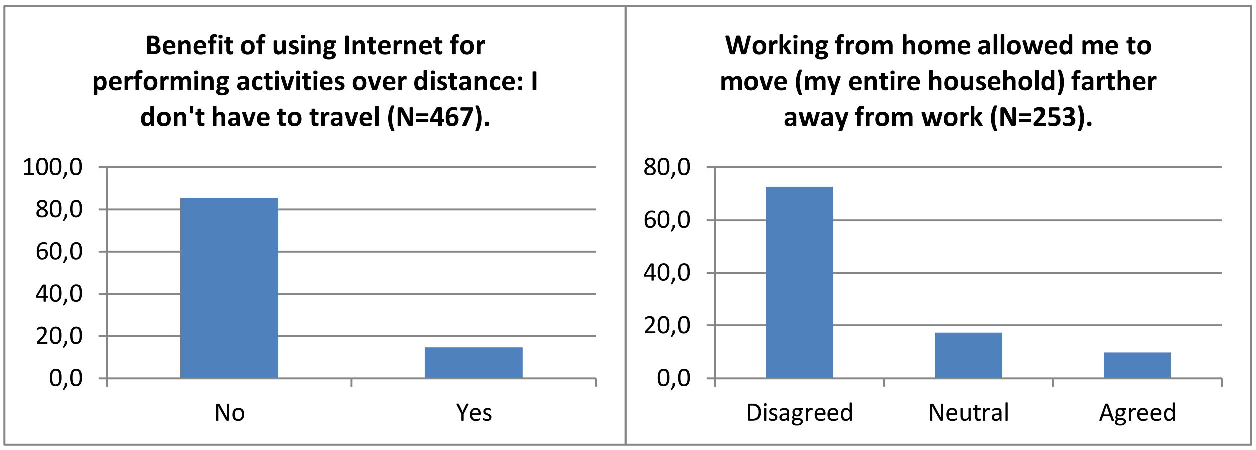


Figure 4.12: Stated behavioural changes related to tele-working and travel.

4.3.2.2 THE AMOUNT OF COMMUTER TRAVEL

The variation in travel amounts for the working population is calculated over two measures of 'tele-working' (introduced in 3.1.2.3).

If the variation in the amount of work related travel is calculated over the groups with varying amounts of 'working over distance with use of the internet', the first tele-working variable, only the average travel distance per commuter trip and the travel distance per day are significantly different ($\alpha<0.01$ – Table 4-13). The difference in the average travel distance per commuter trip is mainly high between the group who incidentally works over distance via the Internet and the groups who work over distance weekly or daily. The frequency of working over distance via the Internet might in this case however just be a good indicator of a different characteristic like type of work. People who work behind a desk all day per definition work less over distance and might travel over smaller distances than entrepreneurs, who are trying to build up their start-up companies.

When considering the second tele-working related variable (hours working from home over distance in a recent representative week) only the differences in the average amount of commuter trips per day is significant ($\alpha<0.05$ – Table 4-14). The average amount of commuter trips decreases with 0.41 trips per day if the full-time tele-working group is compared to the group who didn't tele-work. The average travel distance per commuter trips increases for the group who were part-time or full-time tele-working. The average amount of commuter travel distance per day is lower for the part-time and full-time tele-working group compared to the group who didn't tele-work.

Indicator (average per person) *=α<0.10, **=α<0.05, ***= α<0.001	Incidental working over distance	Weekly working over distance	Daily working over distance
#Commuter trips per day	1.05	1.11	1.02
Commuter travel distance per day* **	16.94	27.30	26.00
Travel distance per commuter trip* **	16.97	25.35	25.84

Table 4-13: Calculated commuter travel amounts over working over distance

Indicator (average per person) *=α<0.10, **=α<0.05, ***= α<0.001	No tele-working	Part-time tele-working	Full-time tele-working
#Commuter trips per day**	1.07	.98	.66
Commuter travel distance per day	20.63	19.2	13.01
Travel distance per commuter trip	20	22.95	23.82

Table 4-14: Calculated commuter travel amounts over tele-working from home

4.3.3 REFLECTION

Important to mention again here is that the calculated travel amounts are influenced by the decision to include days without travel, independent of the reason behind not travelling and that the amount of trips towards the activity and from that activity towards home might differ because of the structure of the data (see section 3.2.2.1). The total amount of travel of the total population is rather different when averaged over groups with low, medium and high Internet use in hours per day. The group with high amounts of Internet use compared to the group with low use make on average 0.5 trips less per day, while the average distance per trip has increased just a bit less than 5 kilometres. The specific and complex character of the variation in the total amount of travel became clear when considering age and the work situation of respondents as was shown in Figure 4.9. For any of the observed variation counts that reasons behind the observed variation might be the result of changing activity patterns as a result of the possibilities that ICTs offer, but this isn't proven.

Looking specifically at the variation in leisure and shopping related travel, it was observed that only the average amount of trips per day is significantly different. The average travel distance per trip varies slightly but the means aren't significantly different. A possible explanation for the observed variation might be again that the use of ICTs allows individuals to travel less, for example because we become more efficient in combining activities.

Looking at the commuter amount of travel of the working population, considering two indicators of tele-working, it is shown that the direct relation of tele-working from home and the amount of travel is clearly present and results in significant different average number of trips per day. This direct relation seems obvious and is confirmed in the results in this research. Working over distance via the Internet (independent of location) however only shows significant different average travel distances per trip.

4.4 ICT AND MODE CHOICE

In the following section sample 4 is used, including all trips and their trip makers as is described in section 3.2.3. In this section the estimation results of different discrete choice models are presented. The stated behavioural changes are presented first after which the results of all estimated parameters from the models are presented and interpreted. Additional results like the odds ratio and the lower and upper boundaries of the 95% confidence interval are presented in appendix P, Q, R, S and T.

4.4.1.1 STATED BEHAVIOURAL CHANGES

20% of 90 respondents who answered the question (Figure 4.13 on the left) stated that they use a different modality on days that they do work (part of a day) from home compared to a day on which they don't work from home. This can for example be the case when people are able to change their departure time because of working from home during peak-hours, which then can result in a different modality decision. Related to the ability to work during a train trip, only around 8-10% of the 209 respondents stated that they choose their modality based on the ability to work during that trip. This however doesn't mean directly that the ability to work during a trip, for example via a tablet and 4G Internet doesn't influence mode choice. It only points out that the main reason to travel by a particular mode for these respondents isn't the ability to work on that modality.

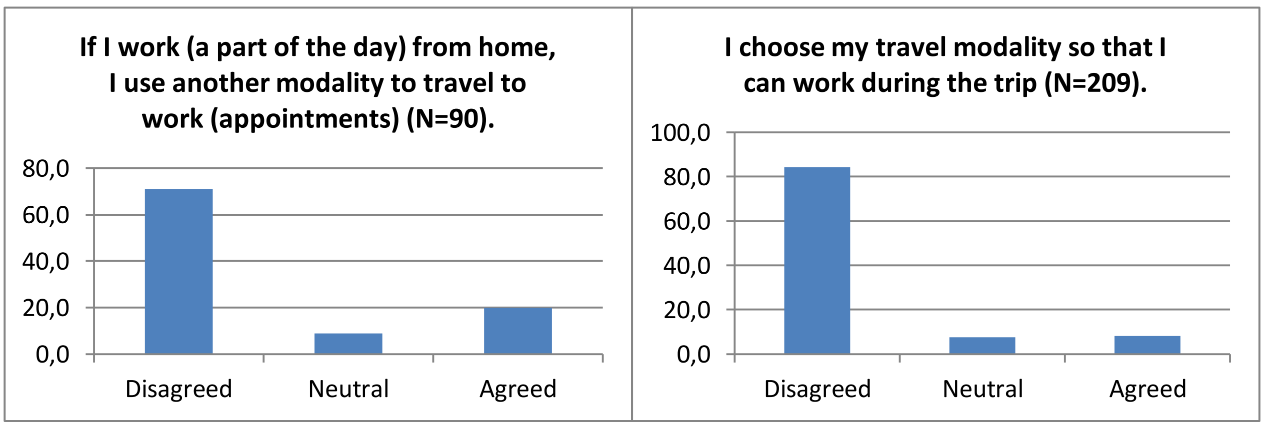


Figure 4.13: Stated behavioural changes related to ICT and mode choice.

4.4.1.2 TESTING FOR ASSUMPTIONS

Table 4-15 shows the estimations of the parameter values (B) with their corresponding level of significance for model 1 to 7. After testing for linearity between all continuous variables (trip, spatial characteristics) and the logit of the outcome variable it is clear that only trip distance and distance from the departure location to the closest railway station meet the assumption of having a linear relation with the log transformation of the categorical outcome variable (mode choice - car/train). Testing for multi-collinearity between the continuous variables showed that the tolerance (<0.1) and VIF (>10) values of trip distance and travel time by car indicated a collinearity issue but without any problematic consequences to this research (for test results see appendix N).

All other (categorical) variables were tested for multi-collinearity by using the chi-square test of independence and the correlation coefficient, Cramer's V. A correlation coefficient of 0.6 or higher is assumed to be a threat. Only the correlation coefficient between smartphone possession and access to Internet via 4G was higher (0.659), which consequently aren't included simultaneously in a model (for test results see appendix O).

Another check before interpreting the any parameter values and their significance levels is whether the lower and upper boundaries of the 95% confidence interval for the odds ratio of a specific category don't cross one.

4.4.1.3 MODEL 1 TO 7 - ESTIMATION RESULTS

Focus is applied to interpretation of the parameter values of those variables which meet all assumptions of logistic regression models and the odds ratio check. The pseudo p^2-value (Nagelkerke) of model 1 is 0.846, which means that the independent variables could explain 84.6 percent of the variation in commuting mode-choice behavior for long-distance trips. The included ICT variables are only able to contribute 0.9% of the explanatory power to model 1 (observing the reduction in the predictive strength of model 1.2). Important to mention here are that the variables, numbers of cars in the household and modality preferences are treated with suspicion. With zero cars in a household, people are almost forces to travel by public transport, which makes the variable less relevant. The preference for home-work trips was asked in the MPN questionnaire in such a manner that people might have interpreted the question wrong and answered their actual used modality for home-work trips. With these predictor variables left out of the model (1.1) still 75.6% of the variation can be explained.

When the cost of a train or a car trip increases, people are more likely to take respectively their car or the train. Furthermore, when the distance to a train station increases, the change of people choosing the car also increases. Non-western immigrants compared to Dutch natives are more likely to travel by car than by train, which is similar for a couple with children compared to a couple without children. Respondents who live in a household with one or more cars are more likely to travel by car. No striking results are present related to the ICT related variables that were included. In the separate models however, this is different.

In the separate models (2 to 7), an increased amount of significant explanatory variables are observed. Applying focus to the ICT related variables first, it is shown that only 3.2% of the variation in mode choice between car and train for long-distance commuter trips can be explained by ICT characteristics of an individual and that only the parameter value of tablet possession is significant; a person that owns a tablet is more likely to travel by car.

The pseudo-p^2 value (Nagelkerke) is particularly high for model 2 which includes only the trip (0.643), model 6 which includes stated modality preferences (0.570) and model 5 which includes only the household characteristics (0.469). A particularly strong predictor in model 5 is the number of cars that are in possession of a trip maker's household. Model 3, which includes the spatial characteristics of the trip, is also relatively strong in predicting the variance in mode choice for long-distance home-work trips (0.190).

Furthermore, when looking at the parameter values, their significance and considering the lower and upper boundaries of the odds ratio of the separate models 2 to 7, trip distance, trip cost by car and train, all spatial characteristics, age, numbers of cars in the household, modality preferences and tablet possession seems reliable and important predictors for mode choice.

Train relative to car	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 1.1	Model 1.2
Variables	B	B	B	B	B	B	B	B	B
Trip characteristics									
Distance	-,044	-,065**						-,055**	-,042
Travel time by car	,051**	,065**						,044*	,052**
Travel time by train	,004	-,008						,002	,001
Trip cost by car	,627**	,943***						1,083***	,597**
Trip cost by train	-,705***	-,909***						-1,097***	-,661***
Spatial characteristics (related to departure location)									
Distance to highway entrance	-,060		,076**					,060	-,058
Distance to train station	-,235*		-,379***					-,355**	-,234**
Distance to subway/metro stop	-,008		-,012***					-,004	-,008
Distance to bus stop	-1,666		-2,270***					-1,284	-1,612
Socio-demographic characteristics									
Gender: Female vs Male	,183			,007				,522	,198
Age: 18-29 years vs >50 years	,997			1,086***				1,206**	,687
Age: 30-39 years vs >50 years	-,718			,061				-,227	-1,007
Age: 40-49 years vs >50 years	-1,320*			-,131				-,181	-1,382**
Education: Medium vs Low or non	-1,437**			,006				-1,607**	-1,683**
Education: High vs Low or non	-1,483**			,637				-1,853**	-1,306*
Western immigrant vs native	,848			,741**				-,239	,704
Non-western immigrant vs native	-2,711**			,425				-3,383***	-2,508**
Household characteristics									
One person household vs Couple	,048				-,334			1,306**	,116
Couple with children vs Couple	1,290**				,358			,122	1,261**
One parent with children vs Couple	,772				-,367			-,500	,777
Number of cars in the household: 1 car vs no car	-3,952***				-4,909***				-4,015***
Number of cars in the household: 2 cars vs no car	-5,122***				-6,647***				-5,031***
Number of cars in the household: >2 cars vs no car	-6,474**				-6,706***				-6,618**
Urban density: >2500 inhabitants/km2 vs <500	0,196				1,037**			,259	-,243
Urban density: 1500-2500 inhabitants/km2 vs <500	-0,950				,811			-,110	-1,212
Urban density: 1000-1500 inhabitants/km2 vs <500	-,868				,634			-,118	-,940
Urban density: 500-1000 inhabitants/km2 vs <500	-2,190**				-,665			-1,226	-2,324**
Mobility preferences									
Preferred modality for commuter trips car: Yes vs No	-2,385***					-2,865***			-2,183***
Preferred modality for commuter trips train: Yes vs No	2,187**					3,308***			2,114**
ICT characteristics									
Internet use in hours per day: Medium vs Low	-,624						,089	-1,130**	
Internet use in hours per day: High vs Low	-,532						,563	-,996	
Internet use for tele-working: Daily vs Incidental	1,000*						,203	,621	
Internet use for tele-working: Weekly vs Incidental	,802						,261	,902	
In possession of a Smartphone: Yes vs No	-,565						-,210	-,278	
In possession of a Tablet: Yes vs No	-,920*						-,647***	-,571*	
Nagelkerke ρ^2	0.846	0.643	0.190	0.081	0.469	0.570	0.032	0.756	0.837
Cases	971	971	971	971	971	971	971	971	971

*Notes: *=α<0.10, **=α<0.05, ***= α<0.001*

Table 4-15: BNL model 1 – 7, 1.1 and 1.2 estimated parameter values.

4.4.1.4 MODEL 8 – ESTIMATION RESULTS

Linking the work related amount of travel per person (averaged per day or trip) to mode choice seems to be explaining only around 1.2% of the total variance in mode choice between car and train for long-distance commuter trips. The averaged travel distance per commuter trip significantly predicts mode choice, but with a minor effect. If the average commuter travel distance of a person increases, the change of choosing the train increases slightly.

Train relative to car	**Model 8**
Variables	**B**
Travel amounts (calculated averages)	
# commuter trips per day	,000
Travel distance per commuter trip	,009**
Nagelkerke ρ^2	0.012
Cases	971
*Notes: *=α<0.10, **=α<0.05, ***= α<0.001*	

Table 4-16: BNL model 8 estimated parameter values.

4.4.1.5 MODEL 7.1 & MODEL 7.2 – ESTIMATION RESULTS

The models are estimated for two sub-groups of the total population. For the group of respondents that are below the age of 35 years, ICT characteristics seem to be a better predictor for mode choice for long-distance home-work trips than for the group of respondents above 34 years of age with respectively a pseudo-p^2 value (Nagelkerke) of 0.035 and 0.020. This however also means that only 3.5 and 2.0 percent of the variation in mode choice can be explained by the included ICT related characteristics. Tablet possession again significantly ($\alpha<0.05$) predicts mode choice, with an increased change of choosing for the car over train when a person owns a tablet. For the age group above 34 years of age, the group of daily tele-workers (relative to the incidental group) are significantly ($\alpha<0.1$) more likely to travel by train.

Train relative to car	**Model 7.1 (<35 years)**	**Model 7.2 (>34 years)**
Variables	**B**	**B**
ICT characteristics		
Internet use in hours per day: Medium vs Low	-.030	.000
Internet use in hours per day: High vs Low	.515	.166
Internet use for tele-working: Daily vs Incidental	-.095	.497*
Internet use for tele-working: Weekly vs Incidental	-.0.076	.459
In possession of a Smartphone: Yes vs No	-.117	-..045
In possession of a Tablet: Yes vs No	-.529**	-.520**
Nagelkerke ρ^2	.035	.020
Cases	312	659
*Notes: *=α<0.10, **=α<0.05, ***= α<0.001*		

Table 4-17: BNL model 7.1 and 7.2 estimated parameter values.

4.4.1.6 MODEL A, B & C – ESTIMATION RESULTS

Based on the observed variation and predictive strength of a combination of socio-demographic and ICT related characteristics of and individual, mainly in section 4.1 and 4.2 two simple sub-models are estimated with interaction between relevant characteristics. The interaction terms are age and Internet use (model A), and tablet possession and access to the Internet via 3G/4G (model B). Model C includes both interaction terms and is the strongest in explaining the variation in mode choice (7.8%).

The group of respondents between the age of 18 and 29 with medium or high internet use is significantly more likely to travel by train compared to the group of respondents above 50 years of age with low Internet use. It is however important to consider that respondents in the age group 18-29 years might by definition be people who are travelling more by train, being for example a student. If a person owns a tablet and has access to the Internet via 4G, it significantly increases the change of that person travelling by train.

Train relative to car	**Model A**	**Model B**	**Model C**
Interaction terms	**B**	**B**	**B**
Age*Internet use *(relative to >50 years, Low Internet use)*			
18-29 years, Medium Internet use	1.026***		.873**
18-29 years, High Internet use	1.781***		1.543***
30-39 years, Medium Internet use	.321		.251
30-39 years, High Internet use	.245		.102
40-49 years, Medium Internet use	.124		.092
40-49 years, High Internet use	-.318		-.430
Access to the Internet via 4G*tablet possession (relative to no access via 4G and no tablet)			
Access via 4G, owns a tablet		.885***	.676***
Nagelkerke ρ^2	.060	.035	.078
Cases	971	971	971
*Notes: *=α<0.10, **=α<0.05, ***= α<0.001*			

Table 4-18: BNL model A, B and C estimated parameter values.

4.4.2 REFLECTION

Looking at the stated behavioural changes or preferences of individuals, it was expected that the impact of ICTs on mode choice for example via the possibility to work during a trip is minor. This is confirmed by the results of the estimated models. ICT seems only to be able to explain 0.9% of the total variance in mode choice between car and train. The highest explanatory strength was found in the full model 1, which explains 84.6% of the variation. Among the other sub-models with specific blocks of explanatory variables; trip characteristics and modality preferences are showing the most explanatory strength, which seems realistic when looking at conclusions from other literature.

Tablet possession is one explanatory variable that is significant in all models. Tablet possession increases the change of a person choosing the car if included as a single predictor variable, while increasing the change of a person choosing the train when combined with the access to 4G. Additional research is needed to extend the analysis presented in this research in-depth, for example to explore the inclusion of interaction terms in the full mode choice model or to explore varying (categorizations of) ICT related variables.

CHAPTER 5. DISCUSSION

This chapter discusses the results that were presented in the previous chapter. First the variation in ICT access, possession and use (and drivers behind this variation) is discussed, then the results related to the relation between ICT and the amount of travel is discussed and finally the results related to the relation of ICT and mode choice are discussed.

5.1 VARIATION IN ICT ACCESS, POSSESSION AND USE

In section 4.1 the variety of the selected ICT variables were presented and their variation analysed over personal characteristics of respondents. In the authors opinion the results from the short and compact analysis are very insightful.

5.1.1 INTERNET USE

The exact reasons behind the observed variation is hard to identify precisely (correlation doesn't mean causality). One can imagine that younger individuals are more eager to learn from and adapt to new technologies, which might be an explanation for the observed variation. Similar reasons might be present for the higher percentage of daily users for the groups with higher completed educations or incomes, possibly these individuals need to use Internet every day for their study or jobs. However, it might also be possible that the higher income groups simply have more money to buy the newest smartphones and Internet subscriptions and use them comfortably.

The variation in the percentage of daily Internet users between groups with a different dominant modality for home-work trips shows an interesting trend. Almost all groups with a higher than average (>+10%) predominantly use a modality to complete home-work trips during which their 'hands are free'; public transport and walking. A complex relation might be present here, but needs more time and effort to explore in-depth. In essence, when people are travelling by public transport or walking they are more able to use the Internet which for commuter trips is often already for five times per week. People then might get used to using the Internet resulting in daily use, also on days which people don't travel to work.

In order to really understand Internet use more specific Internet related activities have to be considered at the disaggregated level. The MPN dataset contains additional information on Internet use, but it is debatable whether the truth complexity of Internet use can be represented in datasets when the data is collected through questionnaires. Measuring Internet use for example via the used devices is possibly the only suitable method to represent the truth variety and complexity of use. Measuring ICTs is considered for the collection of MPN data, but not achievable with high enough confidence and quality at this point.

Considering the Internet use in hours per day, it is important to acknowledge that estimating your own Internet use in hours per day is extremely difficult. Try for yourselves to estimate this amount and you'll probably find that a lot of questions come up. It is clear that the younger generations (below the age of 35) are using the Internet for the highest amounts. This seems only logical considering the recent introduction of the most innovative devices and techniques. When trying to determine where the variation in Internet use in hours per day comes from, similar issues as were formulated above arise. The fact that the use of Internet strongly varies over the age and work situation of an individual doesn't prove anything. Numerous other hidden factors that determine the observed variation can be thought of, including for example the influence of social networks.

Respondents might be introduced to and convinced to use ICT by friends and families or might buy a smartphone or tablet so that contact with a close relative or friend who emigrated remained possible. Another important aspect to consider is the use of Internet for specific purposes. It is shown in the results that both the group of students, incapacitated and unemployed respondents use Internet for a high amount of hours per day. It can however easily be agreed upon that students will predominantly use Internet for the study related purposes but maybe also online entertainment (dependent on the ambition of the student) but that incapacitated individuals might use the Internet predominantly for the purpose of entertainment or keeping in touch with society.

5.1.2 SMARTPHONE AND TABLET POSSESION

Smartphones and tablets are becoming more and more devices of the 'common people' independent of income, education or work situation, high percentages of smartphone and tablet possession are observed. Also in the groups with 'older' respondents, relative high percentages of tablet possession are observed (around 30%). Access to the Internet via 3G/4G technology is strongly linked to smartphone possession, which makes sense considering the fact that most of the smartphones are currently bought in combination with a subscription including this access.

Also important to discuss here is that the state-of-the-art devices are becoming increasingly different in build-quality, speed and price. As a result the variation in available devices is already large at this point and is expected to grow even more. Phablets are for example currently sold more and more as being an 'in-between option' for people who desire a bit larger smartphone or a bit smaller tablet. Furthermore, a recent goal that was communicated to society by ex-employees of google was to develop a tablet in the future that could be a full replacement of the laptop. These developments are ongoing and are expected by the author to change so rapidly in the coming years that most of the population can't even comprehend the full range of possibilities and doesn't have time to adapt directly.

Then, when considering all these terms for a particular device, smartphone, tablet, phablet, laptop, ultra book et cetera, the question is raised whether these terms are actually representing a particular type of device. And even if the terminology is clear for experts, the common people might not be able to understand the differences. A phablet with the screen size maybe between 5 and 7 inches might be a tablet to one person but a smartphone to another. Again here, the current diversity of ICTs makes it difficult to draw unambiguous conclusions and to consider these technologies properly in research.

5.2 ICT AND THE AMOUNT OF TRAVEL

Below the results that were presented in section 4.3, which showed variation in travel amounts over groups with different frequencies of Internet use and tele-working, are elaborated on. It is important here to consider the complexity of determining travel amounts for specific purposes. (daily) Activity patterns, which are assumed in literature to be based on primary and secondary tours consist of multiple trips, possibly with multiple purposes and are as a result not easily separated for the purpose of calculating travel amounts. Difficulties with the considerations of trips towards home arise for example when a trip is made from home to work, from work to the shop and from the shop home instead of from home to work, from work to home, from home to the shop and from the shop home.

5.2.1 INTERNET USE AND TRAVEL

The results presented in 4.3.1.1 on the stated behavioural changes of respondents fuelled the expectation that some effect would be present, but that the overall impact would be minor with just below 20% of the population stating that a benefit of the Internet is either that they don't have to travel or that they can combine activities.

The observed variation in the total amount of travel (section 4.3.1.2) showed a clear trend and the calculated averages for the amount of trips per day and travel distance per trip proved to be significantly different over groups with low, medium and high Internet use. Moreover, when the travel amounts are calculated over two profiles of respondents considering a combination of their, (1) age and Internet use and (2) (work) situation and Internet use additional trends were observed. Interesting to point out here is that for students, the amount of trips was higher both for the group with medium Internet use, compared to the group with low Internet use and for the group with high Internet use, compared to the group with medium Internet use. For unemployed respondents, this effect was observed in the opposite direction with fewer trips per day for the group medium compared to low and high compared to medium. Possibly this might be the result of students using Internet predominantly during travelling and unemployed individuals using Internet at home. It is also observed that the amount of trips per day decrease strongly in the age group 41-60 if Internet use increases. Respondents of that age group on average make around 3.5, 3.1 and 2.7 trips per day for the groups with respectively low, medium and high Internet use measured in hours per day. A similar trend is shown for the age group 21-40. The average distance per trip over Internet use however only varies strongly for the age group 21-40. These results support the importance of considering context factors like age and work situation and prove that the relation of Internet use and the amount of travel might be very specific for different type of individuals; for specific profiles. This means that the variation in travel amounts might show additional patterns if the group of students with high Internet use are separated based on their living situation (dorm room or at home with parents).

It is acknowledged by the author that the observed variation in travel amounts might not even be the result of ICT use directly. Variation in ICT access, possession or use might as well be the result of variation in travel amounts or different levels of ICT adaptation might represent a particular type of person, with a corresponding amount of travel. The observed trends however tend to support the expectation that ICTs, and Internet use being an important one, has the potential for individuals to change their activity patterns, which results in different travel amounts.

5.2.1.1 LEISURE RELATED TRAVEL

The impact of Internet use on the amount of leisure related travel seems relatively small looking at Table 4-11 in 4.3.1.3. A reduction of 0.14 trips per day for the group of respondents with high Internet use and an increase of 2.55 kilometres on average per leisure related trip compared to the group with low Internet use isn't very extreme. However, the calculated average leisure related trips per day over groups with low, medium and high internet use proved to be significantly different.

The fact that over 30% of the respondents stated that the people they met via the Internet live further away supports the globalisation trend and might result in fewer trips on average, but also in larger average distances per trip. It is possibly easier for people to maintain long-distance friendships or relationships, decreasing the perceived distance between locations. Whether people then substitute short-distance friendships (and trips) for long-distance friendships (and trips) is then again a complete different mechanism that needs further sociologic and psychological research.

5.2.1.2 SHOPPING RELATED TRAVEL

In a paper from Hoogendoorn-Lanser, Schaap, and Olde Kalter (2014b), using the MPN data it was already shown that it is difficult to determine the exact effect of ICTs on shopping related travel. E-shopping might substitute for travel (decreasing the number of trips per day on average), people might shop farther away because they now can collect comprehensive information on discounts or they might not change their behaviour at all.

In section 4.3.1.4 it was shown that over 30% of the population from the MPN that stated they shop less often and between 10-15% of the respondents stated that they shop farther away because of the Internet. In essence, this is acknowledged by the data. A significant reduction in the amount of trips per day on average of 0.19 trips per day and an insignificant increase of 0.6 kilometres per trip on average is however again a minor effect. It is possible that the aggregated effects are mitigated by the differences in individual behaviour; the effect might be very strong for one person with high Internet use, but very weak for another person with high Internet use. This again would need additional complex disaggregated research, for example by considering the full process of 'buying a product online', including looking for information, buying the product and getting the product home of one person in context of their ICT use.

5.2.2 TELE-WORKING AND COMMUTER TRAVEL

For tele-working and the amount of work related travel it is important to define these two aspects very precise. For tele-working in this research, two different indicators were used. One representing the frequency of working over distance via the Internet (independent of location) and the other represented the amount of hours per week, tele-working from home. The variation in commuter related travel over these two indicators was clearly different. The direct relation of a person working from home and the reduction of that persons work related travel is confirmed in the results (section 4.3.2.2), which showed that the calculated average number of commuter trips per day over three groups was significantly different with 0.4 less commuter trips per day per person on aggregate for the group ''full-time tele-working'' versus the group ''no tele-working''. Here however other indirect effects of tele-working aren't taken into consideration. For example the rebound effect, other household members using the car when a person doesn't use that car because he works from home, might influence the total amount of household travel strongly.

The variation in travel amounts over groups with incidental, weekly or daily use of the Internet for working over distance was only significant when measured in the average travel distance per trip and not in the amount of trips per day. The difference in the average travel distance per trip for the group with daily use and incidental use was almost 10 kilometres, increasing the average trip distance from around 16 to around 25 kilometres per trip. These two different indicators might show the differences in effect from the 'old-way' of tele-working; from home behind the desktop PC, to the 'modern' form of tele-working; independent of time and space by using ICTs. The old way of tele-working obviously results in less commuter trips, but might contain other strong effects like the described rebound effect. The modern way of tele-working might not decrease the number of daily commuter trips, but people who tend to work over distance (throughout the country?) might increase their average trip distance for commuter trips heavily.

5.3 ICT AND MODE CHOICE

It is shown in the result from model 1, 7 and 1.2 that the link between personal ICT characteristics like Internet use, tele-working frequencies and the possession of a smartphone or tablet when analysed in a discrete choice model isn't particularly strong. It has to be acknowledged however that in the binomial logit model one particular direction is considered; the influence of ICT characteristics on mode choice. The influence of mode choice on ICT related characteristics (buying a tablet because a person travels by train on a daily basis) might as well be much stronger. Additional research is required to consider this direction of the relation.

The full mode choice model (model 1), which includes a variety of explanatory variables, is able to explain 84.6% of the variation in mode choice between the car and train for home-work long distance trips. Excluding the number of cars in a household and preference for the car or train as modality for long-distance home-work trips results in a lower explanatory strength of the model, but this model (model 1.2) is still able to predict 75.6% of the variance in mode choice. The included ICT variables are able to explain only 0.9% of the total 84.6%.

From the sub-models 7.1 and 7.2 it is clear that for the younger generations (below the age of 35), the impact of ICTs is larger, but the main reason behind this might be that the younger generation simply uses ICTs more. Model A, B and C including interaction terms of personal characteristics and ICT use show interesting results. Where in model 1, 1.1 and 7 it was shown that the possession of a tablet increases the chance of an individual travelling by car, the interaction term between tablet possession and access to the Internet via 3G/4G predicted mode choice in favour of the train. Using common sense, arguments can be thought of for both relations. However, the possession of a tablet and access to the Internet via 3G/4G (via that tablet) might be one of the most realistic indicators of the possibility to work during a trip (considering the MPN dataset), which might support the decision to choose the train as modality to complete long-distance home-work trips. Considering the described relations that were found in available literature, the selected ICT variables might have to be improved to find more conclusive results.

Furthermore, it is debatable whether the effect of ICTs is particularly strong on the considered type of trips with the corresponding choice set in this research; long-distance home-work trips by car or train. As was known from the exploration of literature, travel time use might decrease the disutility of that trip characteristic but this isn't shown clearly in the results. Using common sense, it might also be true that travel time by car and train can both be used more efficiently nowadays because of ICTs. It is also questionable whether ICTs are currently perceived as a strong enough benefit to influence mode choice. Other factors that are commonly agreed upon to influence mode choice like trip and spatial characteristics might as well remain the strongest determinants in times to come.

Finally, it is important to consider the limitations of discrete choice modelling and the chosen approach to include ICT characteristics as explanatory variables of mode choice for long-distance home-work trips when drawing conclusions on the observed results. Attempts in literature that include ICT related variables in any way are limited and therefore theoretical support for the decisions that needed to be made lacking. As a result, lack of observed significant relations in this research might not be the results of no relation between ICTs and mode choice, but might be the result of the characteristics of the data and the chosen methodology. Learning from new attempts with comprehensive datasets like the MPN can however be extremely useful towards the possibly even more complex ICT and Mobility related future and scientific landscape.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the final conclusions and recommendations of this research. First of all, the conclusions are presented, which address the research questions that were formulated in chapter two. Secondly, the limitations of this research are presented considering limitations of the data, contextual and methodological limitations. Finally, recommendations for both researchers and policy makers are formulated.

6.1 CONCLUSIONS

It is important to consider that the objective of this research was to contribute to the understanding of the relation between ICTs and the amount of travel and mode choice. Also, when analysing data it is always important to interpret the results in consideration of the specific characteristics of that data and the chosen approach. That having said it is shown that strong variations in travel amounts are present when analysed over groups with similar ICT characteristics. On average the group of respondents with higher amounts of Internet use or frequencies of tele-working make less trips per day, but make that trips over a larger distance. This trend could be the result of many factors, with modern-day possibilities to change travel patterns through ICT use like the fragmentation of activities or the increased efficiency and pleasure of travel time use being one of those factors.

In total and specifically for leisure and shopping trips, the average number of trips over groups with low, medium and high internet use in hours per day is significantly different with lower amount of trips for the group medium compared to low and high compared to medium. For the total amount of trips, the average distance per trip is also significantly different over Internet use with higher distances for the medium group compared to low and the high group compared to medium. For leisure and shopping trips also an increase in the average distance per trip is observed but the differences aren't significant and relatively minor. The variation in work related travel is different when calculated over two different types of tele-working indicators. When the number of trips and average distance per trip are analysed over an indicator that represents the amount of working over distance via the Internet, independent of location, only the average distance per trip varies significantly; trip distance increases when the amount of tele-working over distance via the Internet increases. The variation of commuter trips per day over this indicator is minor and insignificant. For the tele-working indicator that represents the amount of hours in a recent week that a person worked from home, only the number of commuter trips per day vary significantly with less trip for the group part-time tele-working compared to the group with no tele-working and for the full-time tele-working group compared to the part-time tele-working group. The average travel distance per trip increases a little when tele-working from home increases but the variation is insignificant.

When looking at the impact of ICT and mode choice, some significant relations are observed but an overall conclusion can't be formulated with confidence. The model with all explanatory variables is able to explain 84.6% of the variance in mode choice between car and train for long-distance home-work trips, with the included ICT variables only explaining 0.9% of the variation. Tablet possession seems to influence mode choice, but the direction of this relation isn't proven. Tablet possession as a separate indicator seems to increase the chance of a person travelling by car (both in the full model 1 and in sub-models), but an interaction term of tablet possession and access to the Internet via 4G increases the chance of a person travelling by train. Additional (qualitative) research is required to explore the observed statistical relations more in-depth.

The objective of contributing to the understanding of the relation between ICTs, the amount of travel and mode choice is met. With only the first wave of the MPN data being available for this research, trends couldn't be researched over time and this is one of the main reasons for the lack of hard evidence for specific effects of ICT. It is shown empirically that travel amounts vary clearly over groups with similar personal and ICT related characteristics at the aggregated level. The impact of ICT on mode choice is shown statistically but showed to be weak when analysed via the method that is used in this research. Furthermore, it can be concluded that the relation between ICTs and mode choice can be very different for different type of people, which supports the expectation that the relation is not only very complex but also extremely diverse at the disaggregated level.

6.1.1 ICT AND PERSONAL CHARACTERISTICS

Internet access, Internet use, frequencies of working over distance via the Internet, smartphone possession and tablet possession are all varying strongly in context of an individual's personal characteristics. Age was expected and proves to be an important factor behind the variation in ICT use and possession. The variation is also noticeable when shown over a person's (work) occupation, highest completed education, household composition or urban density at housing location amongst other variables. Confirming this complexity of modern-day ICT use is important for further research and future understanding of any relation in the ICT and mobility landscape.

6.1.2 ICT AND THE AMOUNT OF TRAVEL

The increased ICT integration in our daily lives and the increased possibilities to travel support the perceived trend of a 'smaller', more globalized world. Were some decades ago, people would work, consume and relax in our around their villages, nowadays people work, consume and relax all over the country or even abroad. Internet provides the opportunity to substitute for the smaller less important trips so that energy can be saved for longer trips with higher intensities especially for shopping or leisure activities. Commuter trips are hard to substitute for because of the need for face-to-face contact and traditions that are in place for centuries. This could however change if the new generation grows up with increased familiarity to Internet and other ICT related products and services. As at any moment in time, activity patterns are changing continuously and one catalyst for these changes might as well be the modern day possibilities of ICTs.

A significant reduction of trips per day on average and a significant increase of average distance per trip are observed when Internet use increases and is represented by groups with high, medium and low Internet use. Looking specifically at travel amounts as a derived demand from leisure and shopping related activities, again a clear trend is observed. For both leisure and shopping related travel amounts, the number of trips varies significantly over Internet use. The average distances per trip increases slightly but the differences are insignificant. Respondents also stated that travelling less but farther away are results of Internet use for both leisure and shopping related trips. The relation between ICTs and activity patterns is evident, but the net-effect on travel remains difficult to grasp. The variation in work related travel varies in different ways when analysed over different indicators of tele-working with significant variation in the number of trips when analysed over a tele-working indicator that represents the hours in a recent week working from home and significant differences in the average travel distance pet rip when analysed over another tele-working indicator that represents the frequency (incidental, weekly, daily) of working over distance via the Internet independent of location.

Again here, the specific and individual nature of personal and ICT related characteristics and the interweaving of that complex ICT landscape and the physical world make it difficult to point out specific and clear relations and effects.

Additional research is required to determine the link between disaggregated and aggregated effects so that the truth relation between ICTs and travel amounts can be found and proven. Additional research can for example be in the direction of using different methods to collect disaggregated qualitative data via Interviews of focus groups looking for similarities in the empirically or statistically observed trends and specific descriptions of the possible interactions of ICT and mobility by individuals. More on recommendations for further research can be found in section 6.3.

6.1.3 ICT AND MODE CHOICE

The influence of ICTs on mode choice between the car and train for long-distance home-work trips is also difficult to state with confidence. Via the method used in this research 84.6% of the variation in mode choice between the car and train could be explained. ICT related personal characteristics of individuals that were included in the model showed only to explain 0.9% of the variation in mode choice. Additional sub-models showed that for younger respondents (34 years of age or younger) the ICT variables were able to explain more variance of mode choice than for the older group of older respondents (35 years of age or older) but whether the impact of ICTs on mode choice in reality is indeed stronger or that the younger generations simply use more ICT remains unclear at this point. Again, disaggregated and qualitative research might support the statistical insight obtained in this research.

From the included ICT related variables, tablet possession proved to be significant in multiple models with an increased chance of a person who is in possession of a tablet choosing to travel by car. However, when the possession of a tablet with access to the Internet via 4G is combined and as a single explanatory variable included in a sub-model (model B) as an interaction term, opposite effects are observed; the group with respondents who are in possession of a tablet and have access to the Internet via 4G have an significantly increased chance of choosing the train to complete their long-distance home-work trips.

Finally, it is important to consider that the chosen model and included variables are of great influence on the found results, and that the results might not be able to represent the reality in a good enough manner to find any relations. For example the consideration of short-term and long-term effects is missing, mainly because only the first wave of the MPN data was available for this research. ICTs might influence mode choice on the long-term, for example by people choosing to change their lifestyle by selling their car and moving to a city centre because they like to travel by, and work on the train in the future.

6.2 LIMITATIONS

Every research contains some limitations, especially when analysing complex relation in a complex landscape like the one of ICT and mobility. The limitations of this research considering both the limitations of the data and the limitations of the research approach are mentioned in the sections below.

6.2.1 SPECIFICATION OF ICT USE

Specific limitations of the used ICT variables were presented in section 3.3. As mentioned before, ICTs in our modern day society are available in such an extreme variety of devices, services and applications that it can be used for an almost unlimited amount of specific purposes, unrestricted by time our space that the effects on an individual level can be extremely specific and personal both on the short- and long-term. Catching these possibilities under the term 'ICT' and measuring it with a restricted amount of variables is (almost) impossible and limits the researchers' ability to identify and detect specific relations by itself.

The variation in ICT use, mobility and the interactions between them are ideally researched with multiple coherent and detailed datasets over a number of years, which will be able when more data collections of the Dutch Mobility Panel are completed. In any research considering ICT and mobility specific and detailed data is preferred in order to represent the truth complexity of ICT use. Related to Internet use it would for example be useful to know;

> *when (exact time) and where (exact location) a person uses Internet for how long (in seconds), for what purpose (specific service or application), via which type of device (Iphone 6, Samsung galaxy s3, et cetera) and via which technology (WiFi, 3G, 4G) per day.*

This is obviously extremely difficult for respondents to remember exactly and therefore (almost) impossible to represent and measure in a questionnaire. This type of specific information can possibly only be obtained by measuring the use when it is occurring (for example via the devices the use takes place on). Desires to measuring ICT use to obtain data about for example Internet use is becoming more and more evident in the research community. Technological and privacy issues however limit the current possibility of obtaining detailed and high-quality data through measuring at this moment in time.

6.2.2 METHODOLOGICAL LIMITATIONS

The difficulty with this research was mainly that the intention was to statistically analyse the impact of ICTs on mobility while during the execution of the research it became clear that there was limited qualitative knowledge on the current situation to back up important methodological decisions. If relations are as complex as is the case between ICTs and mobility, a strong qualitative and conceptual framework is needed to provide context to the interpretation of the quantitative results which contain numerous limitations. Another difficulty with this research arose because the starting points were mainly based on an exploration of the literature and expectations from the author rather than taking the data as a central starting point.

As a result, it is acknowledged by the author that the used approach is in most cases unable to represent the presented mechanisms in chapter 2, like for example the use of travel time or the fragmentation of activities.

Furthermore, it was mentioned in chapter 2 that both the context of relations between ICT and mobility and interweaving of the digital and the physical world are extremely important to consider in research. The context of personal characteristics is represented in this research rather well, but is (almost) impossible to represent completely. Especially because the digital and physical are so integrated, every minor detail of one's personal live might interact with ICT use and vice versa. It is acknowledged by the author that this research only considers a limited side of the relations context and that the interweaving of the digital and the physical world might be the main reason for the lack of ability to prove any causality.

6.2.2.1 DETERMING THE EFFECT OF ICT ON THE AMOUNT OF TRAVEL

Determining the exact drivers behind the variation or the net-effect might, as is mentioned time and time again in literature, almost impossible. Also when considering the presented decision framework (section 2.1.4) and the concept of daily activity schedules it is easily agreed upon that ICT has the potential to influence short- and long- term decisions on an individual, household, regional, national or global level which makes it difficult to draw unambiguous conclusions. In this research, the intention was not to represent the truth changes in activity schedules. Trip tours are as a result not represented in detail, which limits the possibility to determine the presence of specific relations.

The used approach has led to results that provide a good indication of the impact of ICTs on travel amounts, which meets the objective of this research. However, additional research is required to truly understand the present relations. Finally, it has to be said that research on the variation of travel amounts in context of personal and ICT related characteristics of individuals with use of the MPN data is a direction of research that can truly occupy a team of multiple researchers for months in the authors believe.

6.2.2.2 DETERMINING THE IMPACT OF ICT ON MODE CHOICE

The mode choice experiment contains numerous limitations. Only the binomial logit model by itself and the assumptions and mathematical techniques it is based on are strong simplifications of reality. More complex models that do a better job at representing the real life situation like the mixed-logit or nested logit are available but aren't considered in this research. Furthermore, the set of explanatory variables that are considered weren't designed specifically for this research, which was noticeable in the differences between the ideal and actual characteristics of those variables.

The sample size when considering only long-distance home-work trips also limited the possibility to select an ideal trip set. Furthermore, other limitations were mentioned, for example the missing link with route choice, an extensive analysis of the link between travel amounts and mode choice or the inclusion of habits. Finally, as is the case in almost all researches on mode choice, the set of explanatory variables is far from perfect and can't be used to truly predict mode choice with high confidence. Using the conclusions to improve any transport models is therefore not advisable.

6.3 RECOMMENDATIONS

Nowadays, maybe more than ever, we are facing some pressing issues related to transportation that are becoming more and more evident. Air pollution, congestion, the lack of space and decreasing accessibility of high-density city centres alongside a high urbanization rate are just some examples of these issues, which are posing a major threat to social, economic and environmental mechanisms all over the world. Moreover, some of these developments are threatening the freedom of mobility itself for example by continuously congested city centres or decreased visibility as a result of extremely bad air quality in some Chinese cities.

So, it is clear that change is needed in order to tackle these issues and protect the quality of living and freedom of mobility in its current state. However, in which form and direction will this change need to go? Will technological developments provide the answer for example by the development of alternative fuels or high quality Public Transportation or do we need to force ourselves to simply travel less for example by restrictive policies? 40 somewhat years ago, numerous researchers, policy makers and others believed that the development of information and communication technologies would solve most of the current problems. However, currently we understand that the relation of ICT and transport is evident and contains numerous possibilities but also some major threats and is by itself not expected to be a comprehensive solution.

Keeping up with the rapid innovations and the impacts on mobility by researching the possible interactions is and will be forever extremely important. Maybe first and far most for policy makers, who are pressed more and more to find creative and efficient solutions (with smaller budgets) for our ever-growing issues related to mobility.

6.3.1 FOR RESEARCHERS

The MPN dataset provides numerous opportunities for further research. Not only the relation between ICT and the amount of travel and mode choice, but also the relation between ICT and other more specific aspects of mobility like departure times of commuter trips can be researched with the first wave of the MPN data. Important to consider in any research related to ICT and mobility are the three 'starting points' mentioned in the literature; interweaving of the digital and physical world, the importance of context and limiting technological determinism is vital to the quality of any research. Furthermore, it is important to consider that ICTs in our modern day society are so diverse and integrated in our daily lives that the possible interactions with any aspect of our lives, including mobility, can be expected to be extremely numerous, diverse and complex in both directions.

Looking specifically at the relation between ICTs and the amount of travel it will be interesting to extend the analysis to find disaggregated interactions, which can support the observed aggregated trends but might also improve our understanding of the truth complexity and diversity of the present relations. Furthermore, the empirical analysis in context of personal characteristics might be executed more in-depth if time is available in order to specify the exact drivers behind the observed variation in travel amounts. This can possibly be achieved by creating specific profiles of individuals and analysing their activity patterns and related travel amounts. A separation of work, shopping and leisure related trips are advised because the interactions of ICT to those trips are expected to be very different. Furthermore, an analysis of the observed effects over time (among other trends) can be executed when the other data waves from the MPN become available. If possible, more detailed ICT related variables of respondents need to be collected, for example by measuring Internet use, so that the link between use and mobility changes at a specific moment in time can be researched. This direction includes the research related to the decoupling or fragmentation of activities, which in the authors' perception is very promising.

Researching the relation between ICTs and mode choice, the used method and presented results are only the beginning of a research direction. When more knowledge becomes available on ICTs, when the adaption of recent innovations become more saturated and in consideration of the extensive and complex techniques that are available it might be possible in the future to really determine the impacts of ICTs on mode choice. Possibly, qualitative data can be collected to improve the understanding of the present relations so that methods can be specified with more confidence and in line with reality. Again, if the other data waves of the MPN dataset become available research of changes over time are expected to be an extremely useful addition.

Furthermore, it might be important to consider the importance of the globalisation trend in research on the relation between ICTs and mobility. Country borders are fading in the perception of society and the impact of global travel might have a strong impact on mobility, including travel amounts and mode choice. Also acknowledged in current literature is the importance of social networks, which is obviously also heavily influenced by ICTs. These contextual factors are of vital importance for the understanding of the observed effects. It is also important to consider however that we find ourselves just at the start of ICT related innovations. If autonomous vehicles, or fully integrated ICTs (like for example a google glass) become available to the public, the mechanisms that are of influence might again change drastically which demands new approaches, techniques and efforts of researchers to keep up.

6.3.2 FOR POLICY MAKERS

Our modern world is very dynamic and changing continuously. In recent decades, and in the decades to come, these changes might be catalysed by the globalisation trend that is supported by ICTs. Even with extensive research over many years by many different researchers it is difficult to fully comprehend let alone understand the interactions, relations and factors that are present. This is in the authors' perception very important to acknowledge by policy makers, who tend to base decisions on short term expectations or personal agendas with limited amounts of theoretical prove.

Knowledge institutes like the Netherlands Institute for Policy Analysis (KiM) might play an increasingly important role in supporting policy decisions in the future because of their proven knowledge on current developments and future changes. Integrating the scientific knowledge in the development of policy might allow for a chance of an important balance between conceptual visions and observed real-life trends. Attempts at the Dutch ministry of Infrastructure and Environment to facilitate the described integration are promising and should, in the authors' perception, be encouraged and pursued more actively. In the current situation, it might even be rewarding to create jobs with the specific purpose of integrating scientific knowledge and policy considering that in the current situation, the demand for such integration isn't of first priority to both researchers and policy makers.

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The impact of personal ICTs on mobility behaviour

A study on the impact of personal ICTs on the amount of travel and mode choice using the first wave of the Dutch Mobility Panel.

UNIVERSITY OF TWENTE.

Ministry of Infrastructure and the Environment

The Netherlands Institute for Transport Policy Analysis | KiM

Master thesis - Appendix
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6 February 2015

APPENDIX A. SAMPLE DESCRIPTION

Variable	Value	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)
Socio-demographic		N=6126	N =3904	N= 1938	N = 971
Gender	Male	46.7	46.5	48.2	57.7
	Female	53.3	53.5	51.8	42.3
Age	12-14	3.0	3.2	.4	
	15-17	3.7	3.9	.7	
	18-19	2.1	2.1	4.5	.8
	20-24	5.1	5.1	12.5	3.3
	25-29	7.0	7.6	13.5	13.8
	30-34	8.1	8.8	14.2	14.2
	35-39	8.7	9.3	13.9	14.1
	40-44	9.1	9.2	12.6	16.5
	45-49	8.8	8.9	12.7	12.5
	50-54	8.7	8.8	9.3	11.4
	55-59	8.0	8.6	5.1	7.6
	60-64	7.8	8.3	.4	4.4
	65-69	7.4	7.2	.2	.8
	70-74	6.3	5.0	.1	.4
	75-79	4.2	2.8	.1	.1
	80 years and older	2.0	1.3	.4	
Personal monthly net income	Less than € 1.000	18.2	17.4	10.7	6.4
	€1.001 to €1.500	16.2	16.1	17.6	12.5
	€1.501 to €2.000	18.2	19.1	25.8	28.1
	€2.001 to €2.500	11.5	12.4	16.3	20.5
	€2.501 to €3.000	5.7	6.1	7.7	10.0
	€3.001 to €3.500	2.3	2.5	3.1	4.7
	€3.501 to €4.000	1.0	1.0	1.2	1.9
	€4.001 to €4.500	0.3	.3	.3	.3
	€4.501 to €5.000	0.2	.2	.2	.4
	More than €5.000	0.6	.5	.5	.8
	I don’t know	11.8	11.2	14.9	13.0
	No own income	13.6	12.8	1.7	1.2
	Unknown	0.5	.3	.3	.2
Highest completed education	No education	2.5	2.5	.1	
	Basic education	8.0	7.0	1.8	.6
	LBO\VBO\VMBO (kader- en beroepsgerichte leerweg)	15.6	12.2	9.8	6.4
	MAVO\1e 3 jaar HAVO-VWO\VMBO (theoretische en gemengde leerweg)	8.7	7.9	5.2	3.8
	MBO	28.7	28.6	32.7	31.2
	HAVO en VWO bovenbouw \ WO en HBO propedeuse	8.8	9.5	8.0	7.7
	HBO\WO bachelor of kandidaats	19.4	22.5	28.7	32.3
	WO-doctoraal of master	8.2	9.7	13.8	17.9
	Unknown	0.2	.1		

Table A-1: Sample 1, 2, 3 and 4 with percentage of respondents per category.

Variable	Value	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)
		N=6126	N =3904	N= 1938	N = 971
Work situation	Entrepreneur	5.2	4.9	7.2	2.5
	Paid labour (outside governments)	35.7	38.0	68.6	71.3
	Paid labour (inside governments)	8.2	9.4	17.3	16.6
	Incapacitated	4.3	4.0		.6
	Unemployed	4.0	3.8		.9
	Retired	20.3	17.8		2.2
	Student	10.7	11.0		1.0
	Housemen/housewife	6.6	5.8		.3
	Multiple occupations including paid work	3.7	4.1	6.9	4.3
	Multiple occupations – no paid work	1.1	1.1		.1
	Unknown	0.2	.2		.2
Household					
Household composition	One person household	21.2	23.3	21.1	21.8
	Couple	33.8	33.3	29.6	30.3
	Couple with kids	37.4	36.4	42.7	43.7
	Couple with kids + other(s)	1.3	.9	1.2	.9
	Couple + other(s)	0.8	.7	.7	.4
	Single parent with kids	4.4	4.3	3.6	2.8
	Single parent with kids + other(s)	0.2	.3	.3	.1
	Different composition	0.8	.8	.9	
Urban density at housing location inhabitants/km2	2500 or more	1123	18.5	20.5	17.2
	1500 -2500	1876	31.1	29.8	31.3
	1000-1500	1387	22.8	22.1	22.0
	500-1000	1181	18.3	18.0	17.5
	Less than 500	559	9.3	9.5	11.9
Mobility					
Dominant modality for commuting over the previous 12 months	Car (as a driver)	31.9	33.7	60.0	75.7
	Car (as a passenger)	1.1	1.2	2.0	1.0
	Motor	0.3	0.4	.7	.5
	Train	3.3	3.7	6.6	11.8
	Bus/tram/metro	1.9	2.2	3.8	1.0
	Moped/scooter	0.8	0.7	1.2	.2
	Bike/e-bike	11.4	12.5	22.9	4.0
	Walking	1.1	1.0	1.5	.1
	Other	0.3	0.3	.5	.1
	Unknown	0.7	0.8	.8	.3
	Not asked, person not working paid labor	47.1	43.6		5.1

Table A-2: Sample 1, 2, 3 and 4 with percentage of respondents per category.

Variable	Value	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)
		N=6126	N =3904	N= 1938	N = 971
ICT					
Internet hours per day	< 1 hour	15.4	16.2	13.8	12.4
	1 to 2 hours	35.7	37.0	38.9	37.7
	2 to 3 hours	21.8	22.6	23.9	24.4
	3 to 4 hours	11.7	11.8	11.4	11.5
	4 to 5 hours	5.8	5.7	5.3	6.8
	5 to 6 hours	2.5	2.3	2.0	1.9
	>6 hours	4.6	4.3	4.8	5.4
	Don't know	0.6			
	Not asked, (almost) never uses Internet	2.0			
Working over distance with use of the Internet	<1 day per quarter or non	72.9	5.5	8.6	9.9
	1 to 2 days per quarter	4.1	9.8	15.1	20.5
	1 to 3 days per month	6.6	7.4	12.5	16.0
	1 to 3 days per week	8.7	4.6	7.2	7.0
	4 days or more per week	5.7	72.7	56.6	46.7
	Not asked, (almost) never uses Internet	2.0			
Smartphone possession	Yes	61.1	64.2	74.6	76.8
	No	38.9	35.8	25.4	23.2
Tablet possession	Yes	49.0	50.2	58.0	60.1
	No	51.0	49.8	42.0	39.9
Fixed Internet (Lan) connection via Desktop pc or laptop	Yes	75.6	75.4	73.3	69.8
	No	24.4	24.6	26.7	30.2
Internet access via WiFi per (a combination of) device(s)	Desktop PC or laptop	12.2	11.3	7.8	8.8
	Tablet	7.7	7.2	5.2	4.6
	Smartphone	6.9	7.3	6.4	6.3
	Desktop PC or Laptop and tablet	6.5	6.9	7.0	7.7
	Desktop PC or Laptop and smartphone	18.4	19.7	20.9	20.3
	Tablet and smartphone	9.4	9.8	12.3	12.6
	All devices	22.9	24.1	31.7	33.6
	Non	16.0	13.8	8.7	6.2
Internet access via 3G/4G per (a combination of) device(s)	Desktop PC or laptop	1.8	1.1	1.0	.8
	Tablet	1.0	.7	.6	.4
	Smartphone	38.3	41.5	52.7	55.9
	Desktop PC or Laptop and tablet	0.3	.2	.2	2.1
	Desktop PC or Laptop and smartphone	1.9	1.9	2.0	4.9
	Tablet and smartphone	3.2	3.2	4.3	1.3
	All devices	1.2	1.1	1.4	34.5
	Non	52.3	50.3	37.8	.8

Table A-3: Sample 1, 2, 3 and 4 with percentage of respondents per category.

APPENDIX B. SAMPLE 4 SPECIFICATION

Variables	Category	Reference category	Total (N=971)	Car (N=831)	Train (N=140)
Personal characteristics			[%]	[%]	[%]
Gender	Male	X	58	86.8	13.2
	Female		42	83.9	16.1
Age	18-29 years		18	71.8	28.2
	30-39 years		28	86.9	13.1
	40-49 years		29	89.7	10.3
	50 years and older	X	25	89.2	10.8
Education	No or low	X	7	89.7	10.3
	Medium		35	90.6	9.4
	High		58	82.1	17.9
Origin	Western immigrant		7	76.9	23.1
	Non-western immigrant		2	77.3	22.7
	Native	X	91	86.4	13.6
Household characteristics					
Household composition	One person household		22	68.4	31.6
	Couple	X	30	88.1	11.9
	Couple with children		45	92.0	8.0
	One parent household with children		3	89.3	10.7
Number of cars in the household	No car	X	6	3.3	96.7
	1 car		36	83.5	16.5
	2 cars		52	95.9	4.1
	> 2 cars		5	96.1	3.9
Urban density at housing location (inhabitants/km2)	> 2500		17	68.9	31.1
	1500-2500		31	83.2	16.8
	1000-1500		22	87.9	12.1
	500-1000		18	97.1	2.9
	<500	X	12	94.8	5.2
Mobility preferences					
Preferred modality for work-related trips is car	Yes		71	98.0	2.0
	No	X	29	55.9	44.1
Preferred modality for work-related trips is train	Yes		8	9.1	90.9
	No	X	92	92.2	7.8

Table B-1: Explanatory variables of mode choice with percentages per category.

APPENDIX C. CATEGORIZATION OF VARIABLES

Variable	Categorization	Original categories
Internet hours	Low	<1 hour
	Medium	1 – 2 hours 2 – 3 hours 3 – 4 hours
	High	4 – 5 hours 5 – 6 hours 6> hours
Working over distance	Incidental	1 day per quarter or non 1 - 2 days per quarter
	Weekly	1 - 3 times per month
	Daily	1 – 3 days per week >4 days per week
Tele-working from home	No	Less than 12 hours per week
	Part-time	12 to 20 hours per week 20 to 25 hours per week
	Full-time	25 to 30 hours per week 30 to 35 hours per week 35 hours per week or more
Education	No or low	No education Basic education LBO\VBO\VMBO
	Medium	MAVO\1e 3 jaar HAVO-VWO\VMBO MBO
	High	HAVO en VWO bovenbouw \ WO en HBO propedeuse HBO\WO bachelor of kandidaats WO-doctoraal of master
(Work) occupation	Student	Student
	Incapacitated	Incapacitated
	Unemployed	Unemployed/looking for work Houseman/woman Retired Multiple occupations but no paid labour
	Paid labour	Paid labour outside the government Paid labour inside the government Multiple occupations including paid labour
Household composition	One person household	One person household
	Couple	Couple Couple + other(s)
	Couple with kids	Couple with kids Couple with kids + other(s)
	One parent household	One person household One person household + other(s)
Dominant modality	PMT	Car Motorbike Moped/scooter
	PT	Train Bus/tram/metro
	NMT	Walking Cycling

Table C-1: Representation of original and aggregated categories of variables.

APPENDIX D. ACCESS TO THE INTERNET VIA LAN, WLAN OR 3G/4G

Variable	Value	N=6126	LAN	WLAN	3G/4G
Socio-demographic			% yes	% yes	% yes
Gender	Male		78.2	84.8	49.9
	Female		73.2	83.2	45.7
Age	12-14		63.0	94.6	39.7
	15-17		67.8	94.7	49.3
	18-19		74.0	91.3	68.5
	20-24		67.9	94.9	73.1
	25-29		69.2	96.5	78.3
	30-34		66.3	97.0	72.7
	35-39		72.0	92.9	66.9
	40-44		72.4	91.2	60.0
	45-49		77.9	89.8	53.1
	50-54		81.7	83.4	42.1
	55-59		81.6	79.1	39.5
	60-64		80.0	77.7	29.9
	65-69		81.5	67.2	18.5
	70-74		81.9	66.3	15.5
	75-79		85.0	52.3	13.8
	80 years and older		79.3	51.2	5.8
Personal monthly net income	Less than € 1.000		74.0	79.8	39.3
	€1.001 to €1.500		77.7	81.0	46.5
	€1.501 to €2.000		76.5	85.6	53.3
	€2.001 to €2.500		75.4	87.9	54.2
	€2.501 to €3.000		71.6	85.9	57.2
	€3.001 to €3.500		70.9	89.4	48.2
	€3.501 to €4.000		87.3	88.9	58.7
	€4.001 to €4.500		71.4	81.0	42.9
	€4.501 to €5.000		66.7	91.7	41.7
	More than €5.000		91.2	82.4	70.6
Highest completed education	No education		68.0	91.5	43.8
	Basic education		72.2	80.8	37.2
	LBO\VBO\VMBO (kader- en beroepsgerichte leerweg)		81.0	73.1	33.4
	MAVO\1e 3 jaar HAVO-VWO\VMBO (theoretische en gemengde leerweg)		78.0	76.7	38.5
	MBO		77.3	86.1	50.5
	HAVO en VWO bovenbouw \ WO en HBO propedeuse		72.6	89.9	54.9
	HBO\WO bachelor of kandidaats		74.1	88.3	55.0
	WO-doctoraal of master		68.5	89.3	60.3
Work situation	Entrepreneur		80.1	88.6	63.0
	Paid labour (outside governments)		73.7	90.5	60.9
	Paid labour (inside governments)		74.6	91.8	60.6
	Incapacitated		76.5	80.3	42.4
	Unemployed		76.4	85.1	48.3
	Retired		82.1	65.7	18.2
	Student		68.3	93.8	54.4
	Housemen/housewife		76.5	73.0	21.8
	Multiple occupations including paid work		71.1	92.5	67.1
	Multiple occupations – no paid work		80.1	88.6	36.2

Table D-1: Access to the Internet with percentages 'yes' per category (sample 1).

Variable	Value	N=612	LAN % yes	WLAN % yes	3G/4G % yes
Household					
Household composition	One person household		75.8	77.3	45.5
	Couple		78.7	78.6	37.4
	Couple with kids		73.1	91.7	55.7
	Couple with kids + other(s)		81.8	88.3	67.5
	Couple + other(s)		80.8	88.5	63.5
	Single parent with kids		69.7	90.4	56.8
	Single parent with kids + other(s)		80.0	86.7	60.0
Urban density at housing location inhabitants/km2	2500 or more		73.3	84.8	53.8
	1500 -2500		76.4	83.5	49.3
	1000-1500		76.6	83.9	46.3
	500-1000		75.0	85.4	43.9
	Less than 500		75.8	81.2	41.3
Mobility					
Dominant modality for commuting over the previous 12 months	Car (as a driver)		73.9	92.2	65.1
	Car (as a passenger)		80.9	89.7	52.9
	Motor		85.0	90.0	45.0
	Train		69.3	96.0	68.8
	Bus/tram/metro		73.7	90.7	67.8
	Moped/scooter		76.0	78.0	50.0
	Bike/e-bike		75.3	87.1	53.3
	Walking		78.5	81.5	46.2

Table D-2: Access to the Internet with percentages 'yes' per category (sample 1).

APPENDIX E. PERCENTAGE OF DAILY INTERNET USERS

Variable	Value	%
Socio-demographic		
Gender	Male	82,7
	Female	81,3
Age	12-14	0,0
	15-17	0,0
	18-19	82,6
	20-24	89,0
	25-29	92,9
	30-34	93,9
	35-39	92,3
	40-44	90,9
	45-49	91,2
	50-54	87,5
	55-59	85,0
	60-64	77,2
	65-69	84,3
	70-74	74,9
	75-79	68,9
	80 years and older	66,3
Personal monthly net income	Less than € 1.000	78,1
	€1.001 to €1.500	80,7
	€1.501 to €2.000	82,1
	€2.001 to €2.500	85,8
	€2.501 to €3.000	84,5
	€3.001 to €3.500	83,7
	€3.501 to €4.000	88,9
	€4.001 to €4.500	95,2
	€4.501 to €5.000	75,0
	More than €5.000	85,3
Highest completed education	No education	83,7
	Basic education	76,5
	LBO\VBO\VMBO (kader- en beroepsgerichte leerweg)	71,7
	MAVO\1e 3 jaar HAVO-VWO\VMBO (theoretische en gemengde leerweg)	78,0
	MBO	82,6
	HAVO en VWO bovenbouw \ WO en HBO propedeuse	88,3
	HBO\WO bachelor of kandidaats	87,6
	WO-doctoraal of master	88,5
Work situation	Entrepreneur	82,0
	Paid labour (outside governments)	85,9
	Paid labour (inside governments)	88,9
	Incapacitated	87,5
	Unemployed	88,4
	Retired	68,7
	Student	89,5
	Housemen/housewife	69,3
	Multiple occupations including paid work	90,4
	Multiple occupations – no paid work	75,4

Table E-1: Percentage of daily Internet users per category of personal characteristics.

Variable	Value	%
Household		
Household composition	One person household	86,1
	Couple	75,8
	Couple with kids	84,3
	Couple with kids + other(s)	77,9
	Couple + other(s)	75,0
	Single parent with kids	92,3
	Single parent with kids + other(s)	93,3
Urban density at housing location inhabitants/km2	2500 or more	86,1
	1500 -2500	81,7
	1000-1500	80,8
	500-1000	80,0
	Less than 500	81,4
Mobility		
Dominant modality for commuting over the previous 12 months	Car (as a driver)	86,7
	Car (as a passenger)	89,7
	Motor	90,0
	Train	89,1
	Bus/tram/metro	86,4
	Moped/scooter	80,0
	Bike/e-bike	84,9
	Walking	87,7

Table E-2: Percentage of daily Internet users per category of personal characteristics.

APPENDIX F. INTERNET USE IN HOURS PER DAY

Variable	Value	Internet hours per day
Socio-demographic		
Gender	Male	2,48
	Female	2,32
Age	12-14	2,27
	15-17	2,99
	18-19	3,27
	20-24	3,31
	25-29	2,96
	30-34	2,68
	35-39	2,47
	40-44	2,45
	45-49	2,22
	50-54	2,32
	55-59	2,26
	60-64	2,06
	65-69	1,89
	70-74	1,90
	75-79	1,71
	80 years and older	1,83
Personal monthly net income	Less than € 1.000	2,50
	€1.001 to €1.500	2,31
	€1.501 to €2.000	2,29
	€2.001 to €2.500	2,31
	€2.501 to €3.000	2,45
	€3.001 to €3.500	2,58
	€3.501 to €4.000	2,33
	€4.001 to €4.500	2,64
	€4.501 to €5.000	2,17
	More than €5.000	2,33
Highest completed education	No education	2,55
	Basic education	2,57
	LBO\VBO\VMBO (kader- en beroepsgerichte leerweg)	2,19
	MAVO\1e 3 jaar HAVO-VWO\VMBO (theoretische en gemengde leerweg)	2,33
	MBO	2,32
	HAVO en VWO bovenbouw \ WO en HBO propedeuse	2,60
	HBO\WO bachelor of kandidaats	2,45
	WO-doctoraal of master	2,53
Work situation	Entrepreneur	2,68
	Paid labour (outside governments)	2,33
	Paid labour (inside governments)	2,41
	Incapacitated	2,84
	Unemployed	2,86
	Retired	1,91
	Student	2,96
	Housemen/housewife	2,04
	Multiple occupations including paid work	3,02
	Multiple occupations – no paid work	2,29

Table F-1: Calculated Internet hours per day per category of personal characteristics.

Variable	Value	Internet hours per day
Household		
Household composition	One person household	2,57
	Couple	2,21
	Couple with kids	2,42
	Couple with kids + other(s)	2,20
	Couple + other(s)	2,44
	Single parent with kids	2,71
	Single parent with kids + other(s)	2,17
Urban density at housing location inhabitants/km2	2500 or more	2,67
	1500 -2500	2,37
	1000-1500	2,34
	500-1000	2,27
	Less than 500	2,31
Mobility		
Dominant modality for commuting over the previous 12 months	Car (as a driver)	2,40
	Car (as a passenger)	2,41
	Motor	2,63
	Train	2,87
	Bus/tram/metro	2,73
	Moped/scooter	2,20
	Bike/e-bike	2,27
	Walking	2,68

Table F-2: Calculated Internet hours per day per category of personal characteristics.

APPENDIX G. FREQUENCY OF WORKING OVER DISTANCE

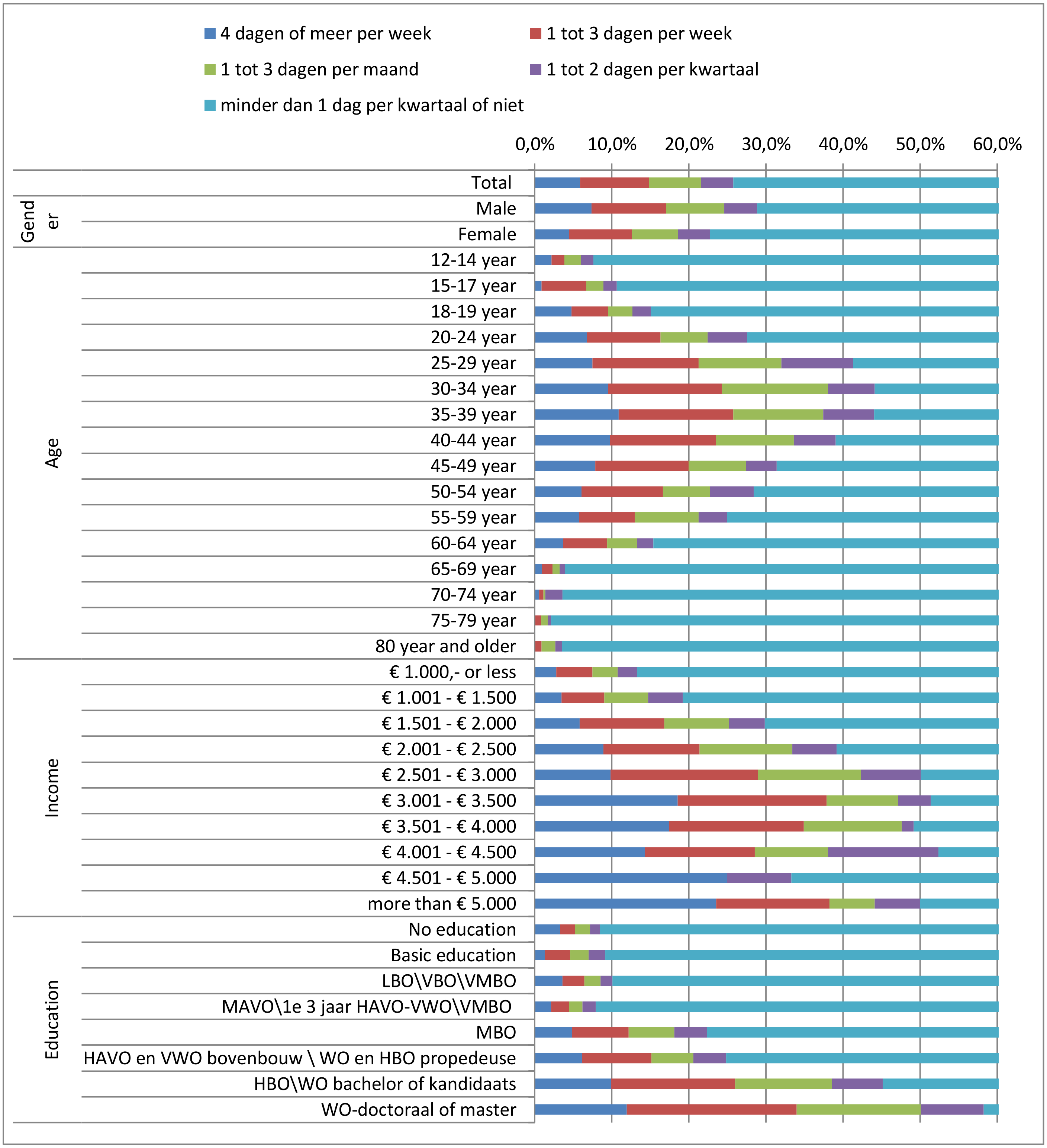

Figure G.1: Working over distance via the Internet per category of personal characteristics.

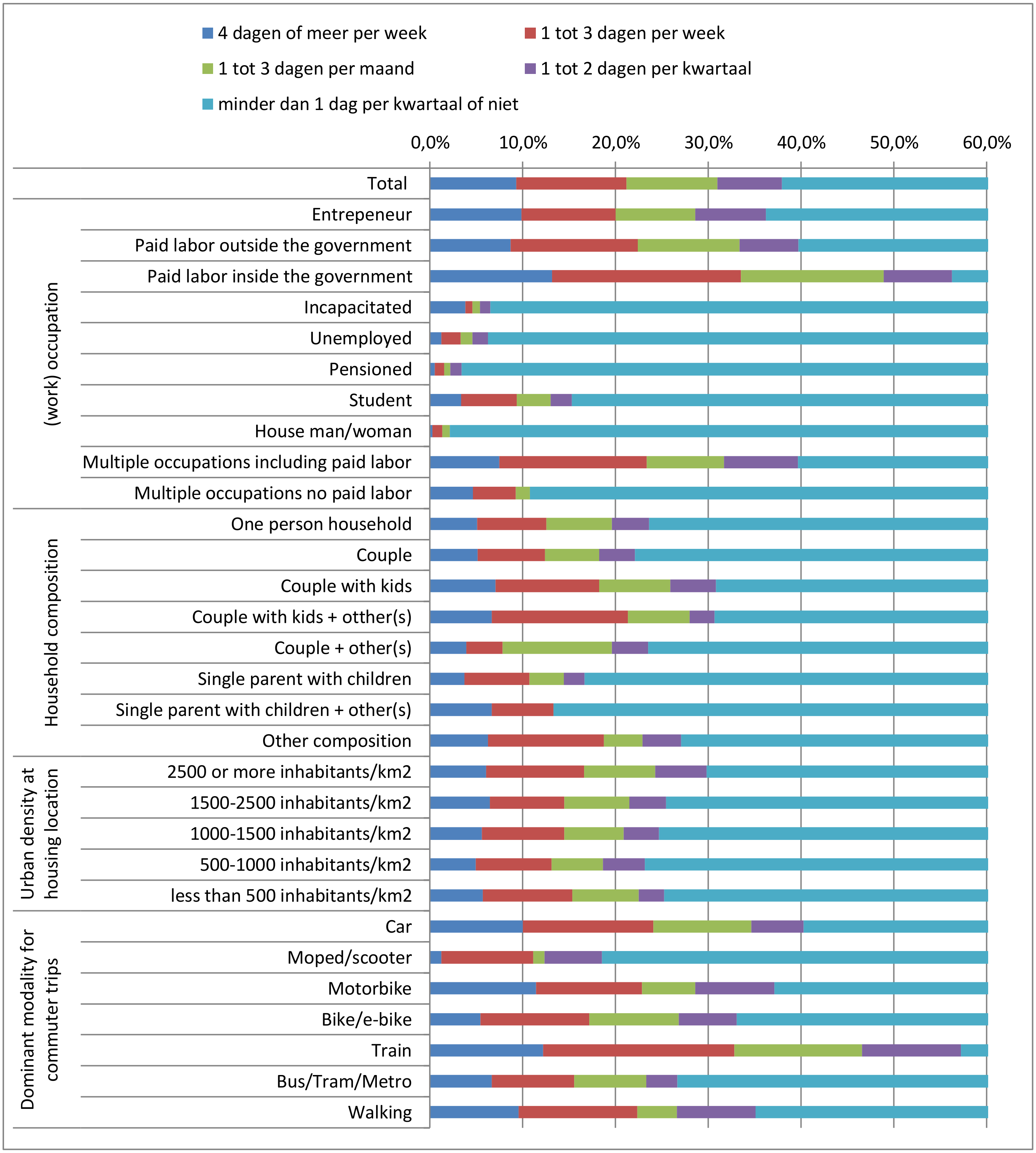

Figure G.2: Working over distance via the Internet per category of personal characteristics.

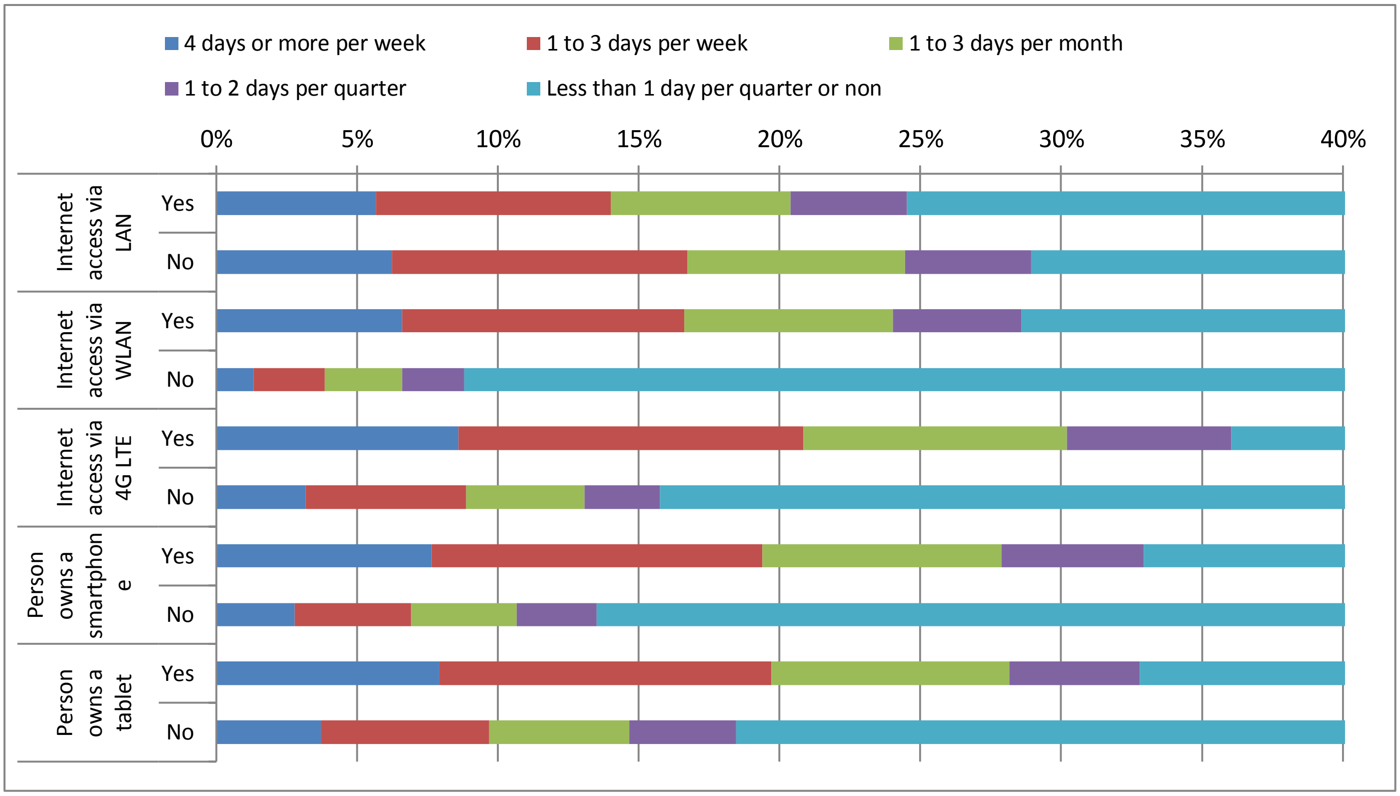

Figure G.3: Working over distance via the Internet per category of personal characteristics

APPENDIX H. SMARTPHONE AND TABLET POSSESSION

	Respondent owns a smartphone		Respondent owns a tablet	
Total	Yes [%]	No [%]	Yes [%]	No [%]
Gender				
Male	62,5	37,5	49,6	50,4
Female	59,9	40,1	48,5	51,5
Age				
12-14 year	77,2	22,8	41,3	58,7
15-17 year	81,9	18,1	30,4	69,6
18-19 year	86,6	13,4	27,6	72,4
20-24 year	85,6	14,4	35,6	64,4
25-29 year	86,2	13,8	49,1	50,9
30-34 year	88,1	11,9	56,8	43,2
35-39 year	79,9	20,1	62,6	37,4
40-44 year	76,5	23,5	58,2	41,8
45-49 year	69,0	31,0	58,6	41,4
50-54 year	55,5	44,5	52,3	47,7
55-59 year	50,5	49,5	49,1	50,9
60-64 year	40,5	59,5	48,9	51,1
65-69 year	29,3	70,7	45,4	54,6
70-74 year	23,6	76,4	44,3	55,7
75-79 year	14,6	85,4	30,8	69,2
80 year and older	7,4	92,6	30,6	69,4
Personal monthly net income				
€ 1.000,- or less	53,0	47,0	41,3	58,7
€ 1.001 - € 1.500	57,3	42,7	46,6	53,4
€ 1.501 - € 2.000	64,4	35,6	52,0	48,0
€ 2.001 - € 2.500	65,4	34,6	56,9	43,1
€ 2.501 - € 3.000	66,4	33,6	59,8	40,2
€ 3.001 - € 3.500	58,2	41,8	65,2	34,8
€ 3.501 - € 4.000	69,8	30,2	66,7	33,3
€ 4.001 - € 4.500	57,1	42,9	52,4	47,6
€ 4.501 - € 5.000	50,0	50,0	66,7	33,3
more than € 5.000	70,6	29,4	58,8	41,2
Highest completed education				
No education	75,2	24,8	38,6	61,4
Basic education	57,9	42,1	32,9	67,1
LBO\VBO\VMBO	45,0	55,0	41,1	58,9
MAVO\1e 3 jaar HAVO-VWO\VMBO	51,7	48,3	43,8	56,2
MBO	63,4	36,6	53,2	46,8
HAVO en VWO bovenbouw \ WO en HBO propedeuse	68,2	31,8	49,2	50,8
HBO\WO bachelor of kandidaats	67,5	32,5	56,9	43,1
WO-doctoraal of master	70,4	29,6	55,4	44,6

Table H-1: Smartphone and tablet possession per category of personal characteristics.

	Respondent owns a smartphone		Respondent owns a tablet	
Total	Yes [%]	No [%]	Yes [%]	No [%]
(work) situation				
Entrepeneur	71,5	28,5	57,0	43,0
Paid labor outside the government	74,0	26,0	57,7	42,3
Paid labor inside the government	75,5	24,5	61,2	38,8
Incapacitated	53,4	46,6	43,2	56,8
Unemployed	63,2	36,8	42,6	57,4
Retired	25,9	74,1	42,4	57,6
Student	81,4	18,6	31,6	68,4
House man/woman	38,1	61,9	42,8	57,2
Multiple occupations including paid labor	75,9	24,1	40,8	59,2
Multiple occupations no paid labor	47,8	52,2	49,3	50,7
Household composition				
One person household	56,8	43,2	41,5	58,5
Couple	46,4	53,6	50,9	49,1
Couple with kids	74,2	25,8	52,5	47,5
Couple with kids + otther(s)	80,5	19,5	57,1	42,9
Couple + other(s)	67,3	32,7	48,1	51,9
Single parent with children	74,9	25,1	38,0	62,0
Single parent with children + other(s)	86,7	13,3	53,3	46,7
Urban density at housing location				
2500 or more inhabitants/km2	65,1	34,9	48,3	51,7
1500-2500 inhabitants/km2	61,8	38,2	49,4	50,6
1000-1500 inhabitants/km2	60,1	39,9	50,0	50,0
500-1000 inhabitants/km2	58,9	41,1	48,9	51,1
less than 500 inhabitants/km2	57,6	42,4	47,2	52,8
Dominant modality for commuter trips				
Car	76,2	23,8	57,0	43,0
Moped/scooter	69,1	30,9	44,4	55,6
Motorbike	71,4	28,6	62,9	37,1
Bike/e-bike	65,9	34,1	50,4	49,6
Train	77,1	22,9	62,6	37,4
Bus/Tram/Metro	79,1	20,9	44,0	56,0
Walking	58,9	41,1	44,2	55,8

Table H-2: Smartphone and tablet possession per category of personal characteristics.

APPENDIX I. CHI-SQUARE TEST OF INDEPENDENCE RESULTS

Variables	Dominant modality	Age	Education	Income	Work situation	Smartphone	Tablet	Household composition
Dominant m		.146	.119	.148	.112	.115	.041	.133
Age			.342	.396	.403	.496	.194	.367
Education				.383	.250*	.179	.149	.167
Income					.435**	.075	.157	.173
Work						.423	.194	.308
Smartphone							.207	.254
Tablet								.098
HH comp								

Table I-1: Chi-square test of independence results – Cramer's V – for personal characteristics
*20,2% of the cells have expected count less than 5.
**22,7% of the cells have expected count less than 5.

APPENDIX J. REGRESSION MODEL RESULTS – INTERNET USE

		95% CI for Odds Ratio		
Low use relative to medium use	B (SE)	Lower	Odds Ratio	Upper
Smartphone possession yes vs no	-.787(.080)***	.389	.455	.533
Student vs paid labour	-.462(.159)**	.462	.630	.860
Unemployed vs paid labour	.136(.105)	.931	1.145	1.408
Retired vs paid labour	.363(.093)***	1.198	1.438	1.726
High use relative to medium use				
Smartphone possession yes vs no	.533(,097)***	1.411	1.705	2.060
Student vs paid labour	.488(.111)***	1.310	1.629	2.025
Unemployed vs paid labour	.368(.108)**	1.169	1.445	1.787
Retired vs paid labour	-.276(.133)**	.585	.759	.984

Table J-1: Regression results - Outcome variable Internet use: model 1
* sig. <0.10, ** sig. <0.05, *** sig. <0.001

		95% CI for Odds Ratio		
Low use relative to medium use	B (SE)	Lower	Odds Ratio	Upper
Smartphone possession yes vs no	-.799(.111)***	.362	.450	.559
PT vs PMT	-.088(.176)	.649	.916	1.292
NMT vs PMT	-.121(.127)	.691	.886	1.137
High use relative to medium use				
Smartphone possession yes vs no	.634(.151)***	1.403	1.885	2.532
PT vs PMT	.486(.148)***	1.216	1.626	2.176
NMT vs PMT	-.160(.138)	.650	.852	1.117

Table J-2: Regression results – Outcome variable Internet use: model 2
* sig. <0.10, ** sig. <0.05, *** sig. <0.001

APPENDIX K. REGRESSION MODEL RESULTS – TELE-WORKING

		95% CI for Odds Ratio		
Daily relative to incidental tele-working	B (SE)	Lower	Odds Ratio	Upper
Smartphone yes vs no	.529(.103)***	1.387	1.697	2.077
Tablet yes vs no	.654(.085)***	1.626	1.922	2.273
Education High vs no or low	1.467(.133)***	3.342	4.335	5.622
Education medium vs no or low	.343(.143)**	1.065	1.409	1.863
Student vs paid labour	-.734(.156)***	.353	.480	.652
Unemployed vs paid labour	-2.021(.191)***	.091	.133	.193
Retired vs paid labour	-2.851(.246)***	.036	.058	.094
Weekly relative to incidental tele-working				
Smartphone yes vs no	.310(.135)**	1.047	1.364	1.777
Tablet yes vs no	.469(.114)***	1.278	1.598	2.000
Education High vs no or low	1.657(.200)***	3.541	5.242	7.760
Education medium vs no or low	.572(.214)**	1.165	1.711	2.693
Student vs paid labour	-.870(.232)***	.266	.419	.660
Unemployed vs paid labour	-2.544(.342)***	.040	.079	.154
Retired vs paid labour	-2.989(.364)***	.025	.050	.103

Table K-1: Regression results – Outcome variable tele-working: model 1
* sig. <0.10, ** sig. <0.05, *** sig. <0.001

		95% CI for Odds Ratio		
Daily relative to incidental tele-working	B (SE)	Lower	Odds Ratio	Upper
Smartphone yes vs no	.442(.104)***	1.268	1.556	1.909
Tablet yes vs no	.652(.086)***	1.621	1.919	2.273
Education High vs no or low	1.412(.133)***	3.160	4.104	5.331
Education medium vs no or low	.300(.144)**	1.019	1.350	1.788
Student vs paid labour	-.853(.159)***	.312	.426	.581
Unemployed vs paid labour	-2.085(.192)***	.085	.124	.181
Retired vs paid labour	-2.794(.246)***	.038	.061	.099
Internet hours per day High vs Low	1.216(.170)***	2.416	3.373	4.708
Internet hours per day Medium vs Low	.481(.147)***	1.213	1.618	2.160
Weekly relative to incidental tele-working				
Smartphone yes vs no	.266(.136)**	1.000	1.305	1.703
Tablet yes vs no	.465(.115)***	1.272	1.592	1.993
Education High vs no or low	1.619(.200)***	3.410	5.050	7.479
Education medium vs no or low	.551(.214)**	1.141	1.735	2.639
Student vs paid labour	-.933(.233)***	.249	.394	.622
Unemployed vs paid labour	-2.574(.342)***	.039	.076	.129
Retired vs paid labour	-2.957(.364)***	.025	.052	.106
Internet hours per day High vs Low	.685(.225)***	1.277	1.984	.3083
Internet hours per day Medium vs Low	.304(.185)*	.943	1.355	1.948

Table K-2: Regression results – Outcome variable tele-working: model 2
* sig. <0.10, ** sig. <0.05, *** sig. <0.001

APPENDIX L. PERSONAL CHARACTERISTICS AND TRAVEL AMOUNTS

Variable	Value	# Trips per day	Travel distance per day	Travel distance per trip
Gender	Male	3.0	41.2	13.9
	Female	3.2	30.7	9.7
Age	12-14	2.6	18.0	6,9
	15-17	2.5	21.4	8,6
	18-19	2.4	34.4	14.1
	20-24	2.8	44.4	15.6
	25-29	3.0	45.6	15.4
	30-34	3.3	44.1	13.3
	35-39	3.5	42.5	12.1
	40-44	3.2	41.4	12.8
	45-49	3.2	40.4	12.7
	50-54	3.0	37.7	12.4
	55-59	3.1	30.0	9.7
	60-64	3.2	31.8	10.1
	65-69	3.2	27.4	8.6
	70-74	3.0	24.3	8.0
	75-79	2.8	23.2	8.2
	80 years and older	2.3	20.1	6.9
Highest completed education	No or low education	2.8	24.8	9.0
	Medium education	3.1	35.5	11.3
	High education	3.3	46.0	13.9
Work situation	Entrepreneur	3.2	37.7	11.9
	Paid labour	3.2	45.1	14.1
	Incapacitated	2.5	17.9	7.2
	Unemployed	3.0	22.4	7.4
	Retired	3.1	26.6	8.7
	Student	2.7	29.1	10.8
	Housemen/housewife	3.1	17.1	5.5
	Multiple occupations including paid work	3.3	41.5	12.5
	Multiple occupations – no paid work	3.0	24.7	8.2

Table L-1: Calculated average travel amounts per category of personal characteristics.

APPENDIX M. PROFILES AND TRAVEL AMOUNTS

Profile		# trips per day	Distance per day	Distance per trip
Internet use and age	N=			
Low, 0-20	33	2.55	20.55	8.31
Medium, 0-20	262	2.52	23.29	10.81
High, 0-20	62	2.54	24.95	10.03
Low, 21-40	108	3.50	36.64	13.45
Medium, 21-40	884	3.20	43.35	16.05
High, 21-40	210	3.01	49.48	19.35
Low, 41-60	240	3.57	38.94	12.41
Medium, 41-60	997	3.12	37.77	13.63
High, 41-60	146	2.59	34.21	13.19
Low, 61>	250	3.07	27.06	8.76
Medium, 61>	649	3.08	27.84	10.41
High, 61>	63	2.76	27.56	11.84
Internet use and (work) occupation				
Low, student	36	2.41	20.42	9.09
Medium, student	312	2.69	29.96	12.81
High, student	80	2.85	30.53	11.93
Low, unemployed	106	3.67	21.28	7.19
Medium, unemployed	385	2.85	19.18	7.99
High, unemployed	83	2.12	15.94	8.49
Low, retired	184	3.11	27.35	8.69
Medium, retired	465	3.08	26.77	10.35
High, retired	47	2.67	26.57	14.99
Low, paid labour	304	3.39	41.81	13.86
Medium, paid labour	1627	3.21	43.59	15.58
High, paid labour	269	3.00	50.58	18.52

Table M-1: Calculated travel amounts per category of personal profiles.

APPENDIX N. TESTING FOR LINEARITY OF THE LOGIT

	Sig.
Distance*LN(distance)	,964
Travel time by car*LN(travel time by car)	,090
Travel time by train*LN(travel time by train)	,000
Trip cost by car*LN(trip cost by car)	,000
Trip cost by train*LN(trip cost by train)	,017
Distance to highway entrance*LN(distance to highway entrance)	,054
Distance to railway station*LN(distance to railway station)	,158
Distance to metro/subway stop*LN(distance to metro/subway stop)	,009
Distance to bus stop*LN(distance to bus stop).	,050

Table N-1: Test results for linearity of the logit (BNL model 2 and 3)

APPENDIX O. TESTING FOR MULTI-COLLINEARITY

	Collinearity Statistics	
	Tolerance	VIF
Trip cost by car	,278	3,603
Trip cost by train	,273	3,665
Trip distance	,067	14,972
Travel time by car	,077	13,007
Travel time by train	,297	3,362
Distance from departure location to closest highway entrance	,763	1,311
Distance from departure location to closest train station	,758	1,319
Distance from departure location to closest metro/subway station	,878	1,139
Distance from departure location to closest bus stop	,960	1,041

Table O-1: Test results for multi-collinearity (BNL model 2 and 3)

APPENDIX P. MODEL 1, 1.1 AND 1.2 ADDITIONAL RESULTS

Model 1						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Trip characteristics							
Distance	,031	1,997	1	,158	,957	,900	1,017
Travel time by car	,030	2,856	1	,091	1,052	,992	1,116
Travel time by train	,008	,250	1	,617	1,004	,989	1,019
Trip cost by car	,188	11,159	1	,001	1,872	1,296	2,704
Trip cost by train	,135	27,356	1	,000	,494	,380	,644
Spatial characteristics (related to departure location)							
Distance to highway entrance	,073	,683	1	,408	,942	,816	1,086
Distance to train station	,119	3,902	1	,048	,791	,627	,998
Distance to subway/metro stop	,007	1,499	1	,221	,992	,979	1,005
Distance to bus stop	1,288	1,672	1	,196	,189	,015	2,361
Socio-demographic characteristics							
Gender: Female vs Male	,526	,120	1	,729	1,200	,428	3,367
Age: 18-29 years vs >50 years	,683	2,133	1	,144	2,710	,711	10,328
Age: 30-39 years vs >50 years	,700	1,052	1	,305	,488	,124	1,923
Age: 40-49 years vs >50 years	,696	3,590	1	,058	,267	,068	1,046
Education: Medium vs Low or non	,768	3,502	1	,061	,238	,053	1,070
Education: High vs Low or non	,755	3,858	1	,050	,227	,052	,997
Western immigrant vs native	,945	,805	1	,370	2,334	,366	14,866
Non-western immigrant vs native	1,227	4,882	1	,027	,066	,006	,736
Household characteristics							
One person household vs Couple	,732	,004	1	,948	1,049	,250	4,407
Couple with children vs Couple	,628	4,217	1	,040	3,634	1,061	12,455
One parent with children vs Couple	1,288	,359	1	,549	2,164	,173	27,018
Number of cars in the household: 1 car vs no car	1,059	13,932	1	,000	,019	,002	,153
Number of cars in the household: 2 cars vs no car	1,259	16,565	1	,000	,006	,001	,070
Number of cars in the household: >2 cars vs no car	1,944	11,094	1	,001	,002	,000	,070
Urban density: >2500 inhabitants/km2 vs <500	1,092	,032	1	,858	1,216	,143	10,339
Urban density: 1500-2500 inhabitants/km2 vs <500	,975	,950	1	,330	,387	,057	2,613
Urban density: 1000-1500 inhabitants/km2 vs <500	,994	,763	1	,382	,420	,060	2,945
Urban density: 500-1000 inhabitants/km2 vs <500	1,155	3,593	1	,058	,112	,012	1,077
Mobility preferences							
Preferred modality for commuter trips car: Yes vs No	,548	18,971	1	,000	,092	,031	,269
Preferred modality for commuter trips train: Yes vs No	,826	7,013	1	,008	8,907	1,765	44,944
ICT characteristics							
Internet use in hours per day: Medium vs Low	,700	,796	1	,372	,536	,136	2,111
Internet use in hours per day: High vs Low	,905	,345	1	,557	,588	,100	3,462
Internet use for tele-working: Daily vs Incidental	,590	2,868	1	,090	2,718	,854	8,645
Internet use for tele-working: Weekly vs Incidental	,699	1,317	1	,251	2,230	,567	8,770
In possession of a Smartphone: Yes vs No	,548	1,063	1	,302	,568	,194	1,664
In possession of a Tablet: Yes vs No	,482	3,639	1	,056	,398	,155	1,026

Table P-1: BNL model 1 – additional results

Model 1.1						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Trip characteristics							
Distance	,028	3,817	1	,051	,947	,896	1,000
Travel time by car	,026	2,756	1	,097	1,045	,992	1,101
Travel time by train	,007	,060	1	,806	1,002	,987	1,017
Trip cost by car	,178	37,064	1	,000	2,953	2,084	4,184
Trip cost by train	,122	81,336	1	,000	,334	,263	,424
Spatial characteristics (related to departure location)							
Distance to highway entrance	,054	1,259	1	,262	1,062	,956	1,181
Distance to train station	,109	10,689	1	,001	,701	,567	,867
Distance to subway/metro stop	,005	,782	1	,377	,996	,986	1,005
Distance to bus stop	,900	2,038	1	,153	,277	,047	1,614
Socio-demographic characteristics							
Gender: Female vs Male	,402	1,687	1	,194	1,686	,766	3,709
Age: 18-29 years vs >50 years	,518	5,428	1	,020	3,340	1,211	9,212
Age: 30-39 years vs >50 years	,530	,183	1	,669	,797	,282	2,254
Age: 40-49 years vs >50 years	,498	,132	1	,716	,834	,314	2,215
Education: Medium vs Low or non	,637	6,373	1	,012	,200	,058	,698
Education: High vs Low or non	,636	8,477	1	,004	,157	,045	,546
Western immigrant vs native	,717	,111	1	,739	,788	,193	3,212
Non-western immigrant vs native	,939	12,972	1	,000	,034	,005	,214
Household characteristics							
One person household vs Couple	,495	6,960	1	,008	3,690	1,399	9,732
Couple with children vs Couple	,487	,063	1	,802	1,130	,435	2,934
One parent with children vs Couple	1,104	,205	1	,651	,607	,070	5,283
~~Number of cars in the household: 1 car vs no car~~							
~~Number of cars in the household: 2 cars vs no car~~							
~~Number of cars in the household: >2 cars vs no car~~							
Urban density: >2500 inhabitants/km2 vs <500	,833	,097	1	,756	1,296	,253	6,629
Urban density: 1500-2500 inhabitants/km2 vs <500	,771	,020	1	,887	,896	,198	4,059
Urban density: 1000-1500 inhabitants/km2 vs <500	,795	,022	1	,882	,889	,187	4,222
Urban density: 500-1000 inhabitants/km2 vs <500	,968	1,604	1	,205	,293	,044	1,957
Mobility preferences							
~~Preferred modality for commuter trips car: Yes vs No~~							
~~Preferred modality for commuter trips train: Yes vs No~~							
ICT characteristics							
Internet use in hours per day: Medium vs Low	,574	3,878	1	,049	,323	,105	,995
Internet use in hours per day: High vs Low	,726	1,882	1	,170	,369	,089	1,533
Internet use for tele-working: Daily vs Incidental	,452	1,892	1	,169	1,862	,768	4,514
Internet use for tele-working: Weekly vs Incidental	,522	2,982	1	,084	2,465	,885	6,863
In possession of a Smartphone: Yes vs No	,436	,405	1	,524	,758	,322	1,781
In possession of a Tablet: Yes vs No	,360	2,514	1	,113	,565	,279	1,145

Table P-2: BNL model 1.1 - additional results

Model 1.2						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Trip characteristics							
Distance	,030	1,970	1	,160	,959	,905	1,017
Travel time by car	,029	3,309	1	,069	1,054	,996	1,115
Travel time by train	,007	,012	1	,914	1,001	,987	1,015
Trip cost by car	,176	11,446	1	,001	1,816	1,285	2,565
Trip cost by train	,121	29,943	1	,000	,517	,408	,654
Spatial characteristics (related to departure location)							
Distance to highway entrance	,074	,619	1	,431	,943	,816	1,091
Distance to train station	,115	4,157	1	,041	,791	,632	,991
Distance to subway/metro stop	,006	1,493	1	,222	,992	,981	1,005
Distance to bus stop	1,281	1,585	1	,208	,199	,016	2,454
Socio-demographic characteristics							
Gender: Female vs Male	,498	,157	1	,692	1,219	,459	3,236
Age: 18-29 years vs >50 years	,636	1,164	1	,281	1,987	,571	6,918
Age: 30-39 years vs >50 years	,647	2,421	1	,120	,365	,103	1,299
Age: 40-49 years vs >50 years	,692	3,993	1	,046	,251	,065	,974
Education: Medium vs Low or non	,749	5,044	1	,025	,186	,043	,807
Education: High vs Low or non	,709	3,394	1	,065	,271	,068	1,087
Western immigrant vs native	,869	,657	1	,418	2,022	,368	11,096
Non-western immigrant vs native	1,080	5,391	1	,020	,081	,010	,676
Household characteristics							
One person household vs Couple	,688	,028	1	,866	1,123	,291	4,328
Couple with children vs Couple	,599	4,434	1	,035	3,528	1,091	11,409
One parent with children vs Couple	1,277	,370	1	,543	2,174	,178	26,575
Number of cars in the household: 1 car vs no car	1,043	14,821	1	,000	,018	,002	,139
Number of cars in the household: 2 cars vs no car	1,233	16,636	1	,000	,007	,001	,073
Number of cars in the household: >2 cars vs no car	1,923	11,838	1	,001	,001	,000	,058
Urban density: >2500 inhabitants/km2 vs <500	,993	,060	1	,806	,784	,112	5,486
Urban density: 1500-2500 inhabitants/km2 vs <500	,911	1,772	1	,183	,298	,050	1,773
Urban density: 1000-1500 inhabitants/km2 vs <500	,932	1,018	1	,313	,390	,063	2,427
Urban density: 500-1000 inhabitants/km2 vs <500	1,084	4,593	1	,032	,098	,012	,820
Mobility preferences							
Preferred modality for commuter trips car: Yes vs No	,514	18,033	1	,000	,113	,041	,309
Preferred modality for commuter trips train: Yes vs No	,787	7,219	1	,007	8,277	1,771	38,677
ICT characteristics							
~~Internet use in hours per day: Medium vs Low~~							
~~Internet use in hours per day: High vs Low~~							
~~Internet use for tele-working: Daily vs Incidental~~							
~~Internet use for tele-working: Weekly vs Incidental~~							
~~In possession of a Smartphone: Yes vs No~~							
~~In possession of a Tablet: Yes vs No~~							

Table P-3: BNL model 1.2 - additional results

APPENDIX Q. MODELS 2 - 7 ADDITIONAL RESULTS

Model 2						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Trip characteristics							
Distance	.026	6.131	1	.013	.937	.890	.987
Travel time by car	.022	8.857	1	.003	1.067	1.022	1.114
Travel time by train	.006	1.356	1	.244	.992	.980	1.005
Trip cost by car	.157	36.092	1	.000	2.567	1.887	3.492
Trip cost by train	.082	122.637	1	.000	.403	.343	.473
Model 3						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Spatial characteristics (related to departure location)							
Distance to highway entrance	.032	5.572	1	.018	1.079	1.013	1.150
Distance to train station	.068	31.431	1	.000	.684	.599	.781
Distance to subway/metro stop	.003	15.852	1	.000	.989	.983	.994
Distance to bus stop	.665	11.638	1	.001	.103	.028	.381
Model 4						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Socio-demographic characteristics							
Gender: Female vs Male	.195	.001	1	.971	1.007	.687	1.476
Age: 18-29 years vs >50 years	.278	15.267	1	.000	2.962	1.718	5.106
Age: 30-39 years vs >50 years	.282	.046	1	.830	1.062	.611	1.847
Age: 40-49 years vs >50 years	.289	.203	1	.652	.878	.498	1.547
Education: Medium vs Low or non	.450	.000	1	.990	1.006	.417	2.429
Education: High vs Low or non	.426	2.239	1	.135	1.891	.821	4.357
Western immigrant vs native	.321	5.335	1	.021	2.098	1.119	3.936
Non-western immigrant vs native	.530	.642	1	.423	1.529	.541	4.322
Model 5						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Household characteristics							
One person household vs Couple	.341	.955	1	.329	.716	.367	1.399
Couple with children vs Couple	.304	1.382	1	.240	1.430	.788	2.596
One parent with children vs Couple	.671	.299	1	.584	.693	.186	2.580
Number of cars in the household: 1 car vs no car	.746	43.308	1	.000	.007	.002	.032
Number of cars in the household: 2 cars vs no car	.795	69.858	1	.000	.001	.000	.006
Number of cars in the household: >2 cars vs no car	1.058	40.160	1	.000	.001	.000	.010
Urban density: >2500 inhabitants/km2 vs <500	.519	3.999	1	.046	2.822	1.021	7.799
Urban density: 1500-2500 inhabitants/km2 vs <500	.498	2.653	1	.103	2.251	.848	5.977
Urban density: 1000-1500 inhabitants/km2 vs <500	.519	1.492	1	.222	1.886	.682	5.217
Urban density: 500-1000 inhabitants/km2 vs <500	.653	1.040	1	.308	.514	.143	1.847
Model 6						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Mobility preferences							
Preferred modality for commuter trips car: Yes vs No	.312	84.328	1	.000	.057	.031	.105
Preferred modality for commuter trips train: Yes vs No	.426	60.267	1	.000	27.321	11.853	62.976
Model 7						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
ICT characteristics							
Internet use in hours per day: Medium vs Low	,301	,088	1	,766	1,094	,606	1,973
Internet use in hours per day: High vs Low	,355	2,517	1	,113	1,756	,876	3,522
Internet use for tele-working: Daily vs Incidental	,216	,886	1	,346	1,225	,803	1,870
Internet use for tele-working: Weekly vs Incidental	,258	1,022	1	,312	1,298	,783	2,154
In possession of a Smartphone: Yes vs No	,234	,804	1	,370	,811	,512	1,283
In possession of a Tablet: Yes vs No	,191	11,466	1	,001	,524	,360	,762

Table Q-1: BNL models 2 to 7 – additional results.

APPENDIX R. MODEL 8 ADDITIONAL RESULTS

Model 8						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Travel amounts (calculated averages)							
# commuter trips per day	.124	.000	1	.998	1.000	.784	1.276
Travel distance per commuter trip	.003	7.115	1	.008	1.009	1.002	1.015

Table R-1: BNL model 8 – additional results.

APPENDIX S. MODEL 7.1 AND 7.2 ADDITIONAL RESULTS

Model 7.1 – Younger than 35						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
ICT characteristics							
Internet use in hours per day: Medium vs Low	.591	.003	1	.960	.971	.305	3.094
Internet use in hours per day: High vs Low	.633	.662	1	.416	1.674	.484	5.793
Internet use for tele-working: Daily vs Incidental	.336	.081	1	.776	.909	.470	1.756
Internet use for tele-working: Weekly vs Incidental	.375	.041	1	.839	.927	.444	1.933
In possession of a Smartphone: Yes vs No	.469	.062	1	.803	.890	.355	2.229
In possession of a Tablet: Yes vs No	.292	3.283	1	.070	.589	.333	1.044
Model 7.2 – Older than 34						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
ICT characteristics							
Internet use in hours per day: Medium vs Low	.356	.000	1	1.000	1.000	.497	2.011
Internet use in hours per day: High vs Low	.490	.115	1	.734	1.181	.452	3.084
Internet use for tele-working: Daily vs Incidental	.289	2.956	1	.086	1.644	.933	2.899
Internet use for tele-working: Weekly vs Incidental	.363	1.601	1	.206	1.583	.777	3.225
In possession of a Smartphone: Yes vs No	.287	.024	1	.876	1.046	.596	1.834
In possession of a Tablet: Yes vs No	.265	3.844	1	.050	.595	.353	1.000

Table S-1: BNL models 7.1 and 7.2 – additional results.

APPENDIX T. MODELS A, B AND C ADDITIONAL RESULTS

Model A						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Age*Internet use (relative to >50 years, Low Internet use)							
18-29 years, Medium Internet use	.276	13.782	1	.000	2.789	1.623	4.794
18-29 years, High Internet use	.364	23.916	1	.000	5.935	2.907	12.116
30-39 years, Medium Internet use	.277	1.341	1	.247	1.378	.801	2.371
30-39 years, High Internet use	.474	.266	1	.606	1.277	.504	3.235
40-49 years, Medium Internet use	.284	.191	1	.662	1.132	.648	1.977
40-49 years, High Internet use	.759	.176	1	.675	.727	.164	3.217
Model B						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Access to the Internet via 4G*tablet possession (relative to no access via 4G and no tablet)							
Access via 4G, owns a tablet	.190	5.176	1	.023	.648	.446	.942
Model C						95% C.I. for Exp(B)	
Variables	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Age*Internet use (relative to >50 years, Low Internet use)							
18-29 years, Medium Internet use	.279	15.429	1	.000	2.993	1.732	5.171
18-29 years, High Internet use	.366	23.864	1	.000	5.971	2.915	12.230
30-39 years, Medium Internet use	.280	2.200	1	.138	1.516	.875	2.627
30-39 years, High Internet use	.477	.502	1	.479	1.402	.550	3.572
40-49 years, Medium Internet use	.287	.513	1	.474	1.228	.700	2.155
40-49 years, High Internet use	.760	.117	1	.733	.771	.174	3.423
Access to the Internet via 4G*tablet possession (relative to no access via 4G and no tablet)							
Access via 4G, owns a tablet	.197	5.406	1	.020	.633	.430	.931

Table T-1: BNL models A, B and C – additional results.