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UNDERSTANDING THE VALUE OF TRAVEL TIME: ADVANCED MODELLING TECHNIQUES APPLIED TO THE NATIONAL GERMAN VALUE OF TRAVEL TIME AND TRAVEL TIME RELIABILITY STUDY

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Abstract

Project appraisal is an essential part of policy making, in transportation and elsewhere. To this end, different valuation methods are used. One of the most important evaluation tool is the Cost-Benefit-Analysis.

Often, travel time savings account for the largest share of the gains in Cost-Benefit-Analyses. Therefore, they are a central element of the analyses, making its accurate determination of great importance for transport policy appraisal and investment decisions. The time changes are evaluated using the willingness to pay of travellers to save time resulting in the most important number in transport economics: the value of travel time.

The *German Value of Time and Value of Reliability Study* was the first official national study estimating values of travel time for Germany. For this purpose a large nationwide data set was collected. It covered six travel modes and five trip purposes, included several transport related attributes and different kinds of stated preference experiments, as well as two time horizons in the choice experiments. This great complexity and detail and the large sample size allows the investigation of various aspects and perspectives of time valuation.

This thesis makes use of this rich data to compare a variety of approaches for travel time valuation, comparing different state-of-the-art model formulations, and covering more controversial topics, such as the use of values of time from long-term decisions.

The values of time are derived using various model formulations and splits of the data. The impact of the method on the accuracy and trustworthiness of the estimates is evaluated, and used to make recommendations for future studies.

The results show various interesting aspects. First, business as a travel purpose was found to be very special, and should thus ideally be modeled separately. Also shopping trips show different characteristics than the other purposes. Second, the VTT follows systematic patterns with changing agglomeration size, indicating that a differentiation on this level might be beneficial. Differentiating by local income, on the opposite, did not exhibit a recognisable pattern. Using a proven method to estimate the standard error of the estimated VTT, it was shown that for the formulation with the best model fit, a latent class model, accuracy in the VTT estimates was actually worse, illustrating how important error estimates are in the process of selecting the best model.

A formulation of the VTT based on long term decisions did not bring any satisfying results. In particular, it seems that the other attributes that were part of the choice were valued much more strongly than changes in travel times.

This thesis presents an in-depth and comprehensive evaluation of travel time with data from a national VTT study. The conclusions drawn from the analyses can be used as guidance for future transport project evaluation and policy making.

Zusammenfassung

Projektevaluation ist ein wesentlicher Bestandteil des Planungsprozesses und aus diesem Grund von großer Bedeutung in der Politik, der Verkehrsplanung und vielen anderen Bereichen. Im Planungsprozess werden verschiedene Bewertungsverfahren verwendet. Eines der wichtigsten Analyseinstrumente ist hier die Kosten-Nutzen-Analyse.

In der Verkehrsplanung entfällt der größte Anteil des Nutzengewinns in der Kosten-Nutzen-Analysen oft auf die sogenannten Reisezeitgewinne. Sie sind daher ein zentrales Element einer solchen Analyse und ihre genaue Bestimmung ist für die verkehrspolitische Beurteilung und Investitionsentscheidung von großer Bedeutung. Die Zeitveränderungen werden anhand der Zahlungsbereitschaft für Zeiteinsparungen von Reisenden ausgewertet und resultieren in dem wohl wichtigsten Wert der Verkehrswirtschaft: dem Wert der Reisezeit beziehungsweise den Zeitkosten.

Die *Deutsche Zeitkosten Studie* war die erste offizielle, nationale Studie, in der der Wert der Reisezeit für Deutschland geschätzt wurde. Zu diesem Zweck wurden in einer großen landesweiten Erhebung Daten gesammelt, die unter anderem Informationen zu sechs verschiedenen Verkehrsmodi, fünf Wegezwecken und viele weitere verkehrsbezogene Attribute enthalten. Das Studiendesign beinhaltet neben zwei Zeithorizonten zudem verschiedene Formen von sogenannte Stated Preference Experimenten. Durch diese große Komplexität der Experimente und die Stichprobengröße ermöglicht es die Untersuchung verschiedenste Aspekte und Perspektiven der Zeitbewertung zu untersuchen.

Diese Doktorarbeit nutzt den umfangreichen Datensatz, um eine Vielzahl von Ansätzen zur Reisezeitbewertung zu vergleichen, State-of-the-Art-Modellformulierungen anzuwenden, jedoch auch noch neuere, (noch) umstrittene Ansätze, wie zum Beispiel die Verwendung von Zeitwerten aus langfristigen Entscheidungssituationen, zu testen.

Die Zeitwerte werden aus den resultierenden Parametern des jeweiligen Modells und Teilstichproben für verschiedene Modi und Wegezwecke berechnet und interpretiert. Es werden zudem die Auswirkungen der verschiedenen Methoden auf die Genauigkeit und Glaubwürdigkeit der Schätzwerte evaluiert und daraus Empfehlung für zukünftige Forschung abgeleitet.

Die Analyse der Daten resultiert in mehreren interessanten Ergebnissen. Zum einen wird der gewerbliche Weg von den Befragten sehr unterschiedlich zu den anderen Wegezwecken bewertet und sollte von daher idealerweise separat modelliert werden. Auch Einkaufswege weisen gesonderte Charakteristiken im Vergleich zu den anderen Wegezwecken auf. Des Weiteren zeigen die Zeitwerte eine systematische Veränderung mit der Größe der Agglomeration, was darauf hindeutet, dass eine Differenzierung auf dieser Ebene von Nutzen sein könnte. Die regionale Unterscheidung nach mittlerem lokalen Einkommen hat hingegen zu keinen zufriedenstellenden Ergebnissen geführt. Die verwendete Methode zur Schätzung des Standardfehlers der Zeitwerte hat gezeigt, dass das Modell mit dem besten Model Fit, ein *Latent Class Modell*, eine höhere Ungenauigkeit in der Schätzung der Zeitwerte aufweist. Dieses Ergebnis unterstreicht wie wichtig die Fehlerberechnung bei der Wahl des besten Modells ist. Eine auf langfristigen Entscheidungen basierende Berechnung des Zeitwertes brachte keine zufriedenstellenden Ergebnisse. Es scheint insbesondere, dass die anderen Attribute der langfristigen Entscheidungssituation, wie zum Beispiel das Gehalt, viel stärker als Reisezeitveränderungen bewertet wurden.

Diese Arbeit präsentiert eine detaillierte und umfassende Auswertung der Deutschen Zeitkosten Studie. Die aus den Analysen gezogenen Schlussfolgerungen können als Orientierungshilfe für die künftige Bewertung von Verkehrsprojekten, sowie für die Politikgestaltung in der Verkehrspolitik dienen.

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Chapter 1

Introduction

Project appraisal is an essential part of policy making, in transportation and elsewhere. During the planning phase, the potential project is evaluated by comparing its realization against the current state. To this end, different valuation methods are used. One of the most important evaluation tool is the Cost-Benefit-Analysis (CBA). CBA compares the cost of a planned project with the monetized expected utility gains (Small, 1999).

Often, travel time savings make up the largest share of the gains in CBAs (Mackie *et al.*, 2001). Those travel time savings are evaluated using the willingness to pay of travelers for travel time savings, or value of travel time (VTT). Therefore, the value of travel time is a central element of CBA, making its accurate determination of great importance for transport policy appraisal.

Micro-economic models of time allocation have been used to derive the valuations of technologically constrained time use since Becker (1965), Beesley (1965) and DeSerpa (1971), especially on the value of travel time (e.g. Truong and Hensher, 1985; Bates, 1987; Jara-Diaz, 1990).

The current state of practice draws largely upon past British (Wardman, 1998; Mackie *et al.*, 2003; Department for Transport, 2015; Wardman *et al.*, 2016), Dutch (Significance *et al.*, 2012), and Scandinavian studies (Börjesson and Eliasson, 2014; Ramjerdi *et al.*, 2010; Fosgerau *et al.*, 2007).

Over the years time valuation moved from revealed preference (RP) data to a growing reliance on personalized stated preference (SP) experiments, and finally to a combination of both RP and SP to estimate the values of time and values of reliability. Those estimates are derived from suitably formulated discrete choice models of travel behaviour, especially of route and mode choice. Today, a personalised stated choice survey is the standard approach (e.g. Small, 2012).

The *German Value of Time and Value of Reliability Study* was the first official national study estimating values of time for Germany using SP data. For this purpose a very large nationwide data set covering six modes and four purposes, using several transport related attributes and different kind of stated preference experiments, as well as two time horizons was collected. This great complexity and large sample size allows the investigation of various aspects and perspectives of time valuation.

This thesis makes use of this rich data to compare a variety of approaches for travel time valuation, comparing different state-of-the-art model formulations, and covering more controversial topics, such as the use of values of time from long-term decisions.

The values of time are derived using various model formulations and splits of the data. The impact of the method on the accuracy and trustworthiness of the estimates is evaluated, and used to make recommendations for future studies.

This thesis presents an in-depth and comprehensive evaluation of travel time with data from a national VTT study. The conclusions drawn from the analyses can be used as guidance for future transport project evaluation, study design and policy making.

1.1 Structure of the Thesis

The outline of the thesis is as follows.

First Chapter 2 presents an overview of the (mostly) national value of time study literature with a special emphasis on stated and revealed preference studies in Germany (Section 2.2) and the treatment of small travel time savings (Section 2.3). Research on the more recent value of reliability is presented in Section 2.4.

Chapter 3 presents the survey work of the *German Value of Time and Value of Reliability Study*. It discusses the survey design (Section 3.1), reports experience of the field phase and analyses the response behaviour of the sample (Section 3.2). Additionally it provides a descriptive analyses of the collected data (Section 3.3).

Chapter 4 provides a summary of the most important results of the national *German Value of Time and Value of Reliability Study*. First the methodology to determine the value of time and the main results are presented in Section 4.1. The section also includes an empirical evaluation of small travel time savings in particular Section 4.1.4. The chapter ends with an analyses of the value of reliability (Section 4.2) undertaken by the author within the project framework.

Chapter 5 presents the models estimated with the German VTT data within the short-term framework. Section 5.1 starts with a description of the base Multinomial Logit Model (MNL) which is used to compare all other models forms with. Section 5.2 covers the regional differences in valuing travel time in Germany. Sections 5.3 and 5.4 describe the methodology and the results of more advanced and complex choice models. Section 5.5 summarizes and compares the modelling results and calculated values of travel time. It also provides a comparison and draws conclusions of all the models estimated within the short-term experiments.

Chapter 6 investigates not only the impact of different time horizons but also the type of long-term decision on the valuation of time. Using a joint model including all relevant choice situations, the difference in the valuation of time coming from different kind of choice experiments are investigated.

Finally Chapter 7 summarizes and concludes the thesis and gives an outlook on future work which can be done within this framework.

1.2 Original Papers and Contribution

An important part of the work presented in this thesis is based on existing papers. The following paragraphs link individual chapters to papers.

- Chapter 2:
    - Chapter 2 is based on the literature review of Axhausen *et al.* (2015a) which was done by Ilka Dubernet and has now been updated to cover the most recent developments in research since the project. Of course it also draws on the literature reviews of all subsequently cited papers.
    - Section 2.3 is based on Ehreke (2016) and was also a chapter of the project report (Axhausen *et al.*, 2015a). Ilka Dubernet did the technical work and analysis, Kay Axhausen provided guidance, comments, and editing.

- Chapter 3 is based on Dubernet and Axhausen (2017), where Ilka Dubernet did the technical work and analysis, Kay Axhausen provided guidance, comments, and editing.
- Chapter 4:
    - Chapter 4 is based on Axhausen *et al.* (2015a) were Ilka Dubernet was the main author of the project report and did most of the analysis, figures and tables. Stephane Hess developed the modelling code. Kay Axhausen and Kai Nagel provided scientific guidance and comments. Kay Axhausen wrote the proposal for the project and designed the study. Jana Monse and Andreas Sauer provided guidance, comments, and editing. Claude Weis and Christian Jödden were responsible for the first set-up of the survey and together with Ilka Dubernet the main contributors to the interim report. Christian Jödden also provided content for the description of the CATI interviews, guidance, comments, and editing on the final report and was responsible for the RP data archiving whereas Ilka Dubernet was responsible for archiving all other data and documents of the project.
    - Section 4.2 ist based on Ehreke *et al.* (2015), Ilka Dubernet did the technical work and analysis, Stephane Hess developed the modelling code, Kay Axhausen provided guidance, comments, and editing.
- Chapter 5:
    - Sections 5.1 and 5.2 and Sections 5.4 and 5.5 are not yet published
    - Section Section 5.3 is not published yet, but is based on the work done for Dubernet *et al.* (2018b) where Ilka Dubernet did the technical work and analysis, Thibaut Dubernet provided guidance and comments on the modelling code and Kay Axhausen provided guidance, comments, and editing.
- Chapter 6 is not published yet, but based on Dubernet *et al.* (2018a), where Ilka Dubernet did the technical work and analysis, Thibaut Dubernet provided guidance and comments on the modelling code and Kay Axhausen provided guidance, comments, and editing.

Chapter 2

Literature Review VTT and VOR

As the literature on valuing time used for transport project appraisal, the data collection phase and methodology used to derive the parameters for the calculations, seems to be almost inexhaustible the next section (Section 2.2) provides an overview of the major national VTT studies which played an important role for the design of the *German Value of Time and Value of Reliability Study*. In-depth reviews of European values of travel time studies and results and/or appraisal in Europe can be e.g. found in Wardman *et al.* (2016) or Bristow and Nellthorp (2000) Specific literature essential for describing the methodologies or which is important to classify the modeling results and interpret the output can be found in the corresponding chapters. Given its importance and controversial discussion in (German) appraisal, this literature review also puts a special emphasis on the treatment of small travel time savings in Section 2.3. The chapter ends with an overview of the development of the more recent research topic of the value of reliability (VOR) in Section 2.4.

In line with the argumentation of Daly and Hess (2018) in this thesis the term *value of travel time* and its abbreviation *VTT* is used to describe the monetary valuations of travel time although the terms *value of time* and its abbreviation *VOT*, if used, have the same meaning.

2.1 Discrete Choice Models

Discrete choice models are at the core of modern approaches to the estimation of VTT. Thus, before going any deeper on the history and methodologies of VTT estimation, this section gives a small introduction to discrete choice models for the reader who is not familiar with them. More sophisticated formulations will be described in the chapters they are used in.

Discrete choice models are statistical models of situations where a decision maker is facing a choice between a finite number of discrete and mutually exclusive alternatives (Ben-Akiva and Lerman, 1985). Given a set C of possible alternatives, the *choice set*, the model gives the probability $P(i \mid C)$ that any element $i \in C$ is chosen.

All classical statistical discrete choice models rely on the assumption of decision makers with *rational* preferences. A preference-indifference operator $\geq$ is said to represent rational preferences over a set C if it obeys two key properties:

- *transitivity*: $(i \geq j) \wedge (j \geq k) \Rightarrow (i \geq k)$
- *completeness*: $\forall i \in C,\ \forall j \in C, (i \geq j) \vee (j \geq i)$

To transform those assumptions into an operational statistical model, it is enough to note that given any function $u : C \longrightarrow \mathbb{R}$, $u(i) \geq u(j) \Rightarrow i \geq j,\ \forall i \in C,\ \forall j \in C$ defines a rational preference ordering. This function is called the *utility*, and can in theory be any function of the decision maker's and alternative's attributes. All classical models of discrete choice are concerned with finding a formulation for this function that reproduces the observed choices with high confidence.

Of course, finding a deterministic function that fully explains a real dataset is impossible for various reasons:

- the researcher might be missing data that was used by the decision makers to make their choices
- the measured data might be noisy
- the actual decision process might deviate from the ideal model of rational, full information choice

For all those reasons, the classical approach to discrete choice modelling is the specification of *Random Utility Models*, wherein the outcome of the utility function is a random variable, rather than a deterministic value.

The classical way to parameterize this function is to separate it between a *deterministic part* and an *error term*:

$$U_i = V_i + \varepsilon_i \tag{2.1}$$

where V_i is a deterministic function of the decision maker's and alternative i's attributes, and ε_i is a random variable of mean 0. Assuming that the set of error terms ε_i, $\forall i \in C$ are iid Gumbel distributed random variables with location parameter 0 and scale parameter μ gives the classical multinomial logit model, where the probability of choosing an alternative is:

$$P(i \mid C) = \frac{e^{\mu \cdot V_i}}{\sum_{j \in C} e^{\mu \cdot V_j}} \tag{2.2}$$

Alternative ways to specify the utility lead to different model formulations, some of which will be described in later chapters.

The deterministic part of the utility, V_i, is a function of the attributes of the alternative. The ratio of the partial derivatives of the utility respective to two parameters define the marginal rates of exchange of the parameters, that is, how much one of the parameters must change in reaction to a change in the other for the utility (and thus the preferences) to remain unchanged. In particular, dividing by the derivative regarding to cost gives the willingness to pay for the attribute, that is, how much the decision maker would be ready to pay to avoid a loss in the other attribute. This kind of reasoning is at the base of using those models to estimate the VTT, which is the willingness to pay for travel time savings (or the willingness to accept travel time losses).

2.2 The Value of Travel Time (VTT)

Given its central role in Cost Benefit Analysis (CBA), and its specificity to particular areas, the estimation of the Value of Travel Time (VTT) is a topic of high research interest since its introduction.

Those research projects are often government-led, with the objective of deciding on the values to use for publicly funded project appraisal.

The following subsections provide an overview of such projects, their approaches, findings and limitations for different countries.

2.2.1 United Kingdom

Research on the valuation of travel time in Great Britain started with a series of research studies during the 1960s. Those studies generated estimates of the valuation of travel time based on simple aggregate models, themselves based on Revealed Preferences (RP) data, that is, data about reported actual behaviour. This methodology remained relatively unchanged until the 1980s, when a methodologically innovative study was conducted under the guidance of the Ministry of Transport. This study, sometimes called the "first UK study" (MVA Consultancy *et al.*, 1987), was the first of a series of methodologically similar studies initiated by the Ministry.

This seminal study was the first to use stated preference (SP) data for the estimation of an official VTT, that is, data about the choice of respondents in hypothetical, carefully designed situations. Those studies formulated important extensions of neo-classical consumer behaviour theory relative to the state of the art at the time, It provided a bridge between the microeconomic literature and discrete choice models. This study derived values of time for commuting, business and leisure purpose, based on mode choice experiments comprising car, bus and rail, as well as car route choice experiments. This study revealed that the valuation of travel time savings in congested conditions was 40% higher than in free flow conditions.

A follow-up study was initiated by the Ministry in 1994 (Accent and Hague Consulting Group, 1999), focusing on the valuation of travel time savings for road-based transportation. Using SP experiments again, the main targets of the study were:

- The derivation of VTT for car drivers, car passengers, bus passengers and transport of goods (from the perspective of the vehicle owner).
- The differentiation of those values with various stress factors, such as congestion, high number of trucks on the road, presence of pedestrians and cyclists. . .
- The differentiation of those values per road type (free-way, main road, urban).

- The derivation of the willingness to pay to avoid delays.
- The analysis of the variables that have an influence on travel time valuation.
- The analysis of potential differences in travel time savings valuation between small and big travel time savings.
- The analysis of the difference of valuation for travel time savings or losses.
- The analysis of regional differences in travel time valuation.

The study mostly focused on car drivers and passengers, with 12 survey designs corresponding to four distance classes and three road types, for commuting, business and "other" purpose. Based on those experiments, the average VTTs were derived from a simple model with no other explanatory variable as travel time and cost. In addition to the VTT, the study resulted in a few important findings:

- Travel time savings are given a lower value than corresponding travel time losses, independent from the initial travel time. However, Wardman (1998) questioned this result, pointing to a possible influence of the method used to derive it.
- Travel time savings under 5 minutes can be ignored for trips not related to professional purposes
- Changes in travel time or cost have a bigger influence on the valuation of travel time if they represent a higher fraction of the initial time or cost.
- VTT in London is higher than in other regions
- Average VTT is higher on highways and lower in urban settings
- VTT increases with the car occupancy rate for commuting trips, but decreases for shopping trips
- VTT decreases with the amount of available leisure time

- Income elasticities need to be taken into account when extrapolating future values

In 2000, the study was re-analysed under the supervision of the Department of Transport (Mackie *et al.*, 2003). This study introduced a method where travel time variation depends on income and travel distance.

In 2015 the results of the newest British VTT study have been published (Arup *et al.*, 2015a,b). Compared to the previous Dft WebTag guidance the authors suggest an increase of around 50% in values for commute and a reduction of around 25% for other non-work—relative. The business VTT represents now a methodological shift away from the cost saving approach (CSA) which was traditionally used in WebTag to willingness-to-pay (WTP). These WTP-based business values show marked increase by distance (Batley *et al.*, 2017).

2.2.2 The Netherlands

In the Netherlands, in 1984, a series of important transport infrastructure plans motivated the authorities to fund several extensive studies to help design CBA methods to evaluate those plans. In particular, a study about VTT aimed at answering the following questions:

- How are travel time savings and losses monetarily valued?
- What factors influence this valuation?
- How does the willingness to pay for travel time savings vary across population groups?
- How are those willingness to pay estimates influenced by the conditions of travel?

The study was based on two sources of data, for which two different methods were developed. First, RP data from the household travel survey, which pre-existed the study, were used to perform first analyses. Second, and based on the results of the analyses of the first dataset, a sample of travellers was recruited to participate in a series of SP experiments specifically designed for the study. Those were route choice experiments, wherein respondents faced situations where they had to choose one of two car or public transport options, that differed only by cost and travel time. Based on this data, separate models were estimated for the purposes of commuting, business travel and “other”, with segmentation by person type, household type and conditions of travel. The segmentations revealed significant differences in travel time valuation between the segments and travel purposes. In particular, income, age and gender were found to have a significant influence on the valuation of travel time; valuations of travel time savings were found to be lower for public transport than for car; and drivers in congested conditions valued travel time differences higher than drivers in free flow conditions. More recently, Significance *et al.* (2012) reported actualized values for travel time savings and reliability valuation in the country, by estimating Latent Class Models on a SP survey. This study estimated VTT for freight transport as well.

2.2.3 Scandinavia

2.2.3.1 Sweden

The Swedish study was also aimed at producing values for CBA. Particular attention was directed at taking into account the sign and magnitude of the travel time differences (Börjesson and Eliasson, 2012). The study focuses on car, bus, rail, as well as airplane, using an SP approach.

2.2.3.2 Norway

The Norwegian study was also based on SP data (Ramjerdi *et al.*, 1997), focusing mostly on urban and inter-urban travel. VTTs were derived for commuting, business and other private purposes, for car, public transport, air-plane and ferry. The study design took into account the British and Dutch experiences.

A new study was conducted in 2010. The new estimates are in the same range as in the previous study and in the Swedish one (Ramjerdi *et al.*, 2010).

2.2.3.3 Finland

In 1989, Finland launched a study integrating the international experiences, in particular from Great Britain and the Netherlands. Two studies followed, in 1992 and 1996, focusing on the Helsinki Region (Pursula and Kurri, 1996).

The aim of the first study was to produce a quantitative analysis of the importance of various attributes in the choices of public transport users. Using a combined RP/SP methodology, it analysed the route choice behaviour of bus passengers. The second study focused on car route choice. Although the analysis mostly used SP data, RP data was also collected. Valuations of travel time from those various studies lied in the same range.

2.2.3.4 Denmark

In 2000, Denmark saw the development of a very detailed model of travel demand for the Copenhagen metropolitan region (Jovicic and Overgaard Hansen, 2003), based on a combination of RP and SP data. While the RP data came from the national travel survey, collected continually over phone with respondents between 10 and 84 years of age, SP data came from data collection efforts linked to important road construction projects from the 1990's. Interestingly, a separate mode choice model was developed for the Copenhagen-Kastrup International Airport, which yielded valuations of travel time that were three times higher than in the rest of the Model.

A later data collection effort focused on the derivation of VTTs for Denmark (Fosgerau *et al.*, 2007).

2.2.4 Switzerland

Stated preference surveys to determine the value of travel time for appraisal have now been implemented for almost twenty years. A series of intial studies were comissioned by the SVI (Swiss Association of Transport Engineers and Transport Experts): Abay and Axhausen (2000); Axhausen and König (2002); König and Axhausen (2004); König *et al.* (2004). The results were used for the Swiss CBA norm (VSS, 2006) of the VSS (Swiss Association of Road and Transport Professionals). The norm was updated in 2009 (VSS, 2009). In the last ten years serveral follow-up studies have been conducted on behalf of either the SVI, the VSS or relating to the Mobility and Transport Microcensus (MTMC) of the Federal Statistical Office (BFS) and the Federal Office for Spatial Development (ARE): Fröhlich and Axhausen (2012); Fröhlich *et al.* (2012, 2013, 2014); Weis *et al.* (2017).

The Swiss SP studies implement more complex multi-attribute choice situations. While these kind of complex choice surveys have been applied for some years in Switzerland (Axhausen *et al.*, 2008) more recently they were also acknowledged by researcher of other national VTT studies (Hess *et al.*, 2017b,a).

2.3 Small Travel Time Savings

In Germany as well as in other countries, applications for public investments in transport infrastructure are evaluated using cost-benefit-analysis. In this context travel time savings play a major role. With up to over 80 percent, they often represent the largest share of the measured utility gain (Willeke *et al.*, 1979). Hence, travel time savings can pose a strategic factor in decisions about infrastructure projects. The share is clearly decreasing if small travel time savings (STTS) below 2, 3, 5 or 10 minutes are not taken into account (Ecoplan and Metron, 2005). For example in some British CBAs the travel time savings lie between one and three minutes (Welch and Williams, 1997). Thus the decision about the evaluation of small travel time savings can also function as a strategic factor in the decision making process for an infrastructure project.

From this it follows that the importance and the handling of small travel time savings in the international context need further investigation as they have been controversially discussed during the past years. Some research papers with a detailed overview of the recent evaluation methods of small travel time savings in international transportation infrastructure projects and the common state of the art can be found in (Austroads, 2012) and (Daly *et al.*, 2011). In addition to the study of international research publications a special focus lies on German literature on small travel time savings in non-business passenger transport and their previous use in cost-benefit-analysis of German infrastructure projects.

2.3.1 The Evaluation Problem

The quantified gain in CBAs is mostly caused by small travel time savings for a large number of people (Fosgerau and Jensen, 2003). The question of the evaluation of small time changes in value of time studies is an essential research issue and still not entirely resolved. The evaluation problem has already been described in the 1970s and therefore is not a completely new phenomenon (Mackie *et al.*, 2001). Since then several literature overviews of the development of the methodological approach to time values have been published (e.g. Gunn, 2001).

Not later than the early 1980s, stated choice experiments were applied to determine values of times (Daly *et al.*, 2011). Nevertheless in recent years the research focus shifted. Together with the sign of time changes (gains or losses) the issue of small travel time savings is currently often investigated under the term "size and sign effect of the VTTs" (Bates and Whelan, 2001; Austroads, 2012; Börjesson and Eliasson, 2014).

Two different approaches suggest different treatments of small time savings for formal CBAs as a uniform value for all savings (in some cases with separate reporting) or a smaller or zero unit value (Welch and Williams, 1997).

2.3.1.1 Discounted or Zero Unit Value (DUV) Approach

In the determination of VTTs the "Discounted or Zero Unit Value (DUV)" approach integrates small travel time savings with a discounted value . Another approach completely eliminates all time savings under a certain threshold from the evaluation (*zero unit value*) (Daly *et al.*, 2011).

Following arguments for attenuating small travel time changes can be put forward (Mackie *et al.*, 2001):

- Minor time changes under a certain threshold cannot be used very productively, as an alternative activity requires in a minimum amount of time.

- Small travel time savings generate less utility than larger savings. Likewise time losses are valued higher than time gains.

- Transport models cannot predict time savings precisely to the split second, which could cause an impression that small time savings are only model artefacts and lead to a overestimation of project utility gains.

- Small travel time savings under a certain threshold are not noticeable and therefore not valued.

2.3.1.2 Constant or Non-zero Unit Value (CUV) Approach

The “Constant or Non-zero Unit Value (CUV)” approach includes all determined travel time changes whatever size in the utility gain calculation. Underlining this approach are the following arguments can (Mackie *et al.*, 2001):

- Respondents adapt their activity patterns over time and can utilize small travel time saving at least in the long run.
- Some persons may also generate utility gains from small time savings (averaging argument, (MVA Consultancy *et al.*, 1987)). In this context the perception argument (DUV approach) can be considered spurious. Small travel time savings lead to a utility gain even if they are not noticeable. Nevertheless different studies show that in route choice experiments small time savings are very well noticeable.
- Another strong argument is that the choice of a threshold is arbitrary. For example if a person does not use three minutes of his or her time budget than after an improvement of a street the summed up time gain can lie over the threshold (Accent and Hague Consulting Group, 1999).
- New streets have to be seen as part of a network. The improvement of only a part of a street might result in a small travel time saving but several improvements added up together can lead to a time gain higher than the threshold. Not valuing them would therefore cause inconsistent results (Ecoplan and Metron, 2005).
- It does not seem logical to value small differences which occur in parts of a model lower than their aggregate would yield when accounted to the whole model (adding-up argument, (MVA Consultancy *et al.*, 1987)).
- There would be a danger of strategic behavior of the applicants of infrastructure projects. An unwanted but huge and reasonable project could be devided in smaller parts and therefore be neglected. Additionally small projects, which normally gain smaller time savings, would have a disadvantage against bigger projects. The reverse argument would be to join several small unprofitable projects to a

single profitable one. Both cannot be reasonable for a serious utility gain determination of a project (Ecoplan and Metron, 2005).

Since the 1990th further problems have been identified in national value of time studies in different countries (but especially in the British VTT study of 1994):

- VTTs are not linear as gains are valued less than losses. Further small gains are proportionally less valued than bigger gains (Accent and Hague Consulting Group, 1999). Thus, the valuation of travel time changes depend on its size in relation to travel time (Daly *et al.*, 2011)
- What is the definition of “small”? To avoid misinterpretation some suggest to better express changes as percentage share than as absolute numbers (Ramjerdi *et al.*, 1997). Further there is no consensus that the way how “small” is defined has a significant influence on the outcome of a survey (Austroads, 2012).
- How accurate can a model be estimated that gains and losses of travel time can be expressed in seconds? How reliable are forecasts if small travel time savings are for example 30 seconds? As a consequence are models that show the utility of a bigger number of small travel time savings less reliable than models that show the utility of few large travel time savings?
- Transport models used for the forecasts describe differences in possible scenarios. In this context it is not valid to identify differences only as gains and losses of travel time (Daly *et al.*, 2011).
- In addition, the accuracy of transport models or better the calculation of the required equilibrium made major progress in recent times (Bar-Gera and Boyce, 2003). Therefore the computational accuracy is controlled by the user who can achieve it by implying longer computational times.
- The study design influences the estimated VTTs: a survey that contains more travel time losses or bigger travel time changes will lead to higher values of time than a study with more travel time gains

> and smaller travel time changes. SP surveys of the past years rather confirmed the results of lower values of time for small travel time changes. The question remains, if this reflects a real effect (Daly *et al.*, 2011).

From this review, it is clear that the definition of small travel time savings influences the valuation and result of a survey.

In general the question arises if the measured effects of small travel time savings can be interpreted as real or only as effects of the applied choice models? If these effects are so called "study-design-artefacts" it would be more adequate to eliminate them (Bates and Whelan, 2001).

2.3.2 Methods of the German Federal Infrastructure Planning

In the current German Federal Infrastructure Plan travel time savings in non-business passenger transportation are ascertained using a normative deduced evaluation (Birn *et al.*, 2005). At the start of a project evaluation the general labour costs for every transportation method are used as a point of reference. This serves as a benchmark for the comparison of services and to provide a plausible relation of time costs to GNP. In a second step stated preference surveys are used to determine the different VTTs in relation to trip purpose, trip mode and means of transport. Hence, the utility of a specific project is calculated comparing the target state with the current state in a transportation model (Rothengatter, 2000). Under the assumption of a threshold for the perception of small time savings under five minutes current methods in the road sector discount all time savings with 30% according to the guidelines established by the German Federal Infrastructure Plan 1992 and 1998 (Willeke and Paulußen, 1991; Federal Minister for Transport, 1993). In contrast, the commercial transportation sectors (roads and railways) valued time savings independently from their sizes (BVU *et al.*, 2009).

Hence the German approach uses a discounted method for the measurement of time savings, diverging from the methods used in all other European countries as well as in many countries outside of Europe. The described method for the measurement of small time savings stems from the 1970s and has been employed without changes in the German Federal

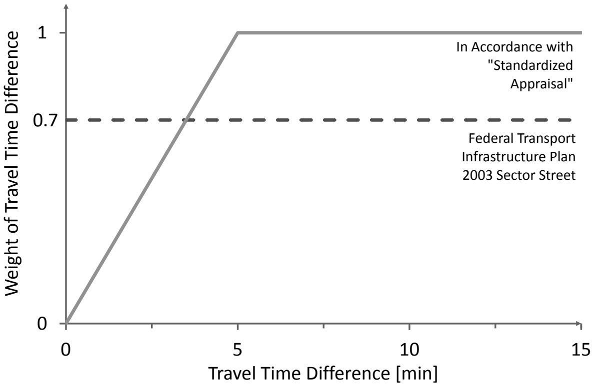
Infrastructure Plan ever since (see Rothengatter, 2000). The threshold was established, due to the assumption, that these savings are not recognized and thus, are not used in other, economically relevant activities. But even then, the authors pointed out the problem in using a fixed threshold (for example five minutes) in cost-benefit-analysis and stated a considerable need for further research in this area, and advocated using multiple, alternative threshold values (Willeke *et al.*, 1979, p.61). However the general idea to use threshold values at all was not questioned (Willeke *et al.*, 1979, p.57ff).

Later publications focus on the role of small time savings (for example Willeke and Paulußen, 1991; Paulußen, 1992). Again they concentrate on the relevance of small time savings in the German Federal Infrastructure Plan. Stating that small time savings are not recognized below a certain threshold and hence, are not used in other activities, they draw the conclusion that including these in the calculations would yield unrealistic results. Though referring to plausible findings in the international literature (Paulußen, 1992, p.71 and p.121) advocates an equal treatment of small time savings nevertheless various different discount methods based on the trip, the length and the idle time are discussed. She continues to discuss the relevance of the British and Dutch studies, and underlines the advantages of using stated preference experiments to ascertain the value of travel time. Concluding that a uniform valuation of time gains is becoming the accepted approach in international research. However, she does not advocate adopting this approach, stating instead, that the five minute threshold is valid.

Other publications demand a complete overhaul of the German evaluation methods for traffic infrastructure projects and point out that this has not been re-evaluated since the 1970s, due, among other reasons, German unification (Rothengatter, 2000). Though the discount method for small time savings is discussed, in spite of opposing findings in international research, its validity is not questioned. Since, small time savings and their valuation methods in cost-benefit-analysis have hardly been discussed in German literature. (BVU *et al.*, 2009) suggest a continuous discount rate for small time savings under 5 minutes for all demand segments (see Fig. 2.1).

However, in the context of a preliminary study regarding the Swiss value of time study, Abay and Axhausen (2000) apply a uniform valuation of time savings according to international standards and reference the unsolved problems in this area. The following publication does not discuss small time savings explicitly, mentioning them only in the appendix. Later publications

Figure 2.1: Weighting of Travel Time Savings in Germany



regarding the Swiss value of study (Axhausen *et al.*, 2007, 2008) do not discuss small time savings.

Ecoplan and Metron (2005) summarize the current research regarding small time savings as a basis for a Swiss cost-benefit-analysis of traffic infrastructure projects. They also advocate a uniform measurement (Ecoplan and Metron, 2005, p.126).

Obermeyer *et al.* (2014) assume that certain thresholds exist in human behaviour and discuss how these can be defined and which effects they can have on economic appraisal. Despite that no empirical evidence is available at the moment the authors discuss the problem of adding up several projects. They state that there is still a demand for research: even if a threshold in human behaviour can be identified the question remains, if it is valid to take it into account in economic appraisal.

2.3.3 State of the Art International Practice

Small travel time savings are equally valued in many countries which are integrating a time value in their cost-benefit-analysis. But this approach has often been questioned. This is based on the argument that persons do obtain utility gains from travel time savings of just a few seconds but that a large amount of these small time savings have a major share of the measured utility gain. This argument has been supported by some stated choice experiments which state that even time savings up to five minutes can be neglected (Austroads, 2012).

As Section 2.3.1 described the problems of the scientific evaluation of small travel time savings this section focuses on the application in the international evaluation procedure. The German and the Swiss approaches have been discussed in detail in the previous section and won't be dealt with in this section. Table 2.1 shows the findings of the literature review.

Table 2.1: Comparison of international valuation of small travel time savings for non-business travel

Country	Def. of "small" in min.	Valuation small travel time savings	Method	Reference
Germany	5	smaller unit value 30% (road)	mixture of wage cost and stated choice	Willeke and Paulußen (1991); Rothengatter (2000); Birn *et al.* (2005); BVU *et al.* (2009)
Australia	5	uniform value, no special treatment	stated choice	Austroads (2012)
Denmark	10	uniform value, no special treatment	stated choice	Fosgerau *et al.* (2007)
EU	3	uniform value, separate reporting	stated choice	Bickel *et al.* (2006)
Canada	5	exclude if <5min.	wage cost	Transport Canada (1994)

To be continued on the next page

Country	Def. small in min.	Valuation STTS	Method	Reference
Netherlands		uniform value, no special treatment	stated choice	Hague Consulting Group (1998)
Norway	2-5	uniform value	stated choice, <2min. excluded by survey design (1997)	Ramjerdi *et al.* (1997, 2010); Hjorth and Fosgerau (2011)
Sweden	10-20	uniform value, no special treatment	stated choice	Hultkrantz *et al.* (2001); Börjesson and Eliasson (2012)
Schwitzerland	5	uniform value, no special treatment	stated choice	Abay and Axhausen (2000)
USA		uniform value, no special treatment	stated choice	Small (2012); U.S. Department of Transportation (1997)

Extended from (Daly *et al.*, 2011) and (Austroads, 2012)

In the UK the value of time research has a long tradition and can be traced back to the 1960s (Wardman, 1998). The first research focused on the difference of small and large travel time savings in evaluations, was based on the data of the "Value of Time Study" from 1993. Back then recommendation of a constant valuation of all time savings was proposed (Bates and Whelan, 2001). The NATA Refresh Report (Department for Transport, 2009) suggests for future research to display time gains and losses disaggregated to improve the analysis of this effects according to the new objectives of the British Department for Transport. The British Department for Transport applies this suggestion in its WebTag (Department for Transport, 2011) and uses a classification of small travel time savings in -5 minutes, -5 until -2 minutes, -2 until 0 minute, 0-2 minutes, 2-5 minutes and more than 5 minutes. Nevertheless for the calculation of utility gains the constant unit value approach is still applied.

Likewise, the Dutch VTT study research did not directly cover the investigation of small travel time savings. Even though the existing data was analysed using a similar method to the British data (Gunn, 2001). In the most recent English publication of the Dutch VTT study no remark on small travel time savings can be found, which points to an equal treatment of all travel time savings.

The Danish VTT explicitly deals with the problem of the size of travel time savings (Fosgerau *et al.*, 2007). As in the British and Dutch VTT studies the main result of the investigation is that time changes of the order of a few minutes are valued lower than larger time changes. Similarly to the British VTT study this fact is associated with the study design. An equal treatment of small travel time savings is recommended as well. The discounted unit value approach for the valuation of small travel time savings is considered to be inappropriate and not logical (Fosgerau *et al.*, 2007, p.13).

Within the framework of the Swedish VTT study a working report dealing explicitly with small travel time changes was published (Börjesson and Eliasson, 2012). In this report different valuations of small and large time gains are called “study design artefacts” which need to be controlled. The analysis concludes that no threshold value effect exists and that also time savings beneath five minutes have a certain value. Nevertheless it is concluded that VTT of small time changes are valued too low in stated preference experiments and a time change of 15 to 20 minutes in the study design is recommended to receive independent VTT estimates. Additionally attention is drawn to the influence of the choice of the study design on the results which can occasionally lead to false recommendations.

Small travel time savings of less than 2 minutes were avoided by study design in the Norwegian VTT study (Ramjerdi *et al.*, 1997). Nevertheless the determined values are treated equally. Neither in the summary of the recent study (Ramjerdi *et al.*, 2010) nor in the annex of the main study information on a special treatment or study design can be found. It is only stated that the VTT studies is orientated on the findings of the Danish and Swedish study. Hence an unmodified valuation of small travel time savings can be assumed. More recent analysis of the Norwegian data contain both treatments of the size as well as the sign of travel time savings (Hjorth and Fosgerau, 2011).

The European Union initialized the project "Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO)" in 2005. The Deliverable 5 contains a short passage about the treatment of small travel time savings in cost-benefit-analysis (Odgaard *et al.*, 2005). A constant valuation of all time savings (hour, minutes or seconds) is recommended. As the measurement of small travel time savings appears as a potential error source it is suggested that the share of economic utility which is gained from time savings of less than three minutes shall be further examined.

The US Department of Transport recommends a constant valuation of time changes (U.S. Department of Transportation, 1997). In absence of a valid proof of the opposite, the uniform treatment of small and high time gains is considered appropriate. The same publication cites a study stating that older studies recommending the use of thresholds for small time savings, are not considered to be plausible.

Canada is, besides Germany, the only country that advocates a special treatment for small time savings in cost-benefit-analysis for traffic infrastructure projects (Transport Canada, 1994). The value of travel time is determined using labour costs and not via stated preference experiments. Time savings smaller then five minutes are deemed small but are not evaluated at a different rate. Instead, in the Canadian recommendation, small travel time savings are eliminated from the calculation supporting the investment decision and reported as a separate factor to the decision makers. Note that German as well as Canadian recommendations are based on older research regarding the valuation of small time gains.

In Australia VTT are determined depending on the mode of transport (Daly *et al.*, 2011). To date small travel time savings were not explicitly mentioned in practice, but neither were they treated differently nor eliminated. A recent publication deals intensively with small time gains in infrastructure projects (Austroads, 2012).The publication argues that a threshold for small time savings is outmoded and recommends an improved definition and better measurements for small time savings. The authors also argue that a more reliable travel time is more important than determining an absolute value for time savings (p.25).

2.3.4 Conclusions

Even after thirty years of value of time research the problem of evaluating small travel time gains has not been solved satisfactorily. In international practice, maybe due to the lack of alternatives, a uniform treatment is the de facto standard. Most studies use a constant time value for pragmatic reasons in order to avoid a cumulative effect in aggregation. This is stated as the standard approach and the a result of many studies (Mackie *et al.*, 2001). In a memorandum of the US Department of Transport the reliability of studies that use a discounted method is questioned (U.S. Department of Transportation, 1997).

As shown in Table 2.1, most countries (except Canada) use the constant unit value (CUV) approach for the valuation in cost-benefit-analysis. The German valuation method should correspond to the international standards to allow for international comparison and evaluate all time savings uniformly in the future, independently of their nature and size.

It should also be noted, that current research does not discuss a threshold for small time savings, but instead considers a uniform treatment of time savings as prerequisite. The focus of the current research is the different valuation of various time travel changes, depending on study design as well as the appropriate measurement methods to determine and predict travel time changes. In combination with the sign of the travel time change this is known as the "size and sign effect of the VTT". Hence, future research should focus on these questions rather then determining the appropriate discount rate.

The empirical literature on short-term changes in travel behaviour shows that small travel time changes are often ignored or not perceived by the travellers. Still, in the long-term logic of Cost-Benefit Analyses (CBA) this effect is irrelevant. To account for the effect would be inconsistent with assumptions of it and would open the chance to manipulate its results through dividing or aggregating projects into smaller or larger units.

Possible errors can arise through a lack of precision in the calculations of the transport volumes and speeds by the transport models of the with- and without conditions. These errors can in particular be reduced with the appropriate specifications of the accuracy of the equilibrium of the assignment model. If possible, sensitivity tests should be performed to establish their impact on the overall results of the CBA.

The results of the empirical test (see Section 4.1.4) did not indicate an impact of the size (and sign) of the differences on the estimated parameters. This shows that the sign of travel time difference did not influence the sensitivities. Thus, large travel time differences between the alternatives did not lead to different sensitivities, and therefore values of time, than smaller differences.

Therefore, and also to ensure international comparability, the recommendation for the German evaluation procedure was to follow the international state-of-the-art and treat all travel time changes equal in the future no matter of which nature or size they are. This ensures that the evaluation of travel time will not depend on the definition of “small travel time savings” or the kind of project. Furthermore, a uniform treatment of travel time savings will contribute to harmonize the evaluation of transport models, For example those which already include travel time difference between different routes to the second. If possible the robustness of the results of small travel time savings can be validated by using sensitivity analyses.

2.4 The Value of Travel Time Reliability (VOR)

The valuation of reliability or the variability of travel time is the topic of several international studies which mostly uses stated preference surveys to determine these values. These surveys discuss the different option to present reliability in the choice experiments and to derive the appropriate willingness-to-pay (WTP).

Cook *et al.* (1999) and Bates *et al.* (2001) present reliability in SP experiments as sequences of early and late arrivals vis-a-vis to the desired arrival time. They include the expected values of the deviation as an attribute in the experiment.

Bates *et al.* (2001) conclude that the willingness-to-pay for late arrival is twice as high as the WTO for arriving early. Asensio and Matas (2006; 2008) carry out a similar survey with commuters in Barcelona and find a WTP for a delayed arrival at the work-place which is up to three times higher than the WTP for travel time savings.

De Jong *et al.* (2004) show three different possibilities to present reliability in SP survey: mean vs. variance, the difference between the 90th percentile and the mean as well as delay opponent to the desired arrival time. The authors discuss the pros and cons of the forms of presentation and give an overview of previous studies which implement the described concepts.

In de Jong and Bliemer (2015) the authors present the outcome from expert interviews on how to incorporate the value of reliability in appraisal. They conclude that using a *schedule delay model* would be best. Given the fact that the overall transport model would need a departure time choice model to implement reliability they suggest to use the standard deviation in the medium run instead.

Hollander (2005) compares two bus connections with five different variations. De Palma and Picard (2005) investigate the route choice behaviour between one alternative with no travel time uncertainty and one alternative where travel time deviates within a certain interval (positive and negative) from this mean.

Bhat and Sardesai (2006) present reliability as the mean travel time and as the maximum negative deviation it can take. The willingness-to-pay for a reduce of delayed arrival was especially for commuters with fixed working hours higher as for travel time savings.

Brownstone and Small (2005) point out that WTP measures derived from SP experiments depending on differences in perceptions my lead to biased results. Carrion-Madera and Levinson (2010) perform a meta-analyses of comparable reliability studies and show that the range of reliability valuations compared to travel time lies between 0.1 and 1.5. They assume that the large bandwidth is due to the different study designs e.g. RP/SP and regional differences.

Tseng *et al.* (2009) test the comprehensibility of eight different forms of the presentations of reliability. Listing reliability verbally (without visualisation) to the respondents leads to the highest quality answers to the SP choices. It is used for example by Small *et al.* (1999).

Fosgerau *et al.* (2008) is a comprehensive study of the valuation of reliability in Denmark. It also include a comparison of different modelling methods. Noland and Polak (2002) perform a meta-analyses of studies published before 2001.

Li *et al.* (2010) present another meta-analyses. They summarize the methodical development of the last decade especially combined RP and SP surveys. Noland and Polak (2002) use the *scheduling model* to analyse their data. The underlying assumption is that a negative utility appears if the arrival time at a destination does not fit to the scheduled arrival which can be an early or late arrival:

$$\begin{aligned} U_i = {} & \varphi E(T_i) + \kappa E(max([SDE]_i, 0)) \\ & + \mu E(max([SDL]_i, 0)) + \tau E(T_i) \end{aligned} \tag{2.3}$$

In comparison the *mean variance model* implies a negative utility of the variance of travel time.

$$U_i = \gamma E(T_i) + \delta\sigma(T_i) \tag{2.4}$$

As a third theoretical approach Li *et al.* (2010) present the *mean lateness model* which was introduced by Batley and Ibáñez (2009). The model only uses delay as a source for negative utility not early arrival.

$$U_i = \alpha E(max(AT_i - ST_i, 0)) + \beta ST_i \tag{2.5}$$

Furthermore, Li *et al.* (2010) distinguish between two different presentations of reliability in SP experiments: type 1 is the frequency of a certain duration of reliability compared to the mean travel time. Type two is a sequence of alternatives where all other attributes remain unchanged but travel time varies in a certain range. The respondents were informed that travel time would vary as often as shown in the experiment but the order may vary randomly.

The authors conclude the presentation of reliability used by Small *et al.* (1999) is the ideal one. It covers the stochastic distribution of travel time and is the easiest to understand for the respondents (Tseng *et al.*, 2009). Further the collected data allow an estimation with both approaches: *mean variance* and *scheduling model*.

Further, Li *et al.* (2010) argue that the use of RP data together with SP data is to some extend desirable but difficult in most of the cases. First, for route choice, the alternatives are chosen from a very large pool of alternatives and to measure of reliability is very difficult. It is possible to use such data in situations where the alternatives are easy to separate for example a tolled and not tolled road. In this case travel times can be measured for a longer time interval and the distribution can be captured.

The meta-analysis shows that models developed from data which uses the type one form of reliability presentation lead to lower *reliability ratios* than type two forms of presentations. *Reliability ratio* is the ratio of travel time and reliability parameters. It is more suitable to compare different studies than the willingness to pay as for example exchange rates and inflation rates differ over time. They also find that the reliability ratio for public transport is usually higher than the one for car.

Li *et al.* (2010) also introduce their own study which is described in detail in Hensher *et al.* (2011). The respondents choose between three alternatives: their reported route and two alternatives. Reliability is presented in different ways: the probability of an early, on time or late arrival. The presented early and late arrival were calculated by experimental design.

The collected data allow the estimation of discrete choice models with both the *mean-variance* and the *scheduling approach*. The authors estimate a *Multinomial Logit Model (MNL)* and a *Mixed Logit Model (MMNL)* with randomly distributed parameters. Further attributes they control for are travel time (free floating, slow-moving and congested), travel cost and tolls. If possible the attribute are calculated with *PiVTT Design* depending on the reported trip.

The calculated values for commuters in the *MMNL* show that travel are willing to pay avoid delay. The calculated taste heterogeneity which can also be derived with the *MMNL* shows that the respondents evaluate travel time different (high variance of the WTP) but experience reliability similar (low variance). The value of reliability calculated with the *mean variance* approach lies above the value of time which can be interpreted that respondent prefer more reliable trips than shorter travel times.

If the WTPs for reliability are calculated in the described way Li *et al.* (2010) see consequences on three levels:

- for appraisal, where neglecting these reliability variables can lead to substantial economic losses
- for transport models, where the shortest path search takes only generalised cost depending on travel time but not reliability values into account
- for measuring service quality or the availability of information on reliability for the user of the transport system and the influence on the reduction of delay

Hensher *et al.* (2011) point out that decision makers tend to overestimate unlikely values of an attribute and to neglect more frequent ones. The authors give an overview of the possibilities to implement this fact in the model with different weightings of the deterministic part of the utility function based on the occurrence probability of the different values. This perspective differs from the one from Small *et al.* (1999) who use the same probability for all characteristics.

Hensher (2010) introduce a model which implements *probability weighting* and allows a non-linear estimation of the utility function for different attributes (especially risk evaluation). In an empirical analyses using the described method in an *MMNL* the authors derive a willingness-to-pay which they call *reliability embedded value of travel time savings (REVTTS)* and which includes a density function.

Innovatively they leave out separate WTPs for saving travel time and a higher reliability (as they were standard in previous studies) but acknowledge that this might lead to controversial discussions. This approach allows to correctly calculate the VTT depending on the probability of arriving on time. If this probability is 100% reliability is not accounted for and the value of time is equivalent with the "traditonal" VTT. Higher uncertainty can lead the an increase of up to 30% in the VTT which is again consistent to results of previous studies (e.g. Bates *et al.*, 2001).

Fosgerau (2017) expresses his scepticism of determining reliability with stated preference data. Nevertheless he thinks that omitting reliability in CBA is also not an option and that could imply a bias towards projects. He suggest to make use of the growing amount of large revealed preference data set instead.

Chapter 3

The Survey Work

Swiss studies followed a variant path, when compared to international practice by employing more complex SP experiments including multiple modes and multiple elements of the generalized costs of travel in a series of overlapping choice contexts (Axhausen *et al.*, 2004, 2008; Weis *et al.*, 2012; Fröhlich *et al.*, 2013). While these kind of complex choice surveys have been applied for some years in Switzerland more recently they were also acknowledged by researcher of other national VTT studies (e.g. Hess *et al.*, 2017b).

The design of the *German Value of Time and Reliability Study* builds on the experience of those studies in Switzerland. As described above the features of the survey are complex multi-attribute experiments of different types covering various aspects of short and long-term travel choice attributes, designed for the estimation of random utility models.. During his decision process the respondent has to take all these attributes into consideration. This makes the choice situation more realistic (Louviere *et al.*, 2000). Furthermore overlapping variables of the stated and revealed preference experiments are suitable for a joint estimation on the whole data. Additionally numerous socio-demographic and attitudinal questions plus the large sample size for business and non-business trips make it a unique dataset offering various aspects of travel behaviour and their valuations to explore.

This chapter presents the design of the *German Value of Time and Reliability Study* in detail. Further, it will report on the field phase of the study and analyse the response behaviour and the character of the attributes of the sample.

3.1 The survey and study design

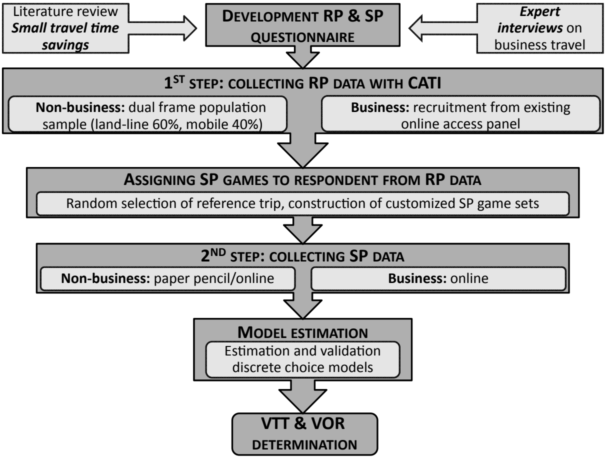
3.1.1 The survey idea and design considerations

The first official value of time and reliability estimation for Germany required utmost diligence. Choice experiments with multiple attributes are complex and sometimes difficult to understand for the respondents. Thus, different blocks of choice experiments were conducted. A combination of mode choice and departure time for the estimation of the VOR would even have been too complex which is why some relevant attributes were included in route choice experiments. Also some modes are not relevant for certain groups as not everyone has a car available. This information was gathered beforehand in the socio-economic questions and used for the questionnaire assignment. It was not only important for the estimation to include actual decisions of a single trip or route but also long-term decisions to measure the effect of future trips. These long-term decisions gave the respondents the opportunity to implement major changes in their choices but also include a discounted evaluation of the total of their short-term trips. All experiments included common variables which made it possible to estimate the required joint model by pooling the data and even include the collected RP data as a reference. This approach was most useful to create a realistic rather than only a hypothetical choice situation. It was even possible to estimated a pooled short-term and long-term model (Dubernet *et al.*, submitted, 2018a).

Fig. 3.1 shows the steps of the study. As business travel is concentrated in a small share of the population, a complementary sample of such travellers was recruited in addition to a population-based sample to achieve an adequate sample size. Business travel was defined as all employment-related travel, but excluding commute trips, emergency services and driving as work (delivery, bus, coach drivers, etc.). The category includes various kinds of business travellers from local craftsmen to lawyers and consultants. The additional sample of business travellers was recruited with an on-line access panel.

On the basis of the revealed preference (RP) data collected, a stated choice (SC) questionnaire was designed in a second step. The short-term SP experiments include mode choice, route choice and route choice and reliability experiments. They are described in detail in Section 3.1.2. In

Figure 3.1: Study process



order to allow the cross-checking of the results, this approach was further expanded to include long term choice contexts, which also involve travel as an element (residential and work place location choice), which also had been trialled in an earlier Swiss study (e.g. Weis *et al.*, 2012). The long-term SPs include residential and work place choice situations and are described in Section 3.1.3. At the end of each stated choice block all respondents had the opportunity to mark whether one or whether all of the attributes had no impact on their decision in the different choice situations or if all attributes were important to the respondents. The results are described in Section 3.3.5. All the SP questionnaires included additional attitudinal questions on risk acceptance, environmental protection and variety seeking in daily life. A descriptive analysis of the attitudinal questions can be found in Section 3.3.6.

In addition to the survey itself two secondary subjects of interest were investigated in the first phase of the project for further validation of the survey approach and design. The first issue was that business travellers are sometimes not free to choose the mode or even the route of their travel due to company policy and thereby cannot contribute valid SP experiments. This was checked before the main survey by conducting a small-scale qualitative study. Twenty-four decision makers had been recruited to cover the regions of Germany as well the range of firm sizes. While many firms indeed had policies in place, the sample reported that their employees were free to choose their routes and in the vast majority also the mode of travel. This allowed us to go ahead with the SC experiments without having to fear a major bias in the results (see Chapter 3, Axhausen *et al.*, 2015a, for a detailed description).

3.1.2 Design of the short-term experiments

In the non-business survey RP data on three trips undertaken by the respondents were collected in a first step. The purposes of the RP trips were pre-specified: commuting to work and the trips to the most important shopping and leisure (< 50 km) destinations.

Also information on the last long-distance trip over 50 km distance was collected, where, if the latter was ground-based, data on the most recent air trip was also collected. On some occasions the purpose of the reported last long-distance trip was business so that the non-business sample also contains a small number of business trips. The rationale behind the approach of collecting information on short and long distance trips is based on the observation that the bulk of a person's everyday travel is to a very small number of destinations (Ahas *et al.*, 2010a,b; Schönfelder and Axhausen, 2010). So within a relatively short computer assisted telephone interview (CATI) a good range of trips could be obtained. Business travellers reported their last three business trips.

Table 3.1: Survey design and attribute levels short term experiments

Attribute	Attribute levels	Alternative					
		Walk	Bike	Car	PT	Coach	Plane
		Mode choice (SP 1)					
Travel time	-30%, -10%, +20% of current state	x	x	x	x	x	x
Access/ egress time	5%, 10%, 20% of travel time	-	-	x	x	x	x
Congestion/ waiting time	5%, 10%, 20% of travel time	-	-	x	x	x	x
Travel cost	-20%, +10%, +30% of current state	-	-	x	x	x	x
Transfers	-1, +/-0, +1 time	-	-	-	x	x	x
Headway	-1, +/-0, +1 step	-	-	-	x	x	x
Share delayed trips	5%, 10%, 20%	-	-	x	x	x	x
		Route choice (SP 2)					
Travel time	-30%, -10%, +20% of current state	-	-	x	x	-	-
Access/ egress time	5%, 10%, 20% of travel time	-	-	x	x	-	-
Congestion/ waiting time	5%, 10%, 20% of travel time	-	-	x	x	-	-
Travel cost	-20%, +10%, +30% of current state	-	-	x	x	-	-
Transfers	-1, +/-0, +1 time	-	-	-	x	-	-
Crowding	low, medium, high	-	-	-	x	-	-
Delay every x. trip	5, 10, 20	-	-	x	x	-	-
		Departure time and reliability (SP 3)					
Travel time	-30%, -10%, +20% of current state	-	-	x	x	-	-
Access/ egress time	5%, 10%, 20% of travel time	-	-	x	x	-	-
Congestion/ waiting time	5%, 10%, 20% of travel time	-	-	x	x	-	-
Travel cost	-20%, +10%, +30% of current state	-	-	x	x	-	-
Transfers	-1, +/-0, +1 time	-	-	-	x	-	-

To be continued on the next page

Attribute	Attribute levels	Alternative					
		Walk	Bike	Car	PT	Coach	Plane
Share arriving early	5%, 10%, 20%	-	-	x	x	-	-
Share arriving on time	100% -share early -share delayed	-	-	x	x	-	-
Share arriving delayed	10%, 20%, 40%	-	-	x	x	-	-
Time arriving early	5%, 15%, 25% of travel time	-	-	x	x	-	-
Time arriving late	10%, 20%, 30% of travel time	-	-	x	x	-	-

The reference trip of a respondent was chosen randomly but aiming for an overall share of about one third long-distance trips and two-thirds daily trips, so the reference trip was selected with a bias to longer trips given their rarity and the interest of the BVWP in long-distance travel. This selection was corrected in the analysis through a re-weighting to match the distance-purpose distribution observed in the most recent German national travel diary survey (Follmer *et al.*, 2010). The most recent trip became the reference in the business sample. During the CATI the destinations and the route of the reference trip were geocoded using the software *Trip Tracer* (DDS Digital Data Services GmbH, 2012). The gathered trip information was complemented with the usual socio-demographic information and information about mobility tools as well as attitudinal questions.

The SP experiments were constructed around the reference trip. Information about the non-chosen options were added. The non-chosen alternatives and their attributes were based on information from a number of sources. Door-to-door car travel times were computed based on the average travel times reported by Tom-Tom Stats and a NavTeq – network for Germany using the MATSim framework (Horni *et al.*, 2016). The average car travel cost were calculated based on the 2012 ADAC (General German Automobile Club) price-per-kilometer estimate for an average sized car in each car segment (range from mini to caravan) (ADAC, 2012). The travel times, headways, transfers and prices on public transport including air travel were obtained from the relevant websites with an internet bot programmed by IVT.

Table 3.2: Allocation of SP experiments for non-business sample

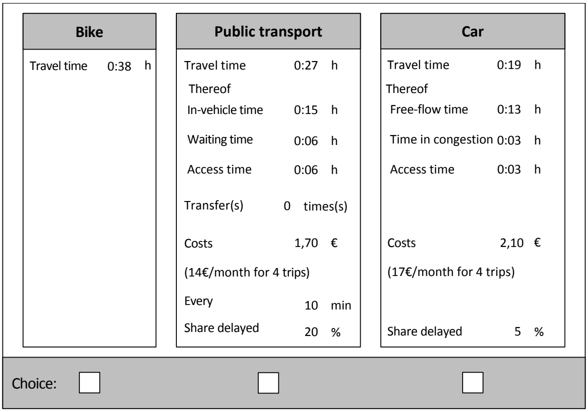
From RP		*Allocated SP*				
Reference trip	Travel mode	Mode choice	Route choice	Reliability	Long-term	No
Daily trip (2/3 of all trips)	Walk	Walk / PT / Car	–	–	Work place	1
	Walk	Walk / PT / Car	–	–	Home location	2
	Bike	Bike / PT / Car	–	–	Home location	3
	Bike	Bike / PT / Car	–	–	Work place	4
	PT	Bike / PT / Car	–	PT type 1	Work place	5
	PT	–	PT	PT type 2	Home location	6
	Car	Walk / PT / Car	–	Car type 1	Home location	7
	Car	–	Car	Car type 2	Work place	8
Long distance trip (1/3 of all trips)	PT	Coach / PT / Car	–	PT type 3	Work place	9
	PT	–	PT	PT type 1	Home location	10
	Car	Coach / PT / Car	–	Car type 3	Home location	11
	Car	–	Car	Car type 1	Work place	12
	PT	PT / Car / Plane	–	PT type 2	Work place	13
	PT	–	PT	PT type 3	Home location	14
	Car	PT / Car / Plane	–	Car type 2	Home location	15
	Car	–	Car	Car type 3	Work place	16
	Plane	PT / Car / Plane	–	Plane type 1	Work place	17
	Plane	PT / Car / Plane	–	Plane type 2	Home location	18

The SP experiments had to be generated in a way to gather as much information as possible with the smallest possible sample size. To this end, an efficient design based on variations of the reported attribute levels - a so called pivot design - was computed using the software *Ngene* (Rose *et al.*, 2009). In a pivot design the attribute levels shown to the respondents are pivoted from reference alternatives of each respondent (ChoiceMetrics, 2018). Table 3.1 shows the design and attribute levels of the different short term experiments.

Both samples received the SP experiments within a maximum of two weeks of having participated in the CATI. The business trip sample responded via a web-based survey system. The non-business sample could choose to respond with a paper-and-pencil form or with a web-based survey.

Respondents in the non-business survey received three different SP experiments. To keep the response burden low the business sample respondents only received two types of SP experiments - either a mode choice, route choice or departure time choice (reliability) experiment but no long-term SP. So in total, respondents were offered between 16 and 24 choice situations. Each type of SP experiment contained 8 choice situations. Table 3.2 shows the 18 possible combinations of the different SP experiments for the non-business sample where each combination represents one type of questionnaire. The design of the business sample was basically the same only without the long-term experiments of home and work place location choice.

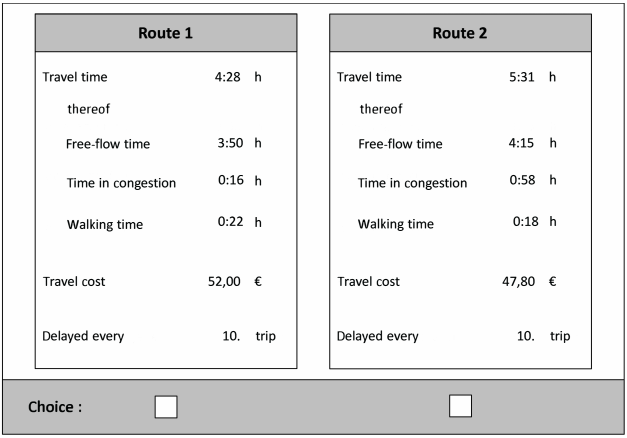
Figure 3.2: Example of mode choice task (SP 1)
(Translated from German)



Bike	Public transport	Car
Travel time 0:38 h	Travel time 0:27 h	Travel time 0:19 h
	Thereof	Thereof
	In-vehicle time 0:15 h	Free-flow time 0:13 h
	Waiting time 0:06 h	Time in congestion 0:03 h
	Access time 0:06 h	Access time 0:03 h
	Transfer(s) 0 times(s)	
	Costs 1,70 €	Costs 2,10 €
	(14€/month for 4 trips)	(17€/month for 4 trips)
	Every 10 min	
	Share delayed 20 %	Share delayed 5 %
Choice: ☐	☐	☐

In the mode choice experiments the respondent had to choose between three modal alternatives. The modes offered depended on the reported reference mode and were either walking, cycling, car, public transport (PT) and the various long distance modes: train, air and coach. At the time of the survey, coach travel had just been de-regulated. The resulting lack of familiarity with the coach as a scheduled long-distance alternative resulted in unreliable estimates and no results for the coach option were reported. (Belgiawan *et al.*, 2017) faced similar problems when comparing the mode

Figure 3.3: Example of car route choice task (SP 2)
(Translated from German)



	Route 1			**Route 2**	
Travel time	4:28	h	Travel time	5:31	h
thereof			thereof		
Free-flow time	3:50	h	Free-flow time	4:15	h
Time in congestion	0:16	h	Time in congestion	0:58	h
Walking time	0:22	h	Walking time	0:18	h
Travel cost	52,00	€	Travel cost	47,80	€
Delayed every	10.	trip	Delayed every	10.	trip
Choice :	☐			☐	

choice experiments to other context depending data and deriving values of time for the coach option. Fig. 3.2 shows an example of a mode choice experiment with the three alternatives bike, public transport and car.

In the route choice experiments respondents were offered two route alternatives for either car or public transport. In the long-term experiments the respondents could choose between their current work or living situation and a constructed alternative. Fig. 3.3 shows an example of a car route choice experiment.

The departure time and reliability experiment was formulated as route-departure time choice with an indication of travel time variability. Three formats of different complexity were tested, but each allowing to estimate the mean-variance model of scheduling (Li *et al.*, 2010). All three formats were retained after the pre-test, as it indicated no clear preference between them in spite of their growing complexity. Fig. 3.4 shows the three different presentation types of reliability using the example of public transport where each column (PT type 1, PT type 2, PT type 3) represents one type of experiment.

Figure 3.4: Different types of reliability experiments (SP 3)
(Translated from German)

PT type 1

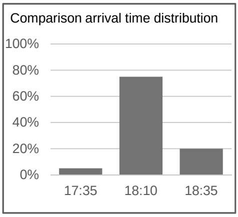
trip 1 - type 1		
Departure time	12:00	h
Expected travel time	0:40	h
thereof in-vehicle time	0:26	h
thereof waiting time	0:05	h
thereof access time	0:09	h
Expected arrival time	12:40	h
share 25min early	10	%
share on time	80	%
share 35min delay	10	%
Transfer(s)	0	time(s)
Costs	4.80	€
Choice	☐	

PT type 2

trip 1 - type 2		
Departure time	6:06	h
Expected travel time	2:09	h
thereof in-vehicle time	1:43	h
thereof waiting time	0:17	h
thereof access time	0:09	h
Expected arrival time	8:15	h
(55 % of the cases)		
5 % of the cases	8:05	h
40% of the cases	8:25	h
Transfer(s)	2	time(s)
Costs	4.80	€
Choice	☐	

PT type 3

trip 1 - type 3		
Departure time	16:55	h
Expected travel time	1:15	h
thereof in-vehicle time	1:04	h
thereof waiting time	0:04	h
thereof access time	0:07	h
Expected arrival time	18:10	h
(75 % of the cases)		
5 % of the cases	17:35	h
20 % of the cases	18:35	h
Transfer(s)	1	time(s)
Costs	1.80	€
Choice	☐	



The travel time reliability was varied by providing different congestion probabilities and average congestion times (delay) for automobile travel and by providing the probability of delays (in minutes) from scheduled arrival time for public transport travel (delays were a percentage of the specified tolerance from the RP survey). Furthermore the mode choice experiments included the share of delayed arrivals and the route choice experiments the share of trips delayed.

As a result of the pre-test the RP questionnaire was shortened for the main survey. To make the trade-offs easier to understand for the respondents it was decided to also show monthly and not only trip based costs in the SP questionnaire in the main survey.

3.1.3 Design of the long-term experiments

Most value of time studies consider short term decisions by framing experiments around a situation where respondents are presented with variations to travel time and cost of different modes or routes. The questions arises if the focus on short term decisions is the most appropriate? Can for example a commuter vary much of his daily commute in the short run or is it perhaps more reasonable that changes in commutes occur because of longer term decisions that people make such as where to work or where to live? (Beck *et al.*, 2017).

Workplace and residential location influence many other behavioural choices of travellers as they define the marginal cost of further travel and the distances involved. Therefore the focus of several more recent empirical studies shifted to understand and explain everyday travel behaviour as a routine activity changing due to key events such as residential relocation or workplace decisions. A recent article by (Müggenburg *et al.*, 2015) reviews the theoretical framework and the most important studies investigating mobility behaviour in a long-term choice context. (Schirmer *et al.*, 2014) give a comprehensive overview of residential location choice literature and show that travel time, commuting and employment changes are significant determinants of choices.

Table 3.3: Survey design and attribute levels long-term experiments

Attribute (Current altenative (RP))	*Unit*	*Attribute levels (New alternative (SP))*	*Alternative*	
			Current	*New*
		Workplace choice (SP 4)		
Car commute time	(min)	–30%, –10%, +20%	x	x
Car commute cost	(€/month)	–20%, +10%, +30%	x	x
PT commute time	(min)	–30%, –10%, +20%	x	x
PT commute cost	(€/month)	–20%, +10%, +30%	x	x
Salary before tax	(€/month)	–10%, +/–0%, +10%	x	x
Staff managed	(number)	–50%, +20%, +100%	x	x

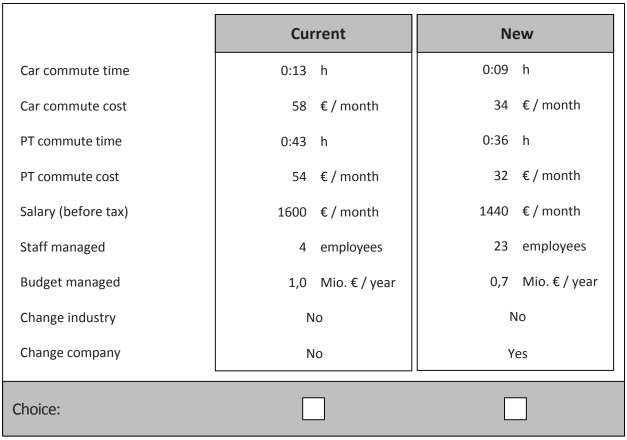
To be continued on the next page

Attribute (Current altenative (RP))	*Unit*	*Attribute levels (New alternative (SP))*	*Alternative Current*	*New*
Budget managed	(million €/year)	–50%, +20%, +100%	x	x
Change of industry needed	(yes/no)	no, yes	no	x
Change of company needed	(yes/no)	no, yes	no	x
		Residential location choice (SP 5)		
Type	(house/apartment)	house, apartment	x	x
Size	(m^2)	–20%, +10%, +30%	x	x
Standard	(new/renovated/old)	new, renovated, old	x	x
Exterior	(none/garden/balcony)	none, garden, balcony	x	x
Rent/mortgage	(€/month)	–20%, +10%, +30%	x	x
Area	(urban/suburban/rural)	urban, suburban, rural	x	x
Car travel time:				
- Commute	(min)	–30%, –10%, +20%	x	x
- Shopping	(min)	–30%, –10%, +20%	x	x
Car travel costs:				
- Commute	(€/month)	–20%, +10%, +30%	x	x
- Shopping	(€/month)	–20%, +10%, +30%	x	x
PT travel time:				
- Commute	(min)	–30%, –10%, +20%	x	x
- Shopping	(min)	–30%, –10%, +20%	x	x
PT travel costs:				
- Commute	(€/month)	–20%, +10%, +30%	x	x
- Shopping	(€/month)	–20%, +10%, +30%	x	x

Trading workplace or residential location, however, represents a long term choice; it is a decision that is not made easily and cannot be changed quickly. The alternatives in the choice situations include travel related variables and in addition a description and variation of work and residential attributes of the respondents. The respondents were asked to make trade-offs between these transport and workplace or residence related attributes.

In the workplace games we presented choices via a labelled choice experiment where respondents were asked to choose between their current workplace and an alternative workplace that varied in commute times, commute costs, salary and other workplace attributes. The SP experiments were generated in the same way using efficient design as described in Section 3.1.2. The attributes and their variation can be found in Table 3.3. An example of this choice task is shown in Fig. 3.5. A respondent received eight long-term choice tasks in total.

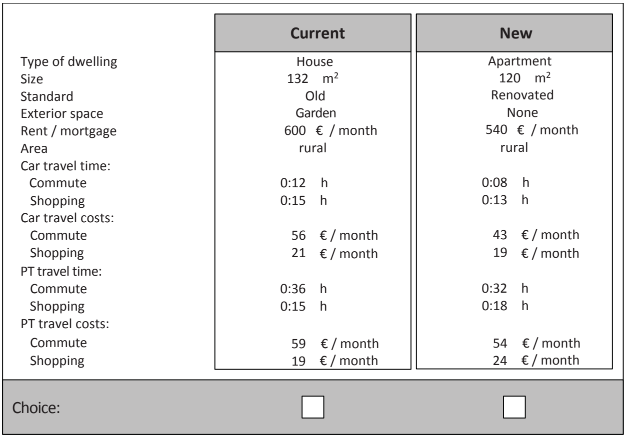
Figure 3.5: Example of work place choice task (SP 4)
(Translated from German)



	Current	**New**
Car commute time	0:13 h	0:09 h
Car commute cost	58 € / month	34 € / month
PT commute time	0:43 h	0:36 h
PT commute cost	54 € / month	32 € / month
Salary (before tax)	1600 € / month	1440 € / month
Staff managed	4 employees	23 employees
Budget managed	1,0 Mio. € / year	0,7 Mio. € / year
Change industry	No	No
Change company	No	Yes
Choice:	☐	☐

The residential location games were similar to the workplace ones but with residential attributes. In addition to the travel cost and time for commute trips the alternatives also show the time and cost for car and public transport to the nearest shopping location. The residential attributes regard the appearance and location of the dwelling. All attributes and their variation can be found in Table 3.3. An example of this choice task is shown in Fig. 3.6.

Figure 3.6: Example of residential location choice task (SP 5)
(Translated from German)



	Current	New
Type of dwelling	House	Apartment
Size	132 m^2	120 m^2
Standard	Old	Renovated
Exterior space	Garden	None
Rent / mortgage	600 € / month	540 € / month
Area	rural	rural
Car travel time:		
Commute	0:12 h	0:08 h
Shopping	0:15 h	0:13 h
Car travel costs:		
Commute	56 € / month	43 € / month
Shopping	21 € / month	19 € / month
PT travel time:		
Commute	0:36 h	0:32 h
Shopping	0:15 h	0:18 h
PT travel costs:		
Commute	59 € / month	54 € / month
Shopping	19 € / month	24 € / month
Choice:	☐	☐

3.2 Response behaviour

After the pre-test in May 2012 the two-step survey was carried out in six subsequent waves from July to October 2012. For their participation in the whole survey respondents of the non-business sample received a lottery ticket (benefiting the charity "Aktion Mensch", worth about 35 Euro) as an incentive. Respondents of the business sample were recruited by an online access panel and received the usual reward for their participation in the form of reward points for their panel account.

The population based non-business sample was drawn from a dual frame of land-line and mobile numbers (60% and 40%) to ensure that the growing share of mobile-only persons are included (ADM Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V., 2014). The sample was incrementally controlled over the survey period so as to ensure spatial quotas in terms of the German federal states.

Before sending out the SP game sets of the first wave (pre-test) the expected response rates for the paper-pencil and on-line non-business and business sample were predicted following and compared to other surveys conducted at the IVT to calculate the number of contacts needed for the aimed-for number of participants (Axhausen *et al.*, 2015b). In the end all three observed rates settled in the expected range (see Fig. 3.7). The response rate was even higher than for the IVT Swiss value of time study (Axhausen *et al.*, 2004).

A recruitment rate of over 30% for the CATI and 73% completion rate for the first phases of the RP survey and response rates of 68% (non-business sample) and 91% (business sample) for the second phases in spite of the complexity of the instruments indicate a strong interest in the topic.

Figure 3.7: Response burden and response rates

Source: Adaptated from (Axhausen *et al.*, 2015b)

In the RP survey over 4,000 persons completed the questionnaire providing socio- demographic characteristics and information on recent trips. During the recruitment phase the data was checked and controlled so that there was a sufficiently large sample of responses for all trip purposes.

Including the pre-test data over 2,400 non-commercial and over 830 commercial respondents completed the questionnaire including the SP games provided to them. Hence the sample contains almost 64,000 choice situations (Table 3.5). Fig. 3.7 and Table 3.4 show that the response rate of the commercial study is overall higher than in the non-commercial study as participants were recruited in a business market research on-line panel.

Table 3.4: Response rates

	Non-business sample			*Business sample*			*Total sample*		
	Paper pencil	On-line	Total	Paper pencil	On-line	Total	Paper pencil	On-line	Total
Pretest									
Contacts	–	–	667	–	–	260	–	–	927
RP (CATI)	–	–	200	–	–	77	–	–	277
			(30%)			(30%)			(30%)
SP survey	126	18	144	53	–	53	180	18	198
	(72%)	(83%)	(73%)	(71%)		(71%)	(72%)	(83%)	(73%)
Main survey									
Contacts	–	–	9,491	–	–	1,112	–	–	10,603
RP (CATI)	–	–	3,155	–	–	864	–	–	4,003
			(33%)			(76%)			(38%)
SP survey	2,162	98	2,260	–	786	786	2,162	884	3,046
	(69%)	(51%)	(68%)		(91%)	(91%)	(69%)	(84%)	(73%)
Total									
Contacts	–	–	10,158	–	–	1,372	–	–	11,530
RP (CATI)	–	–	3,355	–	–	925	–	–	4,280
			(33%)			(67%)			(37%)
SP survey	2,288	116	2,404	53	786	839	2,341	902	3,243
	(69%)	(55%)	(68%)	(71%)	(93%)	(91%)	(69%)	(84%)	(73%)

Table 3.5 gives an overview about the distribution of the number of the completed choice tasks by type of experiment and sample. Sufficient data for all five types of SP experiments was collected. Only the reliability experiments for business trips with the plane do not contain many cases. As some of the long-distance flights of the non-business sample were also business trips the number increased to 10 person and 80 completed SPs. However any disaggregated modelling for this trip purpose, mode and SP experiment has to be done carefully as it not always led to reasonable results.

Fig. 3.8 shows the response rates by waves sample and medium. As mentioned above respondents in the business sample have an overall higher response rate (except in the pre-test). In the pre-test it was tested to recruit respondents for the business sample the same way as for the non-business

Table 3.5: Number of completed valid SP games by type of experiment

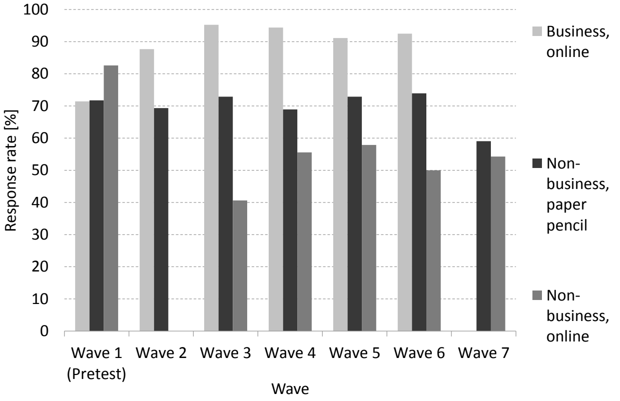
	Non-business			*Business*			*Total*		
Experiment	SPs	Pers,*	Response (%)	SPs	Pers,*	Response (%)	SPs	Pers,*	Response (%)
Mode choice	12,267	1,631	64	3,439	431	90	15,706	2,062	68
Route choice car	3,961	508	74	2,658	333	91	6,619	841	80
Route choice pt	1,787	241	72	600	75	90	2,387	316	76
Reliability car	8,141	1,116	69	5,362	672	91	13,503	1,788	76
Reliability pt	5,321	699	70	1,301	163	91	6,622	862	73
Reliability plane	946	123	76	32	4	80	978	127	77
Work place	9,504	1,224	73	–	–	–	9,504	1,224	73
Home location	8,634	1,160	69	–	–	–	8,634	1,160	69
Total	50,561	2,404	68	13,392	839	91	63,953	3,243	73

** max, 3 different SP with 8 choice situations each per person*

sample by calling respondents and ask them to participate. Significantly fewer respondents could be recruited for the business sample. To avoid hidden refusal it was decided to collect this data with an online access panel.

The aimed-for number of participants in the business study was already reached after wave six so that in the seventh wave only non-business SP game sets were sent out. In the non-business survey respondents were free to choose between completing the questionnaire on-line or as paper-and-pencil. From almost 3200 respondents who indicated their willingness to participate in the SP experiments only 5.6% or 186 person in total chose to complete the questionnaire on-line. Hence, the response rate of the on-line non-business sample varies more than the other samples' rates as its sample is much smaller. In any case, the response rates for that medium were the lowest.

Figure 3.8: Response by sample, medium and wave

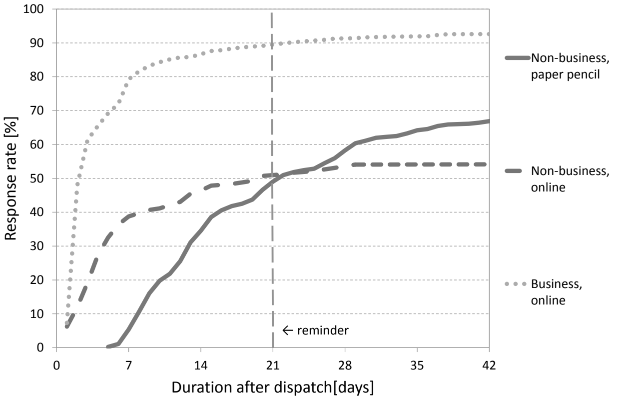


To complete the full on-line SP questionnaire respondents in the business sample needed between 1 minute 18 seconds and 43 minutes 48 seconds and on average 9 minutes 24 seconds. Participants in the non-business survey needed more time, taking between 5 minutes 6 seconds and 58 minutes and on average 17 minutes to fill in the survey questionnaire. As the long-term experiments were only given to the respondents in the non-business sample they had to answer to an additional block of 8 different choice situations. Nevertheless the absolute number of respondents of the non-business on-line SP survey is about ten times smaller than the absolute number of participants in the business on-line access panel.

Within two weeks after participating in the CATI respondents received the SP games and the overall time it took them to send back the questionnaires was recorded. Those who did not answer within 21 days after the send-out received a reminder by that time. Fig. 3.9 shows that the reminder had only little impact on the two on-line-surveys but did so on the paper pencil one.

Responses to the two online samples were faster than to the paper pencil survey. Over half of the respondents of the online business sample answered within two days. After one week 80% of respondents had already completed the SP games. The reminder had almost no effect as responses did not

Figure 3.9: SP response time in days

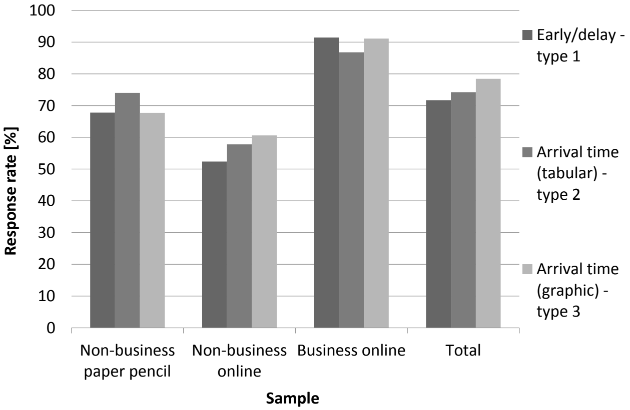


substantially increase after it was sent out. In the non-business sample half of the respondents took a maximum of 4 days to answer the SPs. Most of the respondents (80%) answered within 14 days. The reminder increased responses by about 2%.

Sending questionnaire by post and back takes more time in general than answering an on-line survey. First completed SP arrived after 5 days and half of the questionnaires were sent back within two weeks. The reminder, which also included the full questionnaire, sent after 21 days motivated an increase between 15% and 20% additional responses after an additional time interval of about four days. 80% of the questionnaires arrived within 28 days. So it took the respondent almost the twice as long to complete the written questionnaire however not including the additional time by sending it through post. The last questionnaire arrived after 151 days.

Besides experience from the pre-test the main study confirmed that all three types of reliability presentation delivered equally high response rates (see Fig. 3.10). Between the presentation types no clear pattern is recognizable. In the written paper pencil non-business survey the reliability presentation type 2 got most responses whereas respondents in the non-business on-line survey responded best to type three presentation of reliability. Type 1 turned out to gain most responses in the on-line business survey whereas in total the difference between type 3 and type 1 is about 7%. If one has to decide between the different presentation types it seems reasonable to prefer a graphical presentation of reliability as it is easier for respondents to understand the experiment. Tseng *et al.* (2009) found an opposite result since some respondents have difficulties reading the presented graphs correctly.

Figure 3.10: Response by presentation of reliability



3.2.1 Non-traders, lexicographic behaviour and item non-response

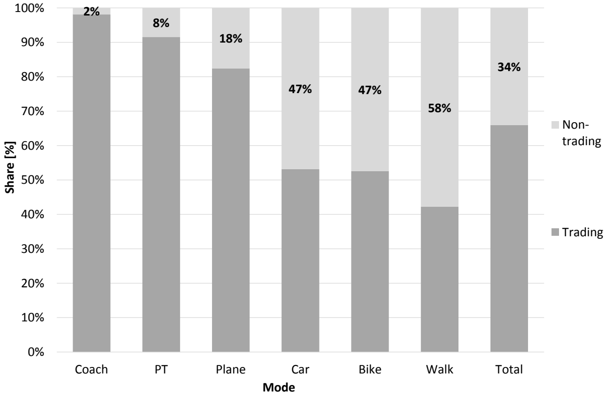
3.2.1.1 Non-traders

Non-traders in a stated preference survey are respondents who always choose the same alternative among their choice sets regardless of the available alternatives' attributes. This may have several reasons, one of which is the presence of very strong preference in the context of utility maximisation. Other reasons could be picking the same alternative for every situation in order to reduce response burden or misunderstanding the questions (Hess *et al.*, 2010).

The total share of non-traders across the five different choice experiments is 25 %. Non-trading occurs far less often in unlabelled choice situations because it does not invite a general preference of the respondent for one of the alternatives. But it still can happen for example, if the respondents always chooses the left or right alternative (Hess *et al.*, 2010). In the *German Value of Time and Reliability Study* the route choice (SP2) and reliability experiments (SP3) are unlabelled choice experiments whereas the mode choice (SP1) and both long-term experiments - workplace (SP4) and residential choice (SP5) are labelled experiments.

In the *German Value of Time and Reliability Study*, in total 34% of the respondents never varied their choices in the mode choice experiments (see Fig. 3.11). Differentiated by mode, it can be seen that the share of non-traders is higher for car user and persons using non-motorised transport whereas public transport user are more willing to vary their choices. Non-trading does not necessarily imply inconsistent responses. Hence, the relevant variables, such as trip distance and purpose and the availability of mobility tools were included in the modelling process rather than excluding non-traders.

Figure 3.11: Share of non-traders by mode in the mode choice experiments



In the long-term workplace choice experiment the share of non-traders was about 43% with 14% always choosing the new workplace. In the residential location choice experiment the share of non-trader was a bit higher with 51% with only 7% always choosing the new residential alternative. Overall the share of non-traders was in the expected range and for some modes even lower than expected (Fröhlich *et al.*, 2013).

For the reasons described above, the unlabelled experiments (SP 2 and SP 3) include far less non-traders. Overall only 26 respondents (0.1 %) always chose the left or right alternative. With 22 respondents non-trading occurred mostly in the route choice and departure time experiments (SP3). Over the two labelled experiments 12 respondents always chose the left and 14 always the right alternative. The car route choice experiments had included overall more non-traders (18 respondents) than the public transport choice experiments.

3.2.1.2 Lexicographic behaviour

Lexicographic behaviour occurs when over the course of the experiment the respondent evaluates the choice alternatives on a basis of a subset of attributes for example by always choosing the cheapest or fastest alternative (Hess *et al.*, 2010). The authors state in the same paper that true lexicographic behaviour is hard to detect especially in complex choice situations with multiple attributes as in this survey. For example in a choice situation where the respondent always chooses the cheapest alternative and not the more expensive one in a certain situation could also be due to more transfers during the trip. Also it is sometimes hard to distinguish between lexicographic and non-trading behaviour (Hess *et al.*, 2010). Nevertheless it is interesting to see how often the respondents decided to always choose the fastest or cheapest alternative where in this case the five different types of choice experiments can be even more revealing.

In the mode choice experiments (SP1) which contains data of in total 2062 respondents 390 respondents (19%) always chose the fastest option which was offered to them. 18% (376) always chose the cheapest option. 13% (264) always chose the alternative with the smallest share of delayed trips. As mentioned above, especially in mode choice experiments it is extremely hard to detect real lexicographic behaviour. For example a person who always chooses the bike alternative could be either a non-trader with a general preference for taking the bike or could really chose the bike because it is the cheapest option with zero costs.

In the car route choice experiments 47% of the respondents (396 from 841) always chose the fastest in-vehicle time and 26% (224) of the respondents the fastest overall travel time. 23% (195) always decided for the cheapest alternative. In the public transport experiments 19% (60 from 316 respondents) only chose the cheapest option and 35% (112) the fastest. For the route choice and reliability experiments (SP3) the shares are lower. As these experiments contain even more variables (reliability related) this might be another sign that no true lexicographic behaviour can be identified.

Again in SP4 and SP5 it can not be distinguished if a respondent chooses his current situation or a lexicographic attribute for example always the highest salary (40%) in SP 4 or the lowest commute time (41%) or rent (56%) in SP5.

Nevertheless even if it is not possible to see true lexicographic behaviour the results give us a general insight for the importance and dominance of certain attributes in the choice set. Also the findings match with the ones of the variable importance questions (Section 3.3.5). Furthermore, they validate the trade-offs generated through experimental design as most of the respondents did not always choose only one certain low or high attribute of a choice situation.

3.2.1.3 Item non-response

Another important issues for a survey is item non-response, which means that respondents do not answer to a particular item among the questions. In social sciences these are often sensitive private information like income or education. The German VOT study showed only minor problems with item non-response, generally the shares of missing values were less 2% or occurred for less important variables. The questions about being an academic, number of jobs, children living in the household and the profession had a share of missing values higher than 20%, but where more or less covered by other questions, for example, by education in general, the number of person living in the household of a respondent, or the type of employment (all less than 1% missing values). The variable household income which was essential for modelling and usually is also one of the more sensitive questions showed an item non-response rate of only 12.9%.

A possible solution to discover patterns or groups behind the non-response at a later stage is to estimate a separate coefficient for missing income. All other variables in the survey not shown in Table 3.6 had item non-response rates of less than 2%.

Table 3.6: Item non-response

	Do not know	Do not say	Missing	Total	Share (in %)
Academic yes/no	2	1	1356	1359	41.9
Number of jobs	6	2	755	763	23.6
Profession	2	1	754	777	23.4
Children <14y in HH	–	5	737	742	22.9
Income	94	255	69	419	12.9
Car availability	1	2	285	288	8.9

3.3 Descriptive analysis

This section presents an overview of the collected data using basic descriptive analyses. The same socio-demographic attributes (Section 3.3.1) were collected in both samples whereas the data of the reference trip (Section 3.3.2) differ slightly between the samples. For validation the sample was compared with other German nationwide travel behaviour survey data - the *Mobilität in Deutschland 2008 (MiD 2008)* (Follmer *et al.*, 2010). The collected SP data (Section 3.3.3) is again the same for both samples only differing by trip purpose.

3.3.1 Socio-demographic attributes

Table 3.7 shows the categorical distribution (number of cases) and the percentage share of the socio-demographic attributes. Both columns show the unweighted number of person of each sample.

The total number of cases in Table 3.7 differs between the variables as not all 3,243 respondents answered all of the socio-demographic questions. However, only the valid percentage share of the levels are shown.

Table 3.7: Unweighted socio-demographic variables: SP sample and MID 2008

		German VOT		*MiD 2008*	
Attribute	*Level*	*N*	*%*	*N*	*%*
Gender	Female	1,497	46	30,761	51
	Male	1,746	54	29,948	49
Age group	< 18	–	–	10,886	18
	18-24	146	5	4,854	8
	25-44	1188	37	12,114	20
	45-59	1287	40	16,418	57
	60-64	251	8	4,002	7
Age group	>65	369	11	12,327	20
Household size	1	737	23	4,410	7
	2	1,246	39	21,227	35
	3	603	19	12,057	20
	4+	654	20	23,013	40
Children < 14 y. in household	0	1,748	54	42,075	69
	1	425	13	9,027	15
	2	260	8	7,473	12
	3	56	2	1,704	3
	4+	11	0.3	434	0.7
Children < 18 y. in household	0	1,537	47	35,401	58
	1	479	15	10,260	17
	2	369	11	10,795	18
	3	96	3	3,214	5
	4+	5	0.6	1,043	2
Education	Hauptschule	363	11	10,312	27
	Realschule	923	29	12,991	34
	Abitur	1887	59	12,922	33
	None	13	0.4	150	0.4
	Other	–	–	2,121	6
University degree	Yes	1,242	38	9,402	16
	No	642	20	16,488	27

To be continued on the next page

		German VOT		*MiD 2008*	
Attribute	*Level*	*N*	*%*	*N*	*%*
	Missing	1,359	42	34,800	57
Employment	Full time	1,979	61	18,371	30
	Part time	516	16	7,466	12
	Education (pupil, student,...)	127	4	11,982	20
	Job seeking	57	2	1,087	2
	Housewife/-man	66	2	4,470	7
	Retired	471	15	13,367	22
	Else	26	1	3,934	6
Net household income (MID class)	<1000€ (<900=€)	142	5	1,608	3
	1000-1500€ (900-1500€)	232	8	5,233	9
	1500-2000€	356	13	7,637	13
	2000-2500€ (2000-2600€)	402	14	10,299	17
	2500-3000€ (2600-3000€)	437	16	6,217	10
	3000-3500€ (3000-3600€)	313	11	7,597	13
	3500-4000€ (3600-4000€)	295	10	3,177	5
	4000-4500€ (4000-4600€)	201	7	3,772	6
	4500-5000€ (4600-5000€)	147	5	1,589	3
	5000-5500€ (5000-5600€)	87	3	1,826	3
	5500-6000€ (5600-6000€)	54	2	642	1
	6000-6500€ (6000-6600€)	39	1	707	1
	>6500€ (>6600€)	120	4	1,506	3
Driver's license (car & motorcycle)	Yes	3,143	97	33,479	87
	No	100	3	4,825	13
Number of cars in household	0	285	9	4,302	7
	1	1,508	47	27,565	45
	2	1,155	36	22,778	38
	3	213	7	4,706	8
	>4	75	2	1,342	2
Car availability	Always	2,677	83	27,677	46
	Sometimes	273	8	4,278	7
	Never	5	0.3	2,967	5
PT season ticket	None	2,694	83	7,410	12
	Monthly	205	6	1,045	2
	Annual	158	5	3,471	6
	Else (student, weekly,...)	185	6	26,557	44
Bahncard	None	2,745	85	–	–

To be continued on the next page

		German VOT		*MiD 2008*	
Attribute	*Level*	*N*	*%*	*N*	*%*
(national) discount railway ticket	25% reduction	286	9	–	–
	50% reduction	193	6	–	–
	100% reduction	13	0.5	–	–
Number of bikes in household	0	413	13	8501	14
	1 (>=1 in MID)	552	217	37,392	81
	2	936	29	–	–
	3	531	16	–	–
	>4	803	25	–	–
Federal State	Schleswig-Holstein	105	3	2,464	4
	Hamburg	85	3	1,598	3
	Lower Saxony	303	9	6,106	10
	Bremen	30	1	1,634	3
	North Rhine-Westphalia	705	22	10,632	18
	Hesse	229	7	5,525	9
	Rhineland-Palatinate	152	5	3,320	6
	Baden-Wuerttemberg	396	12	6,769	11
	Bavaria	503	16	6,368	10
	Saarland	33	1	1,810	3
	Berlin	158	5	2,582	4
	Brandenburg	105	3	2,102	4
	Mecklenburg-Western Pom.	70	2	1,481	2
	Saxony	183	6	3,772	6
	Saxony-Anhalt	98	3	2,192	4
	Thuringia	88	3	2,358	4

The education category *Hauptschule* represents the lower secondary education with 8 (*Volksschule*) to 10 (*Hauptschule*) school years. *Realschule* represents secondary education with 10 school years usually followed by an apprenticeship. The category *Abitur* includes the German *Abitur or Allgemeine Hochschulreife* and *Fachabitur* which allows the pupil to enter higher education either at a university or at a *Fachhochschule* (technical college) with a *Fachabitur*.

The lower bound of the income categories shown is always above the printed value and the upper bound vice versa, e.g. income class 1000-1500 € represents an income above 1,000 and below 1,500 € per month.

In the collected sample older higher educated male respondents working full-time and owning a car are over-represented compared to the population average (Statistisches Bundesamt, 2014; Follmer *et al.*, 2010). One reason is the over-sampling of business trips but often this socio economic group is also more likley to participate in surveys (e.g. Follmer *et al.*, 2010). The data set contains three weighting variables to achieve representativeness if needed. First, it contains a person weight which can be used to match the weighted numbers of the MID on the following dimension: age, gender, education, employment, region, driver's license and car availability (PFAKT). The second weight variable (WFAKT) is based on the person weight and additionally contains a factor for trip frequency, trip length, trip purpose and the main mode of transport. The third weight (WFAKT2) additionally includes a weight factor for business trips which is based on the representative CATI sample, regional trip distribution and trip frequency. For weighting the sample it is recommended to use the the weight variable WFAKT2 as it contains all weighting factors.

3.3.2 Reference trip

The following Table 3.8 shows the same variables as described above for the reported reference trip of the two samples. The parameters for the trip purposes commute, shopping and leisure and long-distance are derived from the non-business sample. The business sample provides the derived parameters for business trips. The questions differed slightly for long-distance and business trips which results in the different or fewer variables shown in the table. The variables show that the collected data lies within the expected, plausible range compared to other SP surveys which have been conducted at the institute.

Table 3.8: Trip variables for the reference trips of the SP experiment

Attribute	*Level*	*N*	*%*	*Mean*	*Std. dev.*	*Min.*	*Max.*
			Commuting				
Travel time (min)	–	736	99	26.88	26.32	0	240

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Attribute	*Level*	*N*	*%*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Frequency (days/week)	1-7	739	100	4.73	1.04	1	7
Arrival time (hh:mm)	–	709	96	08:05	01:59	03:30	21:45
Noticable delay (min)	–	700	95	14.57	16.96	0	270
Frequency delay	Never	238	32	–	–	–	–
	< 1/month	198	27	–	–	–	–
	< 1/week	96	13	–	–	–	–
	∼ 1/week	81	11	–	–	–	–
	∼ 2/week	50	7	–	–	–	–
	> 2/week	72	10	–	–	–	–
	Don't know/say	4	.5	–	–	–	–
Regularity of mode choice	Always same	506	69	–	–	–	–
	Switching	231	31	–	–	–	–
Shopping							
Travel time (min)	–	747	100	9.55	7.38	1	60
Frequency (days/week)	1-7	734	98	2.05	0.47	1	7
Arrival time (hh:mm)	–	641	86	13.41	03.42	06.30	22:00
Noticable delay (min)	–	594	79	10.61	9.00	0	60
Frequency delay	Never	515	69	–	–	–	–
	< 1/month	125	17	–	–	–	–
	< 1/week	38	5	–	–	–	–
	∼ 1/week	44	6	–	–	–	–
	∼ 2/week	14	2	–	–	–	–
	> 2/week	8	1	–	–	–	–
	Don't know/say	4	.5	–	–	–	–
Regularity of mode choice	Always same	510	68	–	–	–	–
	Switching	238	32	–	–	–	–
Leisure < 50 km							
Travel time (min)	–	718	98	19.13	20.18	0	160
Frequency (days/week)	1-7	565	94	2.48	1.64	1	7
Frequency (days/month)	1-31	126	94	2.71	2.23	1	15

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Attribute	*Level*	*N*	*%*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Arrival time (hh:mm)	–	644	88	15.18	03.55	00.00	22:00
Noticable delay (min)	–	618	84	13.25	12.92	0	135
Frequency delay	Never	427	59	–	–	–	–
	< 1/month	158	22	–	–	–	–
	< 1/week	69	10	–	–	–	–
	~ 1/week	33	5	–	–	–	–
	~ 2/week	13	2	–	–	–	–
	> 2/week	20	3	–	–	–	–
	Don't know/say	0	0	–	–	–	–
Regularity of mode choice	Always same	475	65	–	–	–	–
	Switching	253	34	–	–	–	–
Long distance trip							
Travel time (min)	–	2974	89	541.22	579.87	30	4200
Arrival time (hh:mm)	–	2979	89	13.59	04.28	00.00	23:59
Number of long distance trips within last 12 month	None	318	10	–	–	–	–
	1	375	11	–	–	–	–
	2	328	10	–	–	–	–
	3	317	10	–	–	–	–
	4-10	917	27	–	–	–	–
	11+	1085	32	–	–	–	–
	Don't know/say	11	.3	–	–	–	–
Arrival	Same day	2562	77	–	–	–	–
	1 day later	375	11	–	–	–	–
	2+ days later	83	3	–	–	–	–
	Don't know/say	2	.1	–	–	–	–
Travel mode airplane	Yes	956	29	–	–	–	–
	No	2063	62	–	–	–	–
	Don't know/say	3	.1	–	–	–	–
Most recent business trip							
Travel time (min)	–	908	98	169.44	167.64	1	1380
Number of destinations	1-9+	923	100	1.37	1.23	1	9+
Frequency	>1x/day	36	4	–	–	–	–

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Attribute	*Level*	*N*	*%*	*Mean*	*Std. dev.*	*Min.*	*Max.*
	Daily	40	4	–	–	–	–
	Every 2nd day	69	8	–	–	–	–
	1x/week	91	10	–	–	–	–
	1x/2 weeks	78	9	–	–	–	–
	1x/month	99	11	–	–	–	–
	1x/2 months	101	11	–	–	–	–
	1x/3 months	99	11	–	–	–	–
	< 1x/3 months	310	34	–	–	–	–
Arrival time (hh:mm)	–	910	99	11.41	03.34	01.30	23:00
Arrival	Same day	907	98	–	–	–	–
	1 day later	15	2	–	–	–	–
	Don’t know/say	1	.1	–	–	–	–
Noticable delay (min)	–	893	97	32.29	34.89	0	420
Punctuality: Arrival	As planned	513	57	–	–	–	–
	Much earlier	82	9	–	–	–	–
	Much later	13	1	–	–	–	–
	Don’t know/say	1	.1	–	–	–	–
Fixed appointment	Yes	609	66	–	–	–	–
	No	313	34	–	–	–	–
	Don’t know/say	1	.1	–	–	–	–
Purpose	Service	304	33	–	–	–	–
	Training	230	25	–	–	–	–
	Customer visit	125	14	–	–	–	–
	Branch visit	111	12	–	–	–	–
	Conference	90	10	–	–	–	–
	Exhibition	63	7	–	–	–	–

The information on long-distance trips was collected from all respondents whereas the total number of cases of the daily trips shows the total number of assigned reference trips. The variables for leisure trips in the table are only for reported trips under 50km distance. Leisure trips over 50 km distance were recorded as long-distance trips.

However, even if the selection of the reference trip were randomized it would have controlled for a more or less even distribution of respondents across each trip purpose. The numbers of cases within the trip purpose differ because again not all questions were answered at all or with "I don’t know" or "I don’t want to say". If a for the SP part elementary variable value was missing in the RP data set a mean value was used in the SP experiments.

3.3.3 Short-term SP attributes

Fig. 3.12 shows the travel distance distribution by type of the short-term SP experiment. Logically the trip distance for flight trips is higher than the distance for car and public transport trips. The SP experiment type which shows the shortest trip distances are the mode choice games as only these include the non-motorized transport modes bike and walk.

Figure 3.12: Travel distance short-term experiments

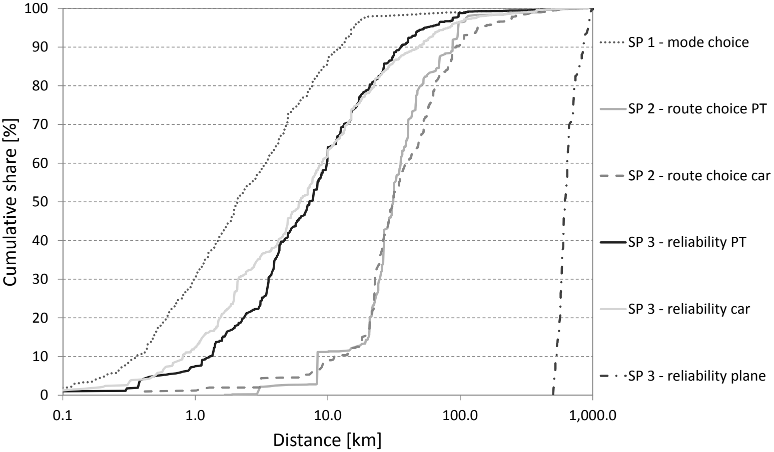
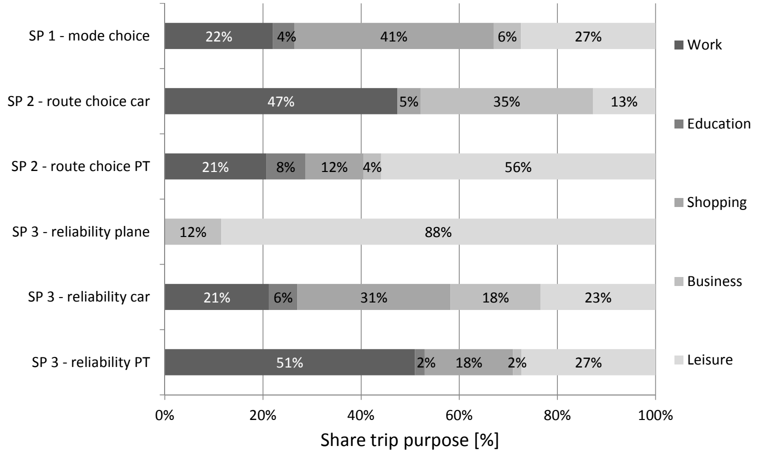


Fig. 3.13 shows the trip purpose distribution by experiment type for the whole SP sample containing all non-business and business trips. „Business trips“ in the total sample are all trips from the business sample and additionally a small number of trips from the non-business sample were respondents could also state „business trip“ as purpose of their reported trip. A further differentiation of these trips into the different kinds of travelling for business was not intended. For the transport mode flight only

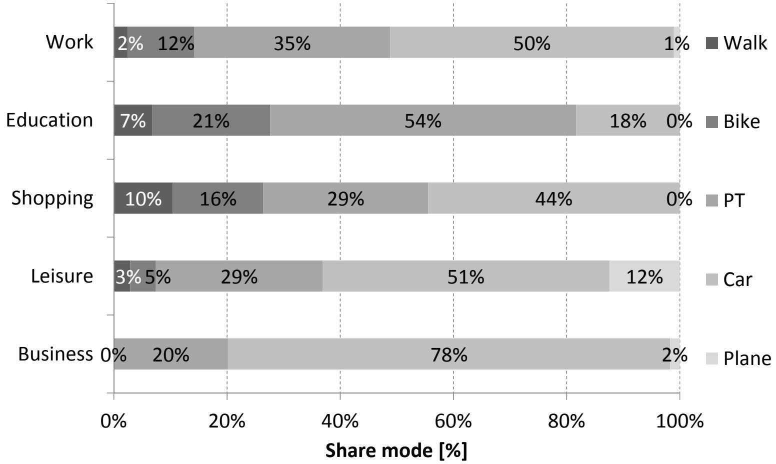
Figure 3.13: Trip purpose by SP experiment



the purposes leisure and business were surveyed. As expected commute, shopping and educational trips are the ones dominating in the mode choice experiments.

The distribution of the chosen alternative in the mode choice experiments for every trip purpose is shown in Fig. 3.14. Again the results are as expected. Car is the dominant mode for all trip purposes except educational trips. The share of taking the car is especially high for business trips. Walking as a mode has the highest share for shopping and educational trips. The bike is often chosen for commute and leisure trips. Public transport has the highest share for commute trips especially for educational reasons.

Figure 3.14: Chosen transport mode by trip purpose in the experiment



3.3.4 Long-term SP attributes

The two following tables (Tables 3.9 and 3.10) show the parameters of the chosen alternative variables of the single choice experiments. In this description chosen alternative means the respondent's choice regarding work place or home location. The number of cases shows how often respondents chose an alternative. The parameters show that the collected data lies within the expected, plausible range.

Table 3.9: Descriptive statistics of work place choice variables (SP4)

N = 9504

attribute	*unit*	*level*	*current*	*new*
choice	overall (%)	–	6,749 (71.0)	2,755 (29.0)
car commute time [min/trip]	(mean (sd))	–	26.2 (37.7)	24.5 (36.6)
car commute cost [€/month]	(mean (sd))	–	95.4 (100.7)	84.9 (90.9)
pt commute time [min/trip]	(mean (sd))	–	46.7 (79.9)	44.2 (78.4)
pt commute cost [€/month]	(mean (sd))	–	114.4 (256.7)	105.5 (237.3)
salary before tax [€/month]	(mean (sd))	–	2,734.4 (1357)	2,732.4 (1362)
staff managed [No. of pers.]	(mean (sd))	–	9.7 (70.9)	23.9 (103.3)
budget managed [€/year]	(mean (sd))	–	1.2m (1.2m)	1.7m (1.6m)
change of industry needed	overall (%)	no	9,504 (100)	4,991 (52.5)
	overall (%)	yes	0 (0)	4,513 (47.5)
change of company needed	overall (%)	no	9,504 (100)	4,499 (47.3)
	overall (%)	yes	0 (0)	5,005 (52.7)

Table 3.10: Descriptive statistics of residence choice variables (SP5)

N = 8634

attribute	*unit*	*level*	*current*	*new*
choice	overall (%)	–	7,229 (83.7)	1,405 (16.3)
rent/mortgage [€/month]	(mean (sd))	–	258.0 (335.6)	263.7 (344.7)
type	overall (%)	house	4,457 (51.6)	3,312 (38.4)
	overall (%)	apartment	4,177 (48.4)	5,322 (61.6)

To be continued on the next page

N = 8634

attribute	*unit*	*level*	*current*	*new*
size [qm^2]	(mean (sd))	–	132.5 (155.4)	125.0 (149.7)
standard	overall (%)	new	1881 (21.8)	2647 (30.7)
	overall (%)	renovated	4988 (57.8)	4333 (50.2)
	overall (%)	old	1765 (20.4)	1654 (19.2)
exterior	overall (%)	none	530 (6.1)	2011 (23.3)
	overall (%)	balcony	4509 (52.2)	2940 (34.1)
	overall (%)	garden	3595 (41.6)	3683 (42.7)
area	overall (%)	urban	4024 (46.6)	3729 (43.2)
area	overall (%)	suburban	2202 (25.5)	2116 (24.5)
	overall (%)	rural	2408 (27.9)	2789 (32.3)
car travel time:				
- commute [min/trip]	(mean (sd))	–	13.33 (25.18)	12.53 (23.76)
- shopping[min/trip]	(mean (sd))	–	10.63 (14.44)	10.14 (14.11)
car travel cost:				
- commute [€/month]	(mean (sd))	–	47.99 (79.47)	50.97 (86.71)
-shopping [€/month]	(mean (sd))	–	17.33 (21.73)	18.65 (24.11)
pt travel time:				
- commute [min/trip]	(mean (sd))	–	23.06 (61.29)	21.68 (57.82)
- shopping [min/trip]	(mean (sd))	–	10.63 (14.44)	9.88 (13.74)
pt travel cost:				
-commute [€/month]	(mean (sd))	–	41.89 (76.64)	44.45 (82.79)
-shopping [€/month]	(mean (sd))	–	14.82 (14.38)	16.00 (15.88)

3.3.5 Variable importance

At the end of each block all respondents had the opportunity to mark the impact of the attributes on their decision in the different choice situations. The respondents were asked to tick the attributes which they thought were rather unimportant to them or did not influence their choice at all. They could also state that they took all variables into consideration when choosing the alternative. So all the variables they did not chose were coded as important or if they stated all attributes were equally important to them all the variables were also coded as important.

Table 3.11: Overview importance of variables

SP	Type of choice experiment	Number overall respondents	All equally important
1	Mode choice all	2.062	380 (14%)
1	Mode choice combination 1 (pt - car - walk)	585	104 (18%)
1	Mode choice combination 2 (pt - car - bike)	595	128 (22%)
1	Mode choice combination 3 (pt - car - coach)	668	130 (19%)
1	Mode choice combination 4 (pt - car - plane)	213	18 (8%)
2	Route choice public transport	76	21 (28%)
2	Route choice car	334	334 (100%)
3	Route choice and departure time public transport	2	1 (50%)
3	Route choice and departure time car	0	0 (–%)
3	Route choice and departure plane	0	0 (–%)
4	Workplace choice	256	70 (27%)
5	Residential choice	256	69 (27%)

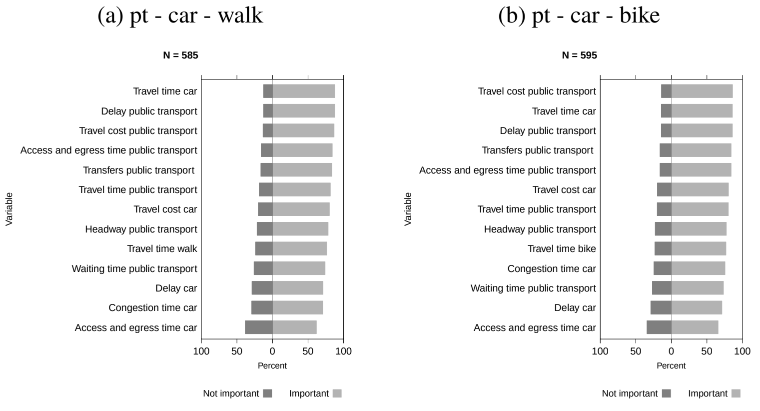
Table 3.11 gives an overview of the overall number of respondents who answered that question either by selecting unimportant variables or by stating that all variables where equally important to them. It can be seen that except for the mode choice games the majority of the respondent did not answer the question at all. In the route choice experiments (SP2 and SP3) mostly all of the variables where important to the respondents or they did not answer to the question for other reasons. For the car route choice experiments all of the 334 respondents stated that they took all of the variables into consideration. The same applies for one out of two respondents in the public transport route choice and departure time experiments

The respondents saw only one of the long-term experiments, either SP4 or SP5, which incidentally were answered by the same number of respondents. About one quarter of the respondents stated that all attributes of the long-term experiments were equally important to them.

As already described in Section 3.1.2, the respondents based on the mode of their reference trip were assigned different mode combination in their mode choice SP games (see Table 3.2 in Section 3.1.2). The two modes car and public transport were available in all SP1 experiments. The third mode was either walk (combination 1), bike (combination 2), coach (combination 3) or air plane (combination 4).

For the variable importance, SP1 had to be distinguished into these 4 combinations as the respondents did not see the attributes of the modes not included. Between 8% and 22% of the respondents stated that all attributes were equally important to them. Especially in the mode choice experiments with an air plane alternative not all attributes were important for the respondents. On the other hand, this is also the combination with the least answers.

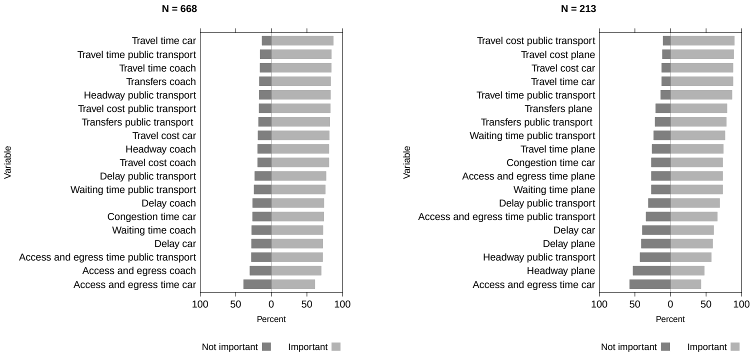
Figure 3.15: Variable importance mode choice combination 1 & 2


(a) pt - car - walk

(b) pt - car - bike

Fig. 3.15 shows the importance of the mode choice attributes of the modes car, public transport and walk or bike. Fig. 3.16 shows the importance of the mode choice attributes of the modes car, public transport and coach or air plane. Throughout all four combinations car travel time and public

Figure 3.16: Variable importance mode choice combination 3 & 4



(a) pt - car - coach

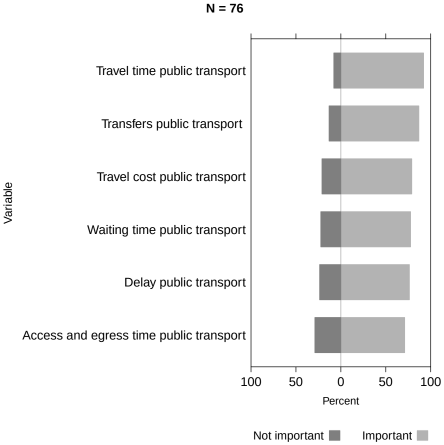
(b) pt - car - plane

transport travel costs are among the three most important attributes. Public transport travel costs in general seemed to be more important than car travel costs. The car attributes except travel time were less important to the respondents than the public transport attributes. The travel times of the two slow modes walk and bike were rather unimportant to the respondents. In the two experiments where a slow mode was included the delay of the public transport alternative was rather important. In the two experiments including only motorized modes either travel time (combination 3 with the coach alternative) or travel cost (combination 4 with the air plane alternative) were the most important attributes for decision of the respondents.

In the public transport route choice experiments travel time followed by the number of transfers was more important than travel costs. The access and egress time seemed to be least important. However the number of cases is very low (Fig. 3.17).

Fig. 3.18 shows the importance of the variables of the long-term experiments. As it could already be seen in analyses of the data (Dubernet *et al.*, 2018a) the salary is by far the most important attribute to the respondents of SP 4. Car commute travel time and cost is important to respondents in contrast to public transport time and cost which is another indication for

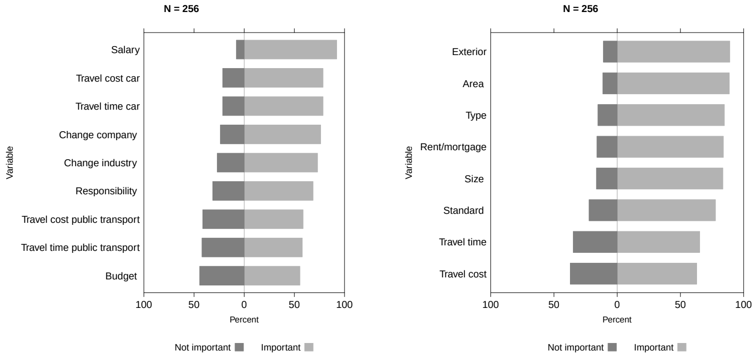
Figure 3.17: Variable importance route choice



the main mode of transport for commute in the data. The least important variable in the work place games is the budget the respondent is responsible for.

The attributes of the dwelling are more important than travel cost and time for the respondents. The exterior and environment of the dwelling seem to be even more important than the monthly rent or mortgage and the size of the apartment or house.

Figure 3.18: Variable importance workplace and residential location choice



(a) workplace choice

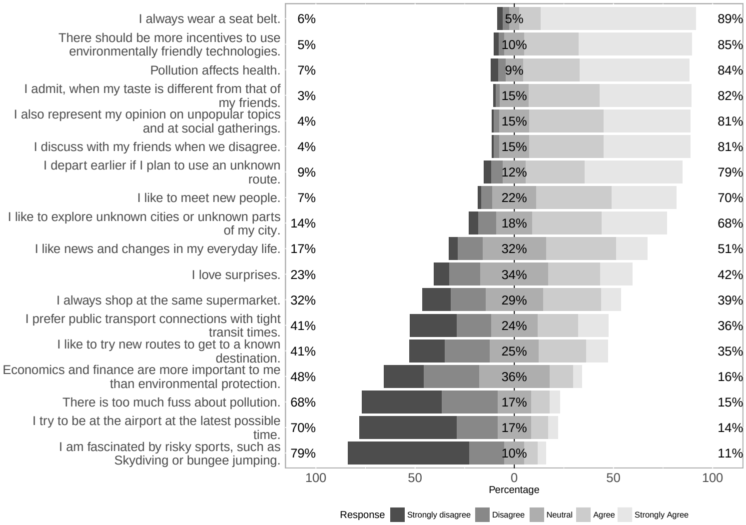
(b) residential location choice

3.3.6 Attitudes

As described above the questionnaires included additional attitudinal questions on risk acceptance, (eight questions), environmental protection (four questions) and seeking for variety in daily life (six questions). Respondents could state their approval or disapproval on a five-point-Liekert-scale. The levels ranged from strong disagreement to neutral to strong agreement with no opt-out. Fig. 3.19 shows percentage distribution of respondents agreement or disagreement to the questions. The percentage on the left side of the figure shows the share of respondents who disagreed with the statement (sum of strongly disagree and disagree). The percentage in the middle shows the share of neither agreement or disagreement (neutral) and the one on the right agreement (sum of agree and strongly agree). Most of the respondents agree with wearing a seat belt and that the environment needs to be protected. With their answers they present themselves as mostly open and interested in fellow humans and new things but the majority of the respondents seems to be more risk averse than venturesome.

For further modelling the attitudinal questions can be used to, for example, assign the respondents to different behavioural groups by using a principal component or factor analysis. The statements the respondents discuss with

Figure 3.19: Attitudinal questions



the friends when they disagree (einst_01) and that they respresent their opinion on unpopular topics and social gatherings (einst_06) are linear functions of one another which has to be considered for further factor analysis (but not for PCA).

3.4 Conclusion

In the *German Value of Time and Reliability Study* new survey methods were applied for estimating new values of time and for the first time values of reliability to support the Federal Transport Plan 2030. This first estimate required special accuracy in the data collection process. Using a combined RP and SP survey reflects the state of the art of transport research.

This chapter presented the experiences made during data collection and preparation for further model estimations. It was shown that the collected data set holds rich information with a promising amount of cases suitable for the calculation of short as well as long-term willingness to pay values. Each type of SP experiment includes enough cases to estimate single models per experiment as well as a joint model with all short-term games. The response rates were in the expected range, although especially the business on-line sample exceeded expectations. All forms of reliability presentation gained similar response rates and could be used in further surveys, although it seems to be easier for respondents to understand the experiment with a graphical display. Non-traders were in the expected range. The item non-response was very low for most of the variables.

The *German Value of Time and Reliability Study* was conducted in 2012. In addition to the project report (Axhausen *et al.*, 2015a), research work based on this data was published on various occasions covering different aspects of the survey since then.The modelling results of this work, inter alia, highlighted limitations of the survey design which should be reconsidered for future surveys:

- estimates for the hypothetical “coach” mode were not robust, highlighting the difficulty to include modes the respondents are not yet familiar with (Axhausen *et al.*, 2015a, and Chapter 5)
- air travel as a mode also presented modelling challenges. It is likely that this mode follows different decision processes than the others (in terms of planning horizon for instance) (Chapter 5).
- reference shopping trips were often very short, leading to very small variations in the stated choice experiments. A way to mitigate this effect in future studies might be to put a lower bound (in minutes) on the variations for the SP (Chapter 5).
- the long term experiments included a large number of attributes for realism. This, however, made estimation of the VOT challenging, as the effect of those attributes was higher than the effect of time or cost of travel for the level of variation present in the dataset (Dubernet *et al.*, 2018a, submitted).
- in the long-term cases, where the decision was always to keep the status quo or change to a new situation, a strong difference was observed in terms of gains versus losses (eg. of salary). This makes

> the definition of a VOT in this case difficult, and future experiments should take this fact into account in the design (Dubernet *et al.*, 2018a, submitted).

Some aspects could be improved based on the literature. For instance, the valuation of business travel time savings demand more attributes for adequate estimation as travel time can be used for i.e. working (see Hensher, 1977; Wardman *et al.*, 2013, 2015). This effect might be important for other purposes as well (Kouwenhoven and de Jong, 2018). Additionally the methods and approaches should be developed further with every new estimation.

Nevertheless this has been the first official national value of time and reliability study collecting valuable data on transport behaviour and valuation in Germany.

Chapter 4

The German Federal Ministry of Transport and Digital Infrastructure's Project on the VTT and VOR for Passenger Transport

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) has recently published the 2030 Federal Transport Investment Plan (Bundesverkehrswegeplan, BVWP), its medium- to long-term investment strategy for the country's transport infrastructure serving longer distance travel (BMVI, 2016). As part of this, it updated the overall methodology of its central evaluation tool, cost-benefit analysis (CBA). The effects of hundreds of infrastructure projects in transport policies and investments had to be evaluated with it. In this context one project estimated and recommended values of travel time savings (VOT) and reliability (VOR) for personal and business travel (Axhausen *et al.*, 2015a). The new VOTs were estimated to replace existing values which were based on values from the BVWP'92 and had not been verified independently since then (BMVBS, 2003). The VORs were estimated for the first time, although they are (still) not part of the standard appraisal. The aim of integrating reliability into the new BVWP was, in line with practice and science, to make transport systems not only faster but also more reliable (BMVI, 2016). To address this a research team around the IVT (ETH Zurich) estimated the VOT and VOR for the BMVI (Axhausen *et al.*, 2015a). Another BMVI-initiated project calculated VOTs and VORs for freight, but this was not subject of the German VOT project (BVU *et al.*, 2016). This chapter provides a short summary of the methodology used and the main results of the *German Value of Time and Reliability Study*. The study design and data is described in the following Chapter 3.

4.1 Determining the Value of Travel Time

4.1.1 Methodology

Within the project individual models for each experiments were estimated but only the pooled results across all of the short-term SC experiments were reported. The joint estimation was made possible by the presence of common variables. Differences across experiments in terms of the relative influence of the unobserved utility components were accounted for by the estimation of experiment-specific scale parameters.The general preference for a certain mode was accounted for by using alternative specific constants in the mode choice experiments. With the mode choice experiment being the reference for these parameters, they vary between 1.5 and 3.3. They indicate that the generated choices in other experiments are more deterministic.

It is well known that the VTT might change with distance or travel time (e.g. Börjesson and Eliasson, 2014; Hess *et al.*, 2008; Jara-Diaz, 2003; Axhausen *et al.*, 2008). A variety of formulations was tested to account for such non-linearities, including the elasticity continuous interaction terms suggested by Mackie *et al.* (2003) and various non-linear attribute specific transforms, ranging from simple log-transforms to the Tangens-Hyperbolicus. The best results were obtained with formulations of the form:

$$U_i = \cdots + (\beta_{i,j} \cdot x_{i,j} + \alpha_{i,j} \cdot \ln(x_{i,j} + \gamma_{i,j})) \cdot \left(\frac{z_j}{\mu(z_j)}\right)^{\lambda_{i,j,z_j}} + \cdots \qquad (4.1)$$

where

- $x_{i,j}$ is attribute j of alternative i
- $(\beta, \alpha, \gamma)_{i,j}$ are parameters associated with $x_{i,j}$
- λ_{i,j,z_j} the individual sensitivity to attribute j for alternative i with respect to attribute z_j
- $\mu(z)$ is the mean of attribute z

The continuous interaction term z_j depends on the attribute. In particular, for travel time and travel cost, normalized income was selected. For the other attributes, travel time was used as z_j, allowing sensitivities to change depending on travel time.

For attribute specific non-linearity, a combined linear and logarithmic approach was used, with the additional positive offset term $\gamma_{i,j}$ to handle attribute values close to zero.

After weighting for the sample bias and the selectivity in the distance distribution (see Section 3.3.1 for a description of the weight), the recommended VTT by mode and different purpose combinations were calculated as followed. These are based on the final pooled model with the above discussed formulations.

$$VTT = \frac{\delta U / \delta travel\ time}{\delta U / \delta cost} \tag{4.2}$$

With the partial derivative for travel time and cost:

$$\frac{\delta U}{\delta x} = \left(\beta_{i,j} + \frac{\alpha_j}{x_{i,j} + \gamma_j}\right) \cdot \left(\frac{income}{\mu(income)}\right)^{\lambda_{income}} \tag{4.3}$$

where

- $x_{i,j}$ is the travel time or cost of alternative i
- $(\beta, \alpha, \gamma)_{i,j}$ are parameters associated with travel time or cost
- λ_{income} is the income elasticity for travel time or cost
- $\mu(income)$ is the mean income

4.1.2 Results

Table 4.1 shows the calculated values of time for the different trip purposes and main modes.

Table 4.1: Recommended VTT in Euro per hour (weighted for the reported MID 2008 distance distribution)

Purpose	Main mode			
	PT	car	plane	all
Education	4,39	3,90	–	4,26
Work	4,47	4,87	–	4,80
Shopping	5,11	4,29	–	4,62
Leisure	4,35	4,03	25,45	4,35
Business	7,01	8,38	38,76	8,50
Work and education	4,46	4,73	–	4,72
All non-business	4,66	4,32	–	4,56
All	4,83	4,66	33,67	4,83

The evaluated outcomes for business travel were validated against both, the so called Hensher (1977) and the cost-saving approach. As the relevant variables to estimate the full Hensher approach had not been collected, the recent values and simplifications elaborated in the UK were used (Wardman *et al.*, 2013). These estimates were close to the ones from the SC survey. Not detailed enough income questions to estimate the cost-saving approach had been included. In summary, adopting the values derived from the survey had been recommended.

Table 4.2 reports the relative valuations of other attributes included in the different experiments. These are in the expected range within reported values.

The survey included only respondents with age eighteen and older, but the BVWP demanded estimates for education that also includes younger travellers. It was checked whether it would be appropriate to adjust the estimates downwards, but based on additional data from TNS Infratest, potential effects were deemed too small to be necessary.

Table 4.2: Relative valuations with respect to in-vehicle time (weighted for the reported MID 2008 distance distribution)

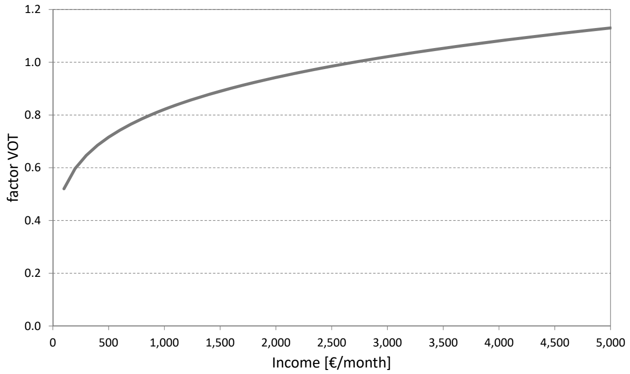
Mode	Attribute	Purpose							
		Education	Work	Shopping	Leisure	Business	Work + Education	Non-business	All
Car	Access time []	0,8	0,9	0,8	0,8	1,1	0,9	0,8	0,9
	Congested time []	1,2	1,2	1,4	1,3	1,3	1,2	1,3	1,3
	Std. dev. []	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7
PT	Access and egress time []	0,8	0,9	0,8	0,8	1,1	0,9	0,8	0,8
	Transfer waiting time []	0,3	0,4	0,3	0,4	0,7	0,4	0,3	0,4
	Transfer [min/transfer]	7,0	7,5	6,7	7,2	10,2	7,4	7,0	7,3
	Headway []	0,1	0,2	0,1	0,1	0,3	0,2	0,1	0,2
	Mean expected unscheduled delay []	1,0	1,0	1,0	1,0	1,7	1,0	1,0	1,0
Plane	Access and egress time []	–	–	–	1,0	1,0	–	–	1,0
	Transfer waiting time []	–	–	–	2,0	2,0	–	–	2,0
	Transfer [min/transfer]	–	–	–	61,4	60,7	–	–	60,7
	Headway []	–	–	–	0,04	0,04	–	–	0,04
	Mean expected unscheduled delay []	–	–	–	1,4	1,4	–	–	1,4

[] no dimension

The estimation results showed a significant dependence of the VTT on income. The estimated factor to be applied to the VTT is depicted in Fig. 4.1. This relationship was however not included in the recommended VTT, in particular because of equity concerns.

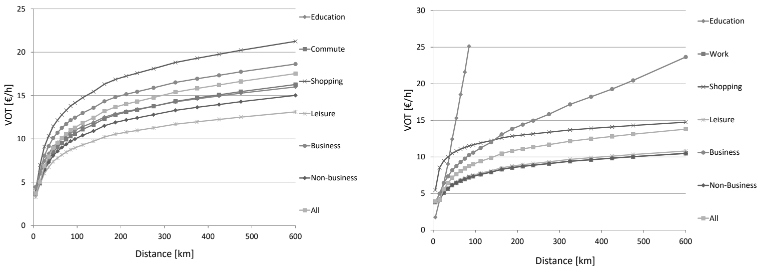
The values depending on distance were calculated for the reported trips and aggregated into distance bands. To smooth the sample values they were regressed against distance and the resulting values were corrected linearly, logarithmically or log-linearly to match the mean values. The

Figure 4.1: Income dependency of the VTT



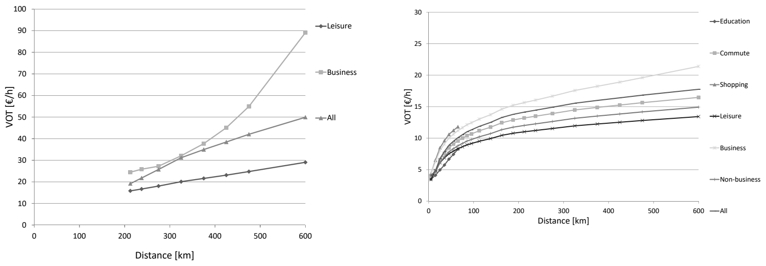
distance-dependent values of time are illustrated in Fig. 4.2. The strong reduction in short distance values implies also a substantial reduction for small time savings, as they are often associated with short distances.

Figure 4.2: Smoothed distance-dependent VTT by mode and purpose



(a) car

(b) public transport



(c) plane

(d) all

As a final result, the mean of the demand elasticities and the cross elasticities from the RP-data (but using the pooled RP-SP parameter estimates) by mode through an aggregation of the trip and individual specific values was calculated.

$$\epsilon_{i,j} = \frac{\delta P_i / P_i}{\delta x_{i,j} / x_{i,j}} \tag{4.4}$$

where

- $\epsilon_{i,j}$ is the elasticity of mode i of attribute j
- P_i is the probability to choose the specific mode

- δP_i is the change of the probability to choose the specific mode
- $x_{i,j}$ is attribute j, which relates to the elasticity
- $\delta x_{i,j}$ is the change of attribute j, which relates to the elasticity

The non-linear utility function described above (Eq. (4.1)) leads the the following derivation of the elasticity for travel time and cost:

$$\epsilon_{i,j} = \left(\beta_{i,j} + \frac{\alpha_{i,j}}{x_{i,j} + \gamma_{i,j}}\right) \cdot \left(\frac{income_{i,j,}}{\mu(income)}\right)^{\lambda_{i,j,income}} \cdot (1 - P_i) \cdot x_{i,j} \tag{4.5}$$

- $\epsilon_{i,j}$ elasticity of mode i of attribute j
- $(\beta, \alpha, \gamma)_{ij}$ parameters associated with travel time or cost
- $\mu(income)$ mean income
- $\lambda_{i,j,z_{i,j}}$ income elasticity for travel time or cost
- P_i probability to choose the specific mode
- $x_{i,j}$ attribute j, which relates to the elasticity

For all other attributes which interact with travel time the equation can be written:

$$\epsilon_{i,j} = \beta_{i,j} \cdot \left(\frac{travel\ time}{\mu(travel\ time)}\right)^{\lambda_{i,j,travel\ time}} \cdot (1 - P_i) \cdot x_{i,j} \tag{4.6}$$

Table 4.3 shows the elasticities for the relevant attribute concerning both cases: reductions and increases.

Table 4.3: Demand elasticity and cross-elasticities in demand by mode (population weighted)

Mode	Attribute	Elasticities				
		Plane	Car	PT	Bike	Walk
Car	time reduction	-0,63	0,12	-0,15	0,07	-0,04
	time increase	0,56	-0,11	0,14	0,06	0,04
	cost reduction	-0,35	0,18	-0,19	-0,13	-0,09
	cost increase	0,31	-0,17	0,18	0,12	0,09
PT	time reduction	-0,22	-0,06	0,16	-0,03	-0,01
	time increase	0,20	0,06	-0,16	0,03	0,01
	cost reduction	-0,15	-0,10	0,32	-0,09	-0,07
	cost increase	0,13	0,09	-0,30	0,08	0,06
Plane	time reduction	0,15	0,00	0,00	0,00	0,00
	time increase	-0,14	0,00	0,00	0,00	0,00
	cost reduction	0,52	0,00	0,00	0,00	0,00
	cost increase	-0,48	0,00	0,00	0,00	0,00
Bike	time reduction	0,00	-0,20	-0,25	0,92	-0,19
	time increase	0,00	0,17	0,21	-0,89	0,18
Walk	time reduction	0,00	-0,13	-0,14	-0,22	0,73
	time increase	0,00	0,11	0,12	0,20	-0,69

4.1.3 Validation of the results

Lacking of data for a secondary analysis of the results of the *German value of time* had to be validated differently. After estimating all models with stated preference data only, a model for a joint estimation of revealed and stated preference data was developed. In this step models with all trips which had been reported but not used to construct the stated choice experiments were tested. The revealed preference trips also included information on the non-chosen alternative. Furthermore, the sample size ensured valid results for the different travel modes, groups of respondents, municipality types and regions. Valid values of time have been derived from the joint

RP and SP estimation and were recommended without any constraints to the BMVI.

Another validation method is to compare the estimation results with values from the international literature. Of course, as the years of collection, the national contexts and the variables collected vary from study to study, as well as the exact specification of the model (for instance the segmentation by purpose), the values cannot be exactly compared.

Table 4.4: International comparison of value of time results (EUR/h for 2012)

Mode	Country Purpose/ Survey (Year)	DE German VTT >50km	DE BVU *et al.* (2009)	CH König *et al.* (2004)	GB Department for Transport (2011)	NL Significance *et al.* (2012)	NO Ramjerdi *et al.* (2010)	SE Börjesson and Eliasson (2012)
Car	Work	10,71	–	17,06	–	9,52	12,49-27,74	9,47-12,45
	Business	13,16	–	26,73	–	∗ 27,02	52,7	–
	Other	⋄ 10,17	–	◦ 14,89	–	7,72	10,67-20,25	6,07-8,03
	Total	11,94	–	–	–	9,52	–	–
Train	Work	–	–	–	–	11,84	–	7,41
	Business	–	–	–	–	∗ 20,33	–	–
	Other	–	–	–	–	7,2	–	5,15
	Total	–	–	–	–	9,78	–	–
Bus, Tram, Metro	Work	▹ 9,18	–	▹ 14,56	–	7,98	–	5,46
	Business	▹ 12,04	–	▹ 24,92	–	∗ 19,56	–	–
	Other	▹ ⋄ 9,18	–	▹ ◦ 11,35	–	6,18	–	2,88
	Total	▹ 10,79	–	–	–	7,2	–	–
Plane	Business	38,76	–	–	–	∗ 88,26	–	–
	Other	⋄ 25,45	–	–	–	48,38	–	–
	Total	33,67	–	–	–	53,27	–	–
Total	Work	10,23	–	–	8,26	–	–	–
	Business	13,63	29,3	23	33,79	–	–	–
	Else	⋄ 12,01	7,85	◦ 22,6	7,53	–	–	–
	Total	12,58	–	–	7,1	–	–	–

∗ *Hensher* ⋄ *Leisure* ◦ *Shopping* ▹ *incl. train*

Table 4.4 compares the results of the *German Value of Time Study* with other international VTT studies. All values were calculated for the year 2012 using the net present value method. The results are comparable to the European values of time. Only the values for business trips are lower than the European ones. As explained above the values in the *German Value of Time study* show the subjective valuation of time for business trips without taking the whole macroeconomic resource consumption into account.

4.1.4 Empirical evaluation of small travel time savings

As part of the BMVI study, it was also tested if the size of the travel time differences offered to the respondents in the SC experiments had an impact on the valuations. To test empirically if time and costs parameters are a function of size differences which are presented to the respondents in hypothetical choice scenarios an additional elasticity term was tested in the models.

For travel time the following variable was defined:

$$\Delta_{TT} = \sqrt{\sum_{j \neq i} \frac{\left(TT_j - TT_i\right)^2}{J}} \tag{4.7}$$

Which corresponds to the absolute difference of the alternatives travel times in the binary case, and is analogous to the standard deviation of travel times in the multinomial case.

The parameter of the associated attribute of the utility function –in this case β_{TT} – was replaced by:

$$\beta_{TT} \left(\frac{\Delta_{TT}}{\widehat{\Delta_{TT}}} \right)^{\lambda_{\Delta_{TT}}} \tag{4.8}$$

Where:

- $\widehat{\Delta_{TT}}$ is the mean of the sum of the comparison between the alternatives
- $\lambda_{\Delta_{TT}}$ is elasticity of the time sensitivity to the size difference in the SP experiments

The empirical tests for the size difference were performed for all significant attributes (travel time, access time, costs, transfer waiting time, headway and expected delay). After accounting for the other non-linearities, the models could not identify such size-effects. The results did not indicate an impact of the size of difference on the parameters. For example the estimated parameters as $\lambda_{\Delta_{TT}}$ were not significantly different from zero. The results also show that the size experimental design did not have an impact on the estimated parameters. This underlines the assumption that the size of time difference does not influence the sensitivity. This means that large time difference between the alternative did not lead to different sensitivities than small travel time changes.

It was also tested if the sign of travel time changes (travel time gains and losses) had an effect on the parameters. Again no such indicators were found. One reason could be that the travel time difference presented to the respondents were not related to the reference values. Therefore, the final model did not take the sign of travel time change into account.

The results of the empirical test (see Section 4.1.4) did not indicate an impact of the size (and sign) of the differences on the estimated parameters. This shows that the sign of travel time difference did not influence the sensitivities. Thus, large travel time differences between the alternatives did not lead to different sensitivities, and therefore values of time, than smaller differences.

4.2 The Value of Travel Time Reliability

4.2.1 Methodology

Different specifications were tested for reliability in the *German Value of Time and Reliability Study*; the final specification used the variance of the travel times for private transport.

Previous to this study, a feasibility study analysed the possibility of a prospective integration of reliability in the BVWP's CBA (Significance *et al.*, 2012). The report included an extended literature review as well as expert interviews with practitioners and researchers on the definition of travel time reliability for Germany. The findings of the study formed the basis of the reliability definition in the *German Value of Time and Reliability Study* and are presented below.

From the point of view of practical transport modelling, the VTT is easier to integrate and could even be used as an approximation for scheduling effects (Fosgerau and Karlström, 2010). Furthermore, as the most recent

German transport model for the BVWP does not include even a partial departure time model, it would be rather difficult to include scheduling variables (Significance *et al.*, 2012).

The methodology is explained with the example of delay, but the same methodology is valid for early arrival. Two kinds of reliability definitions were specified for the estimation of the data. One is reliability defined as the standard deviation of the travel time distribution. An unplanned delay is expressed through the standard deviation of the arithmetic mean; this approach implies that a decrease in the mean of the travel time distribution stands for the travel time savings, and a decrease in the standard deviation can be interpreted as reliability. This is the mean variance approach (Eq. (2.4), (Li *et al.*, 2010)).

This approach works especially well for reliability for unscheduled transport modes like car, because both the car driver's consideration of the planned mean travel time and the driver's sense of unreliability are taken into account (Lam and Small, 2001).

In the mode and route choice experiments the part of the utility related to travel time reliability, for mode m, reads:

$$\beta_{\sigma,m} \cdot \sqrt{p_{delay,m} \cdot \mathrm{delay}_{m,rp}{}^{2}} \cdot tt_{0,m}{}^{\lambda_{SD,m}} \tag{4.9}$$

where:

- $tt_{0,m}$ is the travel time computed for the reference trip, for mode m (in hours). Conceptually, this represents the possible variation of sensitivity to variations of travel time with increasing travel time. The travel time from the RP is used as an instrumental variable to avoid problems during estimation, potentially affecting the estimation of the important marginal utility of travel time.

- $p_{delay,m}$ is the fraction of trips with a noticeable delay for mode m (in percent). This attribute was part of the SP experiment

- $\mathrm{delay}_{m,rp}$ is the smallest duration considered a "noticeable" delay, for mode m, as reported in the questionnaire (as this duration was not part of the SP experiment)

- $\sqrt{p_{delay,m} \cdot \text{delay}_{m,rp}{}^2}$ thus represents an approximation of the standard deviation of delay
- $\lambda_{SD,m}$ is the travel time sensitivity for reliability. If 0, standard deviation of delay is valued for itself. If -1, it is valued as a fraction of travel time. Other values represent variations on those hypotheses.

The route choice and departure time experiments include more variables relating to reliability. Therefore, the standard deviation is written as:

$$\sqrt{p_{delay,r} \cdot t_{delay,r}{}^2 + p_{early,r} \cdot t_{early,r}{}^2} \tag{4.10}$$

where:

- $p_{delay,r}$ is the fraction of late trips for route r, in percent
- $p_{early,r}$ is the fraction of trips arriving early for route r, in percent
- $t_{delay,r}$ is the duration of a delay, if this happens
- $t_{early,r}$ is the time to scheduled arrival, if this happens

The VOR following this approach can be determined as follows:

$$VOR = \frac{\delta U_i / \delta SD_{i,j}}{\delta U_i / \delta cost_{i,j}} \tag{4.11}$$

where *SD* is the standard deviation and *cost* the travel costs.

The partial derivative of the standard deviation can be written as:

$$\frac{\delta U_i}{\delta SD_{i,j}} = \beta_{i,j} \cdot SD_{i,j} \cdot x_{i,j}{}^{\lambda_{SD_{i,j}}} \tag{4.12}$$

The partial derivative of the cost can be written as:

$$\frac{\delta U_i}{\delta cost_{i,j}} = \left(\beta_{i,j} + \frac{\alpha_{i,j}}{x_{i,j} + \gamma_{i,j}}\right) \cdot \left(\frac{income}{\mu(income)}\right)^{\lambda_{i,j,income}} \tag{4.13}$$

For the second kind of reliability definition, reliability is defined for modelling as the mean expected unscheduled delay. The probability of a late arrival is multiplied by the average delay on those journeys that are delayed. If more than one delay and the probability of it occur in the SP experiments, the average of those is taken.

In the mode and route choice experiments, the part of the utility related to travel time reliability, for mode m, reads:

$$\beta_{\sigma,m} \cdot p_{delay,m} \cdot {tt_{0,m}}^{\lambda_{delay,m}} \tag{4.14}$$

where:

- $tt_{0,m}$ is the travel time computed for the reference trip, for mode m (in hours)
- $p_{delay,m}$ is the fraction of trips with a noticeable delay for mode m (in percent)
- $\lambda_{delay,m}$ is the sensitivity

Again the route choice and departure time experiments include more variables relating to reliability. Therefore, the equation for delay is:

$$\begin{gathered}\beta_{exp\ delay} \cdot p_{late,r} \cdot t_{delay,r} + \\ \beta_{early,pt} \cdot p_{early,r} + \beta_{exp\ early} \cdot p_{early,r} \cdot t_{early,r}\end{gathered} \tag{4.15}$$

The VOR is the arithmetic, population-weighted mean of all calculated values for the mean unexpected delay.

For example, a delay of 5min in 15% of the trips and a 10-min delay in 5% of all trips led to a delay of 1.25min or 1min and 15s. This method works for scheduled transport modes (public transport and flight). Respondents can react to the reliability in different ways: they can adjust their departure time or their route or change their mode of transport.

The partial derivation of the mean expected unscheduled delay can be written as:

$$\frac{\delta U_i}{\delta mean\ expected\ delay_{i,j}} = \beta_{i,j} \cdot p_{delay_{i,j}} \cdot \overline{x}_{delay_{i,j}} \tag{4.16}$$

where $p_{delay_{i,j}}$ is the probability of delay and $\overline{x}_{delay_{i,j}}$ is the average delay. The determination of the VOR remains the same as does the partial derivative of cost. Again the same methodology is valid for early arrival.

4.2.2 Results

The VOR was derived as described above in the same manner as for the VTT. Models are available to present the VOR as standard deviation and mean expected unscheduled delay.

Table 4.5 shows VOR (and VTT as a comparison) by trip purpose for a joint model with the standard deviation for car travel and the mean unexpected delay and mean unexpected early arrival for public transport and air travel.

Table 4.5: VOR, VOT, and Reliability Ratio (population weighted)

Mode	Attribute	Value by Purpose					
		Education	Work	Shopping	Leisure	Business Travel	All
Car	Std. dev.	3.21	3.45	3.51	3.09	6.54	3.61
Car	VOT (€/h)	3.90	4.87	4.29	4.03	8.38	4.66
Car	Std. dev./VOT	0.7	0.7	0.7	0.7	0.7	0.7
PT	Mean expec. unsched. delay	4.66	5.10	4.28	4.82	15.97	5.48
PT	Mean expec. unsched. early arrival	1.81	1.98	1.67	1.88	6.22	2.13
PT	VOT (€/h)	4.39	4.47	5.11	4.35	7.01	4.83
PT	VOR_{late}/VOT	0.9	1.0	0.7	0.9	1.7	0.9
PT	VOR_{early}/VOT	0.3	0.4	0.3	0.3	0.7	0.4
Plane	Mean expec. unsched. delay	–	–	–	38.44	51.27	46.60

To be continued on the next page

Mode	Attribute	Value by Purpose					
		Education	Work	Shopping	Leisure	Business Travel	All
Plane	Mean expec. unsched. early arrival	–	–	–	90.16	120.25	109.30
Plane	VOT (€/h)	–	–	–	25.45	38.76	33.67
Plane	VOR_{late}/VOT	–	–	–	1.4	1.4	1.4
Plane	VOR_{early}/VOT	–	–	–	3.3	3.2	3.2

The parameters for expected early arrival were partially non-significant and not recommend for use. The increasing availability of smart-phones, tablets, and other devices has made early arrival more usable for most situations. Although the high values for air travel, which are a result of non-significant parameters, seem to be implausible, they are included for completeness.

Data from Table 4.5 show that a car driver going to work was willing to pay 3.45€/h for reliability. The VTT for driving to work is 4.87€/h (Axhausen *et al.*, 2015a). These results mean that saving travel time is worth more to the respondents than reducing variability.

For example, a 30-min trip of free-flow travel time averages to 1 h of travel time when there is congestion and a 5-min standard deviation. In other words, 65% of all trips take between 55 and 65min and 95% of all trips take between 45 and 75min. The following changes would produce equivalent results:

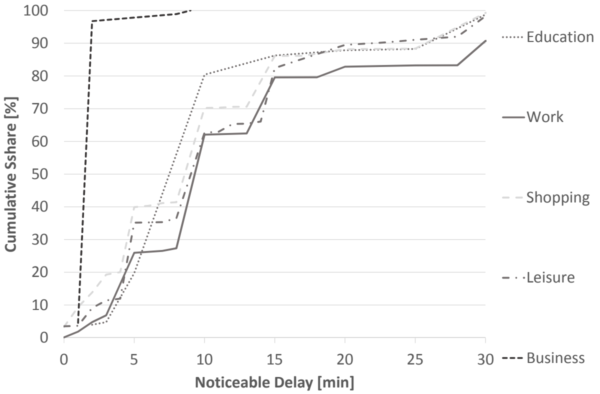
- Reduction of the standard deviation to 2.5min, which would mean that 95% of all trips would take between 52.5 and 67.5min, and
- Reduction of the average travel time to 58min and 5s with a constant standard deviation, which would mean that 95% of all trips would take between 43min and 5s and 73min and 5s.

The willingness to pay for the mean expected unscheduled delay means that the respondents are willing to pay for this delay and thereby increase the reliability.

For example, a value of 5.10€/h means that the willingness to pay for a reduced delay, which occurs in half of the trips and takes exactly 1 h (thus, 30 min for half of the trips), is 2.55€/h.

The calculated VOR are slightly lower and in some cases higher than the VTT (Axhausen *et al.*, 2015a), which means that reliability is less important to the respondents than travel time, except in the case of business trips. On the one hand, it would seem plausible that for business travel arriving on time is essential. The lower value for shopping can be interpreted as indicating that reliability for this activity is less important to the respondents because shopping trips are generally not dependent on an on-time arrival at the destination.

Figure 4.3: Noticeable delay (population weighted)



On the other hand, the relatively low acceptance of a delay (Fig. 4.3) is not in accord with this conclusion. Flight reliability is clearly more important than travel time saving to the respondents. However, the flight parameters were estimated with a high variation and are not significantly different from zero (Axhausen *et al.*, 2015a). Arriving early at a destination, as expected, seems to be less important to the respondents than arriving late or saving travel time. Again, the values for air travel are not plausible.

In addition to the valuation of reliability, it is interesting to know about people's tolerance for a delayed arrival at a destination. In the RP questionnaire the respondents were asked to state in minutes what they considered to be a noticeable delay for their focus trip. As respondents were randomly assigned a focus trip it was possible to compare the acceptable delay for the different trip purposes. The cumulative shares of acceptable delay in minutes are shown in Fig. 4.3.

As expected, the tolerance for being late for a business trip is very low. Surprisingly, the acceptance of a delay when commuting was the highest. This result may be attributable to flexible working hours and can also be understood in the context of the lower tolerance for delay in educational commuting as education schedules are more bounded than business schedules. Also as expected, the acceptance for a delayed leisure trip was quite high. In summary, most of the tolerated delays were between 5 and 30 min, and the steps in 5-min intervals are also clearly visible.

The exchange rate of the VOR and the VTT is also called the reliability ratio (RR) and can be computed as follows:

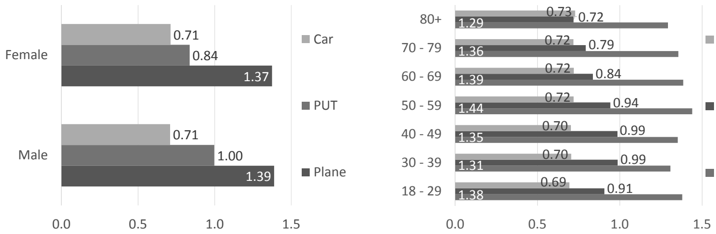
$$RR = \frac{\delta}{\gamma} = \frac{VOR}{VTT} \tag{4.17}$$

where δ is the derivative for the VOR and γ is the derivative for the VTT.

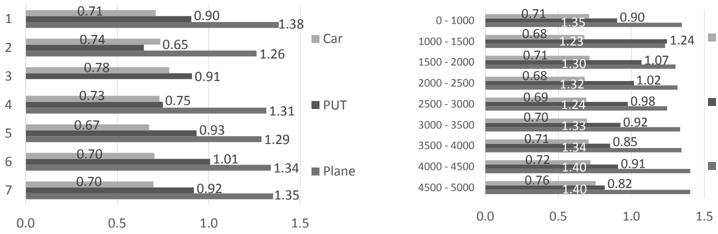
Table 4.5, which shows the reliability ratios calculated from the VOR and VTT of the presented study, can be interpreted in the following way: 1min of mean expected unscheduled delay for a commute by public transport is almost equal to 1min of travel time saving (reliability ratio). This 1min of average delay can represent a delay of 2 min in 50% of the trips or a delay of 4min in 25% of the trips, as well as a combination, such as 1min in 50% of the trips and 2 min in 25% of the trips. For most of the trip purposes the equivalent valuation of the mean expected unscheduled delay was almost equal to a saving of 1min of travel time or even less. Only the ratio for business trips was a bit higher. This result was somewhat unexpected and thus could be explained by respondents undervaluing the probability of the occurrence of undesirable events or even ignoring them as can be seen in other risk situations.

The interpretation of the reliability ratio of the standard deviation is similar: a 1-min standard deviation corresponds to a saving of 0.7min of travel time. However, this result has another simpact: for public transport and air travel, a reduction of the value of the unreliability also causes a reduction of the average travel time, but for car driving the reduction of the standard deviation does not cause a reduction of the average travel time.

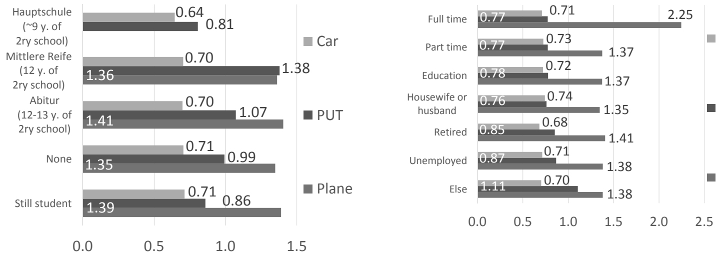
Figure 4.4: Reliability Ratio by socio-demographic indicators


(a) Gender

(b) Age Group


(c) Household Size

(d) Net income per month (EUR)


(e) Education

(f) Employment

Fig. 4.4 presents the calculated reliability ratios by mode of transport for selected socio-demographic indicators. It is obvious that the ratios were more or less evenly distributed among the characteristics for the single modes. Only full-time employees valued reliability twice as much when travelling by air. In contrast to findings of other studies (Lam and Small, 2001), the values (and reliability ratios) for male and female participants did not differ much from each other. In the presented study men valued reliability, as defined here, slightly more than did women.

4.2.3 Validation of the results

In the relatively new research field of reliability valuation the calculated values especially the ones for flight due to the size of the estimated elasticity terms were partially not plausible. One reason could be that the respondents were not asked explicitly for the size of their delay in their CATI interview.

Table 4.6 shows the comparison of the calculated reliability ratios with the ratios shown by Significance *et al.* (2012). The values in this table show the ratio of the standard deviation of travel time with the value of time. The standard deviation for public transport and air plane travel times were also estimated within the project. The values shown in the table are used for a better comparison with the ratios. In general few reliability values for a comparison can be found in international literature than values of time as the topic is rather new. The ratios derived from this study are comparable for the modes car and public transport. However, for air plane are substantially higher but there is also less evidence to compare them.

Table 4.6: International comparison of reliability ratio results (value of standard deviation vs. travel time)

Mode	Country Purpose/ Survey (Year)	DE German VTT	GB Copley *et al.* (2002); ATOC (2002)*	NL Significance *et al.* (2012)	NO Ramjerdi *et al.* (2010)	SE Eliasson (2004)	AU Hensher (2011)	FR MVA Consultancy (2000)
Car	Work	0.7	–	0.4	–	–	–	–
	Business	0.7	–	1.1	–	–	–	–
	Other	0.7	–	0.6	–	–	–	–
	Total	0.7	1.3	–	–	0.3-0.95	0.3-0.4	–

To be continued on the next page

Mode	Country Purpose/ Survey (Year)	DE German VTT	GB Copley *et al.* (2002); ATOC (2002)*	NL Significance *et al.* (2012)	NO Ramjerdi *et al.* (2010)	SE Eliasson (2004)	AU Hensher (2011)	FR MVA Consultancy (2000)
Train	Work	–	–	0.4	–	–	–	–
	Business	–	–	1.1	–	–	–	–
	Other	–	–	0.6	–	–	–	–
	Total	–	0.6 *1.5	–	> 0.69 ≫ 0.54	–	–	–
Bus, Tram, Metro	Work	▹0.5	–	0.4	–	–	–	–
	Business	▹1.0	–	1.1	–	–	–	–
	Other	▹ ⋄ 0.5	–	0.6	–	–	–	–
	Total	▹ 0.5	–	–	> 0.69 ≫ 0.42	–	–	0.24
Plane	Business	1.3	–	0.7	–	–	–	–
	Other	1.4	–	0.7	–	–	–	–
	Total	1.3	–	–	0.2	–	–	–

⋄ *leisure* ▹ *incl. train* > *short* ≫ *long*

Furthermore, Significance *et al.* (2012) mention the importance of reliability measures for further research. Even though there has been some progress in international research no general accepted definition of the monetized value or the estimation of the relative weighting of travel time and travel time reliability exists.

There is less empirical evidence on VOR than on VTT time savings in the international context, as it is only recently that the systematic estimation of the VOR began. In particular the formulation of the mean expected unscheduled delay is rather difficult to compare with other values. The reliability ratios for the standard deviation for car trips and for public transport trips are in the range of the international values reported in a study conducted in the Netherlands (Significance *et al.*, 2012) even though they are low in comparison. The same holds for the VTT in the international comparison, and they deserve a more detailed investigation. However, the VOR is very important for future research, even given the lack of a single accepted formulation of reliability or a common presentation in SP experiments.

4.2.4 Conclusion and Outlook VOR

The *German Value of Time and Reliability Study* worked with different formats to present the reliability of the travel modes in the SP experiments. The formulation of the final model differs in the definitions of reliability for private and public transport. This ultimately unsatisfactory situation arose from the different methods for evaluating the reliability effects of transport policy in the official transport models. It appears that a uniform procedure would be desirable both in the presentation of reliability in SP experiments and the evaluation of transport policy, as well as in the ongoing observation of the traffic situation. Because the parameter for air travel and early arrival do not differ significantly from zero, all of these calculated values do not seem plausible. A different model formulation for estimating those parameters should be tested.

Chapter 5

Part I Valuing Travel Time: Short-term Decisions

This chapter reports on the models estimated within the short-term framework of the study. All estimations make use of the data from the mode (SP1), route (SP2) and route choice and reliability (SP3) experiments and include all six modes surveyed in the study.

As far as possible all estimated models try to implement purpose specific parameters for travel time and cost. As the number of trips for educational purposes was under-represented in the sample (28 respondents) but on the other hand differed too much from the other commute trips (they often resulted as extreme outliers), those were excluded from the sample. The hypothetical alternative long-distance coach only included a very low number of cases of the trip purposes commuting and shopping. For more complex models this often lead to identification issues. For this reason these trips were also excluded from the data. By study design the mode air-plane did not include trips other than with the purpose leisure or business.

Sections 5.1, 5.3 and 5.4 describe the methodology and present the results and analyses of the final model of the respective approach and report the corresponding VTTs. Section 5.2 compares the values of times from a spatial perspective. Section 5.5 synthesizes the results and compares the models under various aspects with respect to appraisal.

5.1 Base Multinomial Logit Model

The Base Multinomial Logit Model is the final non-linear model within an MNL modelling framework. The model was developed to ensure as much comparability and manageability as possible with the other approaches. Therefore, it differs from the final non-linear model of the *German Value of Time and Reliability Study*. For example, it uses the standard deviation for reliability for all modes. It also includes the long-distance coach option for business and leisure trips. By the time of the study, the long-distance coach market was just about to be liberalised but still an unfamiliar, hypothetical choice for the respondents. As the effect of a hypothetical alternative could be recognized in the data analyses the results of the coach option were not recommended for appraisal. The whole modelling approach is described in detail in the following section.

5.1.1 Methodology

The utility functions of the joint model (all types of SP experiments together) are described as follows for the different modes and types of experiments. Different formulations were tested to develop the base model and are reported in the corresponding parts of the description of the utility function.

5.1.1.1 Interaction terms

The base model includes different kinds of interaction terms for different sensitivities in the utilities which are described in detail below. The interaction terms including distance and travel time use the values from the reference trips, that is, the trips from the revealed preference part of the survey that were used as a basis for the computation of the alternatives. Using the reference value allows to make this value constant across alternatives for a given choice situation, with the purpose of isolating time valuation in a few parameters only, while representing the effect of trip length on the relative importance of other attributes.

The first one is an individual distance interaction term for time and cost sensitivity. For a given decision maker i, it is expressed as follows, with *type* taking the values *cost* and *time* for all modes except *walking* and *bike*, as they do not have any cost attribute and therefore only incorporate the one for *time*:

$$\psi_{i,dist,type} = \left(\frac{d_i^{ref}}{\widetilde{d^{ref}}} \right)^{\lambda_{dist,type}} \tag{5.1}$$

where

- d^{ref} is the reported reference distance of respondent i, and $\widetilde{d^{ref}}$ the median distance over all respondents
- $\lambda_{dist,type}$ is a parameter controlling the degree of non-linearity of the distance effect

The decision to implement a distance interaction term in the utility function instead of a log formulation to cover decreasing sensitivities of travel cost and time for longer trips results from the desire to maintain comparability with the other model forms, especially with the multiplicative error term model.

The second term is the income interaction introduced by Mackie *et al.* (2003) which was already implemented in the *German Value of Time and Reliability Study* (Eq. (4.1)). It is only used for cost sensitivity and includes an extra parameter for respondents who did not report their income (average missing income). It is included in all the utilities except *walking* and *bike* – they do not include cost sensitivity – as an individual income interaction term. For a given decision maker i, it is expressed as follows:

$$\psi_{i,tc,type} = \left(\delta_{i,inc} \cdot \frac{\mathrm{inc}_i}{\overline{\mathrm{inc}}} + (1 - \delta_{i,inc}) \cdot \mathrm{inc}_{miss} \right)^{\lambda_{tc,type}} \tag{5.2}$$

where

- $\delta_{i,inc}$ takes value 1 if respondent i reported his income, 0 otherwise
- inc_i is the reported income of respondent i, and $\overline{\mathrm{inc}}$ the average income over all respondents

- inc_{miss} is a parameter representing the average normalised income of all respondents that did not report their income, as revealed by their behavior, and is estimated together with the other parameters of the model. This formulation is equivalent to estimating a separate cost parameter for individuals that did not report their income, but comes with the advantage of being easier to interpret.

- $\lambda_{tc,type}$ is a parameter controlling the degree of non-linearity of the income effect

The third term is the individual interaction term with travel time for all travel related attributes except cost and time sensitivity. The term was not significant for all of the attributes. In the final model those were only included in the utility function with the linear term. The travel time sensitivity was included for the number of transfers, waiting time and access time for public transport. Only waiting time had a significant time sensitivity for the coach alternative. For car time in congestion and access time were included. For the plane alternative no travel time interaction was significant. The reliability (standard deviation of travel time) has one significant term for all modes in the final model as the λ parameters were all about the same magnitude and the additional degrees of freedom did not improve the model fit.

$$\psi_{i,tt,m,type} = \mathrm{tt\_ref}_{m,i}^{\lambda_{tt,m,type}} \tag{5.3}$$

where

- $\mathrm{tt\_ref}_{m,i}$ is the reported reference travel of respondent i for mode m, in hours

- $\lambda_{tt,type}$ is a parameter controlling the degree of non-linearity of the travel time effect

5.1.1.2 Mode Choice (SP1)

The utilities for mode m in $\{walk, bike\}$ and purpose p in $\{commute, shop, business, leisure\}$ can be written as follows:

$$U_{i,m,p} = \mu_{mc} \cdot \left(\alpha_m + \psi_{dist,time} \cdot \beta_{tt,m,p} \cdot \mathrm{tt}_m\right) \tag{5.4}$$

where

- μ_{mc} is the scale for the mode choice experiment
- α_m is the alternative specific constant for mode m
- $\beta_{tt,m,p}$ is the travel time coefficient for mode m and purpose p
- tt_m is the door-to-door travel time with mode m

The utilities for the modes car, public transport, coach and air plane can be written as follows:

$$U_{i,m,p} = \mu_{mc} \cdot \left(\begin{array}{ll} & \alpha_m \\ + & \psi_{dist,time} \cdot \beta_{tt,m,p} \cdot \mathrm{tt}_{i,m} \\ + & \psi_{i,cost} \cdot \psi_{dist,inc} \cdot \beta_{cost,p} \cdot \mathrm{tc}_{i,m} \\ + & \sum_x \psi_{i,tt,m,x} \cdot \beta_x \cdot \mathrm{x}_i \\ + & \sum_{x'} \beta_{x'} \cdot \mathrm{x'}_i \\ + & \psi_{i,tt,sd} \cdot \beta_{m,sd} \cdot \mathrm{SD}_m \end{array} \right) \tag{5.5}$$

where

- $\beta_{cost,p}$ is cost coefficient for purpose p
- tc_i, m is the total travel cost for car
- $\sum_x \psi_{i,tt,m,x} \cdot \beta_x \cdot \mathrm{x}_i$ is the sum of terms that are interacted with travel time:
  - number of transfers (public transport, coach, plane)
  - waiting time (public transport, coach, plane)
  - access time (public transport, coach, plane, car)

  - time in congestion (car)

- $\sum_{x'} \beta_{x'} \cdot$ x'$_i$ is the sum of terms that are not interacted with time: headway, comfort, occupancy level, age, gender, household size
- SD$_m$ is the travel time standard deviation for mode m, inferred from the fraction of trips with a given delay duration.

5.1.1.3 Car and Public Transport Route Choice (SP2)

The utility for car route choice and public transport route choice are identical to the formulation for corresponding mode choice alternative without the alternative specific constant α_m.

5.1.1.4 Car, Public Transport and Airplane Reliability (SP3)

The utilities for the reliability experiments are identical to the ones in the normal route choice experiments, with the difference that the travel time standard deviation is computed from two informations: proportion of trips delayed and proportion of trips arriving early.

5.1.2 Results

Table 5.1 displays the estimation statistics for the base multinomial logit. Those statistics will be looked at more in detail when contrasting them with the results of the more sophisticated models.

Table 5.2 shows the values of the estimates for the base model. Most parameters are significantly different from 0, and signs are as expected. Most of the estimated scale parameters are significantly different from 1, showing a significant difference in scale between the experiments. All λ interaction terms are in the expected $[-1, 0]$ range. This indicates a decreasing sensibility to cost with increasing income, to times (waiting, time in congestion. . .) with increasing travel time, and to time and cost with increasing distance.

Table 5.1: Estimation Statistics Base Model

Statistic	Value
Number of decision makers	3,069
Number of observations	43,856
Null log-likelihood	-36,353
Final log-likelihood	-25,767
Estimated parameters	67
ρ^2	0.29
Adjusted ρ^2	0.29
Akaike Information Criterion	51,484
Bayesian Information Criterion	52,066

Table 5.2: Estimates of the Base Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	0.534	1.17		-1.03	
α_{bike}	4.880	4.17	*	3.31	*
α_{pt}	0.021	0.09		-4.09	*
α_{coach}	-0.409	-1.34		-4.62	*
α_{car}	0.000	NA	NA	NA	NA
α_{plane}	2.954	4.11	*	2.72	*
$\lambda_{inc,cost}$	-0.277	-3.49	*	-16.08	*
$\lambda_{dist,time}$	-0.479	-23.18	*	-71.56	*
$\lambda_{dist,cost}$	-0.593	-17.16	*	-46.11	*
λ_{stdev}	-0.536	-7.83	*	-22.43	*
$\lambda_{tt,transfer,pt}$	-0.228	-7.31	*	-39.32	*
$\lambda_{tt,waiting,pt}$	-0.726	-9.19	*	-21.84	*
$\lambda_{tt,access,pt}$	-0.632	-12.89	*	-33.30	*
$\lambda_{tt,waiting,coach}$	-0.943	-6.26	*	-12.90	*
$\lambda_{time,congestion,car}$	-0.538	-8.61	*	-24.62	*
$\lambda_{time,access,car}$	-0.239	-4.11	*	-21.29	*
$\beta_{stdev,pt}$	-0.016	-6.29	*	-406.22	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{stdev,car}$	-0.013	-5.32	*	-411.18	*
$\beta_{stdev,coach}$	0.004	0.22		-63.35	*
$\beta_{stdev,plane}$	-0.023	-3.45	*	-151.34	*
inc_{miss}	0.637	2.95	*	-1.69	
$\beta_{tt,walk,commute}$	-0.020	-5.94	*	-305.89	*
$\beta_{tt,walk,shop}$	-0.025	-5.88	*	-241.14	*
$\beta_{tt,walk,business}$	-0.028	-4.23	*	-155.87	*
$\beta_{tt,walk,leisure}$	-0.020	-5.15	*	-264.78	*
$\beta_{tt,bike,commute}$	-0.107	-7.35	*	-76.04	*
$\beta_{tt,bike,shop}$	-0.115	-7.28	*	-70.46	*
$\beta_{tt,bike,business}$	-0.097	-5.72	*	-64.62	*
$\beta_{tt,bike,leisure}$	-0.098	-6.56	*	-73.32	*
$\beta_{tt,pt,commute}$	-0.022	-8.97	*	-422.63	*
$\beta_{tt,pt,shop}$	-0.024	-6.39	*	-277.86	*
$\beta_{tt,pt,business}$	-0.017	-8.08	*	-497.11	*
$\beta_{tt,pt,leisure}$	-0.020	-10.12	*	-520.29	*
$\beta_{tt,pt,age}$	-0.006	-1.87		-293.85	*
$\beta_{tt,pt,transfer}$	-0.215	-11.00	*	-62.26	*
$\beta_{tt,pt,waiting}$	-0.017	-7.00	*	-408.98	*
$\beta_{tt,pt,headway}$	-0.006	-5.99	*	-988.63	*
$\beta_{tt,pt,access}$	-0.030	-9.58	*	-333.08	*
$\beta_{tt,pt,med.\_occ.}$	-0.114	-2.76	*	-27.05	*
$\beta_{tt,pt,high\_occ.}$	-0.052	-3.52	*	-71.73	*
$\beta_{tt,coach,business}$	-0.027	-7.36	*	-279.71	*
$\beta_{tt,coach,leisure}$	-0.028	-7.73	*	-288.05	*
$\beta_{tt,coach,male}$	-0.420	-2.55	*	-8.63	*
$\beta_{tt,coach,h\_size}$	0.012	3.66	*	-290.89	*
$\beta_{tt,coach,transfer}$	-0.263	-2.98	*	-14.32	*
$\beta_{tt,coach,waiting}$	-0.080	-5.99	*	-80.57	*
$\beta_{tt,coach,headway}$	-0.002	-5.35	*	-2525.98	*
$\beta_{tt,coach,med.\_occ.}$	-0.246	-2.20	*	-11.14	*
$\beta_{tt,coach,high\_occ.}$	-0.143	-1.58		-12.61	*
$\beta_{tt,car,commute}$	-0.028	-8.95	*	-329.01	*
$\beta_{tt,car,shop}$	-0.012	-4.02	*	-347.59	*
$\beta_{tt,car,business}$	-0.021	-9.42	*	-451.47	*
$\beta_{tt,car,leisure}$	-0.021	-9.85	*	-483.33	*
$\beta_{tt,car,congestion}$	-0.027	-8.99	*	-338.16	*
$\beta_{tt,car,access}$	-0.024	-9.20	*	-390.95	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,plane,business}$	-0.031	-2.80	*	-94.39	*
$\beta_{tt,plane,leisure}$	-0.697	-6.86	*	-16.72	*
$\beta_{tt,plane,waiting}$	-0.017	-2.81	*	-170.02	*
$\beta_{tt,plane,access}$	-0.012	-2.67	*	-232.14	*
$\beta_{cost,commute}$	-0.181	-7.06	*	-46.16	*
$\beta_{cost,shop}$	-0.129	-3.83	*	-33.56	*
$\beta_{cost,business}$	-0.078	-8.11	*	-111.78	*
$\beta_{cost,leisure}$	-0.126	-9.69	*	-86.50	*
μ_{mc}	1.000	NA	NA	NA	NA
$\mu_{rc,pt}$	2.520	10.07	*	6.08	*
$\mu_{rc,car}$	2.800	9.28	*	5.97	*
$\mu_{rel,pt}$	2.117	11.31	*	5.96	*
$\mu_{rel,car}$	2.091	9.42	*	4.91	*
$\mu_{rel,plane}$	1.277	6.49	*	1.41	

5.1.3 Purpose Specific Models

The size of the data set allowed to estimate purpose specific models. The complete results of the base model are shown in Table 5.1, detailed estimation results for the purpose specific models are compiled in Appendix A.1.

The following models show the complete results of the purpose specific MNL Base Models which were estimated using a subsample of the respondents by the purpose they reported in their revealed preference interview. Not all parameters could be estimated for every purpose which is explained in more detail in Section 5.1.3.

Overall, the model outputs do not contain any surprising results.

The VTTs themselves are described in Section 5.5, and compared with the values from other approaches. This section is concerned with the behaviour of the models depending on whether all purposes are grouped in one model or estimated separately. From the base formulation, in the joint model, only the travel time and travel cost parameters are differentiated by purpose, and the other parameters are assumed constant across purposes.

Figure 5.1 to Fig. 5.4 represent the evolution of the VTT with trip distance for the average income. The curves of purposes of the general model are compared to the curve of the subset by purpose, where each line represents one subset. On all figures, substantial differences in behaviour can be observed.

An important effect seems to be the existence of different sensitivities to trip length per purpose. Whereas, in the joint case, all VTTs are forced to follow the same pattern, they are allowed to differ when estimated separately. In all the graphs, it is clear that business benefits from being estimated separately, as it follows a very different pattern. Furthermore, no income effect could be found in the separated business model. This is not surprising, as business trips are typically compensated by the employer, and thus follow completely different valuation processes. The other purposes exhibit much less difference in behaviour.

Table 5.3: Estimation Statistics Base and Purpose Specific Models

Statistic	Base	Commute	Shopping	Business	Leisure
Number of decision makers	3,069	490	461	903	1,215
Number of observations	43,856	6,926	5,330	14,379	17,221
Null log-likelihood	-36,353	-5,689	-4,903	-11,468	-14,235
Final log-likelihood	-25,767	-4,071	-3,045	-8,380	-9,769
Estimated parameters	67	33	33	49	51
ρ^2	0.29	0.28	0.38	0.27	0.31
Adjusted ρ^2	0.29	0.28	0.37	0.26	0.31
Akaike Information Criterion	51,484	8,2078	6,157	16,859	19,640
Bayesian Information Criterion	52,066	8,433	6,374	17,230	20,035

Table 5.4: Estimates of the Base and purpose specific models

	Base		Commute		Shopping		Business		Leisure	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
α_{walk}	0.53	1.17	0.90	1.04	-0.50	-0.70	-0.21	-0.07	0.17	0.22
α_{bike}	4.88	4.17	3.22	2.51	0.38	0.37	6.81	1.01	4.58	2.97
α_{pt}	0.02	0.09	0.73	1.06	-0.16	-0.22	0.47	0.92	-0.48	-1.40
α_{coach}	-0.41	-1.34	–	–	–	–	0.47	0.99	1.45	2.57
α_{car}	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
α_{plane}	2.95	4.11	–	–	–	–	1.97	2.03	1.66	2.01
$\lambda_{inc,cost}$	-0.28	-3.49	-0.43	-2.63	-0.48	-3.40	0.00	NA	-0.31	-3.02
$\lambda_{dist,time}$	-0.48	-23.18	-0.30	-4.19	-0.20	-1.92	-0.52	-15.37	-0.48	-17.93
$\lambda_{dist,cost}$	-0.59	-17.16	-0.32	-3.59	-0.22	-2.66	-0.84	-16.15	-0.65	-18.50
λ_{stdev}	-0.54	-7.83	-0.52	-1.49	-0.07	-0.30	-0.78	-5.16	-0.50	-6.47
$\lambda_{tt,transfer,pt}$	-0.23	-7.31	0.02	0.18	-0.09	-0.81	-0.26	-3.95	-0.19	-3.76
$\lambda_{tt,waiting,pt}$	-0.73	-9.19	-0.40	-1.38	-0.31	-0.66	-0.75	-5.60	-0.77	-5.26
$\lambda_{tt,access,pt}$	-0.63	-12.89	-0.38	-2.08	-0.16	-0.50	-0.76	-7.29	-0.65	-7.53
$\lambda_{tt,waiting,coach}$	-0.94	-6.26	–	–	–	–	-1.39	-5.26	-0.70	-4.75
$\lambda_{time,congestion,car}$	-0.54	-8.61	-0.27	-2.14	-0.93	-0.32	-0.66	-5.52	-0.54	-4.81
$\lambda_{time,access,car}$	-0.24	-4.11	0.13	0.86	-0.25	-0.64	-0.28	-2.41	-0.18	-1.65
$\beta_{stdev,pt}$	-0.02	-6.29	-0.03	-1.78	-0.05	-1.82	-0.01	-1.20	-0.01	-4.53

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	Base		Commute		Shopping		Business		Leisure	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{stdev,car}$	-0.01	-5.32	-0.01	-1.58	-0.05	-1.42	-0.02	-3.57	-0.02	-5.37
$\beta_{stdev,coach}$	0.00	0.22	–	–	–	–	-0.02	-0.55	-0.04	-1.95
$\beta_{stdev,plane}$	-0.02	-3.45	–	–	–	–	-0.02	-2.23	-0.02	-2.79
inc_{miss}	0.64	2.95	3.70	0.90	0.37	2.26	1.00	NA	0.84	2.70
$\beta_{tt,walk,commute}$	-0.02	-5.94	-0.03	-2.93	–	–	–	–	–	–
$\beta_{tt,walk,shop}$	-0.03	-5.88	–	–	-0.05	-3.79	–	–	–	–
$\beta_{tt,walk,business}$	-0.03	-4.23	–	–	–	–	-0.03	-1.73	–	–
$\beta_{tt,walk,leisure}$	-0.02	-5.15	–	–	–	–	–	–	-0.02	-3.33
$\beta_{tt,bike,commute}$	-0.11	-7.35	-0.12	-6.73	–	–	–	–	–	–
$\beta_{tt,bike,shop}$	-0.12	-7.28	–	–	-0.11	-4.63	–	–	–	–
$\beta_{tt,bike,business}$	-0.10	-5.72	–	–	–	–	-0.13	-1.33	–	–
$\beta_{tt,bike,leisure}$	-0.10	-6.56	–	–	–	–	–	–	-0.09	-4.65
$\beta_{tt,pt,commute}$	-0.02	-8.97	-0.04	-6.19	–	–	–	–	–	–
$\beta_{tt,pt,shop}$	-0.02	-6.39	–	–	-0.03	-3.29	–	–	–	–
$\beta_{tt,pt,business}$	-0.02	-8.08	–	–	–	–	-0.02	-5.97	–	–
$\beta_{tt,pt,leisure}$	-0.02	-10.12	–	–	–	–	–	–	-0.02	-6.87
$\beta_{tt,pt,age}$	-0.01	-1.87	-0.01	-1.04	-0.02	-1.59	0.00	-0.27	0.00	-0.38
$\beta_{tt,pt,transfer}$	-0.21	-11.00	-0.30	-5.38	-0.38	-3.37	-0.26	-7.38	-0.22	-6.66
$\beta_{tt,pt,waiting}$	-0.02	-7.00	-0.05	-4.18	-0.03	-1.60	-0.03	-4.03	-0.01	-4.16
$\beta_{tt,pt,headway}$	-0.01	-5.99	-0.01	-3.89	-0.01	-2.83	0.00	-2.65	0.00	-2.90
$\beta_{tt,pt,access}$	-0.03	-9.58	-0.06	-4.87	-0.06	-2.72	-0.04	-6.18	-0.03	-5.59

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	Base		Commute		Shopping		Business		Leisure	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{tt,pt,med.\_occ.}$	-0.11	-2.76	-0.10	-0.85	-0.04	-0.27	-0.28	-3.34	-0.07	-1.21
$\beta_{tt,pt,high\_occ.}$	-0.05	-3.52	-0.10	-1.95	0.01	0.26	-0.09	-2.42	-0.04	-1.97
$\beta_{tt,coach,business}$	-0.03	-7.36	–	–	–	–	-0.04	-6.31	–	–
$\beta_{tt,coach,leisure}$	-0.03	-7.73	–	–	–	–	–	–	-0.04	-7.48
$\beta_{tt,coach,male}$	-0.42	-2.55	–	–	–	–	-0.51	-2.32	-0.25	-1.12
$\beta_{tt,coach,h\_size}$	0.01	3.66	–	–	–	–	0.02	3.77	-0.14	-1.81
$\beta_{tt,coach,transfer}$	-0.26	-2.98	–	–	–	–	-0.19	-1.68	-0.30	-2.09
$\beta_{tt,coach,waiting}$	-0.08	-5.99	–	–	–	–	-0.09	-3.72	-0.05	-2.74
$\beta_{tt,coach,headway}$	0.00	-5.35	–	–	–	–	0.00	-3.38	0.00	-4.50
$\beta_{tt,coach,med.\_occ.}$	-0.25	-2.20	–	–	–	–	-0.28	-2.02	-0.20	-1.05
$\beta_{tt,coach,high\_occ.}$	-0.14	-1.58	–	–	–	–	-0.12	-1.00	-0.10	-0.65
$\beta_{tt,car,commute}$	-0.03	-8.95	-0.05	-5.52	–	–	–	–	–	–
$\beta_{tt,car,shop}$	-0.01	-4.02	–	–	-0.04	-2.61	–	–	–	–
$\beta_{tt,car,business}$	-0.02	-9.42	–	–	–	–	-0.02	-7.31	–	–
$\beta_{tt,car,leisure}$	-0.02	-9.85	–	–	–	–	–	–	-0.02	-7.18
$\beta_{tt,car,congestion}$	-0.03	-8.99	-0.06	-4.58	-0.02	-0.12	-0.03	-6.53	-0.03	-5.37
$\beta_{tt,car,access}$	-0.02	-9.20	-0.07	-4.51	-0.05	-1.71	-0.02	-6.67	-0.02	-5.87
$\beta_{tt,plane,business}$	-0.03	-2.80	–	–	–	–	-0.04	-2.82	-0.03	-2.61
$\beta_{tt,plane,leisure}$	-0.70	-6.86	–	–	–	–	-0.43	-3.80	-0.61	-5.28
$\beta_{tt,plane,waiting}$	-0.02	-2.81	–	–	–	–	0.00	-0.39	-0.02	-2.82
$\beta_{tt,plane,access}$	-0.01	-2.67	–	–	–	–	0.00	-0.57	-0.01	-2.90

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	Base		Commute		Shopping		Business		Leisure	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{cost,commute}$	-0.18	-7.06	-0.34	-6.30	–	–	–	–	–	–
$\beta_{cost,shop}$	-0.13	-3.83	–	–	-0.44	-2.85	–	–	–	–
$\beta_{cost,business}$	-0.08	-8.11	–	–	–	–	-0.15	-7.36	–	–
$\beta_{cost,leisure}$	-0.13	-9.69	–	–	–	–	–	–	-0.12	-8.14
μ_{mc}	1.00	NA	1.00	NA	1.00	NA	1.00	NA	1.00	NA
$\mu_{rc,pt}$	2.52	10.07	1.53	4.80	1.49	3.14	1.91	5.88	2.93	6.48
$\mu_{rc,car}$	2.80	9.28	1.54	4.51	1.86	1.04	2.72	7.01	2.64	6.18
$\mu_{rel,pt}$	2.12	11.31	1.26	5.79	2.11	4.24	1.66	7.56	2.44	6.96
$\mu_{rel,car}$	2.09	9.42	1.20	4.89	1.86	3.00	1.87	6.45	2.30	6.90
$\mu_{rel,plane}$	1.28	6.49	–	–	–	–	3.28	3.43	1.51	5.69

Figure 5.1: Car VTT Comparison Base Model and Subset by Purpose

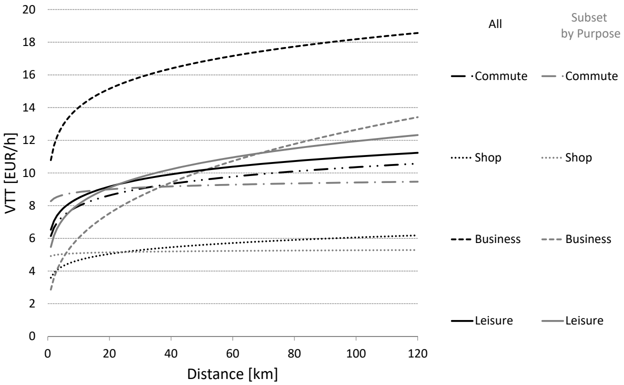


Figure 5.2: Public Transport VTT Comparison Base Model and Subset by Purpose

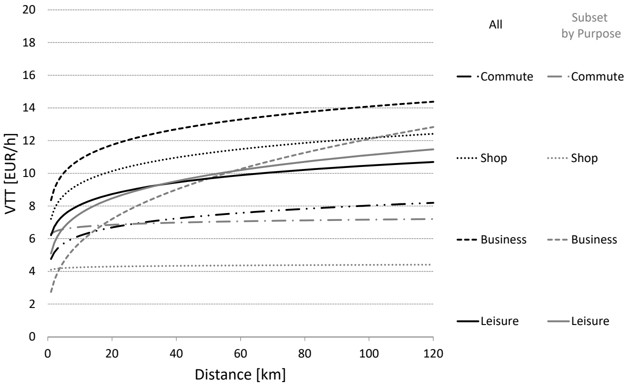


Figure 5.3: Coach VTT Comparison Base Model and Subset by Purpose

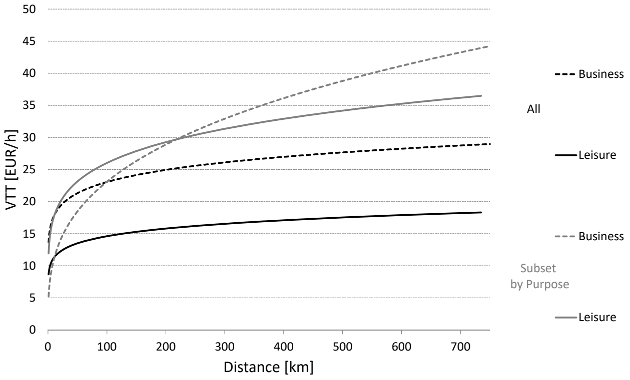
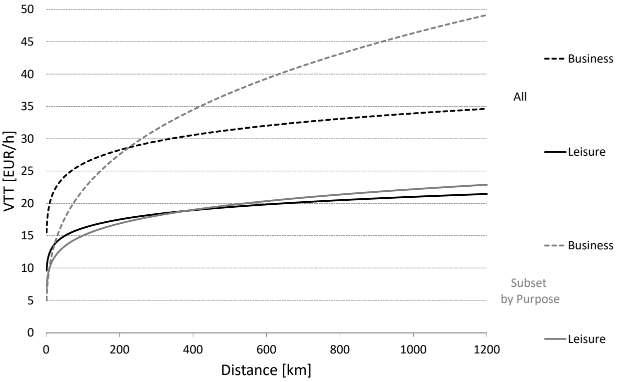


Figure 5.4: Airplane VTT Comparison Base Model and Subset by Purpose



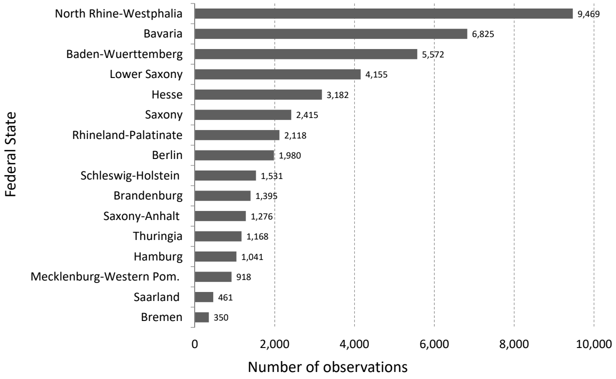
5.2 Spatial VTT Distribution

In this subsection the regional disparities and patterns of the willingness to pay for travel time in relation to the spatial income distribution in Germany are analysed. Again, the large sample size made it possible to estimate separate models for different regions and density types of Germany.

5.2.1 Spatial Attributes in the Data

On NUTS-1 level Germany is structured into 16 states which represent the *'Bundesländer'* (Federal States). On NUTS-3 level it can be divided in 402 districts (*'Kreise and kreisfreie Städte'*), of which about three fourth (326) are located in the former West Germany (FRG) and about one fourth (102) of the districts are located in the former GDR (East Germany). Berlin is assigned to neither. The collected data from the German VTT Study is geo-coded on NUTS 1, 2 and 3 level. This allows a more detailed analyses of the spatial distribution of the German values of travel time. Fig. 5.5 shows the number of observations of the short-term choice situations (SP1, SP2 and SP3) for each Federal State. The disposable income of private households by NUTS level can be found on Eurostat (Eurostat, 2015).

Figure 5.5: Number of observations by Federal State of Germany



It can be seen that number of observations for the smaller Federal States (the cities of Hamburg, Bremen and Berlin, as well as Saarland) is very low, making the estimation of a separate model for each Federal State problematic.

However, assuming purchasing power to be one of the main drivers of differences in values of time, and local prices to be correlated with local average income, grouping regions based on their income can help investigate the spatial variability of VTTS. Germany is known to exhibit strong spatial disparity in terms of income and purchasing power (Vollmer *et al.*, 2013), making such a segmentation meaningful.

Therefore, the sample was divided into quintiles based on the disposable income per inhabitant in 2012 for each Kreis (NUTS-3). The five income categories calculated are:

1Q less than or equal to 18,223 Euro disposable income per year, 615 respondents, 8,728 observations

2Q more than 18,223 Euro and less than or equal to 19,781 Euro disposable income per year, 611 respondents, 8,575 observations

3Q more than 19,781 Euro and less than or equal to 21,084 Euro disposable income per year, 611 respondents, 8,626 observations

4Q more than 21,084 Euro and less than or equal to 22,663 Euro disposable income per year, 630 respondents, 9,189 observations

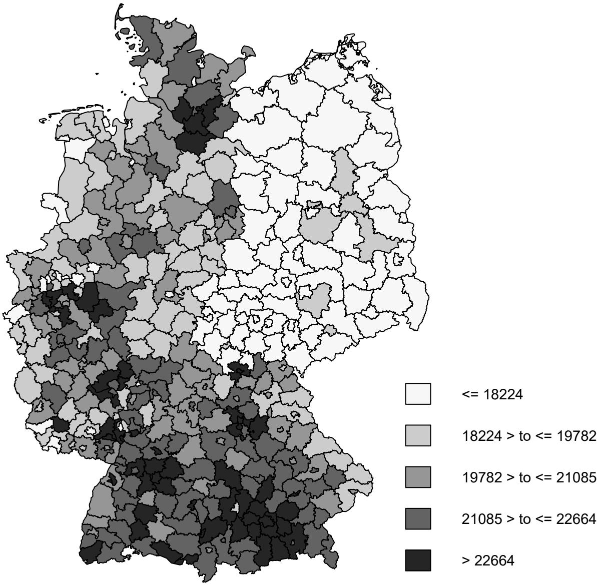
5Q more than 22,663 Euro disposable income per year, 602 respondents, 8,738 observations

Fig. 5.6 shows the five income categories for Germany. The South of Germany (Bavaria and Baden-Wuertemberg) is with a disposable income of 22,700 Euro and 22,378 Euro per year the wealthiest region of Germany. Only the city of Hamburg has a higher disposable income (22,971 Euro) than these two Federal States. The Federal States in the region of the former GDR have the lowest disposable income (between 16,796 Euro and 17,723 Euro per year). The NUTS-3 region with the highest disposable income (36,351 EUR per year in 2012) is Heilbronn in Baden-Wuertemberg the one with the lowest disposable income of 15,647 Euro per year is Gelsenkirchen in Northrhine-Westphalia.

The second spatial attribute in the data set is the classification of the respondents by the size of their community type called *BIK 10*. This type groups regions into ten categories according to the number of inhabitants of the specified socio-economic region, like urban, peripheral regions or agglomerations (BIK Aschpurwis + Behrens GMBH, 2018). This allows the spatial comparison of the data not by the geographical regions but by the type of density and socio-economic area the respondents live in. Fig. 5.7 shows the number of observations of the short-term choice situations (SP1, SP2 and SP3) for each community type.

Before the estimation the classes of community types with very low cases (e.g. rural areas) were joined together. The model formulation of the base model was also used for the estimation of the subsets. Due to a very low number of cases business

Figure 5.6: Disposable income quintiles per inhabitant 2012 (EUR/year)



trips with the modes bike and walking were excluded for modelling, because no meaningful parameter could be obtained. The classification is as follows:

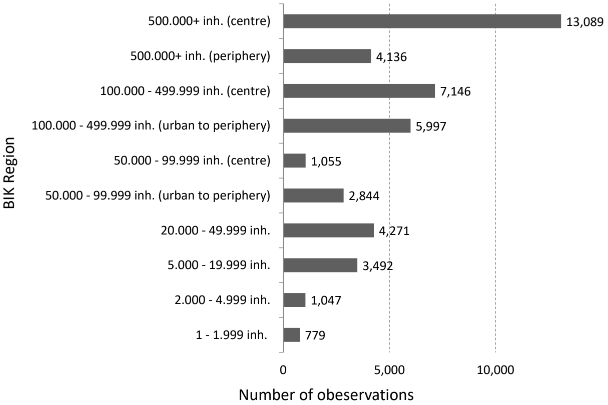
BIK1 500.000+ inhabitants (centre) and 500.000+ inhabitants (periphery), 1,197 respondents, 17,225 observations

BIK2 100.000 - 499.999 inhabitants (centre) and 100.000 - 499.999 inhabitants (urban to periphery), 917 respondents, 13,143 observations

BIK3 50.000 - 99.999 inhabitants (centre) and 50.000 - 99.999 inhabitants. (urban to periphery), 276 respondents, 3,899 observations

BIK4 20.000 - 49.999 inhabitants, 5.000 - 19.999 inhabitants., 2.000 - 4.999 inhabitants and 1 - 1.999 inhabitants , 679 respondents, 9,589 observations

Figure 5.7: Number of observations by BIK Region



5.2.2 Results

For the estimation of the subsets by disposable income quintile and community type the model formulation of the Base MNL defined in Section 5.1 was used to ensure later comparability of the VTT. As the travel time parameter was estimated for every purpose and mode and the travel cost parameter for every purpose, all combinations of mode and trip purpose had to be in the sub-sample with a sufficient number of observation.

Table 5.5 presents the estimation statistics for the model by disposable income quintile. By construction, the five groups have similar size, making comparison easier. All models exhibit similar goodness of fit.

Table 5.6 presents the results for the 5 models. The full results are available in Appendix A.2.1. No systematic pattern can be seen in the estimates with increasing local average income. The models do present important differences. For instance, the relative importance of the various purpose in terms of β_{cost} differs in each model. However, as presented in Section 5.5, this does not result in a recognisable pattern for VTT either.

Table 5.7 presents the estimation statistics for the model by community type. The categories have quite different sample sizes, which makes comparing model fits problematic.

Table 5.8 presents the output of the models by community type. No clear trend can be identified at the level of the parameters. However, as presented in Section 5.5, the resulting VTTs do exhibit clear patterns with changing community type.

All complete outputs of the estimated regional models can be found in Appendix A.2.

Table 5.5: Estimation Statistics disposable income quintiles per inhabitant 2012 (EUR/year)

Statistic	1Q	2Q	3Q	4Q	5Q
Number of decision makers	615	611	611	630	602
Number of observations	8,728	8,575	8,626	9,189	8,738
Null log-likelihood	-7,182	-7,193	-7,178	-7,578	-7,223
Final log-likelihood	-5,073	-5,009	-5,314	-5,157	-5,073
Estimated parameters	65	65	65	65	65
ρ^2	0.34	0.30	0.26	0.32	0.30
Adjusted ρ^2	0.33	0.29	0.25	0.31	0.29
Akaike Information Criterion	9,665	10,148	10,758	10,444	10,275
Bayesian Information Criterion	10,126	10,607	11,217	10,907	10,735

Table 5.6: Estimates of the disposable income quintiles per inhabitant 2012 (EUR/year)

	Q1		Q2		Q3		Q4		Q5	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
α_{walk}	-2.64	-5.55	0.16	0.20	-0.53	-0.58	-0.10	-0.11	-1.35	-1.13
α_{bike}	5.77	2.51	0.48	0.38	3.09	1.63	2.33	1.55	-0.68	-0.36
α_{pt}	0.44	0.78	0.50	1.16	-0.40	-0.66	0.26	0.46	-0.74	-1.41
α_{coach}	-0.05	-0.05	-1.24	-1.15	-0.06	-0.09	-0.27	-0.42	-1.15	-1.55
α_{car}	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
α_{plane}	0.95	0.80	3.19	2.16	3.47	1.53	2.05	1.32	3.40	2.66
$\lambda_{inc,cost}$	-0.24	-1.88	-0.19	-1.53	-0.31	-1.38	-0.16	-0.76	-0.49	-3.33
$\lambda_{dist,time}$	-0.42	-9.72	-0.42	-8.92	-0.44	-9.09	-0.42	-10.33	-0.48	-9.04
$\lambda_{dist,cost}$	-0.72	-15.52	-0.65	-9.41	-0.55	-6.46	-0.71	-8.79	-0.65	-11.15
λ_{stdev}	-0.66	-3.59	-0.59	-4.40	-0.52	-2.67	-0.66	-2.77	-0.59	-3.65
$\lambda_{tt,transfer,pt}$	-0.16	-2.42	-0.28	-4.24	-0.19	-2.57	-0.22	-3.17	-0.31	-4.11
$\lambda_{tt,waiting,pt}$	-0.59	-3.59	-0.81	-5.36	-0.81	-4.78	-1.02	-4.07	-0.66	-4.38
$\lambda_{tt,access,pt}$	-0.67	-6.44	-0.62	-5.84	-0.55	-4.91	-0.61	-3.91	-0.76	-6.55
$\lambda_{tt,waiting,coach}$	-1.80	-3.68	-1.28	-3.01	-0.77	-3.40	-1.12	-2.19	-0.70	-3.03
$\lambda_{time,congestion,car}$	0.07	-15.04	-0.53	-1.66	-0.47	-3.32	-0.30	-2.12	-0.91	-9.27
$\lambda_{time,access,car}$	-0.53	-4.39	0.04	0.21	-0.35	-1.75	-0.22	-1.46	-0.33	-1.23
$\beta_{stdev,pt}$	-0.01	-2.51	-0.02	-3.17	-0.01	-2.18	-0.02	-2.28	-0.02	-2.90

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	Q1		Q2		Q3		Q4		Q5	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{stdev,car}$	-0.01	-2.78	-0.01	-2.44	-0.02	-2.92	-0.01	-1.78	-0.02	-3.97
$\beta_{stdev,coach}$	0.00	0.07	0.02	0.53	-0.01	-0.26	-0.03	-0.58	0.02	0.66
$\beta_{stdev,plane}$	0.00	-0.24	-0.03	-2.18	-0.08	-2.35	-0.01	-0.68	-0.02	-1.16
inc_{miss}	0.90	1.30	0.60	0.94	1.08	1.30	0.64	0.80	0.65	2.89
$\beta_{tt,walk,commute}$	-0.01	-2.74	-0.02	-2.63	-0.02	-3.71	-0.01	-2.58	-0.01	-2.77
$\beta_{tt,walk,shop}$	-0.01	-1.84	-0.02	-2.67	-0.03	-2.61	-0.02	-2.93	-0.02	-1.91
$\beta_{tt,walk,business}$	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
$\beta_{tt,walk,leisure}$	-0.01	-1.55	-0.02	-3.54	-0.02	-3.20	-0.02	-3.44	-0.01	-1.72
$\beta_{tt,bike,commute}$	-0.15	-4.46	-0.04	-2.41	-0.10	-4.23	-0.08	-3.71	-0.03	-1.30
$\beta_{tt,bike,shop}$	-0.18	-4.81	-0.05	-2.21	-0.11	-3.26	-0.07	-2.95	-0.03	-1.09
$\beta_{tt,bike,business}$	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
$\beta_{tt,bike,leisure}$	-0.13	-4.19	-0.04	-1.80	-0.08	-3.19	-0.07	-3.01	-0.03	-1.10
$\beta_{tt,pt,commute}$	-0.02	-3.47	-0.02	-4.52	-0.02	-3.87	-0.03	-5.42	-0.02	-4.08
$\beta_{tt,pt,shop}$	-0.03	-4.27	-0.03	-3.20	-0.03	-3.07	-0.02	-1.32	-0.02	-3.34
$\beta_{tt,pt,business}$	-0.01	-2.45	-0.02	-4.04	-0.02	-4.93	-0.02	-4.17	-0.02	-4.73
$\beta_{tt,pt,leisure}$	-0.02	-5.79	-0.02	-3.71	-0.02	-4.61	-0.02	-4.74	-0.02	-4.43
$\beta_{tt,pt,age}$	-0.02	-2.45	-0.01	-1.15	0.00	0.21	0.00	-0.23	0.00	-0.08
$\beta_{tt,pt,transfer}$	-0.26	-5.86	-0.19	-5.06	-0.25	-5.10	-0.27	-5.54	-0.21	-4.97
$\beta_{tt,pt,waiting}$	-0.02	-3.17	-0.02	-3.02	-0.02	-2.84	-0.02	-2.36	-0.02	-3.60
$\beta_{tt,pt,headway}$	-0.01	-2.40	-0.01	-3.15	-0.01	-3.39	-0.01	-3.54	0.00	-0.44
$\beta_{tt,pt,access}$	-0.03	-4.61	-0.03	-4.21	-0.03	-3.81	-0.03	-4.55	-0.04	-4.95

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	Q1		Q2		Q3		Q4		Q5	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{tt,pt,med.\_occ.}$	-0.21	-2.08	-0.15	-1.65	-0.10	-1.10	-0.14	-1.28	-0.06	-0.71
$\beta_{tt,pt,high\_occ.}$	-0.05	-1.52	-0.09	-2.42	-0.06	-1.42	-0.06	-1.49	-0.02	-0.71
$\beta_{tt,coach,business}$	-0.02	-2.08	-0.01	-1.68	-0.04	-4.81	-0.03	-4.04	-0.03	-2.99
$\beta_{tt,coach,leisure}$	-0.03	-2.89	-0.02	-2.64	-0.04	-4.55	-0.02	-3.52	-0.02	-2.90
$\beta_{tt,coach,male}$	-0.53	-1.16	-0.82	-1.84	-0.26	-0.76	-0.41	-1.24	-0.36	-1.14
$\beta_{tt,coach,h\_size}$	-0.07	-0.51	0.15	0.63	-0.03	-0.22	0.02	4.27	0.08	0.54
$\beta_{tt,coach,transfer}$	-0.29	-1.31	-0.19	-0.70	-0.27	-1.59	-0.28	-1.35	-0.31	-2.12
$\beta_{tt,coach,waiting}$	-0.07	-1.67	-0.05	-1.49	-0.12	-4.17	-0.08	-1.96	-0.09	-4.43
$\beta_{tt,coach,headway}$	0.00	-2.55	0.00	-2.53	0.00	-1.91	0.00	-2.53	0.00	-2.87
$\beta_{tt,coach,med.\_occ.}$	-0.37	-1.52	-0.30	-1.15	-0.50	-2.16	-0.01	-0.04	-0.12	-0.49
$\beta_{tt,coach,high\_occ.}$	-0.25	-1.20	-0.29	-1.55	0.02	0.13	-0.07	-0.28	-0.25	-1.05
$\beta_{tt,car,commute}$	-0.03	-4.84	-0.02	-2.91	-0.04	-5.49	-0.03	-4.31	-0.03	-5.11
$\beta_{tt,car,shop}$	-0.03	-3.72	0.00	-0.16	0.00	0.21	-0.01	-2.95	-0.02	-2.59
$\beta_{tt,car,business}$	-0.02	-5.45	-0.02	-3.23	-0.03	-5.39	-0.02	-4.39	-0.03	-5.66
$\beta_{tt,car,leisure}$	-0.02	-5.82	-0.01	-3.05	-0.03	-5.38	-0.02	-5.03	-0.03	-5.19
$\beta_{tt,car,congestion}$	-0.03	-5.41	-0.02	-2.47	-0.04	-5.24	-0.02	-4.12	-0.04	-6.14
$\beta_{tt,car,access}$	-0.03	-5.97	-0.01	-2.79	-0.04	-5.00	-0.02	-4.45	-0.03	-4.30
$\beta_{tt,plane,business}$	-0.04	-2.44	-0.02	-1.92	-0.05	-2.18	-0.04	-2.56	-0.02	-1.58
$\beta_{tt,plane,leisure}$	-0.82	-4.57	-0.56	-2.86	-0.68	-2.55	-0.64	-2.60	-0.64	-3.03
$\beta_{tt,plane,waiting}$	0.00	-0.09	-0.01	-0.55	-0.04	-1.81	-0.02	-1.71	-0.02	-2.02
$\beta_{tt,plane,access}$	-0.01	-1.06	-0.02	-1.77	-0.01	-0.54	-0.01	-1.36	-0.02	-2.10

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	Q1		Q2		Q3		Q4		Q5	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{cost,commute}$	-0.22	-4.47	-0.20	-3.42	-0.25	-3.87	-0.25	-4.68	-0.07	-1.39
$\beta_{cost,shop}$	-0.12	-1.91	-0.15	-2.29	-0.18	-1.66	-0.07	-1.54	-0.15	-2.73
$\beta_{cost,business}$	-0.10	-4.92	-0.10	-5.53	-0.08	-2.15	-0.08	-3.32	-0.09	-5.06
$\beta_{cost,leisure}$	-0.19	-5.75	-0.14	-4.45	-0.13	-4.13	-0.14	-3.96	-0.16	-6.18
μ_{mc}	1.00	NA	1.00	NA	1.00	NA	1.00	NA	1.00	NA
$\mu_{rc,pt}$	2.24	5.23	2.78	4.43	1.95	4.17	2.27	4.94	2.16	4.94
$\mu_{rc,car}$	2.87	5.86	3.19	3.18	1.66	5.08	3.16	4.69	2.55	5.54
$\mu_{rel,pt}$	1.95	6.34	2.18	4.76	1.81	5.42	1.69	5.16	2.21	4.81
$\mu_{rel,car}$	2.13	6.12	2.61	3.26	1.05	4.39	2.52	4.94	1.88	5.76
$\mu_{rel,plane}$	2.08	3.27	1.20	3.25	0.87	2.72	1.58	3.27	1.88	3.40

Table 5.7: Estimation Statistics BIK Region

Statistic	BIK1	BIK2	BIK3	BIK4
Number of decision makers	1,197	917	276	679
Number of observations	17,225	13,143	3,899	9,589
Null log-likelihood	-14,286	-10,896	-3,236	-7,936
Final log-likelihood	-10,583	-7,380	-1,988	-5,436
Estimated parameters	65	65	65	65
ρ^2	0.26	0.32	0.39	0.32
Adjusted ρ^2	0.25	0.32	0.37	0.31
Akaike Information Criterion	21,296	14,890	4,107	11,001
Bayesian Information Criterion	21,800	15,377	4,514	11,468

Table 5.8: Estimates of the disposable income quintiles per inhabitant 2012 (EUR/year)

	BIK1		BIK2		BIK3		BIK4	
	500.000+ inh.		100,000-499,999 inh.		50,000-99,999 inh.		1-49,999 inh.	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
α_{walk}	-1.00	-1.74	-1.44	-2.64	-0.12	-0.06	-1.40	-2.09
α_{bike}	0.48	0.53	3.92	2.06	6.95	1.31	2.19	1.32
α_{pt}	0.21	0.59	0.24	0.55	-0.65	-0.59	-0.55	-0.91
α_{coach}	-0.55	-1.05	-0.76	-1.03	0.40	0.19	-0.14	-0.27
α_{car}	0.00	NA	0.00	NA	0.00	NA	0.00	NA
α_{plane}	3.03	3.05	0.82	0.70	3.20	1.02	2.92	1.66
$\lambda_{inc,cost}$	-0.29	-2.71	-0.30	-3.05	-0.21	-0.85	-0.32	-2.30
$\lambda_{dist,time}$	-0.41	-12.24	-0.48	-15.10	-0.48	-6.94	-0.44	-9.13
$\lambda_{dist,cost}$	-0.67	-14.58	-0.72	-14.54	-0.59	-5.92	-0.59	-9.20
λ_{stdev}	-0.73	-5.88	-0.47	-5.25	-0.64	-0.74	-0.74	-1.62
$\lambda_{tt,transfer,pt}$	-0.29	-6.33	-0.23	-3.36	-0.21	-2.86	-0.18	-2.19
$\lambda_{tt,waiting,pt}$	-0.86	-6.68	-0.52	-5.26	-0.92	-4.76	-1.26	-3.21
$\lambda_{tt,access,pt}$	-0.73	-8.47	-0.57	-6.53	-0.44	-2.32	-0.66	-5.59
$\lambda_{tt,waiting,coach}$	-0.77	-4.28	-1.13	-0.74	-1.46	-1.39	-1.47	-5.44
$\lambda_{time,congestion,car}$	0.06	-14.64	-0.61	-6.39	-0.11	-0.20	-0.56	-3.94
$\lambda_{time,access,car}$	-0.28	-2.07	-0.13	-1.14	-0.31	-1.37	-0.54	-2.46

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	BIK1		BIK2		BIK3		BIK4	
	500.000+ inh.		100,000-499,999 inh.		50,000-99,999 inh.		1-49,999 inh.	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{stdev,pt}$	-0.01	-3.92	-0.02	-3.52	-0.02	-0.59	-0.01	-0.96
$\beta_{stdev,car}$	-0.01	-3.69	-0.02	-4.65	-0.01	-0.65	-0.01	-1.26
$\beta_{stdev,coach}$	0.01	0.34	-0.02	-0.47	-0.04	-0.13	0.04	1.18
$\beta_{stdev,plane}$	-0.02	-1.80	-0.02	-2.80	-0.02	-0.87	-0.03	-1.34
inc_{miss}	0.40	1.69	2.09	1.45	0.74	1.04	0.48	1.65
$\beta_{tt,walk,commute}$	-0.01	-2.82	-0.02	-4.14	-0.02	-1.90	-0.02	-3.85
$\beta_{tt,walk,shop}$	-0.02	-3.45	-0.01	-2.69	-0.02	-1.84	-0.02	-2.83
$\beta_{tt,walk,business}$	0.00	NA	0.00	NA	0.00	NA	0.00	NA
$\beta_{tt,walk,leisure}$	-0.02	-3.96	-0.01	-5.47	-0.22	-4.05	-0.01	-2.60
$\beta_{tt,bike,commute}$	-0.04	-3.11	-0.10	-4.22	-0.14	-2.08	-0.10	-4.60
$\beta_{tt,bike,shop}$	-0.06	-3.17	-0.11	-4.04	-0.19	-2.69	-0.08	-2.96
$\beta_{tt,bike,business}$	0.00	NA	0.00	NA	0.00	NA	0.00	NA
$\beta_{tt,bike,leisure}$	-0.04	-2.70	-0.09	-3.75	-0.14	-2.24	-0.07	-2.77
$\beta_{tt,pt,commute}$	-0.02	-6.31	-0.02	-5.25	-0.02	-2.20	-0.03	-4.97
$\beta_{tt,pt,shop}$	-0.03	-3.71	-0.03	-4.28	-0.02	-1.91	-0.03	-3.70
$\beta_{tt,pt,business}$	-0.02	-6.28	-0.02	-3.75	-0.01	-2.61	-0.02	-4.16
$\beta_{tt,pt,leisure}$	-0.02	-6.76	-0.03	-6.75	-0.02	-3.35	-0.02	-4.36
$\beta_{tt,pt,age}$	0.00	-0.71	-0.01	-1.73	0.00	-0.24	0.00	-0.40
$\beta_{tt,pt,transfer}$	-0.22	-7.16	-0.24	-6.55	-0.28	-3.84	-0.23	-5.76
$\beta_{tt,pt,waiting}$	-0.02	-4.48	-0.03	-4.84	-0.03	-2.29	-0.01	-1.29

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	BIK1		BIK2		BIK3		BIK4	
	500.000+ inh.		100,000-499,999 inh.		50,000-99,999 inh.		1-49,999 inh.	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{tt,pt,headway}$	0.00	-2.31	-0.01	-3.60	-0.01	-1.29	-0.01	-2.38
$\beta_{tt,pt,access}$	-0.03	-6.51	-0.03	-5.83	-0.03	-2.42	-0.04	-4.39
$\beta_{tt,pt,med.\_occ.}$	-0.14	-2.21	-0.13	-1.60	0.04	0.22	-0.18	-1.70
$\beta_{tt,pt,high\_occ.}$	-0.05	-2.44	-0.07	-2.16	-0.01	-0.19	-0.09	-1.97
$\beta_{tt,coach,business}$	-0.02	-4.02	-0.03	-4.05	-0.04	-2.04	-0.03	-4.25
$\beta_{tt,coach,leisure}$	-0.02	-4.37	-0.03	-4.15	-0.03	-2.80	-0.03	-4.30
$\beta_{tt,coach,male}$	-0.20	-0.85	-0.40	-1.36	-0.20	-0.35	-1.08	-2.41
$\beta_{tt,coach,h\_size}$	0.12	1.11	0.00	0.00	-0.75	-3.15	0.01	3.81
$\beta_{tt,coach,transfer}$	-0.26	-2.18	-0.34	-1.97	-0.85	-1.65	0.02	0.08
$\beta_{tt,coach,waiting}$	-0.11	-5.59	-0.04	-0.56	-0.04	-0.71	-0.13	-3.49
$\beta_{tt,coach,headway}$	0.00	-3.13	0.00	-3.50	0.00	-0.53	0.00	-2.76
$\beta_{tt,coach,med.\_occ.}$	-0.26	-1.63	-0.13	-0.56	0.29	0.46	-0.70	-2.78
$\beta_{tt,coach,high\_occ.}$	-0.17	-1.15	-0.15	-1.01	0.52	1.25	-0.33	-1.74
$\beta_{tt,car,commute}$	-0.02	-5.14	-0.04	-5.60	-0.03	-3.67	-0.04	-5.52
$\beta_{tt,car,shop}$	-0.02	-3.36	-0.01	-3.00	-0.03	-1.88	-0.02	-2.07
$\beta_{tt,car,business}$	-0.02	-5.43	-0.03	-6.37	-0.02	-4.07	-0.02	-4.98
$\beta_{tt,car,leisure}$	-0.02	-5.55	-0.03	-6.03	-0.03	-3.77	-0.02	-5.86
$\beta_{tt,car,congestion}$	-0.02	-5.51	-0.04	-6.15	-0.02	-1.41	-0.04	-5.09
$\beta_{tt,car,access}$	-0.02	-5.14	-0.03	-6.09	-0.03	-3.11	-0.03	-5.21
$\beta_{tt,plane,business}$	-0.02	-1.77	-0.03	-2.84	-0.08	-2.00	-0.06	-2.33

To be continued on the next page

	BIK1		BIK2		BIK3		BIK4	
	500.000+ inh.		100,000-499,999 inh.		50,000-99,999 inh.		1-49,999 inh.	
Parameter	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)	Est.	Rob. t-stat (0)
$\beta_{tt,plane,leisure}$	-0.65	-4.47	-0.58	-3.47	-0.65	-2.10	-0.82	-3.21
$\beta_{tt,plane,waiting}$	-0.02	-1.75	-0.02	-2.07	-0.02	-0.86	-0.01	-0.73
$\beta_{tt,plane,access}$	-0.02	-2.87	-0.01	-1.99	0.00	-0.28	-0.01	-0.47
$\beta_{cost,commute}$	-0.11	-2.85	-0.24	-4.68	-0.22	-2.92	-0.32	-4.56
$\beta_{cost,shop}$	-0.15	-3.94	-0.11	-3.55	-0.43	-2.24	-0.03	-0.61
$\beta_{cost,business}$	-0.08	-6.51	-0.14	-4.28	-0.19	-3.90	-0.09	-3.78
$\beta_{cost,leisure}$	-0.13	-6.80	-0.17	-6.77	-0.17	-3.07	-0.15	-5.47
μ_{mc}	1.00	NA	1.00	NA	1.00	NA	1.00	NA
$\mu_{rc,pt}$	2.59	6.85	2.33	6.26	1.40	2.62	2.18	4.81
$\mu_{rc,car}$	2.86	5.27	2.43	6.00	2.94	4.23	2.14	5.68
$\mu_{rel,pt}$	2.30	7.65	1.78	7.56	1.61	3.77	1.49	4.87
$\mu_{rel,car}$	2.26	5.50	1.89	6.53	1.89	4.18	1.47	5.25
$\mu_{rel,plane}$	1.30	3.97	1.94	3.85	1.15	2.19	0.90	3.97

5.2.3 Income effect

As described in the previous chapters it is well known that the income elasticity of the VTT is not constant but an increasing function of income (Mackie *et al.*, 2003). This effect was also found in the German VTT data (Fig. 4.1).

Fig. 5.8 shows the income effect on the value of travel time derived from the estimated models for the geographical regions on NUTS-3 level determined above. The curves show that respondents with a very low income have a high sensitivity to travel time savings and the respondents with a high income are less sensitive. Further, it can be seen that in regions with a high per capita purchasing power the effects on the income groups is stronger in both directions.

Figure 5.8: Income sensitivity by disposable income quintiles

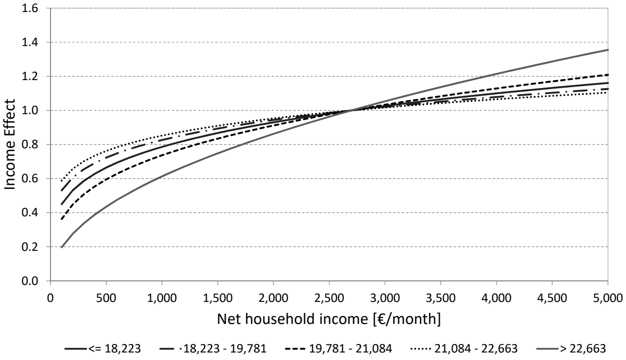
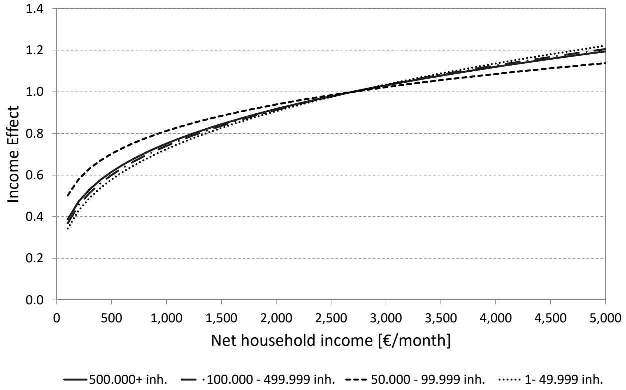


Fig. 5.9 shows the income effect on the VTT derived from the estimated regional models for the four community types. It shows that the sensitivity to income does not vary much between the community types. All the curves show again that respondents with very low income are most sensitive to travel time changes. Then, the slope of the curve flattens. The curves show that the effect of income does not seem to be dependent on the community type the respondents live in.

Figure 5.9: Income sensitivity by BIK Region



5.3 Multiplicative Error Term

Most of the VTT studies employ standard additive error structures when decomposing the utility in a choice model into a deterministic and a random component. An alternative approach is to estimate choice models based on a multiplicative error term formulation (Fosgerau and Bierlaire, 2009; Brilon and Dette, 2002). This was used in the most recent British (Batley *et al.*, 2017) and Danish (Fosgerau *et al.*, 2007) VTT study.

This section shows the implementation of this alternative VTT estimation approach to the complex choice situations of the German VTT survey. The approach is compared to the MNL Base model in terms of estimates, model fit and VTT estimation.

5.3.1 Methodology

In order to make use of the full data, in the model the disutility of travel time per mode is kept constant across experiments but the scale of the error terms is allowed to vary.

Rather than using the standard additive formulation for a choice model, where the random utility of an alternative i, V_i, is expressed as the sum of a deterministic function of the attributes of the decision maker and alternative and an error term, $U_i = V_i + \varepsilon$, this model uses a multiplicative formulation, where the deterministic part of the utility is multiplied with the error term: $U_i = V_i \cdot \varepsilon$. Intuitively, this corresponds to the hypothesis that the probability of choosing one alternative over another might be proportional to the *relative* difference in cost, rather than the absolute difference. To estimate such a model, given a negative utility function, one can transform the model in an additive formulation:

$$P(V_i \cdot \varepsilon_i \geq V_j \cdot \varepsilon_j,\ \forall j) = P(-\log(-V_i) - \log(\varepsilon_i) \geq -\ln(-V_j) - \ln(\varepsilon_j),\ \forall j) \quad (5.6)$$

which can be specified as a logit, assuming that $\ln(\varepsilon_i)$ follows an extreme value distribution.

The model uses the same utility formulations as the base model, without constants. For identification, in a linear-in-parameters formulation, one of the coefficient has to be normalized, as multiplying all parameters by the same amount would result in the same choice probabilities. It is usual to fix the cost coefficient to 1, resulting in having all other parameters directly expressed as willingness to pay. However, due to the formulation retained in the base model, where the cost coefficient is allowed to vary per trip purpose (representing different overall levels of willingness to pay for different purposes), the travel time coefficient for car for leisure purpose is fixed to 1, due to the high number of trips for this purpose and mode.

5.3.2 Results

The following output shows the results of the MNL Base Model which was estimated with the exact same utility function as the Multiplicative Model to allow a direct comparison of parameters and the model performance.

The estimation statistics are summarized in Table 5.9. They show that the multiplicative formulation fits the data better than the base model. This is consistent with what was found on other datasets (Fosgerau and Bierlaire, 2009; Batley *et al.*, 2017).

Table 5.10 shows the estimates and indicates which parameters are significantly different from zero or one. Most of the interaction terms for quantities that increase with travel time (travel, waiting and access time, as well as time in congestion) now have a λ that is not significantly different from 0. This contrasts with the additive case, where all those parameters are significantly negative. The multiplicative formulation seems to absorb those effects in the error term, as the influence of the error term increases with the magnitude of the deterministic part of the utility, and thus with the travelled distance. This allows to simplify the model, without loosing in realism.

Table 5.9: Estimation Statistics Multiplicative Model

Statistic	Multiplicative	MNL Compare
Number of decision makers	3,069	3,069
Number of observations	43,856	43,856
Null log-likelihood	-36,353	-36,353
Final log-likelihood	-25,606	-25,795
Estimated parameters	58	58
ρ^2	0.30	0.29
Adjusted ρ^2	0.29	0.29
Akaike Information Criterion	51,329	51,706
Bayesian Information Criterion	51,833	52,210

Table 5.10: Estimates of the Multiplicative and MNL Compare Model

	Multiplicative					MNL Compare				
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{inc,cost}$	-0.42	-5.95	*	-20.09	*	-0.28	-3.82	*	-17.30	*
$\lambda_{dist,time}$	0.01	0.24		-18.72	*	-0.43	-21.67	*	-71.86	*
$\lambda_{dist,cost}$	-0.35	-6.32	*	-24.55	*	-0.65	-20.94	*	-53.34	*
λ_{stdev}	-0.22	-2.30	*	-12.96	*	-0.62	-8.07	*	-21.19	*
$\lambda_{tt,transfer,pt}$	0.45	5.45	*	-6.80	*	-0.23	-7.33	*	-38.77	*
$\lambda_{tt,waiting,pt}$	-0.04	-0.28		-7.67	*	-0.76	-9.18	*	-21.25	*
$\lambda_{tt,access,pt}$	0.13	1.32		-9.16	*	-0.66	-13.29	*	-33.46	*
$\lambda_{tt,waiting,coach}$	0.27	1.44		-3.84	*	-0.97	-7.95	*	-16.19	*
$\lambda_{time,congestion,car}$	-0.14	-1.72		-14.18	*	-0.61	-8.92	*	-23.47	*
$\lambda_{time,access,car}$	0.06	0.66		-9.80	*	-0.32	-3.66	*	-15.21	*
$\beta_{stdev,pt}$	0.87	5.77	*	-0.89		-0.01	-5.79	*	-405.49	*
$\beta_{stdev,car}$	0.85	7.12	*	-1.21		-0.01	-5.53	*	-413.00	*
$\beta_{stdev,coach}$	0.00	NA	*	NA		0.00	NA	NA	NA	NA
$\beta_{stdev,plane}$	3.13	3.51	NA	2.39	NA	-0.02	-2.88	*	-152.40	*
inc_{miss}	0.95	3.98	*	-0.21	*	0.60	3.03	*	-2.04	*
$\beta_{tt,walk,commute}$	1.52	5.46	*	1.86		-0.02	-6.67	*	-336.35	*
$\beta_{tt,walk,shop}$	2.04	6.18	*	3.15	*	-0.03	-8.74	*	-346.97	*
$\beta_{tt,walk,business}$	2.55	2.14	*	1.30		-0.03	-4.23	*	-151.03	*

To be continued on the next page

	Multiplicative					MNL Compare				
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,walk,leisure}$	1.83	6.21	*	2.81	*	-0.02	-7.00	*	-354.53	*
$\beta_{tt,bike,commute}$	2.73	8.60	*	5.45	*	-0.04	-11.89	*	-276.40	*
$\beta_{tt,bike,shop}$	3.07	7.02	*	4.74	*	-0.04	-9.51	*	-222.37	*
$\beta_{tt,bike,business}$	2.34	3.89	*	2.23	*	-0.03	-3.13	*	-104.54	*
$\beta_{tt,bike,leisure}$	2.21	9.44	*	5.16	*	-0.03	-9.72	*	-307.30	*
$\beta_{tt,pt,commute}$	1.40	7.99	*	2.29	*	-0.02	-9.86	*	-454.51	*
$\beta_{tt,pt,shop}$	1.21	6.17	*	1.08		-0.03	-6.95	*	-272.08	*
$\beta_{tt,pt,business}$	1.50	9.64	*	3.21	*	-0.02	-8.79	*	-560.69	*
$\beta_{tt,pt,leisure}$	1.33	12.94	*	3.22	*	-0.02	-11.37	*	-617.51	*
$\beta_{tt,pt,age}$	0.15	1.45		-8.42	*	-0.01	-2.73	*	-382.50	*
$\beta_{tt,pt,transfer}$	15.62	10.76	*	10.07	*	-0.22	-12.63	*	-69.74	*
$\beta_{tt,pt,waiting}$	1.16	7.11	*	0.98		-0.02	-7.34	*	-421.54	*
$\beta_{tt,pt,headway}$	0.53	4.87	*	-4.37	*	-0.01	-6.25	*	-1024.71	*
$\beta_{tt,pt,access}$	2.22	10.30	*	5.65	*	-0.03	-10.89	*	-362.50	*
$\beta_{tt,pt,med.\_occ.}$	4.78	2.53	*	2.00	*	-0.09	-2.22	*	-26.83	*
$\beta_{tt,pt,high\_occ.}$	0.00	NA	NA	NA	NA	0.00	NA	NA	NA	NA
$\beta_{tt,coach,business}$	2.01	5.93	*	2.98	*	-0.03	-9.31	*	-334.15	*
$\beta_{tt,coach,leisure}$	1.43	5.05	*	1.52		-0.03	-9.95	*	-359.20	*
$\beta_{tt,coach,male}$	40.08	1.81		1.77		-0.46	-2.89	*	-9.11	*
$\beta_{tt,coach,h\_size}$	0.00	NA	NA	NA	NA	0.00	NA	NA	NA	NA
$\beta_{tt,coach,transfer}$	24.21	2.14	*	2.05	*	-0.30	-3.44	*	-14.83	*
$\beta_{tt,coach,waiting}$	10.66	5.17	*	4.69	*	-0.11	-7.63	*	-80.07	*

To be continued on the next page

	Multiplicative					MNL Compare				
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,coach,headway}$	0.21	2.90	*	-10.94	*	0.00	-5.99	*	-2348.30	*
$\beta_{tt,coach,med.\_occ.}$	28.49	1.89		1.82		-0.20	-1.93	*	-11.47	
$\beta_{tt,coach,high\_occ.}$	0.00	NA	NA	NA	NA	0.00	NA	NA	NA	NA
$\beta_{tt,car,commute}$	1.44	9.75	*	2.99	*	-0.03	-9.64	*	-343.34	*
$\beta_{tt,car,shop}$	0.76	6.61	*	-2.13	*	-0.01	-4.61	*	-343.40	*
$\beta_{tt,car,business}$	1.41	13.04	*	3.80	*	-0.02	-10.40	*	-506.46	*
$\beta_{tt,car,leisure}$	1.00	NA	NA	NA	NA	-0.02	-10.82	*	-551.78	*
$\beta_{tt,car,congestion}$	1.95	14.14	*	6.90	*	-0.03	-10.12	*	-347.30	*
$\beta_{tt,car,access}$	1.74	13.28	*	5.63	*	-0.03	-9.56	*	-369.77	*
$\beta_{tt,plane,business}$	1.62	5.63	*	2.16	*	-0.02	-2.83	*	-130.10	*
$\beta_{tt,plane,leisure}$	105.12	4.75	*	4.70	*	-0.66	-6.74	*	-16.89	*
$\beta_{tt,plane,waiting}$	2.06	1.93		0.99		0.01	1.18	*	-224.55	
$\beta_{tt,plane,access}$	1.37	1.88		0.50		0.00	0.13	*	-249.31	
$\beta_{cost,commute}$	9.66	8.63	*	7.73	*	-0.19	-7.06	*	-44.09	*
$\beta_{cost,shop}$	5.85	6.20	*	5.14	*	-0.12	-4.32	*	-39.63	*
$\beta_{cost,business}$	8.92	9.79	*	8.69	*	-0.09	-8.66	*	-108.59	*
$\beta_{cost,leisure}$	8.88	12.07	*	10.71	*	-0.14	-10.92	*	-88.88	*
μ_{mc}	2.32	17.42	*	9.91	*	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	7.03	17.57	*	15.08	*	2.41	11.39	*	6.66	*
$\mu_{rc,car}$	6.80	24.31	*	20.74	*	2.65	10.18	*	6.35	*
$\mu_{rel,pt}$	5.40	24.96	*	20.34	*	2.07	13.24	*	6.85	*
$\mu_{rel,car}$	5.13	31.71	*	25.52	*	1.99	10.23	*	5.08	*

To be continued on the next page

	Multiplicative					MNL Compare				
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rel,plane}$	12.29	7.14	*	6.56	*	1.28	5.95	*	1.30	

5.4 Latent Class Model

5.4.1 Methodology

Latent class models are a family of discrete choice models that allow to represent taste heterogeneity in the population while staying easy to interpret (Greene and Hensher, 2003). They work by postulating the existence of n_c *classes* of decision makers, each class following an MNL model to do decisions. The researcher can only model the *probability* that a decision maker pertains to one class or the other. The decision model thus becomes:

$$P(i \mid C) = \sum_c \pi_c \cdot P_c(i \mid C) \tag{5.7}$$

where:

- C is the choice set, $i \in C$ is the alternative
- π_c is the probability that the decision maker pertains to class c
- $P_c(i \mid C)$ is the choice probability for class c

In its simplest form, the class membership probabilities are constant across decision makers, but this is no requirement, and it can be useful to make the class membership probability depend on attributes of the decision maker. More sophisticated approaches make use of answers to attitudinal questions to improve the class membership model, by assuming that decision makers in each class give similar answers to this type of questions (Hurtubia *et al.*, 2014). The class membership probabilities (or their parameters) are free parameters of the model and are estimated together with the other parameters. The number of classes is a fixed parameter of the model. Greene and Hensher (2003) suggest starting from a maximum number of classes and decreasing the number until the difference in model fit is significant. This approach is very flexible: though often understood as “groups of decision makers with different utility functions”, the class can represent other types of variability, such as unobserved differences in choice/consideration set (Calastri *et al.*, forthcoming). Ideally, the utility functions for the different classes can be interpreted in intuitive categories (“car enthusiasts”, “cyclists”, *etc.*).

Such models are better estimated from panel data, where several decisions are observed for each respondent: one can take into account the fact that a decision maker is assumed to belong to the same class for all of its decision. The log-likelihood thus becomes:

$$LL(Y \mid \beta, \pi) = \sum_{n=1}^{N} \ln \left(\sum_{c \in C} \pi_{n,c} \cdot \prod_{t \in T_n} P(Y_{n,t} = i \mid \beta_c) \right) \tag{5.8}$$

where:

- n represents respondent id
- C represent the set of classes
- $\pi_{n,c}$ is the probability that respondent n belongs to class c
- T_n is the set of responses for respondent n
- $Y_{n,t}$ is respondent n's answer in situation t
- β_c is the part of β relevant for class c

Although what model works best depends on the application and dataset, Greene and Hensher (2003) argue that this kind of model as a strong potential for representing complex taste heterogeneity with relatively weak distributional assumptions, as compared to other approaches, such as the mixed logit.

In the context of VTT, this type of models can be of interest for the following reasons:

- It might simply be a better model of the true decision making processes, reducing bias in the estimates
- It allows to get an idea of variability of VTT within the population, by computing the VTT per class.

When computing the average VTT over choice situations in the dataset, it is possible to improve respondent classification by using their observed choices to refine the definition of their class membership probabilities, a process known a posterior class membership, given by the following formula:

$$\hat{\pi}_{n,c} = \frac{\pi_{n,c} \cdot \prod_{t \in T_n} P(Y_{n,t} = i \mid \beta_c)}{\sum_{s \in C} \pi_{n,s} \cdot \prod_{t \in T_n} P(Y_{n,t} = i \mid \beta_s)} \tag{5.9}$$

The model formulation used here uses the same formulation of the utility as in the base model, but without differentiating the travel time coefficients per purpose for bike and walk, as the limited number of observations for those modes did not allow estimating such models.

5.4.2 Results

Table 5.11 shows the estimates from the latent class model with 3 classes. A model with 2 classes was found to have a significantly lower model fit (estimation results are reported in Appendix A.3). From all the models in this work, this is the one with the best model fit. The weight parameters for class membership correspond to probabilities of 0.52 for class 1, 0.23 for class 2 and 0.25 for class 3. Class 1 seems to correspond to risk averse respondents as the parameters for the standard deviation are more strongly negative than in other classes. Class 2 seems to be mostly strong car users as travel time has a much lower disutility for this mode. Class 3 is more difficult to equate to an intuitive category. The signs of all parameters are significantly different from 0 and are as expected.

Table 5.11: Estimation Statistics Latent Class Model

Statistic	Value
Number of decision makers	3,069
Number of observations	43,856
Null log-likelihood	-36,353
Final log-likelihood	-21,603
Estimated parameters	173
ρ^2	0.41
Adjusted ρ^2	0.40
Akaike Information Criterion	43,552
Bayesian Information Criterion	45,056

Table 5.12: Estimates of the Latent Class Model

	Class 1			Class 2			Class 3		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
ω_{class_1}	0.720	6.93	*	–	–	–	–	–	–
ω_{class_2}	–	–	–	-0.079	-0.66		–	–	–
α_{walk}	-8.156	-5.33	*	1.432	2.44	*	-1.259	-0.96	
α_{bike}	-10.923	-3.11	*	2.507	0.71		76.731	198.81	*
α_{pt}	0.298	0.46		2.030	4.96	*	0.807	0.86	
α_{coach}	-3.416	-5.59	*	2.327	3.3	*	3.428	4.21	*
α_{car}	0.000	NA	NA	0.000	NA	NA	0.000	NA	NA
α_{plane}	3.064	2.05	*	7.362	3.47	*	1.490	0.63	
$\lambda_{inc,cost}$	0.007	0.05		-0.298	-2	*	-0.689	-3.01	*
$\lambda_{dist,time}$	-0.327	-8.63	*	-0.554	-13.87	*	-0.541	-120.45	*
$\lambda_{dist,cost}$	-0.678	-16.67	*	-0.551	-7.4	*	-0.925	-15.36	*
λ_{stdev}	-0.387	-5.12	*	-0.813	-3.37	*	-0.699	-3.67	*
$\lambda_{tt,transfer,pt}$	-0.155	-3.52	*	-0.396	-4.91	*	-0.238	-3.12	*
$\lambda_{tt,waiting,pt}$	-0.569	-4.49	*	-1.398	-7.24	*	-0.556	-6.28	*
$\lambda_{tt,access,pt}$	-0.515	-7.12	*	2.105	2.68	*	-0.578	-6.95	*
$\lambda_{tt,waiting,coach}$	-9.991	-1.41		-1.238	-7.28	*	-1.053	-3.6	*
$\lambda_{time,congestion,car}$	-0.427	-5.62	*	-0.651	-3.74	*	-0.684	-5.61	*
$\lambda_{time,access,car}$	-0.233	-2.45	*	1.880	1.5		-0.478	-2.55	*

To be continued on the next page

	Class 1			Class 2			Class 3		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
$\beta_{stdev,pt}$	-0.043	-4.66	*	-0.014	-1.63		-0.031	-2.72	*
$\beta_{stdev,car}$	-0.027	-6.13	*	-0.011	-1.48		-0.006	-2.11	*
$\beta_{stdev,coach}$	-0.028	-0.4		-0.003	-0.13		-0.049	-1.64	
$\beta_{stdev,plane}$	-0.036	-2.52	*	-0.055	-1.7		-0.020	-0.63	
$\beta_{tt,walk}$	-0.021	-1.94		-0.020	-6.2	*	-0.001	-0.28	
$\beta_{tt,bike}$	0.032	0.68		-0.048	-1.03		-0.985	-206.67	*
$\beta_{tt,pt,commute}$	-0.028	-5.07	*	-0.027	-5.14	*	-0.067	-5.35	*
$\beta_{tt,pt,shop}$	-0.036	-5.04	*	-0.021	-2.35	*	-0.071	-4.3	*
$\beta_{tt,pt,business}$	-0.031	-6.12	*	-0.015	-4.04	*	-0.054	-6.45	*
$\beta_{tt,pt,leisure}$	-0.034	-6.44	*	-0.025	-6.09	*	-0.069	-6.88	*
$\beta_{tt,pt,age}$	-0.030	-2.46	*	0.009	1.39		0.010	0.72	
$\beta_{tt,pt,transfer}$	-0.548	-10.34	*	-0.222	-5.2	*	-0.345	-5.52	*
$\beta_{tt,pt,waiting}$	-0.026	-3.45	*	-0.010	-1.87		-0.071	-6.23	*
$\beta_{tt,pt,headway}$	-0.006	-1.95		-0.007	-4.08	*	-0.006	-1.62	
$\beta_{tt,pt,access}$	-0.065	-7.28	*	0.000	0.43		-0.089	-7.39	*
$\beta_{tt,pt,med.\_occ.u}$	-0.109	-0.87		-0.267	-2.9	*	0.021	0.1	
$\beta_{tt,pt,high\_occ.}$	-0.143	-3	*	-0.094	-1.8		-0.021	-0.24	
$\beta_{tt,coach,business}$	-0.030	-5.11	*	-0.034	-3.61	*	-0.111	-5.82	*
$\beta_{tt,coach,leisure}$	-0.020	-3.17	*	-0.031	-3.9	*	-0.125	-5.57	*
$\beta_{tt,coach,male}$	0.039	0.08		-0.434	-1.43		-0.262	-0.64	
$\beta_{tt,coach,h\_size}$	0.012	2.44	*	0.038	0.28		-0.065	-0.38	
$\beta_{tt,coach,transfer}$	-0.977	-2.84	*	-0.017	-0.12		-0.515	-2.25	*

To be continued on the next page

	Class 1			Class 2			Class 3		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
$\beta_{tt,coach,waiting}$	-0.004	-0.34		-0.085	-3.43	*	-0.118	-3.55	*
$\beta_{tt,coach,headway}$	-0.006	-3.98	*	-0.001	-1.94		-0.003	-3.02	*
$\beta_{tt,coach,med.\_occ.}$	0.262	0.78		-0.248	-1.22		-0.657	-2.46	*
$\beta_{tt,coach,high\_occ.}$	-0.643	-2.56	*	0.163	0.99		-0.359	-1.57	
$\beta_{tt,car,commute}$	-0.040	-3.59	*	-0.017	-4.37	*	-0.076	-5.22	*
$\beta_{tt,car,shop}$	-0.029	-6.27	*	0.008	1.33		-0.039	-3.89	*
$\beta_{tt,car,business}$	-0.045	-8.49	*	-0.009	-2.8	*	-0.034	-4.02	*
$\beta_{tt,car,leisure}$	-0.026	-6.7	*	-0.006	-2.32	*	-0.077	-8.5	*
$\beta_{tt,car,congestion}$	-0.047	-7.77	*	-0.023	-5.04	*	-0.058	-6	*
$\beta_{tt,car,access}$	-0.052	-7.92	*	-0.001	-0.4		-0.051	-5.32	*
$\beta_{tt,plane,business}$	-0.045	-3.55	*	-0.058	-1.78		-0.046	-2.85	*
$\beta_{tt,plane,leisure}$	-1.013	-4.99	*	-0.708	-1.81		-1.268	-3.43	*
$\beta_{tt,plane,waiting}$	-0.020	-1.54		-0.052	-2.32	*	-0.002	-0.08	
$\beta_{tt,plane,access}$	-0.025	-2.23	*	-0.021	-1.65		-0.017	-1.11	
$\beta_{cost,commute}$	-0.433	-7.8	*	-0.086	-1.88		-0.275	-1.99	*
$\beta_{cost,shop}$	-0.230	-4.41	*	-0.176	-3.43	*	-0.340	-3.32	*
$\beta_{cost,business}$	-0.130	-5.77	*	-0.033	-2.46	*	-0.688	-5.96	*
$\beta_{cost,leisure}$	-0.345	-4.72	*	-0.117	-4.72	*	-0.322	-4.19	*
common parameter									
inc_{miss}	0.650	-0.66		–	–	–	–	–	–
μ_{mc}	1.000	NA		–	–	–	–	–	–

To be continued on the next page

	Class 1			Class 2			Class 3		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
$\mu_{rc,pt}$	1.497	10.58	*	–	–	–	–	–	–
$\mu_{rc,car}$	2.431	9.53	*	–	–	–	–	–	–
$\mu_{rel,pt}$	1.175	11.24	*	–	–	–	–	–	–
$\mu_{rel,car}$	1.470	11.19	*	–	–	–	–	–	–
$\mu_{rel,plane}$	0.955	6.83	*	–	–	–	–	–	–

5.5 VTT Comparison

5.5.1 Computation of the VTT and their Uncertainty

As mentioned before, the VTT is the ratio of the derivatives of the utility with regard to time and cost. In the case of the base model, the VTT for mode *m* and purpose *p* is thus:

$$VTT = \left(\frac{inc}{\overline{inc}}\right)^{-\lambda_{inc,c}} \cdot \left(\frac{dist}{\overline{dist}}\right)^{\lambda_{dist,t}-\lambda_{dist,c}} \cdot \frac{\beta_{tt,m,p}}{\beta_{tc,p}} \tag{5.10}$$

Due to the interactions, this value is dependent on the income of the decision maker and the distance of the trip. The average VTT thus depends on the joint distribution of income and travelled distances across the population. Thus, the values reported are the weighted mean of those VTT across the reference trips of the respondents in the dataset. The weighting takes into account the bias that was introduced by the survey design. This formulation is also valid for the multiplicative case.

In the latent class formulation, this formulation gives one VTT per class. The expected VTT for each respondent is then the sum of those VTTs, weighted by the posterior class membership probabilities following Eq. (5.9).

As a function of the estimates, the VTT comes with two types of errors: estimation error and data error. Although estimating the error due to the data is difficult and requires strong assumption about the distribution of those errors, robust methodologies are available in the literature to estimate the estimation error for arbitrary differentiable functions of the estimates. Daly *et al.* (2012) show that the "Delta method", a widely used method for this purpose, does give maximum likelihood estimates of the variance of differentiable functions of the estimates. Given a vector-valued function Φ of the estimates and the covariance matrix Ω of those estimates, the Delta method estimates the covariance matrix of Φ as:

$$cov(\Phi) = \Phi'^{T}\Omega\Phi' \tag{5.11}$$

where Φ' is the Jacobian of Φ.

In the case of Eq. (5.10), the variance is a function of trip distance and decision maker's income. It thus allows to estimate the variance of the VTT for each individual easily, but makes it difficult to estimate the variance of the average VTT, as income and travel distance are correlated and one cannot assume that the errors on VTT are independent across respondents. Thus, in the results below, the standard error used for the computation of the 95% confidence intervals is the standard error computed for average income and travel distance. The true standard error might differ, but those values already give a good idea of the level of confidence one can have in the derived VTT.

5.5.2 VTT Comparison of the Different Approaches

In this section, the VTT derived from the various models are compared and used to propose a description of potential advantages of the various approaches for VTT estimation. Of course, the results are specific to the particular dataset at hand, and might not be generalisable to every possible dataset. However, the results presented here should provide guidance in designing future VTT surveys and models.

Table 5.13 shows the VTT derived from the base model, for each combination of mode and purpose, together with their standard error and 95% confidence intervals. All values are in €/h. The first thing to note is how wide the confidence intervals are: of the order of 5€/h or more. Such uncertainty on the value of time can be problematic if the values are to be used for appraisal. The values for business are high, as it could be expected for trips that are typically paid by the employer. The value for commute is quite similar for car and public transport, whereas the value for shop differs a lot, being about twice as high for public transport. One might try to explain it with characteristics of the mode, such as the discomfort of carrying goods in public vehicles.

Table 5.13: VTT Base Model

		VTT	se	CI_left	CI_right
Car	Commute	7.17	1.09	5.03	9.31
	Shop	4.20	1.64	0.98	7.42
	Business	12.61	2.26	8.17	17.04
	Leisure	7.64	1.06	5.55	9.72
PT	Commute	5.56	0.99	3.63	7.49
	Shop	8.45	3.25	2.08	14.82
	Business	9.78	1.86	6.13	13.42
	Leisure	7.28	1.00	5.32	9.23
Coach	Business	16.00	3.54	9.06	22.95
	Leisure	10.12	2.02	6.15	14.09
Plane	Business	18.13	8.79	0.90	35.36
	Leisure	11.24	5.18	1.08	21.40

Table 5.14 presents the VTT for each group of NUTS 3 regions, grouped by income quantile. Figures 5.10 and 5.11 present the results graphically by trip purpose. Similarly to the income effects pictured in Fig. 5.8, there is no clear monotonous patterns with increasing regional income. This seems to indicate that the region income does not have a big influence on the valuation of travel time, be it through social norms or purchasing power effects. The uncertainties are also much higher, due to the much smaller sample sizes.

Table 5.14: VTT by Disposable Income Quintile

		VTT	se	CI_left	CI_right	VTT	se	CI_left	CI_right
		Q1 <= 18,223 Euro/year				Q2 > 18,223 – <= 19,781 Euro/year			
Car	Commute	5.40	1.85	1.76	9.03	4.16	1.74	0.74	7.58
	Shop	9.51	8.13	-6.43	25.44	0.33	3.33	-6.20	6.86
	Business	6.81	2.36	2.18	11.44	5.96	2.54	0.98	10.93
	Leisure	3.99	0.96	2.10	5.88	3.71	1.34	1.08	6.34
PT	Commute	3.93	2.09	-0.16	8.01	3.86	1.42	1.07	6.65
	Shop	10.25	8.35	-6.11	26.60	7.89	6.88	-5.59	21.37
	Business	3.42	2.32	-1.13	7.97	6.52	2.43	1.76	11.29
	Leisure	4.44	1.07	2.34	6.54	4.17	1.51	1.21	7.13
Coach	Business	8.79	6.98	-4.89	22.48	4.84	4.60	-4.18	13.85
	Leisure	6.53	3.86	-1.04	14.10	5.72	3.70	-1.53	12.98
Plane	Business	14.52	9.07	-3.26	32.29	8.84	7.57	-6.00	23.69
	Leisure	7.80	4.87	-1.75	17.34	6.10	4.95	-3.60	15.79
		Q3 > 19,781 – <= 21,084 Euro/year				Q4 > 21,084 – <= 22,663 Euro/year			
Car	Commute	7.45	2.52	2.51	12.38	5.10	1.30	2.56	7.65
	Shop	-0.84	5.39	-11.41	9.72	7.47	8.29	-8.78	23.72
	Business	18.23	10.17	-1.70	38.16	8.53	3.90	0.90	16.17

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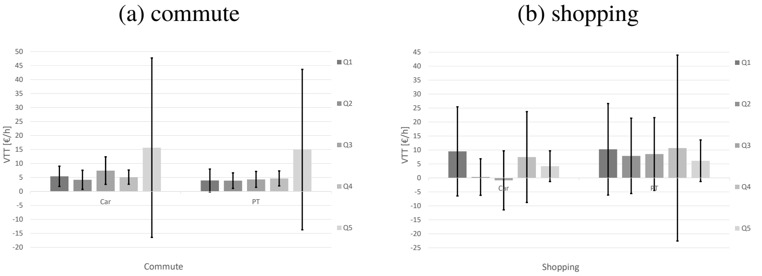
		VTT	se	CI_left	CI_right	VTT	se	CI_left	CI_right
	Leisure	10.89	3.59	3.85	17.93	5.09	1.52	2.12	8.07
PT	Commute	4.30	1.45	1.46	7.15	4.65	1.38	1.96	7.35
	Shop	8.56	6.64	-4.45	21.56	10.69	16.95	-22.54	43.92
	Business	11.98	6.62	-1.00	24.97	9.60	4.41	0.97	18.24
	Leisure	9.02	2.97	3.19	14.85	5.83	2.18	1.55	10.11
Coach	Business	21.46	13.15	-4.32	47.24	14.25	7.85	-1.14	29.63
	Leisure	13.93	5.43	3.29	24.57	6.14	3.18	-0.09	12.36
Plane	Business	30.22	26.82	-22.35	82.78	18.38	13.22	-7.54	44.30
	Leisure	19.26	12.46	-5.16	43.67	10.80	6.45	-1.85	23.44
				Q5 > 22,663 Euro/year					
Car	Commute	15.64	16.39	-16.48	47.77				
	Shop	4.21	2.80	-1.28	9.71				
	Business	12.10	3.79	4.68	19.53				
	Leisure	6.81	1.97	2.94	10.68				
PT	Commute	14.97	14.65	-13.74	43.69				
	Shop	6.15	3.79	-1.28	13.59				
	Business	8.28	2.66	3.08	13.49				
	Leisure	5.17	1.58	2.08	8.26				
Coach	Business	11.89	6.16	-0.19	23.97				
	Leisure	6.08	3.21	-0.21	12.37				
Plane	Business	9.67	9.41	-8.76	28.11				
	Leisure	5.65	5.05	-4.25	15.56				

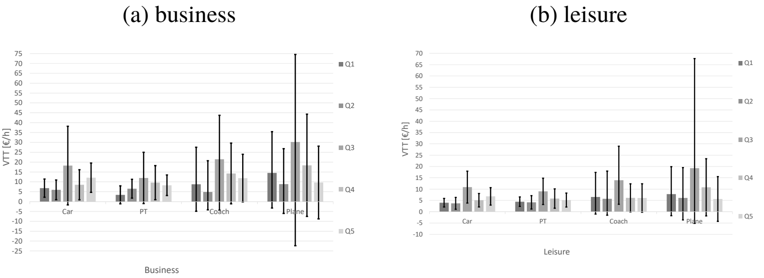
Figure 5.10: VTT comparison commute and shopping by Disposable Income Quintiles



(a) commute

(b) shopping

Figure 5.11: VTT comparison business and leisure by Disposable Income Quintiles



(a) business

(b) leisure

Table 5.15 shows the VTT estimated for the BIK regions and Figs. 5.10 and 5.11 the graphics. Clear trends can be observed. First, The VTT for commute increases with increasing population, which might be linked to different income distributions or type of professional occupation. The business value of time follows the same trend, with the exception of the small BIK regions, where the VTT is highest both for car and public transport. This might be a problem of sample size, as indicated by the high standard error on the estimate. This indicates the potential importance of tailoring the VTT used based on the area of application.

Table 5.15: VTT by BIK Region

		VTT	se	CI_left	CI_right	VTT	se	CI_left	CI_right
		500.000+ inhabitants				100.000 - 499.999 inhabitants			
Car	Commute	7.94	4.66	-1.20	17.07	6.03	1.71	2.68	9.39
	Shop	3.65	2.06	-0.40	7.69	5.32	3.18	-0.91	11.54
	Business	8.35	2.67	3.12	13.58	7.60	2.42	2.86	12.33
	Leisure	4.68	1.32	2.10	7.27	6.02	1.37	3.33	8.71
PT	Commute	8.09	4.41	-0.54	16.73	4.20	1.39	1.48	6.92
	Shop	6.84	4.03	-1.06	14.74	9.96	5.09	-0.02	19.94
	Business	7.30	2.16	3.07	11.53	5.22	2.47	0.39	10.05
	Leisure	5.01	1.26	2.54	7.47	6.39	1.44	3.56	9.23
Coach	Business	10.02	4.45	1.30	18.74	8.19	3.92	0.50	15.88
	Leisure	5.99	2.49	1.12	10.86	7.00	2.68	1.74	12.26
Plane	Business	7.25	6.98	-6.44	20.94	8.12	5.03	-1.73	17.98
	Leisure	4.28	4.00	-3.57	12.13	6.80	3.38	0.18	13.42
		50.000 - 99.999 inhabitants				1 - 49.999 inhabitants			
Car	Commute	5.94	2.14	1.74	10.14	5.50	1.46	2.65	8.35
	Shop	3.38	2.67	-1.84	8.61	20.71	51.64	-80.50	121.91
	Business	5.76	1.66	2.50	9.02	10.59	4.55	1.68	19.50
	Leisure	7.44	2.62	2.30	12.58	6.64	1.88	2.96	10.32
PT	Commute	3.39	2.23	-0.98	7.75	3.57	1.09	1.43	5.71

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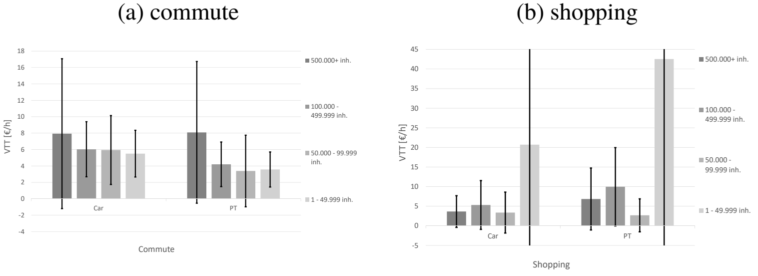
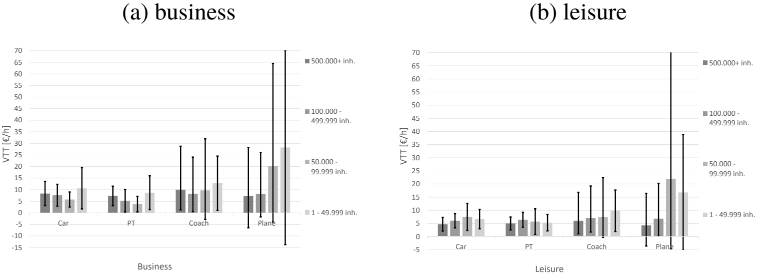
		VTT	se	CI_left	CI_right	VTT	se	CI_left	CI_right
	Shop	2.69	2.15	-1.52	6.89	42.54	106.00	-165.21	250.30
	Business	3.77	1.72	0.40	7.13	8.71	3.74	1.38	16.04
	Leisure	5.69	2.51	0.77	10.60	5.27	1.58	2.17	8.37
Coach	Business	9.71	6.41	-2.85	22.26	12.80	5.99	1.05	24.54
	Leisure	7.36	3.91	-0.31	15.03	9.81	4.03	1.90	17.71
Plane	Business	20.19	12.32	-3.95	44.33	28.22	21.40	-13.73	70.16
	Leisure	21.91	13.53	-4.62	48.44	16.81	11.25	-5.23	38.86

Figure 5.12: VTT comparison commute and shopping by BIK region


(a) commute

(b) shopping

Figure 5.13: VTT comparison business and leisure by BIK region


(a) business

(b) leisure

Table 5.16 compares the results from the purpose specific models with the base model. The purpose specific models exhibit in general less uncertainty in the derived VTT. The values of time also tend to be more uniform for a given purpose, for instance eliminating the strong difference of VTT between car and public transport for shopping. The combination of lower uncertainty and reduction of surprising values makes those results more trustworthy than the ones of the joint model. This confirms the analysis from Section 5.1.3, which showed that joint estimation artificially constrains travel length sensitivity, in particular for business purpose.

Table 5.17 presents the VTT for the multiplicative formulation, together with the ones from the base model estimated for comparison. The values of time do

Table 5.16: VTT Purpose Specific Models

		Purpose Specific				Base Model			
		VTT	se	CI_l	CI_r	VTT	se	CI_l	CI_r
Car	Commute	9.87	1.03	7.86	11.88	7.17	1.09	5.03	9.31
	Shop	4.16	1.15	1.90	6.42	4.20	1.64	0.98	7.42
	Business	8.58	1.20	6.22	10.93	12.61	2.26	8.17	17.04
	Leisure	7.20	1.19	4.87	9.53	7.64	1.06	5.55	9.72
PT	Commute	7.50	0.93	5.67	9.32	5.56	0.99	3.63	7.49
	Shop	3.47	1.20	1.12	5.81	8.45	3.25	2.08	14.82
	Business	8.22	1.66	4.96	11.47	9.78	1.86	6.13	13.42
	Leisure	6.70	1.13	4.48	8.93	7.28	1.00	5.32	9.23
Coach	Business	15.66	3.18	9.43	21.89	16.00	3.54	9.06	22.95
	Leisure	15.69	3.69	8.46	22.92	10.12	2.02	6.15	14.09
Plane	Business	14.95	6.08	3.02	26.87	18.13	8.79	0.90	35.36
	Leisure	9.06	4.74	-0.23	18.36	11.24	5.18	1.08	21.40

not differ substantially, except for business, where the multiplicative formulation gives much lower estimates. The standard errors on the estimates do not differ substantially between the two models. This makes the multiplicative formulation potentially better suited for this dataset.

Table 5.17: VTT Multiplicative and Compare MNL Model

		Multiplicative				MNL Compare			
		VTT	se	CI_l	CI_r	VTT	se	CI_l	CI_r
Car	Commute	5.54	0.92	3.73	7.35	5.98	1.10	3.82	8.14
	Shop	4.80	1.63	1.61	7.98	4.40	1.81	0.85	7.94
	Business	5.86	0.79	4.31	7.42	9.56	1.87	5.90	13.21
	Leisure	4.18	0.56	3.08	5.27	5.64	0.81	4.06	7.22
PT	Commute	5.38	1.00	3.42	7.33	4.59	0.97	2.69	6.49
	Shop	7.68	2.48	2.82	12.55	8.47	3.37	1.85	15.08
	Business	6.23	0.97	4.32	8.13	7.25	1.57	4.18	10.33
	Leisure	5.56	0.78	4.03	7.08	5.29	0.77	3.79	6.80
Coach	Business	8.34	2.16	4.11	12.58	13.06	2.88	7.41	18.70
	Leisure	5.97	1.95	2.15	9.80	8.03	1.44	5.21	10.86
Plane	Business	6.75	2.19	2.46	11.03	10.13	5.72	-1.08	21.34
	Leisure	6.78	2.01	2.85	10.71	6.27	3.37	-0.34	12.89

Table 5.18 show the estimates for the latent class formulation. The values are comparable with the values from the base model, although the standard errors are

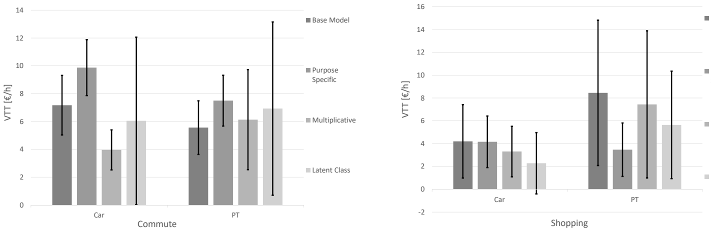
bigger. Those bigger standard errors probably come from the representation of heterogeneity that is part of the model: different classes have different values of the VTT, which create a base level of variance that is not part of other models. The question that arises is whether one could leverage this better representation of heterogeneity, rather that having it as a problem? The analysis of the results showed that the model seemed to identify interpretable traits, such as risk aversion or attachment to driving, which might be good to have in the model. Using parameterized class membership probabilities could help adapt the value of time to the effected sub-population better than the interaction terms, leading to better estimate. For the models presented here, however, the base model should probably be preferred, due to its lower uncertainty, even if the latent class model significantly improves the model fit.

Figures 5.14 and 5.15 show the graphical comparison of all the described models by trip purpose.

Table 5.18: VTT Latent Class Model

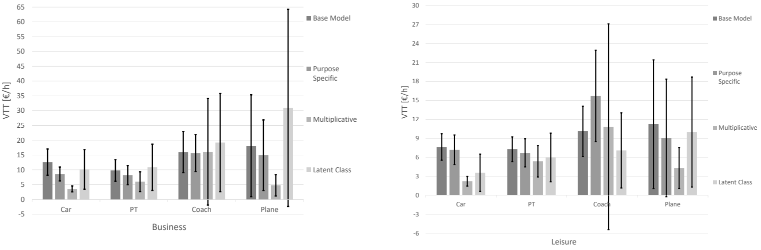
		Latent Class				Base Model			
		VTT	se	CI_l	CI_r	VTT	se	CI_l	CI_r
Car	Commute	6.05	3.07	0.03	12.06	7.17	1.09	5.03	9.31
	Shop	2.28	1.37	-0.41	4.97	4.20	1.64	0.98	7.42
	Business	10.12	3.41	3.44	16.80	12.61	2.26	8.17	17.04
	Leisure	3.57	1.50	0.63	6.51	7.64	1.06	5.55	9.72
PT	Commute	6.93	3.18	0.70	13.15	5.56	0.99	3.63	7.49
	Shop	5.64	2.40	0.93	10.35	8.45	3.25	2.08	14.82
	Business	10.86	3.99	3.04	18.68	9.78	1.86	6.13	13.42
	Leisure	5.98	1.96	2.13	9.83	7.28	1.00	5.32	9.23
Coach	Business	19.20	8.46	2.61	35.79	16.00	3.54	9.06	22.95
	Leisure	7.09	3.03	1.15	13.03	10.12	2.02	6.15	14.09
Plane	Business	30.93	16.99	-2.37	64.24	18.13	8.79	0.90	35.36
	Leisure	9.99	4.44	1.30	18.69	11.24	5.18	1.08	21.40

Figure 5.14: VTT comparison commute and shopping


(a) commute

(b) shopping

Figure 5.15: VTT comparison business and leisure


(a) business

(b) leisure

Chapter 6

Part II Valuing Travel Time: Long-term Decisions

The previous chapter covered the models of the short-term experiments of the *German Value of Time and Value of Reliability Study*. Those decisions can be called "short-term", in the sense that they only have an effect on the decision-maker's utility for a short time frame. For instance, the choice of a sub-optimal route might lead to being late at work on a particular day, but the decision maker has the possibility to make a different decision the next day in order to be on time. On the other side, the decision-maker is able to change a decision once to adapt to particular circumstances (an accident, bad weather), without long-lasting consequences. Most value of time studies consider such short-term decisions, framing their experiments around a situation where respondents are presented with variations to travel time and cost of different modes or routes (see e.g. Wardman *et al.*, 2016, for an overview of value of time studies in Europe). However, there exist other types of decision that have much longer lasting effects. Consider for instance the choice of a residential location. This choice will have long-lasting consequences on the travel patterns of the decision maker, by changing their choice set for future short-term decisions, over periods of time that are typically several years or even decades long. Transportation projects have the same kind of long-lasting consequences, by durably modifying the choice set of travellers. Thus, when estimating willingness-to-pay for policy appraisal, new questions arise: is the focus on short-term decisions most appropriate? Should one consider the willingness-to-pay in the new choice context offered to travellers, or the willingness-to-pay of travellers when they make decisions with a similar time frame?

Beck *et al.* (2017) put this differently, by arguing that travellers anyway have very little possibility to influence their commute in the short-term, but can in the long-term, for instance by changing their residence. From this argument, long-term choices could be more informative regarding the willingness to pay for commute time savings. Beck *et al.* (2017) refers to a recent stream of empirical studies that tries to understand and explain everyday travel behaviour as a routine activity changing due to key events such as residential relocation or workplace decisions. In this context a long-term decision can be defined as a more permanent decision which have an effect on every day travel. Here, the authors compare long and short travel time valuations, using the Swedish stated preference data. In this survey, respondents first faced a set of choices where they had to make cost and travel time trade-offs for their commute with public transport or car; then, the respondents had an additional set of choices, where they considered increases in travel time, in return for a higher salary (Swärdh and Algers, 2016). The authors found no differences in scale between the short-term and long-term trade-off scenarios, but discovered a significantly higher travel time valuation in the long run. Those results suggest that the time horizon over which the choice experiment is being framed results in significantly different values of time.

Müggenburg *et al.* (2015) review the theoretical framework and the most important studies investigating mobility behaviour in a long-term choice context. Schirmer *et al.* (2014) give a comprehensive overview of residential location choice literature and show that travel time, commuting and employment changes are significant determinants of choices.

The aim of this chapter is to contribute to the investigation of the dependence of travel time valuation on the time horizon of the choices. The respondents were presented a series of choice situations including short-term decisions such as route and mode choice, as well as long-term decisions with residential and workplace location. In particular, the long-term experiments asked the respondent to make trade-offs between transport measures and a set of workplace or residence attributes. A first objective is to verify whether the kind of patterns identified by (Beck *et al.*, 2017) can be found in this new dataset. More importantly, while (Beck *et al.*, 2017) only had access to one kind of long-term decision (workplace change), the German data gives access to choices both in terms of residence and workplace. The second objective here is thus to compare the values obtained from those two types of decisions, to give an indication of whether there is one "long-term willingness to pay", or whether this value also depends on the type of decision. Finally, the substantial number of residence and workplace attributes in the German data allows to investigate the relative importance of travel related variables compared to other attributes of the locations, and how this influences the valuation of time.

The remainder of this chapter is structured as follows: The next section is the description of the method used to estimate a joint short- and long-term model (Section 6.1); Section 6.2 outlines the results of the modelling before presenting the final discussion and outlook in Section 6.3.

6.1 Methodology

To test the influence of the type of choice experiment on the value of time, a joint model combining multinomial logit models for all relevant experiments was estimated. Using a joint modelling approach allows one to have the same coefficient part of the utility for different experiments. This allows one to make use of as much information as possible, and also provides an intuitive framework to test differences in valuation depending on the kind of experiments.

The following sections describe the utility functions for all experiments. Parameters that have the same name in various experiments are shared, taking the same value in all utilities they appear in.

The model focuses on workplace choice as a long-term decision, and thus for the short-term experiments, only commuting situations are considered.

Residential choice decisions would also be interesting to analyse, in particular to compare the resulting time valuations with the work case. Unfortunately, analysis revealed that the residential choice experiments in the survey did not include high enough variations in travel time for travel time to matter in the decision. This makes those experiments unsuitable for the estimation of travel time valuations.

In the questionnaires, two time horizons were used to specify travel times and monetary costs, namely per trip or per month. In particular, in the long-term experiments, the two time horizons were used simultaneously, with travel times expressed per trip but monetary travel costs per month. In the model, all times and monetary costs are expressed as averages per month, using the average 4.73 work tours per week from the revealed preferences part of the survey, and an average of 4.28 weeks per month. Work tours are assumed to consist of two identical trips in opposite directions.

In order to be able to compare the models for long and short-term, some variables of the short-term experiments had to be ignored. In particular, only the door-to-door travel time is used, even though more detailed descriptions are available from the short-term experiments. This simplification did not have a substantial impact on the resulting short-term values of time computed elsewhere from the full range of attributes available in the short term experiments, *e.g.* in Table 5.16.

All utilities include individual income interaction terms for time and monetary cost sensitivity. For a given decision maker i, it is expressed as follows, with *type* taking the values *cost* and *time*:

$$\psi_{i,type} = \left(\delta_{i,inc} \cdot \frac{\mathrm{inc}_i}{\overline{\mathrm{inc}}} + (1 - \delta_{i,inc}) \cdot \mathrm{inc}_{miss}\right)^{\lambda_{type}} \tag{6.1}$$

where

- $\delta_{i,inc}$ takes value 1 if respondent i reported his income, 0 otherwise
- inc_i is the reported income of respondent i, and $\overline{\text{inc}}$ the average income over all respondents
- inc_{miss} is a parameter representing the average income of all respondents that did not report their income, and is estimated together with the other parameters of the model
- λ_{type} is a parameter controlling the degree of non-linearity of the income effect

6.1.1 Mode Choice

The utility for mode m in {car, walk, bike} is as follows:

$$U_{i,m} = \mu_{mc} \cdot (\alpha_m + \psi_{i,time} \cdot \beta_{tt,m} \cdot \text{tt}_m + \psi_{i,cost} \cdot \beta_{cost} \cdot c_m) \tag{6.2}$$

where

- μ_{mc} is the scale for the mode choice experiment
- α_m is the alternative specific constant for mode m
- $\beta_{tt,m}$ is the travel time coefficient for mode m
- tt_m is the door-to-door travel time with mode m
- β_{cost} is the monetary cost coefficient
- c_m is the total travel monetary cost for mode m (always 0 for walk and bike)

Public transport uses the same formulation, with the addition of the term $\beta_{trans} \cdot n_{trans}$, that accounts for the number of transfers.

6.1.2 Car Route Choice

The utility for route r is as follows:

$$U_{i,r} = \mu_{rc,car} \cdot (\psi_{i,time} \cdot \beta_{tt,car} \cdot \text{tt}_r + \psi_{i,cost} \cdot \beta_{cost} \cdot c_r) \tag{6.3}$$

where

- $\mu_{rc,car}$ is the scale for the car route choice experiment
- tt_m is the door-to-door travel time with route r
- c_r is the total travel monetary cost for mode r (always 0 for walk and bike)

6.1.3 Public Transport Route Choice

The utility in the public transport route choice is identical to the one of the car route choice, with the addition of the number of transfer as in the mode choice experiment.

6.1.4 Car and Public Transport Reliability

The utilities for the reliability experiments are identical to the ones in the normal route choice experiments ignoring reliability indicators (see Ehreke *et al.*, 2015, for detailed results on the value of reliability).

6.1.5 Workplace Choice

The travel costs and times in the long-term experiments are expressed on a per-mode, per-purpose basis. To be able to include the other monthly monetary value (rent or salary), one needs to aggregate those costs. This is done by integrating the probability of choosing car or public transport for a given purpose, as coming from the mode choice model, ignoring the number of transfers:

$$P_{i,m} = \frac{e^{U_{i,m}}}{e^{U_{i,car}} + e^{U_{i,pt}}} \tag{6.4}$$

The utility of a workplace alternative a in {current,new} is as follows:

$$U_{i,a} = \mu_{wp} \cdot \left(\begin{array}{l} \alpha_a + \\ \psi_{i,time} \cdot \left(\begin{array}{l} P_{i,car} \cdot \kappa_{tt,car} \cdot \beta_{tt,car} \cdot \mathrm{tt}_{car} + \\ P_{i,pt} \cdot \kappa_{tt,pt} \cdot \beta_{tt,pt} \cdot \mathrm{tt}_{pt} \end{array} \right) + \\ \psi_{i,cost} \cdot \beta_{cost} \cdot (P_{i,car} \cdot c_{car} + P_{i,pt} \cdot c_{pt} - \mathrm{salary}_a) + \\ \beta_{industry} \cdot \delta_{industry} + \\ \beta_{company} \cdot \delta_{company} \end{array} \right) \tag{6.5}$$

where

- μ_{wp} is the scale for the workplace choice experiment
- α_a is the alternative specific constant for alternative a
- $\kappa_{tt,m}$ is a parameter indicating the difference between the long-term experiment and the short-term experiments in terms of travel time valuations. If this term is not statistically different from 1, the two kind of experiments yield equivalent values of time

- $\beta_{industry}$ is the value of changing industry
- $\beta_{company}$ is the value of changing company
- $X_{current}$ indicates the value of attribute X for the current workplace, which is always presented as an alternative (do not change job)
- X_{new} indicates the value of attribute X for the (hypothetical) new workplace

6.2 Results

To test the influence of considering only salary gains or losses and gains on the value of time, two models were estimated: one with the full dataset, and one with only those workplace choice situations where the "new" alternative resulted in a salary gain. A model with only salary losses could not be estimated, due to the low number of situations where the new situation was chosen, as pictured on Fig. 6.1.

Figure 6.1: Choice of Workplace Alternative as a Function of Salary Gains and Losses

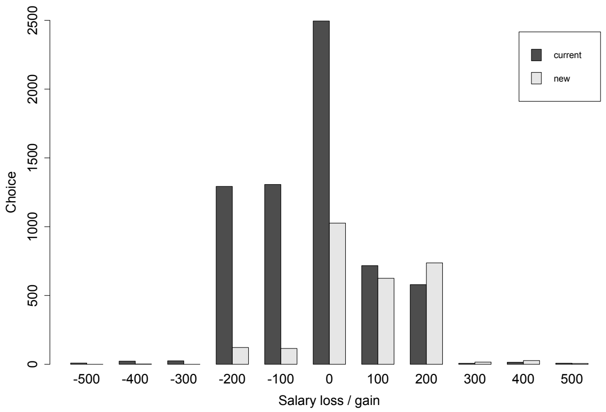


Table 6.1 shows the basic statistics of the estimation.

Table 6.2 and Table 6.3 show the estimates and indicates which parameters are significantly different from zero or one, depending on the case. The significance levels take the intra-personal correlation of error terms into account. All the signs

Table 6.1: Estimation Statistics

Statistic	Value (all)	Value (salary gains)
Number of decision makers	1,297	1,295
Number of observations	15,960	13,064
Estimated parameters	21	21
Null log-likelihood	-11,951	-9,943
Final log-likelihood	-8,979	-8,107
ρ^2	0.25	0.18
Adjusted ρ^2	0.25	0.18
Akaike Information Criterion	18,000	16,256
Bayesian Information Criterion	18,162	16,413

are as expected. Individual income does not seem to have an effect on travel time valuation (λ_{cost} not significantly different from 0).

Most short-term experiments share the same scale as the estimated μ are not significantly different from one. For the workplace experiment the scale is significantly different from one and below one indicating more random choices than in the short-term experiments. Comparing the valuation of time in long- and short-term experiments the $\kappa_{tt,pt,work}$ and $\kappa_{tt,car,work}$ show that additional commute travel time is perceived less negatively in the long run.

Attributes of the workplace, such as budget managed or size of the team, did not have significant effect in any estimated formulation, even controlling for the current value of the attribute (to test the hypothesis that the budget managed only matters for respondents who already have this kind of responsibility). They were thus removed from the final formulation.

Table 6.2: Estimates of the Joint Model

Parameter	Estimate	Rob. Std. Err.	against	Rob. t-stat	Sign.
α_{walk}	0.7563	0.6473	0	1.17	
α_{bike}	1.5769	0.4186	0	3.77	*
α_{pt}	-0.7374	0.2567	0	-2.87	*
λ_{cost}	-0.1583	0.1165	0	-1.36	

To be continued on the next page

Parameter	Estimate	Rob. Std. Err.	sign. against	Rob. t-stat	Sign.
inc_{miss}	7.5032	11.7652	0	0.64	
$\beta_{tt,walk,work}$	-0.0752	0.0261	0	-2.88	*
$\beta_{tt,bike,work}$	-0.2152	0.0255	0	-8.43	*
$\beta_{tt,pt,work}$	-0.0950	0.0138	0	-6.90	*
β_{trans}	-0.3560	0.0480	0	-7.41	*
$\beta_{tt,car,work}$	-0.1244	0.0186	0	-6.67	*
β_{cost}	-0.0133	0.0023	0	-5.73	*
$\beta_{industry}$	-0.8510	0.1840	0	-4.62	*
$\beta_{company}$	-0.6535	0.1452	0	-4.50	*
$\alpha_{new,work}$	-1.2932	0.2543	0	-5.09	*
$\mu_{rc,pt}$	0.8336	0.1916	1	-0.87	
$\mu_{rc,car}$	0.8193	0.1779	1	-1.02	
$\mu_{rel,pt}$	0.9082	0.1411	1	-0.65	
$\mu_{rel,car}$	0.6118	0.1263	1	-3.07	*
μ_{wp}	0.5318	0.0940	1	-4.98	*
$\kappa_{tt,pt,work}$	0.4669	0.1239	1	-4.30	*
$\kappa_{tt,car,work}$	0.5466	0.1266	1	-3.58	*

Table 6.3: Estimates of the Joint Model (Gains Only)

Parameter	Estimate	Rob. Std. Err.	against	Rob. t-stat	Sign.
α_{walk}	0.7646	0.6400	0	1.19	
α_{bike}	1.6011	0.4196	0	3.82	*
α_{pt}	-0.6536	0.2450	0	-2.67	*
λ_{cost}	-0.1178	0.0630	0	-1.87	
inc_{miss}	60.8755	121.7159	0	0.50	
$\beta_{tt,walk,work}$	-0.0750	0.0261	0	-2.87	*
$\beta_{tt,bike,work}$	-0.2158	0.0253	0	-8.52	*
$\beta_{tt,pt,work}$	-0.0973	0.0133	0	-7.29	*
β_{trans}	-0.3682	0.0492	0	-7.48	*
$\beta_{tt,car,work}$	-0.1237	0.0180	0	-6.86	*
β_{cost}	-0.0135	0.0022	0	-6.02	*
$\beta_{industry}$	-1.4780	0.3525	0	-4.19	*

To be continued on the next page

Parameter	Estimate	Rob. Std. Err.	sign. against	Rob. t-stat	Sign.
$\beta_{company}$	-0.8376	0.2061	0	-4.06	*
$\alpha_{new,work}$	-1.1415	0.2584	0	-4.42	*
$\mu_{rc,pt}$	0.8176	0.1847	1	-0.99	
$\mu_{rc,car}$	0.8245	0.1751	1	-1.00	
$\mu_{rel,pt}$	0.8858	0.1337	1	-0.85	
$\mu_{rel,car}$	0.6160	0.1242	1	-3.09	*
μ_{wp}	0.3801	0.0743	1	-8.35	*
$\kappa_{tt,pt,work}$	0.6393	0.1845	1	-1.95	
$\kappa_{tt,car,work}$	0.7076	0.1907	1	-1.53	

The values of times derived from the model are summarized in Table 6.4. As already indicated by the κ estimates the short-term values of time are higher than the ones from the workplace choice experiment. Beck *et al.* (2017) found the opposite result. The two major differences of the data used here compared to theirs is the availability of other factors than salary and travel time, and the inclusion of options with lower salary than the current salary. Even ignoring the cases with a salary loss, the values of time in the long-term are lower than in the short-term. However, ignoring salary losses leads to substantial changes in the long-term values of time, without substantial influence on the short-term values. This seems to indicate a difference in valuation for lost or gained salary. Though such a difference makes intuitive sense and is in line with previous findings, it is incompatible with the estimation of a value of travel time savings based on trade-offs between income and travel time. Thus, the additional data present in this dataset seems to point to a difficulty to define the value of travel time based on workplace location choice decisions, due to issues that did not appear in the data from Beck *et al.* (2017).

Table 6.4: Estimates of the Values of Time (€/h)

Mode	Purpose	Short (all)	Short (gains)	Long (all)	Long (gains)
Car	Commute	9.79	9.98	5.34	7.06
PT	Commute	7.47	7.85	3.48	5.02

6.3 Discussion and outlook

In this chapter the data of the *German Value of Time and Value of Reliability Study* was used to have a look at the difference of valuation of travel time between short- and long-term choice situations. Previous work (Beck *et al.*, 2017) found higher valuations of travel time for long-term decisions, explained by a higher acceptance of long travel times for non-recurring events but a willingness to minimize travel times in the long run. Our results show an opposite effect, most probably due to the inclusion of salary losses, in addition to salary gains, as well as the different framing, where attributes of the work itself are said to change, instead of a simple relocation only causing a longer travel time. More research on this specific issue is needed, as the implications on the derivation of the value of time are not clear. This points for the need of more surveys specifically tailored to investigating this kind of issues. Future surveys should be careful to include high enough variations in travel times (such that small effects could be identified as well), include variations in both directions (instead of only considering increase in salary, as in (Beck *et al.*, 2017)), and be careful to frame the questions so as to avoid confounding the effects of aversion to change with low willingness to pay for travel time savings.

The results presented here confirm a difference in scale of the utility between short- and long-term, indicating a different choice process, the long-term choices having a stronger random component.

The estimation on a subset of the data only including salary gains led to higher values of time than the ones in the full model, especially in the long-run. It indicates a difference in the valuation for gains and losses. Most of the respondents do not want to change their workplace if this would include a salary loss. Even if this seems to make sense for real life situation, it makes it difficult to estimate the trade-off between income and travel time.

The dependence of travel time variation on the time frame of the decision is intriguing, and could modify the understanding of what the "best" value for policy appraisal is. However, the current result show how elusive this value can be, and point for the need of further study. In particular, a theory of travel time valuation that would be able to accommodate for different time horizons endogenously would greatly improve the way we understand how individuals value travel time savings, leading to better informed policy evaluations.

Further the question remains which values of time planers and government should use for evaluating projects. The long-term value of time, as defined here, is the willingness to pay to decrease the average travel time for a given purpose in the long run. The short-term value of time, as it is used today, is the willingness to pay to decrease the travel time for one particular trip. Thus, it would be sensible to choose a value to be used for appraisal based on the type of project. If a project is made to improve social welfare in the long run, considering potential changes in population distribution (for instance new infrastructure), a value based on long-term decisions might be better suited; but if the aim of a project is to provide better options for the current population (for instance traffic signal timings or change in public transport headways), a value based on short-term decisions should be preferred.

Chapter 7

Summary and Conclusions

This thesis is an extension of the *German Value of Time and Value of Reliability Study*. A specificity of the “German” approach to the estimation of the value of time is the inclusion of a variety of trip attributes beyond time and cost, and the aim of this thesis was to explore how one can take advantage of this rich data, and compare different kinds of formulations.

The analysis included looking at differences in VTT depending on the local income and the type of urban area, as well as using different formulations of the model. Finally, an exploration of the use of data about *long-term decisions*, such as residential or workplace choice, was performed.

As for the classical short-term willingness to pay, the results indicated a clear importance of the type of urban area, with more urbanized areas having higher VTT than more rural areas. The separation by local income, however, failed to bring satisfying insights. Even though the base joint model did include purpose-specificity in various forms, results were more satisfying when estimating separate models for different purposes (commuting, leisure, shopping, business). This seems to indicate very different choice processes underlying the decision made for different purposes. In particular, business trips were found to follow a very different kind of decision process. Although using the full data in a joint modelling approach is tempting in order to get as much information in the model as possible, the results presented in this thesis suggest not to neglect the simpler approach of simply splitting the dataset per purpose. As for the test of different model formulations, the best results were obtained with the multiplicative logit model. Interestingly, the model that fit the data the best, the latent class formulation, was also the one that produced the VTT estimates with the highest estimation errors. This might be due to the very specification of the model, where different classes might exhibit very different values of time, bringing variance to their average. The delta method, which gives maximum likelihood estimates for the covariance matrix of any function of the estimates, was instrumental in identifying this effect. This indicates how important it is to report standard errors for VTT estimates. Given the ease of application of the delta method, it is difficult to find any valid argument for not using it systematically.

In all formulations, the VTT estimates for the hypothetical "coach" mode, as well as for plane and shopping purpose, did not give satisfying results, and this even though the survey was designed with care to maximise efficiency. This points to the need of clearly defining what type of VTT should be estimated on the data before the collection, and making choices as to what attributes be collected or not. A rich and diverse dataset is a double sided blade: it might give the possibility to look at much more diverse effects than a simpler dataset, but the numbers of possible combinations of attributes values grows exponentially with the number of attributes, making the identification of those effects problematic.

Some authors postulated that using VTT estimates derived from long- term experiments might give values that are more appropriate for policy appraisal. The survey did include this type of experiments, with much more alternative attributes as experiments from the literature. In contrast to previous studies, the experiment for workplace choice did include both changes that lead to gains and losses in salary, instead of gains only. The direction of that change did have an impact on the valuation of the commute time. This unfortunately makes it difficult to define a VTT based on this kind of decisions. Though this does not mean that using long-term experiments for VTT estimation is impossible, this shows the importance of carefully designing the survey for this purpose, and of refining the underlying theoretical model.

Beyond the question of how to extract the VTT from data, there has been debate as to *how* this value should be used for appraisal. This debate is well summarized by Börjesson and Eliasson (2014). The main issue with value of time, differentiated by income, is the following: given that individuals with higher incomes have a higher willingness to pay, using this willingness to pay to evaluate investments has the consequence of favouring investments in favour of the wealthy. Solutions have been proposed to this problem. An interesting one is to construct the willingness to pay for the project by combining the marginal utility of travel time savings for the beneficiaries, and the marginal utility of money from the paying group. The typical VTT as used in this thesis is then well-suited when the travellers themselves pay back the investment (through fares, taxes or other types of pricing), but in other cases, using the marginal utility of money from the actual (tax) paying group might help solve the dilemma. A counterargument is that travellers are not the only beneficiaries of transport investments, and that the whole economy benefits from those investments.

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Appendix A

Appendix

A.1 Purpose Specific MNL Models

The following models show the complete results of the purpose specific MNL Base Models which were estimated using a subsample of the respondents by the purpose they reported in their revealed preference interview. Not all parameters could be estimated for every purpose which is explained in more detail in Section 5.1.3.

A.1.1 Commute

Table A.1: Estimation Statistics Base Model for Commute

Statistic	Value
Number of decision makers	490
Number of observations	6,926
Null log-likelihood	-5,689
Final log-likelihood	-4,071
Estimated parameters	33
ρ^2	0.28
Adjusted ρ^2	0.28
Akaike Information Criterion	8,207
Bayesian Information Criterion	8,433

Table A.2: Estimates of the Base Model for Commute only

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	0.899	1.04		-0.12	
α_{bike}	3.224	2.51	*	1.73	
α_{pt}	0.729	1.06		-0.4	
α_{car}	0.000	NA	NA	NA	NA
$\lambda_{inc,cost}$	-0.429	-2.63	*	-8.76	*
$\lambda_{dist,time}$	-0.295	-4.19	*	-18.37	*
$\lambda_{dist,cost}$	-0.323	-3.59	*	-14.72	*
λ_{stdev}	-0.517	-1.49		-4.38	*
$\lambda_{tt,transfer,pt}$	0.017	0.18		-10.55	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{tt,waiting,pt}$	-0.401	-1.38		-4.83	*
$\lambda_{tt,access,pt}$	-0.385	-2.08	*	-7.48	*
$\lambda_{time,congestion,car}$	-0.274	-2.14	*	-9.92	*
$\lambda_{time,access,car}$	0.126	0.86		-5.97	*
$\beta_{stdev,pt}$	-0.025	-1.78		-71.81	*
$\beta_{stdev,car}$	-0.012	-1.58		-132.82	*
inc_{miss}	3.697	0.90		0.66	
$\beta_{tt,walk,commute}$	-0.033	-2.93	*	-91.12	*
$\beta_{tt,bike,commute}$	-0.123	-6.73	*	-61.44	*
$\beta_{tt,pt,commute}$	-0.039	-6.19	*	-164.59	*
$\beta_{tt,pt,age}$	-0.013	-1.04		-82.39	*
$\beta_{tt,pt,transfer}$	-0.299	-5.38	*	-23.37	*
$\beta_{tt,pt,waiting}$	-0.049	-4.18	*	-89.87	*
$\beta_{tt,pt,headway}$	-0.013	-3.89	*	-314.24	*
$\beta_{tt,pt,access}$	-0.057	-4.87	*	-90.05	*
$\beta_{tt,pt,med.\_occ.}$	-0.100	-0.85		-9.35	*
$\beta_{tt,pt,high\_occ.}$	-0.103	-1.95		-20.85	*
$\beta_{tt,car,commute}$	-0.051	-5.52	*	-112.78	*
$\beta_{tt,car,congestion}$	-0.058	-4.58	*	-83.84	*
$\beta_{tt,car,access}$	-0.067	-4.51	*	-71.43	*
$\beta_{cost,commute}$	-0.336	-6.30	*	-25.03	*
μ_{mc}	1.000	NA	NA	NA	NA
$\mu_{rc,pt}$	1.525	4.80	*	1.65	
$\mu_{rc,car}$	1.542	4.51	*	1.59	
$\mu_{rel,pt}$	1.265	5.79	*	1.21	
$\mu_{rel,car}$	1.202	4.89	*	0.82	

A.1.2 Shopping

Table A.3: Estimation Statistics Base Model for Shopping

Statistic	Value
Number of decision makers	461
Number of observations	5,330
Null log-likelihood	-4,903
Final log-likelihood	-3,045
Estimated parameters	33
ρ^2	0.38
Adjusted ρ^2	0.37
Akaike Information Criterion	6,157
Bayesian Information Criterion	6,374

Table A.4: Estimates of the Base Model for Shopping only

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-0.497	-0.70		-2.1	*
α_{bike}	0.376	0.37		-0.61	
α_{pt}	-0.157	-0.22		-1.64	
α_{car}	0.000	NA	NA	NA	NA
$\lambda_{inc,cost}$	-0.480	-3.40	*	-10.48	*
$\lambda_{dist,time}$	-0.200	-1.92		-11.51	*
$\lambda_{dist,cost}$	-0.215	-2.66	*	-14.99	*
λ_{stdev}	-0.071	-0.30		-4.53	*
$\lambda_{tt,transfer,pt}$	-0.091	-0.81		-9.72	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{tt,waiting,pt}$	-0.314	-0.66		-2.77	*
$\lambda_{tt,access,pt}$	-0.165	-0.50		-3.56	*
$\lambda_{time,congestion,car}$	-0.931	-0.32		-0.66	
$\lambda_{time,access,car}$	-0.252	-0.64		-3.2	*
$\beta_{stdev,pt}$	-0.051	-1.82		-37.19	*
$\beta_{stdev,car}$	-0.045	-1.42		-33.01	*
inc_{miss}	0.370	2.26	*	-3.86	*
$\beta_{tt,walk,shop}$	-0.045	-3.79	*	-87.68	*
$\beta_{tt,bike,shop}$	-0.107	-4.63	*	-47.74	*
$\beta_{tt,pt,shop}$	-0.032	-3.29	*	-107.16	*
$\beta_{tt,pt,age}$	-0.016	-1.59		-99.87	*
$\beta_{tt,pt,transfer}$	-0.382	-3.37	*	-12.19	*
$\beta_{tt,pt,waiting}$	-0.030	-1.60		-54.79	*
$\beta_{tt,pt,headway}$	-0.011	-2.83	*	-269.48	*
$\beta_{tt,pt,access}$	-0.061	-2.72	*	-47.66	*
$\beta_{tt,pt,med.\_occ.}$	-0.037	-0.27		-7.48	*
$\beta_{tt,pt,high\_occ.}$	0.011	0.26		-23.77	*
$\beta_{tt,car,shop}$	-0.038	-2.61	*	-71.13	*
$\beta_{tt,car,congestion}$	-0.016	-0.12		-8.05	*
$\beta_{tt,car,access}$	-0.053	-1.71		-33.98	*
$\beta_{cost,shop}$	-0.439	-2.85	*	-9.33	*
μ_{mc}	1.000	NA	NA	NA	NA
$\mu_{rc,pt}$	1.487	3.14	*	1.03	
$\mu_{rc,car}$	1.862	1.04		0.48	
$\mu_{rel,pt}$	2.108	4.24	*	2.23	*
$\mu_{rel,car}$	1.863	3.00	*	1.39	

A.1.3 Business

Table A.5: Estimation Statistics Base Model for Business

Statistic	Value
Number of decision makers	903
Number of observations	14,379
Null log-likelihood	-11,468
Final log-likelihood	-8,380
Estimated parameters	49
ρ^2	0.27
Adjusted ρ^2	0.26
Akaike Information Criterion	16,859
Bayesian Information Criterion	17,230

Table A.6: Estimates of the Base Model for Business only

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-0.208	-0.07		-0.43	
α_{bike}	6.808	1.01		0.86	
α_{pt}	0.466	0.92		-1.05	
α_{coach}	0.467	0.99		-1.13	
α_{car}	0.000	NA	NA	NA	NA
α_{plane}	1.966	2.03	*	1	
$\lambda_{inc,cost}$	0.000	NA	NA	NA	NA
$\lambda_{dist,time}$	-0.521	-15.37	*	-44.89	*
$\lambda_{dist,cost}$	-0.843	-16.15	*	-35.31	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
λ_{stdev}	-0.783	-5.16	*	-11.74	*
$\lambda_{tt,transfer,pt}$	-0.264	-3.95	*	-18.91	*
$\lambda_{tt,waiting,pt}$	-0.746	-5.60	*	-13.11	*
$\lambda_{tt,access,pt}$	-0.763	-7.29	*	-16.85	*
$\lambda_{tt,waiting,coach}$	-1.388	-5.26	*	-9.06	*
$\lambda_{time,congestion,car}$	-0.658	-5.52	*	-13.91	*
$\lambda_{time,access,car}$	-0.283	-2.41	*	-10.94	*
$\beta_{stdev,pt}$	-0.014	-1.20		-90.34	*
$\beta_{stdev,car}$	-0.017	-3.57	*	-210.9	*
$\beta_{stdev,coach}$	-0.021	-0.55		-27.36	*
$\beta_{stdev,plane}$	-0.020	-2.23	*	-111.79	*
inc_{miss}	1.000	NA	NA	NA	NA
$\beta_{tt,walk,business}$	-0.027	-1.73		-66	*
$\beta_{tt,bike,business}$	-0.127	-1.33		-11.85	*
$\beta_{tt,pt,business}$	-0.022	-5.97	*	-277.13	*
$\beta_{tt,pt,age}$	-0.002	-0.27		-124.56	*
$\beta_{tt,pt,transfer}$	-0.258	-7.38	*	-35.94	*
$\beta_{tt,pt,waiting}$	-0.026	-4.03	*	-160.75	*
$\beta_{tt,pt,headway}$	-0.005	-2.65	*	-552.06	*
$\beta_{tt,pt,access}$	-0.044	-6.18	*	-146.83	*
$\beta_{tt,pt,med.\_occ.}$	-0.277	-3.34	*	-15.42	*
$\beta_{tt,pt,high\_occ.}$	-0.094	-2.42	*	-28.08	*
$\beta_{tt,coach,business}$	-0.042	-6.31	*	-156.73	*
$\beta_{tt,coach,male}$	-0.510	-2.32	*	-6.88	*
$\beta_{tt,coach,h\_size}$	0.017	3.77	*	-216.01	*
$\beta_{tt,coach,transfer}$	-0.191	-1.68		-10.44	*
$\beta_{tt,coach,waiting}$	-0.090	-3.72	*	-45.2	*
$\beta_{tt,coach,headway}$	-0.002	-3.38	*	-1956.85	*
$\beta_{tt,coach,med.\_occ.}$	-0.281	-2.02	*	-9.22	*
$\beta_{tt,coach,high\_occ.}$	-0.117	-1.00		-9.54	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,car,business}$	-0.023	-7.31	*	-325.17	*
$\beta_{tt,car,congestion}$	-0.027	-6.53	*	-251.59	*
$\beta_{tt,car,access}$	-0.024	-6.67	*	-286	*
$\beta_{tt,plane,business}$	-0.040	-2.82	*	-73.12	*
$\beta_{tt,plane,leisure}$	-0.430	-3.80	*	-12.62	*
$\beta_{tt,plane,waiting}$	-0.004	-0.39		-95.95	*
$\beta_{tt,plane,access}$	-0.005	-0.57		-125.49	*
$\beta_{cost,business}$	-0.148	-7.36	*	-57.13	*
μ_{mc}	1.000	NA	NA	NA	NA
$\mu_{rc,pt}$	1.914	5.88	*	2.81	*
$\mu_{rc,car}$	2.725	7.01	*	4.44	*
$\mu_{rel,pt}$	1.658	7.56	*	3	*
$\mu_{rel,car}$	1.866	6.45	*	3	*
$\mu_{rel,plane}$	3.281	3.43	*	2.39	*

A.1.4 Leisure

Table A.7: Estimation Statistics Base Model for Leisure

Statistic	Value
Number of decision makers	1,215
Number of observations	17,221
Null log-likelihood	-14,235
Final log-likelihood	-9,769
Estimated parameters	51
ρ^2	0.31
Adjusted ρ^2	0.31
Akaike Information Criterion	19,640
Bayesian Information Criterion	20,035

Table A.8: Estimates of the Base Model for Leisure only

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	0.169	0.22		-1.07	
α_{bike}	4.580	2.97	*	2.32	*
α_{pt}	-0.478	-1.40		-4.32	*
α_{coach}	1.452	2.57	*	0.80	
α_{car}	0.000	NA	NA	NA	NA
α_{plane}	1.660	2.01	*	0.80	
$\lambda_{inc,cost}$	-0.310	-3.02	*	-12.76	*
$\lambda_{dist,time}$	-0.482	-17.93	*	-55.12	*
$\lambda_{dist,cost}$	-0.652	-18.50	*	-46.90	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
λ_{stdev}	-0.496	-6.47	*	-19.51	*
$\lambda_{tt,transfer,pt}$	-0.188	-3.76	*	-23.74	*
$\lambda_{tt,waiting,pt}$	-0.771	-5.26	*	-12.08	*
$\lambda_{tt,access,pt}$	-0.650	-7.53	*	-19.13	*
$\lambda_{tt,waiting,coach}$	-0.703	-4.75	*	-11.50	*
$\lambda_{time,congestion,car}$	-0.537	-4.81	*	-13.76	*
$\lambda_{time,access,car}$	-0.177	-1.65		-10.96	*
$\beta_{stdev,pt}$	-0.014	-4.53	*	-340.60	*
$\beta_{stdev,car}$	-0.016	-5.37	*	-349.98	*
$\beta_{stdev,coach}$	-0.045	-1.95		-45.64	*
$\beta_{stdev,plane}$	-0.016	-2.79	*	-175.58	*
inc_{miss}	0.838	2.70	*	-0.52	
$\beta_{tt,walk,business}$	-0.018	-3.33	*	-190.34	*
$\beta_{tt,bike,business}$	-0.094	-4.65	*	-54.30	*
$\beta_{tt,pt,business}$	-0.019	-6.87	*	-372.18	*
$\beta_{tt,pt,age}$	-0.002	-0.38		-227.58	*
$\beta_{tt,pt,transfer}$	-0.219	-6.66	*	-37.10	*
$\beta_{tt,pt,waiting}$	-0.013	-4.16	*	-338.23	*
$\beta_{tt,pt,headway}$	-0.004	-2.90	*	-684.23	*
$\beta_{tt,pt,access}$	-0.025	-5.59	*	-229.34	*
$\beta_{tt,pt,med.\_occ.}$	-0.072	-1.21		-18.10	*
$\beta_{tt,pt,high\_occ.}$	-0.037	-1.97	*	-54.87	*
$\beta_{tt,coach,business}$	-0.044	-7.48	*	-177.39	*
$\beta_{tt,coach,male}$	-0.251	-1.12		-5.56	*
$\beta_{tt,coach,h\_size}$	-0.145	-1.81		-14.29	*
$\beta_{tt,coach,transfer}$	-0.298	-2.09	*	-9.11	*
$\beta_{tt,coach,waiting}$	-0.049	-2.74	*	-59.15	*
$\beta_{tt,coach,headway}$	-0.003	-4.50	*	-1507.39	*
$\beta_{tt,coach,med.\_occ.}$	-0.199	-1.05		-6.30	*
$\beta_{tt,coach,high\_occ.}$	-0.096	-0.65		-7.40	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,car,business}$	-0.020	-7.18	*	-362.62	*
$\beta_{tt,car,congestion}$	-0.029	-5.37	*	-190.17	*
$\beta_{tt,car,access}$	-0.021	-5.87	*	-280.00	*
$\beta_{tt,plane,business}$	-0.025	-2.61	*	-105.46	*
$\beta_{tt,plane,leisure}$	-0.610	-5.28	*	-13.95	*
$\beta_{tt,plane,waiting}$	-0.016	-2.82	*	-177.18	*
$\beta_{tt,plane,access}$	-0.013	-2.90	*	-229.39	*
$\beta_{cost,business}$	-0.119	-8.14	*	-76.57	*
μ_{mc}	1.000	NA	NA	NA	NA
$\mu_{rc,pt}$	2.925	6.48	*	4.26	*
$\mu_{rc,car}$	2.644	6.18	*	3.85	*
$\mu_{rel,pt}$	2.441	6.96	*	4.11	*
$\mu_{rel,car}$	2.300	6.90	*	3.90	*
$\mu_{rel,plane}$	1.506	5.69	*	1.91	

A.2 Spatial Model Outputs

The following models show the complete results of the spatial MNL Base Models which were estimated using a subsample of the respondents by regional disposable income quintiles or BIK-10 region.

A.2.1 Income Quintiles

A.2.1.1 Q1: 1st Disposable Income Quintile (<= 18,223 Euro/year) (2012)

Table A.9: Estimation Statistics Q1 Model

Statistic	Value
Number of decision makers	615
Number of observations	8,728
Null log-likelihood	-7,182
Final log-likelihood	-4,768
Estimated parameters	65
ρ^2	0.34
Adjusted ρ^2	0.33
Akaike Information Criterion	9,665
Bayesian Information Criterion	10,125

Table A.10: Estimates of Q1 Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-2.64	-5.55	*	-7.65	*
α_{bike}	5.77	2.51	*	2.07	*
α_{pt}	0.44	0.78		-0.99	
α_{coach}	-0.05	-0.05		-1.07	
α_{car}	0.00	NA	NA	NA	NA
α_{plane}	0.95	0.80		-0.04	
$\lambda_{inc,cost}$	-0.24	-1.88	*	-9.62	
$\lambda_{dist,time}$	-0.42	-9.72	*	-32.69	*
$\lambda_{dist,cost}$	-0.72	-15.52	*	-37.20	*
λ_{stdev}	-0.66	-3.59	*	-9.04	*
$\lambda_{tt,transfer,pt}$	-0.16	-2.42	*	-17.95	*
$\lambda_{tt,waiting,pt}$	-0.59	-3.59	*	-9.66	*
$\lambda_{tt,access,pt}$	-0.67	-6.44	*	-16.08	*
$\lambda_{tt,waiting,coach}$	-1.80	-3.68	*	-5.73	*
$\lambda_{time,congestion,car}$	-0.57	-15.04	*	-15.04	*
$\lambda_{time,access,car}$	-0.53	-4.39	*	-12.65	*
$\beta_{stdev,pt}$	-0.01	-2.51	*	-175.21	*
$\beta_{stdev,car}$	-0.01	-2.78	*	-225.56	*
$\beta_{stdev,coach}$	0.00	0.07	*	-20.81	
$\beta_{stdev,plane}$	0.00	-0.24	*	-100.37	
inc_{miss}	0.90	1.30		-0.14	
$\beta_{tt,walk,commute}$	-0.01	-2.74	*	-213.46	*
$\beta_{tt,walk,shop}$	-0.01	-1.84	*	-266.13	
$\beta_{tt,walk,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.01	-1.55	*	-226.41	
$\beta_{tt,bike,commute}$	-0.15	-4.46	*	-34.78	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,bike,shop}$	-0.18	-4.81	*	-31.61	*
$\beta_{tt,bike,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.13	-4.19	*	-36.01	*
$\beta_{tt,pt,commute}$	-0.02	-3.47	*	-157.75	*
$\beta_{tt,pt,shop}$	-0.03	-4.27	*	-140.29	*
$\beta_{tt,pt,business}$	-0.01	-2.45	*	-271.46	*
$\beta_{tt,pt,leisure}$	-0.02	-5.79	*	-268.62	*
$\beta_{tt,pt,age}$	-0.02	-2.45	*	-114.52	*
$\beta_{tt,pt,transfer}$	-0.26	-5.86	*	-28.23	*
$\beta_{tt,pt,waiting}$	-0.02	-3.17	*	-164.57	*
$\beta_{tt,pt,headway}$	-0.01	-2.40	*	-422.76	*
$\beta_{tt,pt,access}$	-0.03	-4.61	*	-152.85	*
$\beta_{tt,pt,med.\_occ.}$	-0.21	-2.08	*	-11.93	*
$\beta_{tt,pt,high\_occ.}$	-0.05	-1.52	*	-30.82	
$\beta_{tt,coach,business}$	-0.02	-2.08	*	-91.03	*
$\beta_{tt,coach,leisure}$	-0.03	-2.89	*	-92.23	*
$\beta_{tt,coach,male}$	-0.53	-1.16	*	-3.36	
$\beta_{tt,coach,h\_size}$	-0.07	-0.51	*	-7.82	
$\beta_{tt,coach,transfer}$	-0.29	-1.31	*	-5.83	
$\beta_{tt,coach,waiting}$	-0.07	-1.67	*	-24.65	
$\beta_{tt,coach,headway}$	0.00	-2.55	*	-963.40	*
$\beta_{tt,coach,med.\_occ.}$	-0.37	-1.52	*	-5.65	
$\beta_{tt,coach,high\_occ.}$	-0.25	-1.20	*	-5.97	
$\beta_{tt,car,commute}$	-0.03	-4.84	*	-161.61	*
$\beta_{tt,car,shop}$	-0.03	-3.72	*	-131.57	*
$\beta_{tt,car,business}$	-0.02	-5.45	*	-306.34	*
$\beta_{tt,car,leisure}$	-0.02	-5.82	*	-299.90	*
$\beta_{tt,car,congestion}$	-0.03	-5.41	*	-176.30	*
$\beta_{tt,car,access}$	-0.03	-5.97	*	-201.77	*
$\beta_{tt,plane,business}$	-0.04	-2.44	*	-65.51	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,plane,leisure}$	-0.82	-4.57	*	-10.15	*
$\beta_{tt,plane,waiting}$	0.00	-0.09	*	-74.07	
$\beta_{tt,plane,access}$	-0.01	-1.06	*	-133.44	
$\beta_{cost,commute}$	-0.22	-4.47	*	-24.88	*
$\beta_{cost,shop}$	-0.12	-1.91	*	-18.21	
$\beta_{cost,business}$	-0.10	-4.92	*	-53.29	*
$\beta_{cost,leisure}$	-0.19	-5.75	*	-36.09	*
μ_{mc}	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	2.24	5.23	*	2.90	*
$\mu_{rc,car}$	2.87	5.86	*	3.82	*
$\mu_{rel,pt}$	1.95	6.34	*	3.09	*
$\mu_{rel,car}$	2.13	6.12	*	3.24	*
$\mu_{rel,plane}$	2.08	3.27	*	1.70	

A.2.1.2 Q2: 2nd Disposable Income Quintile (> 18,223 – <= 19,781 Euro/year) (2012)

Table A.11: Estimation Statistics Q2 Model

Statistic	Value
Number of decision makers	611
Number of observations	8,575
Null log-likelihood	-7,193
Final log-likelihood	-5,009
Estimated parameters	65
ρ^2	0.30
Adjusted ρ^2	0.29
Akaike Information Criterion	10,148
Bayesian Information Criterion	10,607

Table A.12: Estimates of Q2 Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	0.16	0.20		-1.06	
α_{bike}	0.48	0.38		-0.42	
α_{pt}	0.50	1.16		-1.15	
α_{coach}	-1.24	-1.15	*	-2.08	
α_{car}	0.00	NA	NA	NA	NA
α_{plane}	3.19	2.16	*	1.48	
$\lambda_{inc,cost}$	-0.19	-1.53	*	-9.47	
$\lambda_{dist,time}$	-0.42	-8.92	*	-30.06	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{dist,cost}$	-0.65	-9.41	*	-23.93	*
λ_{stdev}	-0.59	-4.40	*	-11.92	*
$\lambda_{tt,transfer,pt}$	-0.28	-4.24	*	-19.54	*
$\lambda_{tt,waiting,pt}$	-0.81	-5.36	*	-12.00	*
$\lambda_{tt,access,pt}$	-0.62	-5.84	*	-15.30	*
$\lambda_{tt,waiting,coach}$	-1.28	-3.01	*	-5.38	*
$\lambda_{time,congestion,car}$	-0.53	-1.66	*	-4.81	
$\lambda_{time,access,car}$	0.04	0.21	*	-5.66	
$\beta_{stdev,pt}$	-0.02	-3.17	*	-192.03	*
$\beta_{stdev,car}$	-0.01	-2.44	*	-236.51	*
$\beta_{stdev,coach}$	0.02	0.53	*	-29.73	
$\beta_{stdev,plane}$	-0.03	-2.18	*	-76.50	*
inc_{miss}	0.60	0.94		-0.63	
$\beta_{tt,walk,commute}$	-0.02	-2.63	*	-121.60	*
$\beta_{tt,walk,shop}$	-0.02	-2.67	*	-130.51	*
$\beta_{tt,walk,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.02	-3.54	*	-155.48	*
$\beta_{tt,bike,commute}$	-0.04	-2.41	*	-56.61	*
$\beta_{tt,bike,shop}$	-0.05	-2.21	*	-43.56	*
$\beta_{tt,bike,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.04	-1.80	*	-48.93	
$\beta_{tt,pt,commute}$	-0.02	-4.52	*	-216.79	*
$\beta_{tt,pt,shop}$	-0.03	-3.20	*	-103.67	*
$\beta_{tt,pt,business}$	-0.02	-4.04	*	-236.43	*
$\beta_{tt,pt,leisure}$	-0.02	-3.71	*	-234.18	*
$\beta_{tt,pt,age}$	-0.01	-1.15	*	-142.91	
$\beta_{tt,pt,transfer}$	-0.19	-5.06	*	-31.84	*
$\beta_{tt,pt,waiting}$	-0.02	-3.02	*	-175.35	*
$\beta_{tt,pt,headway}$	-0.01	-3.15	*	-405.72	*
$\beta_{tt,pt,access}$	-0.03	-4.21	*	-138.93	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,med.\_occ.}$	-0.15	-1.65	*	-12.69	
$\beta_{tt,pt,high\_occ.}$	-0.09	-2.42	*	-29.09	*
$\beta_{tt,coach,business}$	-0.01	-1.68	*	-132.02	
$\beta_{tt,coach,leisure}$	-0.02	-2.64	*	-121.95	*
$\beta_{tt,coach,male}$	-0.82	-1.84	*	-4.06	
$\beta_{tt,coach,h\_size}$	0.15	0.63	*	-3.62	
$\beta_{tt,coach,transfer}$	-0.19	-0.70	*	-4.36	
$\beta_{tt,coach,waiting}$	-0.05	-1.49	*	-32.64	
$\beta_{tt,coach,headway}$	0.00	-2.53	*	-1142.72	*
$\beta_{tt,coach,med.\_occ.}$	-0.30	-1.15	*	-5.04	
$\beta_{tt,coach,high\_occ.}$	-0.29	-1.55	*	-6.92	
$\beta_{tt,car,commute}$	-0.02	-2.91	*	-129.65	*
$\beta_{tt,car,shop}$	0.00	-0.16	*	-123.31	
$\beta_{tt,car,business}$	-0.02	-3.23	*	-206.48	*
$\beta_{tt,car,leisure}$	-0.01	-3.05	*	-215.77	*
$\beta_{tt,car,congestion}$	-0.02	-2.47	*	-167.25	*
$\beta_{tt,car,access}$	-0.01	-2.79	*	-215.36	*
$\beta_{tt,plane,business}$	-0.02	-1.92	*	-83.42	
$\beta_{tt,plane,leisure}$	-0.56	-2.86	*	-8.01	*
$\beta_{tt,plane,waiting}$	-0.01	-0.55	*	-95.76	
$\beta_{tt,plane,access}$	-0.02	-1.77	*	-111.47	
$\beta_{cost,commute}$	-0.20	-3.42	*	-20.65	*
$\beta_{cost,shop}$	-0.15	-2.29	*	-18.02	*
$\beta_{cost,business}$	-0.10	-5.53	*	-63.24	*
$\beta_{cost,leisure}$	-0.14	-4.45	*	-36.44	*
μ_{mc}	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	2.78	4.43	*	2.84	*
$\mu_{rc,car}$	3.19	3.18	*	2.18	*
$\mu_{rel,pt}$	2.18	4.76	*	2.57	*
$\mu_{rel,car}$	2.61	3.26	*	2.01	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rel,plane}$	1.20	3.25	*	0.54	

A.2.1.3 Q3: 3rd Disposable Income Quintile (> 19,781 – <= 21,084 Euro/year) (2012)

Table A.13: Estimation Statistics Q3 Model

Statistic	Value
Number of decision makers	611
Number of observations	8,626
Null log-likelihood	-7,178
Final log-likelihood	-5,314
Estimated parameters	65
ρ^2	0.26
Adjusted ρ^2	0.25
Akaike Information Criterion	10,758
Bayesian Information Criterion	11,217

Table A.14: Estimates of Q3 Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-0.53	-0.58		-1.67	
α_{bike}	3.09	1.63		1.10	
α_{pt}	-0.40	-0.66	*	-2.35	

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{coach}	-0.06	-0.09		-1.63	
α_{car}	0.00	NA	NA	NA	NA
α_{plane}	3.47	1.53		1.09	
$\lambda_{inc,cost}$	-0.31	-1.38	*	-5.88	
$\lambda_{dist,time}$	-0.44	-9.09	*	-29.73	*
$\lambda_{dist,cost}$	-0.55	-6.46	*	-18.27	*
λ_{stdev}	-0.52	-2.67	*	-7.80	*
$\lambda_{tt,transfer,pt}$	-0.19	-2.57	*	-16.29	*
$\lambda_{tt,waiting,pt}$	-0.81	-4.78	*	-10.68	*
$\lambda_{tt,access,pt}$	-0.55	-4.91	*	-13.89	*
$\lambda_{tt,waiting,coach}$	-0.77	-3.40	*	-7.83	*
$\lambda_{time,congestion,car}$	-0.47	-3.32	*	-10.34	*
$\lambda_{time,access,car}$	-0.35	-1.75	*	-6.75	
$\beta_{stdev,pt}$	-0.01	-2.18	*	-156.34	*
$\beta_{stdev,car}$	-0.02	-2.92	*	-127.25	*
$\beta_{stdev,coach}$	-0.01	-0.26	*	-36.77	
$\beta_{stdev,plane}$	-0.08	-2.35	*	-32.90	*
inc_{miss}	1.08	1.30		0.09	
$\beta_{tt,walk,commute}$	-0.02	-3.71	*	-204.99	*
$\beta_{tt,walk,shop}$	-0.03	-2.61	*	-84.86	*
$\beta_{tt,walk,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.02	-3.20	*	-204.18	*
$\beta_{tt,bike,commute}$	-0.10	-4.23	*	-46.53	*
$\beta_{tt,bike,shop}$	-0.11	-3.26	*	-32.26	*
$\beta_{tt,bike,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.08	-3.19	*	-42.70	*
$\beta_{tt,pt,commute}$	-0.02	-3.87	*	-171.41	*
$\beta_{tt,pt,shop}$	-0.03	-3.07	*	-98.35	*
$\beta_{tt,pt,business}$	-0.02	-4.93	*	-245.98	*
$\beta_{tt,pt,leisure}$	-0.02	-4.61	*	-195.65	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,age}$	0.00	0.21	*	-126.02	
$\beta_{tt,pt,transfer}$	-0.25	-5.10	*	-25.63	*
$\beta_{tt,pt,waiting}$	-0.02	-2.84	*	-158.12	*
$\beta_{tt,pt,headway}$	-0.01	-3.39	*	-459.88	*
$\beta_{tt,pt,access}$	-0.03	-3.81	*	-139.59	*
$\beta_{tt,pt,med.\_occ.}$	-0.10	-1.10	*	-12.09	
$\beta_{tt,pt,high\_occ.}$	-0.06	-1.42	*	-26.47	
$\beta_{tt,coach,business}$	-0.04	-4.81	*	-136.07	*
$\beta_{tt,coach,leisure}$	-0.04	-4.55	*	-126.48	*
$\beta_{tt,coach,male}$	-0.26	-0.76	*	-3.71	
$\beta_{tt,coach,h\_size}$	-0.03	-0.22	*	-8.01	
$\beta_{tt,coach,transfer}$	-0.27	-1.59	*	-7.40	
$\beta_{tt,coach,waiting}$	-0.12	-4.17	*	-40.19	*
$\beta_{tt,coach,headway}$	0.00	-1.91	*	-1217.72	
$\beta_{tt,coach,med.\_occ.}$	-0.50	-2.16	*	-6.46	*
$\beta_{tt,coach,high\_occ.}$	0.02	0.13	*	-6.00	
$\beta_{tt,car,commute}$	-0.04	-5.49	*	-142.88	*
$\beta_{tt,car,shop}$	0.00	0.21	*	-66.01	
$\beta_{tt,car,business}$	-0.03	-5.39	*	-178.64	*
$\beta_{tt,car,leisure}$	-0.03	-5.38	*	-189.90	*
$\beta_{tt,car,congestion}$	-0.04	-5.24	*	-122.66	*
$\beta_{tt,car,access}$	-0.04	-5.00	*	-131.16	*
$\beta_{tt,plane,business}$	-0.05	-2.18	*	-44.55	*
$\beta_{tt,plane,leisure}$	-0.68	-2.55	*	-6.27	*
$\beta_{tt,plane,waiting}$	-0.04	-1.81	*	-46.47	
$\beta_{tt,plane,access}$	-0.01	-0.54	*	-63.17	
$\beta_{cost,commute}$	-0.25	-3.87	*	-19.17	*
$\beta_{cost,shop}$	-0.18	-1.66	*	-11.02	
$\beta_{cost,business}$	-0.08	-2.15	*	-28.80	*
$\beta_{cost,leisure}$	-0.13	-4.13	*	-36.82	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
μ_{mc}	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	1.95	4.17	*	2.03	*
$\mu_{rc,car}$	1.66	5.08	*	2.03	*
$\mu_{rel,pt}$	1.81	5.42	*	2.43	*
$\mu_{rel,car}$	1.05	4.39	*	0.20	
$\mu_{rel,plane}$	0.87	2.72	*	-0.40	

A.2.1.4 Q4: 4th Disposable Income Quintile (> 21,084 – <= 22,663 Euro/year) (2012)

Table A.15: Estimation Statistics Q4 Model

Statistic	Value
Number of decision makers	630
Number of observations	9,189
Null log-likelihood	-7,578
Final log-likelihood	-5,157
Estimated parameters	65
ρ^2	0.32
Adjusted ρ^2	0.31
Akaike Information Criterion	10,444
Bayesian Information Criterion	10,907

Table A.16: Estimates of Q4 Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-0.10	-0.11		-1.23	
α_{bike}	2.33	1.55		0.89	
α_{pt}	0.26	0.46		-1.30	
α_{coach}	-0.27	-0.42	*	-1.97	*
α_{car}	0.00	NA	NA	NA	NA
α_{plane}	2.05	1.32		0.67	
$\lambda_{inc,cost}$	-0.16	-0.76	*	-5.48	*
$\lambda_{dist,time}$	-0.42	-10.33	*	-34.76	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{dist,cost}$	-0.71	-8.79	*	-21.25	*
λ_{stdev}	-0.66	-2.77	*	-6.96	*
$\lambda_{tt,transfer,pt}$	-0.22	-3.17	*	-17.92	*
$\lambda_{tt,waiting,pt}$	-1.02	-4.07	*	-8.05	*
$\lambda_{tt,access,pt}$	-0.61	-3.91	*	-10.27	*
$\lambda_{tt,waiting,coach}$	-1.12	-2.19	*	-4.15	*
$\lambda_{time,congestion,car}$	-0.30	-2.12	*	-9.11	*
$\lambda_{time,access,car}$	-0.22	-1.46	*	-8.02	*
$\beta_{stdev,pt}$	-0.02	-2.28	*	-139.91	*
$\beta_{stdev,car}$	-0.01	-1.78	*	-223.12	*
$\beta_{stdev,coach}$	-0.03	-0.58	*	-23.15	*
$\beta_{stdev,plane}$	-0.01	-0.68	*	-81.27	*
inc_{miss}	0.64	0.80		-0.46	
$\beta_{tt,walk,commute}$	-0.01	-2.58	*	-188.76	*
$\beta_{tt,walk,shop}$	-0.02	-2.93	*	-139.62	*
$\beta_{tt,walk,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.02	-3.44	*	-156.94	*
$\beta_{tt,bike,commute}$	-0.08	-3.71	*	-49.88	*
$\beta_{tt,bike,shop}$	-0.07	-2.95	*	-44.99	*
$\beta_{tt,bike,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.07	-3.01	*	-45.97	*
$\beta_{tt,pt,commute}$	-0.03	-5.42	*	-192.56	*
$\beta_{tt,pt,shop}$	-0.02	-1.32	*	-69.89	*
$\beta_{tt,pt,business}$	-0.02	-4.17	*	-215.16	*
$\beta_{tt,pt,leisure}$	-0.02	-4.74	*	-236.31	*
$\beta_{tt,pt,age}$	0.00	-0.23	*	-114.03	*
$\beta_{tt,pt,transfer}$	-0.27	-5.54	*	-26.08	*
$\beta_{tt,pt,waiting}$	-0.02	-2.36	*	-122.19	*
$\beta_{tt,pt,headway}$	-0.01	-3.54	*	-435.01	*
$\beta_{tt,pt,access}$	-0.03	-4.55	*	-138.53	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,med.\_occ.}$	-0.14	-1.28	*	-10.34	*
$\beta_{tt,pt,high\_occ.}$	-0.06	-1.49	*	-27.00	*
$\beta_{tt,coach,business}$	-0.03	-4.04	*	-141.81	*
$\beta_{tt,coach,leisure}$	-0.02	-3.52	*	-167.10	*
$\beta_{tt,coach,male}$	-0.41	-1.24	*	-4.23	*
$\beta_{tt,coach,h\_size}$	0.02	4.27	*	-263.85	*
$\beta_{tt,coach,transfer}$	-0.28	-1.35	*	-6.14	*
$\beta_{tt,coach,waiting}$	-0.08	-1.96	*	-27.22	*
$\beta_{tt,coach,headway}$	0.00	-2.53	*	-1015.84	*
$\beta_{tt,coach,med.\_occ.}$	-0.01	-0.04	*	-3.54	*
$\beta_{tt,coach,high\_occ.}$	-0.07	-0.28	*	-4.54	*
$\beta_{tt,car,commute}$	-0.03	-4.31	*	-139.81	*
$\beta_{tt,car,shop}$	-0.01	-2.95	*	-222.92	*
$\beta_{tt,car,business}$	-0.02	-4.39	*	-253.97	*
$\beta_{tt,car,leisure}$	-0.02	-5.03	*	-286.94	*
$\beta_{tt,car,congestion}$	-0.02	-4.12	*	-195.20	*
$\beta_{tt,car,access}$	-0.02	-4.45	*	-202.77	*
$\beta_{tt,plane,business}$	-0.04	-2.56	*	-70.25	*
$\beta_{tt,plane,leisure}$	-0.64	-2.60	*	-6.68	*
$\beta_{tt,plane,waiting}$	-0.02	-1.71	*	-101.86	*
$\beta_{tt,plane,access}$	-0.01	-1.36	*	-130.15	*
$\beta_{cost,commute}$	-0.25	-4.68	*	-23.62	*
$\beta_{cost,shop}$	-0.07	-1.54	*	-23.03	*
$\beta_{cost,business}$	-0.08	-3.32	*	-43.89	*
$\beta_{cost,leisure}$	-0.14	-3.96	*	-32.40	*
μ_{mc}	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	2.27	4.94	*	2.77	*
$\mu_{rc,car}$	3.16	4.69	*	3.21	*
$\mu_{rel,pt}$	1.69	5.16	*	2.11	*
$\mu_{rel,car}$	2.52	4.94	*	2.98	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rel,plane}$	1.58	3.27	*	1.20	*

A.2.1.5 Q5: 5th Disposable Income Quintile (> 22,663 Euro/year) (2012)

Table A.17: Estimation Statistics Q5 Model

Statistic	Value
Number of decision makers	602
Number of observations	8,738
Null log-likelihood	-7,223
Final log-likelihood	-5,073
Estimated parameters	65
ρ^2	0.30
Adjusted ρ^2	0.29
Akaike Information Criterion	10,275
Bayesian Information Criterion	10,735

Table A.18: Estimates of Q5 Model

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-1.35	-1.13	*	-1.98	*
α_{bike}	-0.68	-0.36		-0.89	
α_{pt}	-0.74	-1.41	*	-3.31	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{coach}	-1.15	-1.55	*	-2.90	*
α_{car}	0.00	NA	NA	NA	NA
α_{plane}	3.40	2.66	*	1.88	*
$\lambda_{inc,cost}$	-0.49	-3.33	*	-10.08	*
$\lambda_{dist,time}$	-0.48	-9.04	*	-27.91	*
$\lambda_{dist,cost}$	-0.65	-11.15	*	-28.43	*
λ_{stdev}	-0.59	-3.65	*	-9.88	*
$\lambda_{tt,transfer,pt}$	-0.31	-4.11	*	-17.40	*
$\lambda_{tt,waiting,pt}$	-0.66	-4.38	*	-11.02	*
$\lambda_{tt,access,pt}$	-0.76	-6.55	*	-15.17	*
$\lambda_{tt,waiting,coach}$	-0.70	-3.03	*	-7.39	*
$\lambda_{time,congestion,car}$	-0.91	-9.27	*	-19.46	*
$\lambda_{time,access,car}$	-0.33	-1.23	*	-4.99	*
$\beta_{stdev,pt}$	-0.02	-2.90	*	-161.66	*
$\beta_{stdev,car}$	-0.02	-3.97	*	-204.67	*
$\beta_{stdev,coach}$	0.02	0.66	*	-30.53	*
$\beta_{stdev,plane}$	-0.02	-1.16	*	-60.04	*
inc_{miss}	0.65	2.89	*	-1.53	*
$\beta_{tt,walk,commute}$	-0.01	-2.77	*	-199.12	*
$\beta_{tt,walk,shop}$	-0.02	-1.91	*	-114.88	*
$\beta_{tt,walk,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.01	-1.72	*	-143.04	*
$\beta_{tt,bike,commute}$	-0.03	-1.30	*	-39.75	*
$\beta_{tt,bike,shop}$	-0.03	-1.09	*	-34.15	*
$\beta_{tt,bike,business}$	0.00	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.03	-1.10	*	-39.37	*
$\beta_{tt,pt,commute}$	-0.02	-4.08	*	-169.74	*
$\beta_{tt,pt,shop}$	-0.02	-3.34	*	-153.85	*
$\beta_{tt,pt,business}$	-0.02	-4.73	*	-260.14	*
$\beta_{tt,pt,leisure}$	-0.02	-4.43	*	-228.04	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,age}$	0.00	-0.08	*	-138.72	*
$\beta_{tt,pt,transfer}$	-0.21	-4.97	*	-29.06	*
$\beta_{tt,pt,waiting}$	-0.02	-3.60	*	-202.33	*
$\beta_{tt,pt,headway}$	0.00	-0.44	*	-449.13	*
$\beta_{tt,pt,access}$	-0.04	-4.95	*	-138.24	*
$\beta_{tt,pt,med.\_occ.}$	-0.06	-0.71	*	-11.65	*
$\beta_{tt,pt,high\_occ.}$	-0.02	-0.71	*	-33.34	*
$\beta_{tt,coach,business}$	-0.03	-2.99	*	-115.39	*
$\beta_{tt,coach,leisure}$	-0.02	-2.90	*	-127.52	*
$\beta_{tt,coach,male}$	-0.36	-1.14	*	-4.30	*
$\beta_{tt,coach,h\_size}$	0.08	0.54	*	-6.03	*
$\beta_{tt,coach,transfer}$	-0.31	-2.12	*	-9.05	*
$\beta_{tt,coach,waiting}$	-0.09	-4.43	*	-53.16	*
$\beta_{tt,coach,headway}$	0.00	-2.87	*	-1282.60	*
$\beta_{tt,coach,med.\_occ.}$	-0.12	-0.49	*	-4.55	*
$\beta_{tt,coach,high\_occ.}$	-0.25	-1.05	*	-5.32	*
$\beta_{tt,car,commute}$	-0.03	-5.11	*	-203.82	*
$\beta_{tt,car,shop}$	-0.02	-2.59	*	-172.88	*
$\beta_{tt,car,business}$	-0.03	-5.66	*	-214.76	*
$\beta_{tt,car,leisure}$	-0.03	-5.19	*	-204.43	*
$\beta_{tt,car,congestion}$	-0.04	-6.14	*	-169.77	*
$\beta_{tt,car,access}$	-0.03	-4.30	*	-139.62	*
$\beta_{tt,plane,business}$	-0.02	-1.58	*	-74.66	*
$\beta_{tt,plane,leisure}$	-0.64	-3.03	*	-7.78	*
$\beta_{tt,plane,waiting}$	-0.02	-2.02	*	-116.98	*
$\beta_{tt,plane,access}$	-0.02	-2.10	*	-132.44	*
$\beta_{cost,commute}$	-0.07	-1.39	*	-21.53	*
$\beta_{cost,shop}$	-0.15	-2.73	*	-20.77	*
$\beta_{cost,business}$	-0.09	-5.06	*	-59.23	*
$\beta_{cost,leisure}$	-0.16	-6.18	*	-44.82	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
μ_{mc}	1.00	NA	NA	NA	NA
$\mu_{rc,pt}$	2.16	4.94	*	2.65	*
$\mu_{rc,car}$	2.55	5.54	*	3.36	*
$\mu_{rel,pt}$	2.21	4.81	*	2.64	*
$\mu_{rel,car}$	1.88	5.76	*	2.69	*
$\mu_{rel,plane}$	1.88	3.40	*	1.60	*

A.2.2 BIK 10

A.2.2.1 500,000+ inhabitants

Table A.19: Estimation Statistics BIK 10 Model (500,000+ inh.)

Statistic	Value
Number of decision makers	1197
Number of observations	17,225
Null log-likelihood	-14,286
Final log-likelihood	-10,583
Estimated parameters	65
ρ^2	0.26
Adjusted ρ^2	0.25
Akaike Information Criterion	21,296
Bayesian Information Criterion	21,800

Table A.20: Estimates of BIK 10 Model (500,000+ inh.)

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-1.0002	-1.74	NA	-3.48	*
α_{bike}	0.4796	0.53	NA	-0.57	NA
α_{pt}	0.2064	0.59	NA	-2.28	*
α_{coach}	-0.5494	-1.05	NA	-2.97	*
α_{car}	0	NA	NA	NA	NA
α_{plane}	3.0291	3.05	*	2.04	*
$\lambda_{inc,cost}$	-0.2878	-2.71	*	-12.13	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\lambda_{dist,time}$	-0.4061	-12.24	*	-42.37	*
$\lambda_{dist,cost}$	-0.6747	-14.58	*	-36.2	*
λ_{stdev}	-0.7281	-5.88	*	-13.95	*
$\lambda_{tt,transfer,pt}$	-0.2891	-6.33	*	-28.21	*
$\lambda_{tt,waiting,pt}$	-0.8567	-6.68	*	-14.47	*
$\lambda_{tt,access,pt}$	-0.7326	-8.47	*	-20.04	*
$\lambda_{tt,waiting,coach}$	-0.7682	-4.28	*	-9.84	*
$\lambda_{time,congestion,car}$	-0.7479	-6.27	*	-14.64	*
$\lambda_{time,access,car}$	-0.2809	-2.07	*	-9.45	*
$\beta_{stdev,pt}$	-0.0139	-3.92	*	-285.09	*
$\beta_{stdev,car}$	-0.0135	-3.69	*	-277.76	*
$\beta_{stdev,coach}$	0.0056	0.34	NA	-60.42	*
$\beta_{stdev,plane}$	-0.0202	-1.8	NA	-91.09	*
inc_{miss}	0.3962	1.69	NA	-2.57	*
$\beta_{tt,walk,commute}$	-0.011	-2.82	*	-260.48	*
$\beta_{tt,walk,shop}$	-0.0192	-3.45	*	-182.63	*
$\beta_{tt,walk,business}$	0	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.0176	-3.96	*	-229.8	*
$\beta_{tt,bike,commute}$	-0.0428	-3.11	*	-75.79	*
$\beta_{tt,bike,shop}$	-0.0577	-3.17	*	-58.19	*
$\beta_{tt,bike,business}$	0	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.0396	-2.7	*	-70.93	*
$\beta_{tt,pt,commute}$	-0.024	-6.31	*	-269.82	*
$\beta_{tt,pt,shop}$	-0.0286	-3.71	*	-133.29	*
$\beta_{tt,pt,business}$	-0.0154	-6.28	*	-413.68	*
$\beta_{tt,pt,leisure}$	-0.0179	-6.76	*	-384.45	*
$\beta_{tt,pt,age}$	-0.0035	-0.71	NA	-206.12	*
$\beta_{tt,pt,transfer}$	-0.2183	-7.16	*	-39.95	*
$\beta_{tt,pt,waiting}$	-0.0153	-4.48	*	-296.97	*
$\beta_{tt,pt,headway}$	-0.0035	-2.31	*	-653.18	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,access}$	-0.0303	-6.51	*	-221.4	*
$\beta_{tt,pt,med.\_occ.}$	-0.1367	-2.21	*	-18.41	*
$\beta_{tt,pt,high\_occ.}$	-0.0518	-2.44	*	-49.59	*
$\beta_{tt,coach,business}$	-0.0211	-4.02	*	-194.02	*
$\beta_{tt,coach,leisure}$	-0.0214	-4.37	*	-208.43	*
$\beta_{tt,coach,male}$	-0.2031	-0.85	NA	-5.04	*
$\beta_{tt,coach,h\_size}$	0.1178	1.11	NA	-8.33	*
$\beta_{tt,coach,transfer}$	-0.2576	-2.18	*	-10.67	*
$\beta_{tt,coach,waiting}$	-0.11	-5.59	*	-56.42	*
$\beta_{tt,coach,headway}$	-0.0018	-3.13	*	-1720.8	*
$\beta_{tt,coach,med.\_occ.}$	-0.2567	-1.63	NA	-7.96	*
$\beta_{tt,coach,high\_occ.}$	-0.1689	-1.15	NA	-7.99	*
$\beta_{tt,car,commute}$	-0.0235	-5.14	*	-223.97	*
$\beta_{tt,car,shop}$	-0.0152	-3.36	*	-223.86	*
$\beta_{tt,car,business}$	-0.0176	-5.43	*	-313.7	*
$\beta_{tt,car,leisure}$	-0.0167	-5.55	*	-337.03	*
$\beta_{tt,car,congestion}$	-0.0249	-5.51	*	-227.05	*
$\beta_{tt,car,access}$	-0.0231	-5.14	*	-228.22	*
$\beta_{tt,plane,business}$	-0.0153	-1.77	NA	-117.35	*
$\beta_{tt,plane,leisure}$	-0.6463	-4.47	*	-11.37	*
$\beta_{tt,plane,waiting}$	-0.0155	-1.75	NA	-114.62	*
$\beta_{tt,plane,access}$	-0.0176	-2.87	*	-166.14	*
$\beta_{cost,commute}$	-0.1083	-2.85	*	-29.19	*
$\beta_{cost,shop}$	-0.1529	-3.94	*	-29.69	*
$\beta_{cost,business}$	-0.0772	-6.51	*	-90.81	*
$\beta_{cost,leisure}$	-0.1308	-6.8	*	-58.83	*
μ_{mc}	1	NA	NA	NA	NA
$\mu_{rc,pt}$	2.592	6.85	*	4.21	*
$\mu_{rc,car}$	2.864	5.27	*	3.43	*
$\mu_{rel,pt}$	2.302	7.65	*	4.33	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rel,car}$	2.259	5.5	*	3.07	*
$\mu_{rel,plane}$	1.298	3.97	*	0.91	NA

A.2.2.2 100,000-499,999 inhabitants

Table A.21: Estimation Statistics BIK 10 Model (100,000-499,999 inh.)

Statistic	Value
Number of decision makers	917
Number of observations	13,143
Null log-likelihood	-10,896
Final log-likelihood	-7,380
Estimated parameters	65
ρ^2	0.32
Adjusted ρ^2	0.32
Akaike Information Criterion	14,890
Bayesian Information Criterion	15,377

Table A.22: Estimates of BIK 10 Model (100,000-499,999 inh.)

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-1.4354	-2.64	*	-4.48	*
α_{bike}	3.9173	2.06	*	1.53	
α_{pt}	0.2388	0.55		-1.76	
α_{coach}	-0.7566	-1.03		-2.38	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{car}	0	NA	NA	NA	NA
α_{plane}	0.8245	0.7		-0.15	
$\lambda_{inc,cost}$	-0.3027	-3.05	*	-13.14	*
$\lambda_{dist,time}$	-0.4849	-15.1	*	-46.25	*
$\lambda_{dist,cost}$	-0.721	-14.54	*	-34.71	*
λ_{stdev}	-0.469	-5.25	*	-16.44	*
$\lambda_{tt,transfer,pt}$	-0.2311	-3.36	*	-17.89	*
$\lambda_{tt,waiting,pt}$	-0.5242	-5.26	*	-15.28	*
$\lambda_{tt,access,pt}$	-0.5685	-6.53	*	-18.02	*
$\lambda_{tt,waiting,coach}$	-1.1304	-0.74		-1.39	
$\lambda_{time,congestion,car}$	-0.6057	-6.39	*	-16.94	*
$\lambda_{time,access,car}$	-0.1276	-1.14		-10.07	*
$\beta_{stdev,pt}$	-0.0183	-3.52	*	-195.5	*
$\beta_{stdev,car}$	-0.0183	-4.65	*	-258.48	*
$\beta_{stdev,coach}$	-0.0177	-0.47		-27.07	*
$\beta_{stdev,plane}$	-0.0235	-2.8	*	-121.94	*
inc_{miss}	2.0937	1.45		0.76	
$\beta_{tt,walk,commute}$	-0.0165	-4.14	*	-254.97	*
$\beta_{tt,walk,shop}$	-0.0133	-2.69	*	-204.95	*
$\beta_{tt,walk,business}$	0	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.0146	-5.47	*	-379.99	*
$\beta_{tt,bike,commute}$	-0.104	-4.22	*	-44.85	*
$\beta_{tt,bike,shop}$	-0.1069	-4.04	*	-41.83	*
$\beta_{tt,bike,business}$	0	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.0942	-3.75	*	-43.57	*
$\beta_{tt,pt,commute}$	-0.0244	-5.25	*	-220.53	*
$\beta_{tt,pt,shop}$	-0.0266	-4.28	*	-165.18	*
$\beta_{tt,pt,business}$	-0.0183	-3.75	*	-209.28	*
$\beta_{tt,pt,leisure}$	-0.0267	-6.75	*	-259.48	*
$\beta_{tt,pt,age}$	-0.0117	-1.73		-149.26	*

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,transfer}$	-0.2369	-6.55	*	-34.22	*
$\beta_{tt,pt,waiting}$	-0.0266	-4.84	*	-187.04	*
$\beta_{tt,pt,headway}$	-0.0066	-3.6	*	-550.34	*
$\beta_{tt,pt,access}$	-0.0321	-5.83	*	-187.67	*
$\beta_{tt,pt,med.\_occ.}$	-0.1276	-1.6		-14.12	*
$\beta_{tt,pt,high\_occ.}$	-0.0691	-2.16	*	-33.5	*
$\beta_{tt,coach,business}$	-0.0286	-4.05	*	-145.42	*
$\beta_{tt,coach,leisure}$	-0.0292	-4.15	*	-145.88	*
$\beta_{tt,coach,male}$	-0.4002	-1.36		-4.75	*
$\beta_{tt,coach,h\_size}$	-0.0002	0		-8.86	*
$\beta_{tt,coach,transfer}$	-0.3385	-1.97	*	-7.78	*
$\beta_{tt,coach,waiting}$	-0.0398	-0.56		-14.71	*
$\beta_{tt,coach,headway}$	-0.0026	-3.5	*	-1368.31	*
$\beta_{tt,coach,med.\_occ.}$	-0.1253	-0.56		-5.06	*
$\beta_{tt,coach,high\_occ.}$	-0.1534	-1.01		-7.58	*
$\beta_{tt,car,commute}$	-0.035	-5.6	*	-165.51	*
$\beta_{tt,car,shop}$	-0.0142	-3	*	-214.04	*
$\beta_{tt,car,business}$	-0.0266	-6.37	*	-246.28	*
$\beta_{tt,car,leisure}$	-0.0251	-6.03	*	-245.77	*
$\beta_{tt,car,congestion}$	-0.0352	-6.15	*	-180.95	*
$\beta_{tt,car,access}$	-0.0285	-6.09	*	-219.95	*
$\beta_{tt,plane,business}$	-0.0284	-2.84	*	-102.85	*
$\beta_{tt,plane,leisure}$	-0.5809	-3.47	*	-9.45	*
$\beta_{tt,plane,waiting}$	-0.0152	-2.07	*	-138.04	*
$\beta_{tt,plane,access}$	-0.0124	-1.99	*	-162.28	*
$\beta_{cost,commute}$	-0.2392	-4.68	*	-24.25	*
$\beta_{cost,shop}$	-0.1102	-3.55	*	-35.79	*
$\beta_{cost,business}$	-0.1442	-4.28	*	-33.99	*
$\beta_{cost,leisure}$	-0.1723	-6.77	*	-46.06	*
μ_{mc}	1	NA	NA	NA	NA

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Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rc,pt}$	2.3319	6.26	*	3.57	*
$\mu_{rc,car}$	2.425	6	*	3.53	*
$\mu_{rel,pt}$	1.7816	7.56	*	3.32	*
$\mu_{rel,car}$	1.8927	6.53	*	3.08	*
$\mu_{rel,plane}$	1.943	3.85	*	1.87	

A.2.2.3 50,000-99,999 inhabitants

Table A.23: Estimation Statistics BIK 10 Model (50,000-99,999 inh.)

Statistic	Value
Number of decision makers	276
Number of observations	3,899
Null log-likelihood	-3,236
Final log-likelihood	-1,988
Estimated parameters	65
ρ^2	0.39
Adjusted ρ^2	0.37
Akaike Information Criterion	4,107
Bayesian Information Criterion	4,514

Table A.24: Estimates of BIK 10 Model (50,000-99,999 inh.)

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-0.1232	-0.06		-0.53	
α_{bike}	6.9533	1.31		1.12	
α_{pt}	-0.6489	-0.59		-1.5	
α_{coach}	0.4048	0.19		-0.27	
α_{car}	0	NA	NA	NA	NA
α_{plane}	3.2032	1.02		0.7	
$\lambda_{inc,cost}$	-0.2093	-0.85		-4.93	*
$\lambda_{dist,time}$	-0.4789	-6.94	*	-21.44	*
$\lambda_{dist,cost}$	-0.5871	-5.92	*	-16	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
λ_{stdev}	-0.6371	-0.74		-1.91	
$\lambda_{tt,transfer,pt}$	-0.2059	-2.86	*	-16.78	*
$\lambda_{tt,waiting,pt}$	-0.9244	-4.76	*	-9.91	*
$\lambda_{tt,access,pt}$	-0.4449	-2.32	*	-7.53	*
$\lambda_{tt,waiting,coach}$	-1.4623	-1.39		-2.35	*
$\lambda_{time,congestion,car}$	-0.1137	-0.2		-1.93	
$\lambda_{time,access,car}$	-0.3067	-1.37		-5.83	*
$\beta_{stdev,pt}$	-0.0214	-0.59		-28.2	*
$\beta_{stdev,car}$	-0.0066	-0.65		-98.26	*
$\beta_{stdev,coach}$	-0.0408	-0.13		-3.38	*
$\beta_{stdev,plane}$	-0.0176	-0.87		-50.31	*
inc_{miss}	0.7351	1.04		-0.38	
$\beta_{tt,walk,commute}$	-0.0244	-1.9		-79.72	*
$\beta_{tt,walk,shop}$	-0.0248	-1.84		-76.1	*
$\beta_{tt,walk,business}$	0	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.2192	-4.05	*	-22.5	*
$\beta_{tt,bike,commute}$	-0.1375	-2.08	*	-17.23	*
$\beta_{tt,bike,shop}$	-0.1901	-2.69	*	-16.84	*
$\beta_{tt,bike,business}$	0	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.1444	-2.24	*	-17.73	*
$\beta_{tt,pt,commute}$	-0.016	-2.2	*	-139.7	*
$\beta_{tt,pt,shop}$	-0.0246	-1.91		-79.58	*
$\beta_{tt,pt,business}$	-0.0148	-2.61	*	-179.02	*
$\beta_{tt,pt,leisure}$	-0.0206	-3.35	*	-165.64	*
$\beta_{tt,pt,age}$	-0.0038	-0.24		-63.96	*
$\beta_{tt,pt,transfer}$	-0.2809	-3.84	*	-17.51	*
$\beta_{tt,pt,waiting}$	-0.0293	-2.29	*	-80.16	*
$\beta_{tt,pt,headway}$	-0.0053	-1.29		-243.77	*
$\beta_{tt,pt,access}$	-0.03	-2.42	*	-83.08	*
$\beta_{tt,pt,med.\_occ.}$	0.0404	0.22		-5.28	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,high\_occ.}$	-0.0116	-0.19		-16.44	*
$\beta_{tt,coach,business}$	-0.0382	-2.04	*	-55.35	*
$\beta_{tt,coach,leisure}$	-0.0267	-2.8	*	-107.54	*
$\beta_{tt,coach,male}$	-0.2049	-0.35		-2.03	*
$\beta_{tt,coach,h\_size}$	-0.7532	-3.15	*	-7.32	*
$\beta_{tt,coach,transfer}$	-0.8456	-1.65		-3.61	*
$\beta_{tt,coach,waiting}$	-0.0442	-0.71		-16.67	*
$\beta_{tt,coach,headway}$	-0.0008	-0.53		-650.47	*
$\beta_{tt,coach,med.\_occ.}$	0.2934	0.46		-1.1	
$\beta_{tt,coach,high\_occ.}$	0.5239	1.25		-1.14	
$\beta_{tt,car,commute}$	-0.028	-3.67	*	-134.84	*
$\beta_{tt,car,shop}$	-0.0309	-1.88		-62.72	*
$\beta_{tt,car,business}$	-0.0227	-4.07	*	-183.65	*
$\beta_{tt,car,leisure}$	-0.027	-3.77	*	-143.66	*
$\beta_{tt,car,congestion}$	-0.0241	-1.41		-60.06	*
$\beta_{tt,car,access}$	-0.0271	-3.11	*	-117.91	*
$\beta_{tt,plane,business}$	-0.0794	-2	*	-27.12	*
$\beta_{tt,plane,leisure}$	-0.6505	-2.1	*	-5.34	*
$\beta_{tt,plane,waiting}$	-0.0177	-0.86		-49.61	*
$\beta_{tt,plane,access}$	-0.0032	-0.28		-88.3	*
$\beta_{cost,commute}$	-0.2244	-2.92	*	-15.94	*
$\beta_{cost,shop}$	-0.4349	-2.24	*	-7.4	*
$\beta_{cost,business}$	-0.1871	-3.9	*	-24.78	*
$\beta_{cost,leisure}$	-0.1724	-3.07	*	-20.89	*
μ_{mc}	1	NA	NA	NA	NA
$\mu_{rc,pt}$	1.4029	2.62	*	0.75	
$\mu_{rc,car}$	2.9389	4.23	*	2.79	*
$\mu_{rel,pt}$	1.6077	3.77	*	1.42	
$\mu_{rel,car}$	1.8906	4.18	*	1.97	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rel,plane}$	1.1523	2.19	*	0.29	

A.2.2.4 1-49,999 inhabitants

Table A.25: Estimation Statistics BIK 10 Model (1-49,999 inh.)

Statistic	Value
Number of decision makers	679
Number of observations	9,589
Null log-likelihood	-7,936
Final log-likelihood	-5,436
Estimated parameters	65
ρ^2	0.32
Adjusted ρ^2	0.10
Akaike Information Criterion	11,001
Bayesian Information Criterion	11,467

Table A.26: Estimates of BIK 10 Model (1-49,999 inh.)

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{walk}	-1.4013	-2.09	*	-3.59	*
α_{bike}	2.1917	1.32		0.72	
α_{pt}	-0.5454	-0.91		-2.57	*
α_{coach}	-0.1392	-0.27		-2.2	*
α_{car}	0	NA	NA	NA	NA

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
α_{plane}	2.9172	1.66		1.09	
$\lambda_{inc,cost}$	-0.3245	-2.3	*	-9.39	*
$\lambda_{dist,time}$	-0.4355	-9.13	*	-30.1	*
$\lambda_{dist,cost}$	-0.5929	-9.2	*	-24.73	*
λ_{stdev}	-0.7378	-1.62		-3.81	*
$\lambda_{tt,transfer,pt}$	-0.1848	-2.19	*	-14.06	*
$\lambda_{tt,waiting,pt}$	-1.2587	-3.21	*	-5.75	*
$\lambda_{tt,access,pt}$	-0.6634	-5.59	*	-14.02	*
$\lambda_{tt,waiting,coach}$	-1.4707	-5.44	*	-9.13	*
$\lambda_{time,congestion,car}$	-0.5558	-3.94	*	-11.03	*
$\lambda_{time,access,car}$	-0.54	-2.46	*	-7	*
$\beta_{stdev,pt}$	-0.0097	-0.96		-99.93	*
$\beta_{stdev,car}$	-0.0099	-1.26		-128.31	*
$\beta_{stdev,coach}$	0.0425	1.18		-26.62	*
$\beta_{stdev,plane}$	-0.0264	-1.34		-52.11	*
inc_{miss}	0.4777	1.65		-1.81	
$\beta_{tt,walk,commute}$	-0.0169	-3.85	*	-231.34	*
$\beta_{tt,walk,shop}$	-0.0176	-2.83	*	-162.94	*
$\beta_{tt,walk,business}$	0	NA	NA	NA	NA
$\beta_{tt,walk,leisure}$	-0.0082	-2.6	*	-318.22	*
$\beta_{tt,bike,commute}$	-0.1005	-4.6	*	-50.36	*
$\beta_{tt,bike,shop}$	-0.0807	-2.96	*	-39.66	*
$\beta_{tt,bike,business}$	0	NA	NA	NA	NA
$\beta_{tt,bike,leisure}$	-0.0654	-2.77	*	-45.02	*
$\beta_{tt,pt,commute}$	-0.0275	-4.97	*	-185.61	*
$\beta_{tt,pt,shop}$	-0.0324	-3.7	*	-117.67	*
$\beta_{tt,pt,business}$	-0.0184	-4.16	*	-230.23	*
$\beta_{tt,pt,leisure}$	-0.0187	-4.36	*	-237.71	*
$\beta_{tt,pt,age}$	-0.0037	-0.4		-108.75	*
$\beta_{tt,pt,transfer}$	-0.2349	-5.76	*	-30.3	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\beta_{tt,pt,waiting}$	-0.0104	-1.29		-125.52	*
$\beta_{tt,pt,headway}$	-0.0061	-2.38	*	-391.2	*
$\beta_{tt,pt,access}$	-0.0406	-4.39	*	-112.45	*
$\beta_{tt,pt,med.\_occ.}$	-0.1816	-1.7		-11.09	*
$\beta_{tt,pt,high\_occ.}$	-0.0905	-1.97	*	-23.7	*
$\beta_{tt,coach,business}$	-0.027	-4.25	*	-161.71	*
$\beta_{tt,coach,leisure}$	-0.0347	-4.3	*	-128.15	*
$\beta_{tt,coach,male}$	-1.0787	-2.41	*	-4.65	*
$\beta_{tt,coach,h\_size}$	0.0141	3.81	*	-265.91	*
$\beta_{tt,coach,transfer}$	0.0152	0.08		-4.97	*
$\beta_{tt,coach,waiting}$	-0.1251	-3.49	*	-31.41	*
$\beta_{tt,coach,headway}$	-0.0027	-2.76	*	-1009.92	*
$\beta_{tt,coach,med.\_occ.}$	-0.6956	-2.78	*	-6.77	*
$\beta_{tt,coach,high\_occ.}$	-0.3281	-1.74		-7.05	*
$\beta_{tt,car,commute}$	-0.0424	-5.52	*	-135.77	*
$\beta_{tt,car,shop}$	-0.0158	-2.07	*	-133.04	*
$\beta_{tt,car,business}$	-0.0224	-4.98	*	-227.93	*
$\beta_{tt,car,leisure}$	-0.0235	-5.86	*	-254.99	*
$\beta_{tt,car,congestion}$	-0.0361	-5.09	*	-146.15	*
$\beta_{tt,car,access}$	-0.033	-5.21	*	-163.09	*
$\beta_{tt,plane,business}$	-0.0596	-2.33	*	-41.37	*
$\beta_{tt,plane,leisure}$	-0.8178	-3.21	*	-7.13	*
$\beta_{tt,plane,waiting}$	-0.012	-0.73		-61.11	*
$\beta_{tt,plane,access}$	-0.0077	-0.47		-60.84	*
$\beta_{cost,commute}$	-0.3174	-4.56	*	-18.93	*
$\beta_{cost,shop}$	-0.0314	-0.61		-19.89	*
$\beta_{cost,business}$	-0.087	-3.78	*	-47.19	*
$\beta_{cost,leisure}$	-0.146	-5.47	*	-42.96	*
μ_{mc}	1	NA	NA	NA	NA
$\mu_{rc,pt}$	2.1823	4.81	*	2.6	*

To be continued on the next page

Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Rob. t-stat (1)	Sign. (1)
$\mu_{rc,car}$	2.1419	5.68	*	3.03	*
$\mu_{rel,pt}$	1.4888	4.87	*	1.6	
$\mu_{rel,car}$	1.4733	5.25	*	1.69	
$\mu_{rel,plane}$	0.896	3.97	*	-0.46	

A.3 Latent Classe Model 2 Classes

The following model shows the complete results of Latent Class Model with 2 Classes.

Table A.27: Estimation Statistics Latent Class Model

Statistic	Value
Number of decision makers	3,069
Number of observations	43,856
Null log-likelihood	-36,353
Final log-likelihood	-22,981
Estimated parameters	117
ρ^2	0.37
Adjusted ρ^2	0.36
Akaike Information Criterion	46,197
Bayesian Information Criterion	47,213

Table A.28: Estimates of the Latent Class Model

	Class 1			Class 2		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
ω_{class_1}	0.2471	3.18	*	–	–	–
α_{walk}	-0.9444	-0.69		1.3561	1.93	
α_{bike}	1.0803	0.77		13.043	11.63	*
α_{pt}	0.9786	2.06	*	0.2336	0.54	

To be continued on the next page

	Class 1			Class 2		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
α_{coach}	0.6188	0.88		-0.3187	-0.34	
α_{car}	0	NA	NA	0	NA	NA
α_{plane}	3.0963	2.51	*	3.1313	2.66	*
$\lambda_{inc,cost}$	-0.1253	-0.95		-0.2363	-1.89	
$\lambda_{dist,time}$	-0.4146	-11.16	*	-0.5154	-29.3	*
$\lambda_{dist,cost}$	-0.5735	-12.03	*	-0.7632	-17.86	*
λ_{stdev}	-0.4477	-3.8	*	-0.6008	-6.03	*
$\lambda_{tt,transfer,pt}$	-0.3117	-4.37	*	-0.0102	-0.17	
$\lambda_{tt,waiting,pt}$	-0.6021	-4.5	*	-0.4651	-1.37	
$\lambda_{tt,access,pt}$	-0.5243	-7.32	*	2.2463	4.37	*
$\lambda_{tt,waiting,coach}$	-0.7432	-1.83		-1.2098	-9.66	*
$\lambda_{time,congestion,car}$	-0.5026	-6.83	*	-0.5875	-6.92	*
$\lambda_{time,access,car}$	-0.288	-3.41	*	-0.559	-5.05	*
$\beta_{stdev,pt}$	-0.0309	-3.4	*	-0.014	-1.91	
$\beta_{stdev,car}$	-0.0126	-2.99	*	-0.0193	-4.39	*
$\beta_{stdev,coach}$	-0.1686	-2.83	*	0.0587	2.16	*
$\beta_{stdev,plane}$	-0.022	-2.05	*	-0.0268	-2.31	*
$\beta_{tt,walk}$	-0.0454	-3.38	*	-0.0198	-4.31	*
$\beta_{tt,bike}$	-0.0973	-4.89	*	-0.1977	-14.78	*
$\beta_{tt,pt,commute}$	-0.0338	-7.83	*	-0.0238	-4.58	*
$\beta_{tt,pt,shop}$	-0.0442	-5.6	*	-0.0132	-1.89	
$\beta_{tt,pt,business}$	-0.0161	-6.41	*	-0.0501	-9.11	*
$\beta_{tt,pt,leisure}$	-0.0385	-6.46	*	-0.0277	-7.2	*
$\beta_{tt,pt,age}$	-0.0116	-1.74		-0.0021	-0.37	
$\beta_{tt,pt,transfer}$	-0.293	-7.17	*	-0.3459	-7.22	*
$\beta_{tt,pt,waiting}$	-0.0353	-5.43	*	-0.0132	-1.76	
$\beta_{tt,pt,headway}$	-0.0089	-4.61	*	-0.0054	-3.05	*

To be continued on the next page

	Class 1			Class 2		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
$\beta_{tt,pt,access}$	-0.0535	-9.37	*	0.0003	0.62	
$\beta_{tt,pt,med.\_occ.}$	-0.2362	-2.86	*	-0.0707	-0.79	
$\beta_{tt,pt,high\_occ.}$	-0.0877	-2.57	*	-0.0731	-1.64	
$\beta_{tt,coach,business}$	-0.0313	-4.32	*	-0.0448	-2.98	*
$\beta_{tt,coach,leisure}$	-0.0314	-3.8	*	-0.0279	-3.39	*
$\beta_{tt,coach,male}$	-0.3434	-1.07		-0.1966	-0.68	
$\beta_{tt,coach,h\_size}$	0.0093	2.12	*	-0.1863	-1.38	
$\beta_{tt,coach,transfer}$	-0.2424	-1.73		-0.2677	-1.8	
$\beta_{tt,coach,waiting}$	-0.0999	-4.47	*	-0.097	-4.64	*
$\beta_{tt,coach,headway}$	-0.0016	-2.74	*	-0.003	-4.14	*
$\beta_{tt,coach,med.\_occ.}$	-0.0877	-0.52		-0.4891	-2.24	*
$\beta_{tt,coach,high\_occ.}$	-0.079	-0.6		-0.2062	-1.31	
$\beta_{tt,car,commute}$	-0.0158	-6.11	*	-0.056	-8.97	*
$\beta_{tt,car,shop}$	-0.0094	-1.54		-0.0245	-3.55	*
$\beta_{tt,car,business}$	-0.0416	-8.34	*	-0.0148	-5.32	*
$\beta_{tt,car,leisure}$	-0.0133	-4.47	*	-0.0416	-9.49	*
$\beta_{tt,car,congestion}$	-0.0309	-7.76	*	-0.033	-8.12	*
$\beta_{tt,car,access}$	-0.0277	-6.74	*	-0.0343	-7.39	*
$\beta_{tt,plane,business}$	-0.0345	-2.91	*	-0.0296	-2.01	*
$\beta_{tt,plane,leisure}$	-0.8387	-4.46	*	-0.6669	-4.93	*
$\beta_{tt,plane,waiting}$	-0.0201	-1.92		-0.0187	-2.06	*
$\beta_{tt,plane,access}$	-0.0153	-1.85		-0.0152	-2.4	*
$\beta_{cost,commute}$	-0.1655	-4.3	*	-0.2644	-4.94	*
$\beta_{cost,shop}$	-0.1384	-3.18	*	-0.2457	-5.18	*
$\beta_{cost,business}$	-0.0698	-4.11	*	-0.184	-6.33	*
$\beta_{cost,leisure}$	-0.1747	-7.05	*	-0.1935	-6.2	*

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	Class 1			Class 2		
Parameter	Estimate	Rob. t-stat (0)	Sign. (0)	Estimate	Rob. t-stat (0)	Sign. (0)
common parameter						
inc_{miss}	0.6978	1.91		–	–	–
μ_{mc}	1	NA	NA	–	–	–
$\mu_{rc,pt}$	1.7866	10.18	*	–	–	–
$\mu_{rc,car}$	2.6274	10.12	*	–	–	–
$\mu_{rel,pt}$	1.4785	12.47	*	–	–	–
$\mu_{rel,car}$	1.7835	10.7	*	–	–	–
$\mu_{rel,plane}$	1.1669	6.08	*	–	–	–