Travel behaviour and environmental-transport policy

Theory and empirical studies

Ph.D. Thesis
September 2014

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Summary

This Thesis project aims to study the antecedents of daily travel behaviour in order to inform policy design. It consists of two parts, one theoretical and another more empirical. The first part studies sustainable commuting, assesses core factors and examines the role of bounded rationality in travel behaviour. In the second part these insights are then applied to Barcelona. All studies included within the Thesis focus on alleviating the pressure that transport exerts on the environment through effective and equitable policies. For this reason a special focus is put on travel mode choice.

The first part of the research developed a framework involving seven factors of GHG emissions that operate through affecting variations in commuting distances and travel mode choice (study 1). The framework was applied to the Barcelona Metropolitan Region (BMR). The results indicated that behavioural aspects of travellers are insufficiently recognized, which has led to an insufficient effectiveness of traditional policy interventions aimed at alleviating environmental pressure (e.g., physical planning and infrastructure supply, pollution standards, pricing mechanisms and information provision). Travellers are often limited by information frames and cognitive processes (e.g., habits, emotions and concern about reputation or status). In order to be more effective, environmental-transport policies need to better account for the bounded rationality and heterogeneity of travellers' preferences (e.g., time and social preferences). In the second study this Thesis investigates the application of insights from behavioural research to formulate more effective transport policies.

In the second part of the research, we looked in more detail at the way habits play a role in travel mode choice (study 3). From a representative sample of travellers in the BMR we identified two groups of habitual private vehicle users (motorcycle and car), which need specific policies to break down their unsustainable habits and form more sustainable ones. A third group of travellers, namely *Potential mode switchers,* can be considered a strategic target of policies; they are mainly car users, though familiar with

public transport making a regular use of travel information. Finally, in a fourth study the relative effect of several antecedents of travel mode choice and usage (including habits) for commuting journeys was empirically tested. A behavioural model was developed, which encompassed the insights collected throughout the previous studies forming this Thesis. It took into account the influence of attitudes (i.e. *rationally* formed preferences), constraints —those perceived by the individual and actual constraints (e.g., based on urban form features)— and habits. Results showed the superior explanatory power of habits in predicting both travel mode choice (private vehicle *vs.* public transport) and the variation in its usage.

In conclusion, the present Thesis highlighted the relevance of behavioural approaches in unfolding these *other* antecedents of (un)sustainable travel behaviour. Taking these approaches into account when designing environmental-transport policy would raise the effectiveness of traditional policy, while providing alternative ways to engage and motivate people to behave in an environmentally-friendly way.

Resum

Aquest projecte de Tesi té per objectiu estudiar els antecedents del comportament de viatge diari a fi d'informar el disseny de polítiques. Es compon de dues parts, una teòrica i una altra empírica. La primera part estudia els desplaçaments sostenibles a la feina, n'avalua els factors fonamentals, i examina el paper de la racionalitat limitada en el comportament de viatge. El coneixement adquirit s'aplica després a Barcelona (segona part). Tots els estudis inclosos en la Tesi se centren en l'alleujament de la pressió ambiental que exerceix el transport mitjançant polítiques eficaces i equitatives. Per aquest motiu, es posa un especial èmfasi en l'elecció del mode de transport.

La primera part de la investigació desenvolupa un marc conceptual que inclou set factors de les emissions de GEH que operen a través de l'afectació de les variacions en les distàncies de viatge i l'elecció modal (estudi 1). El marc va ser aplicat a la Regió Metropolitana de Barcelona (RMB). Els resultats indicaren que els aspectes conductuals dels viatgers no són prou reconeguts, el que significa que no són prou efectives les intervencions polítiques tradicionals destinades a alleujar la pressió ambiental (per exemple, la planificació física i la provisió d'infraestructura, els estàndards de contaminació, els mecanismes de fixació de preus i la provisió d'informació). Els viatgers estan sovint limitats per com la informació és comunicada (*framing,* emmarcament o enquadrament) i per processos cognitius propis (com ara hàbits, emocions i qüestions relacionades amb l'estatus). Per tal d'augmentar la seva eficàcia, les polítiques ambientals de transport han de tenir en compte, doncs, la racionalitat limitada i l'heterogeneïtat de les preferències dels viatgers (per exemple, les preferències temporals i socials). En un segon estudi, aquesta Tesi estudia precisament l'aplicació de la perspectiva conductual per la formulació de polítiques de transport més eficaces.

En la segona part de la recerca, estudiem en detall la forma en què els hàbits influeixen en l'elecció del mode de transport (estudi 3). A partir d'una mostra representativa de viatgers de la RMB, es van identificar dos grups d'usuaris habituals

dels vehicles privats (motos i cotxes), que necessiten de polítiques específiques per trencar els seus hàbits insostenibles i formar-ne altres de sostenibles. Un tercer grup de viatgers, l'anomenat *Potential mode switchers*, pot considerar-se un objectiu estratègic de les polítiques ambientals; es tracta principalment d'un grup d'usuaris d'automòbils, encara que familiaritzats amb el transport públic i que sovint s'informen sobre les alternatives modals. Finalment, en un quart estudi es va testar empíricament l'efecte relatiu de diversos antecedents de l'elecció i l'ús dels mitjans de transport (incloent-hi els hàbits) per als desplaçaments a la feina. Es va desenvolupar un model de comportament que integra el coneixement recollit en els estudis previs que conformen aquesta Tesi. El model dóna compte de la influència de les actituds (és a dir, les preferències formades de manera racional), els obstacles —tant els percebuts pels individus com els reals (per exemple, els que fan referència a les característiques de la forma urbana)—, i els hàbits. Els resultats mostraren la gran capacitat predictiva dels hàbits, tant pel que fa a l'elecció del mitjà de transport (vehicle privat *vs.* transport públic), com pel que fa a la variació en el seu ús.

En conclusió, aquesta Tesi posa en relleu la importància de les aproximacions conductuals en la identificació d'aquests *altres* antecedents del comportament de viatge (in)sostenible. Tenir-los en compte en dissenyar la política ambiental per al transport augmentaria l'eficàcia dels instruments tradicionals, alhora que proporcionaria formes alternatives de participació i motivació de les persones per tal que ens comportéssim de manera pro-ambiental.

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Contents

1 Introduction

1.1 Travel behaviour and environmental-transport policy: perspectives, behavioural models and antecedents

Transport creates a great deal of environmental pressure. Behavioural change is therefore crucial to withdraw processes such as excess driving and car-dependency, which otherwise would more than offset energy efficiency improvements and physical changes advanced by strategic urban planning. Despite all the policy efforts to cut down private vehicle usage, people are still driving more and more. As such, travel behaviour, and particularly refraining from driving, makes a perfect example of an environmentally-significant behaviour to study. A special focus on travel mode choice seems inevitable given the disproportional contribution of private vehicles to environmental impact. Similarly, commuting journeys are of great importance since they structure daily travel behaviour and have a notable influence on travel-related choices concerning where to live and work and whether or not to get a car.

Behavioural change can be favoured through effective and equitable environmental policy. For policies to be effective these need to target influential behavioural antecedents leading to (un)sustainable travel. Understanding the determinants of travel behaviour is therefore a prerequisite. Travel behaviour is complex and travel-related decisions involve many underlying factors. With this in mind, the present Thesis aims to open the black box by looking at three main perspectives for environmental policy on transport, namely planning, economic and behavioural perspectives, while focusing especially on this last one. This involves exploring the main behavioural models underlying these three different, yet complementary, approximations, and their fundamental assumptions about the factors influencing daily travel behaviour. In addition, the theoretical insights gained are applied to the case study of the Barcelona Metropolitan Region (BMR).

In order to change a person's travel behaviour, one can either change the conditions under which the person operates (i.e., change the context of decision making) or try to change the person's attitudes towards travel behaviour, namely her perception of the choice situation more generally (Stradling et al. 2000). Planning and economic perspectives favour measures involving structural interventions aimed at changing the context in which decisions are made. That is, changing the relative attractiveness of specific behaviours (e.g., by improving accessibility to public transport or through raising the costs of driving) or directly enforcing certain behaviour through regulations (e.g., prohibiting the entrance of vehicles into city centres). The main objective of strategic planning is to facilitate change in travel behaviour by removing physical barriers. The objective from an economic perspective is to help people make better decisions, which is achieved by means of price signals and information provision. On the other hand, strategies with a psychological basis aim to change people's perceptions, knowledge, beliefs and values, and positive attitudes and norms concerning car use. Such strategies involve educating people to take responsibility for their environmental impact, providing tailored information and feedback, presenting green alternatives (e.g., public transport) as the recommended option, favouring social norms supporting sustainable travel alternatives and role modelling (Abrahamse et al. 2007; Fujii 2006; Metcalfe and Dolan 2012; O'Connor 2002; Stern 1999; Thaler and Sunstein 2008).

Travel behaviour has an undoubtedly spatial component; especially commuting, which is tightly linked to residence and job locations and the transport offer available there. The urban environment and the transport network develop in interaction (Button 1993). Changes in the transport system affect land-use patterns and densities —new places become accessible and gain attractiveness. Meanwhile, changes in where population and economic activities locate (i.e. the distribution of land uses) affect, in turn, travel patterns and future demand for new transport infrastructure. This symbiotic view has lead to the idea that travel behaviour change can be indirectly induced through physical changes; the basis for planning intervention. This belief has been reinforced by the observation of urban sprawl leading to the phenomena of car-dependency. Thus, in order to counteract sprawl and associated car use, planning strategies have focused on the provision of a supportive built environment characterised by compact urban designs where the use of public transport, walking and cycling are favoured through high-densities and intermixing of land-uses (Cervero and Kockelman 1997; Ewing and Cervero 2001, 2010; Handy et al. 2002). The underlying presumption is that people will take advantage of these changes in urban forms. However, evidence concerning the actual influence of the physical environment on travel behaviour, and particularly of the effect of strategic planning, is limited to just people who are motivated to refrain from driving and who want to reside in liveable (i.e., *walkable*) spaces (Handy 2005). For those social groups with strong pro-car attitudes, they tend to self-select living environments that match their travel preference for the car, that is, low-density emplacements (Handy et al. 2005a; Handy and Mokhtarian 2005; Cao et al. 2002). Yet, car-dependency as a phenomenon is more complex to revert. A reinforced pattern of lifestyle and associated car use exists highlighting the importance of distinguish among car-dependent people and car-dependent journeys, a consideration that should be included in policies (Goodwin 1995). For necessary car journeys, planners can explore ways of reducing journey distances or improving accessibility to public transport (Handy et al. 2005b). For driving by choice, policy solutions are more complicated and may involve changing people's attitudes and perceptions towards alternatives to the car. This reveals that the built environment imposes constraints that hinder behaviour, yet behaviour and travel choices are more complex, and so the built environment becomes just one aspect influencing travel behaviour.

The behavioural model underlying the mainstream economic perspective is based on the premise of an ideal traveller who is rational, fully informed, good at computing probabilities and has stable preferences directed at maximising personal utility. This representative traveller values transport alternatives for their instrumental function: enabling them to reach activities at a minimum cost, whether this means time or money expenses (travel as a derived demand). This view favours pricing policies aimed at correcting for sub-optimal and undesirable choices, such as discouraging car use by increasing the costs of driving (see Small and Verhoef 2007). In this vein, travellers are constrained by income, while having to make trade-offs between the costs and benefits of available transport alternatives. However, people (and travellers) hardly behave consistently with pure rationality, as captured by these axiomatic rules. This constricted view of transport choices overlooks, on the one hand, that travellers are heterogeneous and inconsistent in their preferences and expressing bounded rationality in their choices. In fact, their intuitions and perceptions of the transport situation are often biased. On the other hand, it contradicts evidence supporting the fact that the car *is more than a means of transport*. Having a car provides psychological and social benefits (e.g., mastery, self-esteem and prestige), which public transport users do not derive from their transport modes (Ellaway et al. 2003). The car is a symbol of social status and a way of self-representation, while driving evokes feelings of freedom, independence, power and arousal (Steg et al. 2001; Steg 2005). Yet, for most car users their car outperforms public transport not just on functional/instrumental factors (cost, speed, flexibility, comfort, stress-free, reliability, safety, carrying capacity, etc.), but on social-symbolic and affective grounds as well (Steg et al. 2003). Transport costs and the rest of instrumental motives are hence relevant factors influencing travel behaviour, although there are others.

The behavioural or psychological perspective does capture these *other* factors or antecedents of travel behaviour. Psychologically-based approaches rely on descriptive models of decision making, which attempt to describe how people actually behave. In this Thesis, insights from behavioural economics and from environmental and social psychology are analysed.

Behavioural economics merges the fields of economics and psychology (Camerer 1999; McFadden1999; Rabin 1998). Insights from behavioural economics rely on the observation of people's bounded rationality, context-dependent preferences, and social and self-identity concerns. Most daily travel choices are made under uncertainty —travel time, for instance, which varies as a result of traffic (congestion), occasional accidents and vehicle breakdowns. Moreover, travellers are particularly prone to social and self-identity concerns. Basically, our mind plays tricks on us, especially when choices are complex (e.g., options are not readily comparable) and involve prospects (uncertainty). For example, most people misinterpret the information provided on public transport schedules about headways and expected arrival times (Bates et al. 2001; Rietveld 2003). People are bad at computing probabilities and so their estimates about travel time distributions can be inaccurate and leave them with the impression of having to wait for too long for the bus (Avineri 2004). Besides, other-regarding preferences, such as reputation and social concerns, help explain issues like why the purchase of a Toyota Prius (i.e., a hybrid car) is related to the level of environmental concern of one's neighbours (Sexton and Sexton 2011). In the same vein, without recognising the effect of personal norms on behaviour (i.e., feelings of moral obligation to behave pro-environmentally), it would be hard to explain why it is that some people voluntarily choose to refrain from driving when it is in their personal interest to defy. These departures from rational behaviour produce systematic choice errors that contribute to the ineffectiveness of traditional transport policies and thus have to be taken into account in policy design. Therefore, one chapter of this Thesis studies the relevance of insights from behavioural economics to the study of travel behaviour.

Behavioural economics is enjoying increased attention in fields related to environmental economics and policy (Brown and Hagen 2010; Gsottbauer and van den Bergh 2011; Shogren and Taylor 2008; Venkatachalam 2008), covering a variety of environmental behaviours, such as green consumerism, recycling, conservation of natural resources and climate change negotiations (Gsottbauer and van den Bergh 2013; Jackson 2005). It has already received some attention in recent studies on travel behaviour, but so far only few studies have combined it with environmental-transport policy analysis (e.g., Avineri 2012; Metcalfe and Dolan 2012; van Exel 2011; van de Kaa 2008). Yet, these have not resulted in a systematic set of policy recommendations.

A subtheme of bounded rationality particularly relevant for daily travel behaviour is that of habitual behaviour as most of our daily journeys are repetitive. One could anticipate that repetition will lead to learning and improvement, so that better choices are made. However, learning does not guarantee more optimal choices, at least in the mid-term (Erev and Barron 2005). For choices made under imperfect information travellers learn from their experiences, which can be misleading. Travellers overreact to recent, negative experiences such as punctual delays (Mahmassani and Srinivasan 2004), which reduce the probability that this choice is repeated and impede learning about the actual value of the alternative (Denrell and March 2001). Instead, a more reasonable and realistic alternative is that people tend to repeat past actions that resulted in satisfying outcomes and form habits (i.e., automatic responses) (Ouellette and Wood 1998). Habits have a great influence on travel mode choices (Gardner 2009; Gärling and Axhausen 2003; Thøgersen 2006; Verplanken et al. 1994). Habitual travel behaviour violates choice rationality because habitual choices are not reasoned, namely involving preference formation, deliberate information processing and preference-based choice processes (Gärling et al. 2001). Yet, for relatively unimportant decisions, such as what travel mode to use, it makes total sense that people create these mental loops that save them time and effort in decision-making (see Cialdini 1993). Indeed, this is a convenient and relatively efficient strategy to cope with daily choices, which is actually in line with the economic rationale. Unfortunately, when unsustainable habits are formed, these imply the automatic repetition of undesirable behaviours. People with strong travel mode choice habits tend to disregard relevant and compelling information regarding travel alternatives, thus overlooking situational changes and improvements. Moreover, habits moderate the effects of norms and deliberated intentions to change behaviour and lead to misperceptions about the performance of non-habitual travel modes (Aarts and Dijksterhuis 2000a; Anable and Gatersleben 2005; Klöckner et al. 2003; Klöckner and Matthies 2004). A further issue concerning habit generalisation is the fact thathabits may spread to other choice contexts. For instance, the habit of driving to work every morning can be generalised into making all (morning) journeys by car (Verplanken and Aarts 1999). The effort required to break old habits and form new ones should not be underestimated. Yet, personalised, resource intensive interventions are necessary.

Finally, behavioural theories and models from environmental and social psychology identify several types of antecedents of travel behaviour, while taking into account that people's perceptions (i.e., their interpretation of the transport situation) may be biased. Recognised antecedents include motivational factors (attitudes, moral and normative concerns, affect or emotions), perceived and actual constraints in the form of barriers or obstacles precluding behaviour (e.g., availability and accessibility to transport alternatives), and habits as previously described (Steg and Vlek 2009). Attitudes are formed as a result of a reasoned evaluation of transport instrumental factors, contrarily to affective and social factors. Normative and moral factors, on the other hand, regard social and environmental motives, respectively. Certain behaviour, such as travel behaviour, require of resources and opportunities (e.g., physical infrastructure). Yet, constraints and perceived barriers may override people's motivatio to change their current behaviour (Abrahamse et al. 2009; Tanner 1999). Models of environmental and social psychology usually take several of these determinants to explain travel behaviour, particularly travel mode choice. Some models conceive travel mode choice as the result of a deliberative decision-making process, where the pros and cons of available transport alternatives are assessed on the basis of purely evaluative judgement (i.e., attitude) and perceived social pressure (Theory of Planned Behaviour); perspective in line with economic rationality. Others, instead, focus on the effect of affective and altruistic motives (Norm Activation Model), and others see travel mode choices as unconscious, automatic choices, resulting from daily routines and habits (Theory of Interpersonal Behaviour). Nevertheless, these viewpoints are indeed not mutually excluding and so many studies combine several theories in order to avoid taking a partial approach and also to increase the models' explanatory capacity. Attempts have been made to combine several models into a general and comprehensive model of travel behaviour (e.g., Bamberg and Schmidt 2003; Carrus et al. 2008; Klöckner and Blöbaum 2010; Perugini and Bagozzi 2001, 2004), and this Thesis aims to contribute to those.

1.2 Research objectives and questions

The Thesis aims to contribute to debates on how to facilitate environmentally-significant behaviour by taking travel behaviour as an example. This of course places the focal debate on transport (un)sustainability and behavioural change. The main objectives guiding the research undertaken involve, first, the identification of antecedents of (un) sustainable travel behaviour. Our primary concern is with personal travel, and in this respect a special attention is given to travel mode choice and usage. Several approaches to, and behavioural models of transport are analysed. These comprise the mainstream economic model of "representative, rational travellers", the alternative model offered by behavioural economics of bounded rational travellers with social preferences, and various models from social and environmental psychology widely applied to the study of pro-environmental behaviours. Ultimately, travel mode choice is modelled on the basis of the insights gained in these previous research steps. The second objective is to derive implications and put forward recommendations for the design of effective environmental policies focused on transport. Accordingly, a theory-founded policy package is proposed and lessons and guidelines to further improve the design of policy instruments are provided. All in all, the theoretical insights gained are applied to the case study of the Barcelona Metropolitan Region (BMR) and context-specific policy recommendations are made.

Four studies are reported here that provide answers to the following specific questions:

1. Which factors underlie the relation GHG emissions-commuting according to planning, economic and behavioural studies? What would a complete, effective policy package tackling all these factors look like? (Addressed in *Chapter 3*).
2. Which characteristics of travellers produce systematic biases in their behaviour with implications for policy and how can policy be adapted to address them? (Addressed in *Chapter 4*).

3. What types of habitual travel mode users can be identified in the context of the BMR? How does this contribute to the study of habits and to assist policy design? (Addressed in *Chapter 5*).
4. What is the relative contribution of preferences (i.e., attitude), opportunities and habit in explaining variations in both private vehicle usage and public transport usage? (Addressed in *Chapter 6*).

1.3 Overview of the Thesis

The Thesis is structured in four main chapters that elaborate on the research questions mentioned above (Figure 1.1). Two of these four chapters are theoretical (Chapters 3 and 4) and two empirical (Chapters 5 and 6). The outline of the Thesis is as follows:

Chapter 2 introduces the methodologies used in the four main chapters forming this Thesis.

Chapter 3 reviews the perspectives offered on planning, economic and behavioural studies for commuting transport, particularly about the factors underlying increased commuting distances and car usage. Commuting or the journey to work makes up an important part of transport. It should therefore be a target of climate policies that aim to reduce greenhouse gas emissions from transport. To design an effective climate-transport policy package, this article constructs a framework consisting of two core aspects of commuting patterns, namely increased commuting distances and car usage, driven by five categories of underlying factors. Policy implications are derived from this. The set of factors and policies are then studied for the Barcelona Metropolitan Region in Spain. We find that it is essential to limit dispersion of the population and provide spatially adequate public transport services. In addition, the effects of imperfections in labour and housing markets and commuter bias in transport preferences towards car use should also be addressed in policy.

Chapter 4 investigates the potential of combining insights from behavioural economics with the study of travel behaviour and environmental-transport policy analysis. The transport sector creates a great deal of environmental pressure. Many current policies aimed at reducing this pressure are not fully effective because behavioural aspects of travellers are insufficiently recognised. Insights from behavioural economics can contribute to a better understanding of travel behaviour and choices, and the impact of these on policies. Few studies have examined this issue. We review these and provide a broader, more encompassing perspective on environmental policy focused on transport. In doing so, we take into account bounded rationality as well as social preferences, and look at behavioural biases described for both long-term choices affecting daily travel —residential and employment location, owning a driving license and car purchasing— and short-term or daily travel choices —choice of destination or activity, departure time, route and travel mode choices.

Chapter 5 explores travellers' heterogeneous behaviours with a focus on travel mode choice habits. Habits play a key role in travel mode choice. This empirical chapter identifies types of travellers according to their modal habits, in the context of the Barcelona Metropolitan Region (BMR) in Spain. This exercise is of great interest from a policy perspective, since unsustainable modal habits need to be specifically addressed through policy. Clustering procedures were used to classify travellers according to a "habit indicator", namely, the reported frequency of use of travel modes. Data were retrieved from the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006, acronym in Catalan). We identified seven relatively homogeneous types, of which the more challenging, from a policy perspective are: habitual users of the motorcycle or *Motorcycle enthusiasts*, and habitual users of the car or *Car drivers*. A third type, namely *Potential mode switchers*, can be considered a relatively easy target of environmental-transport policies; they are mainly car users, though familiar with public transport.

In *Chapter 6* the influence of various determinants of travel mode usage is empirically tested for both users of private vehicles and users of public transport. Understanding the antecedents of travel mode usage is a critical issue in developing effective environmental-transport policies. With this in mind, a conceptual model was created that combines insights from Frey and Foppa's *ipsative theory of behaviour* (actual and perceived choice constraints) and Ajzen's *theory of planned behaviour* (attitude) with the notion of *habit*. The model was tested through structural equation modelling on a sample of travellers from the Barcelona Metropolitan Region in Spain. Data were retrieved from the *Survey of Daily Mobility of Catalonia 2006*. Results indicated that habit explained as much as 16% of the variance on private vehicle usage and 15% of public transport usage. Other antecedents examined (attitude and choice constraints) turned out to be non significant. Implications for policy are discussed and recommendations are put forward.

Lastly, *Chapter 7* draws the main conclusions.

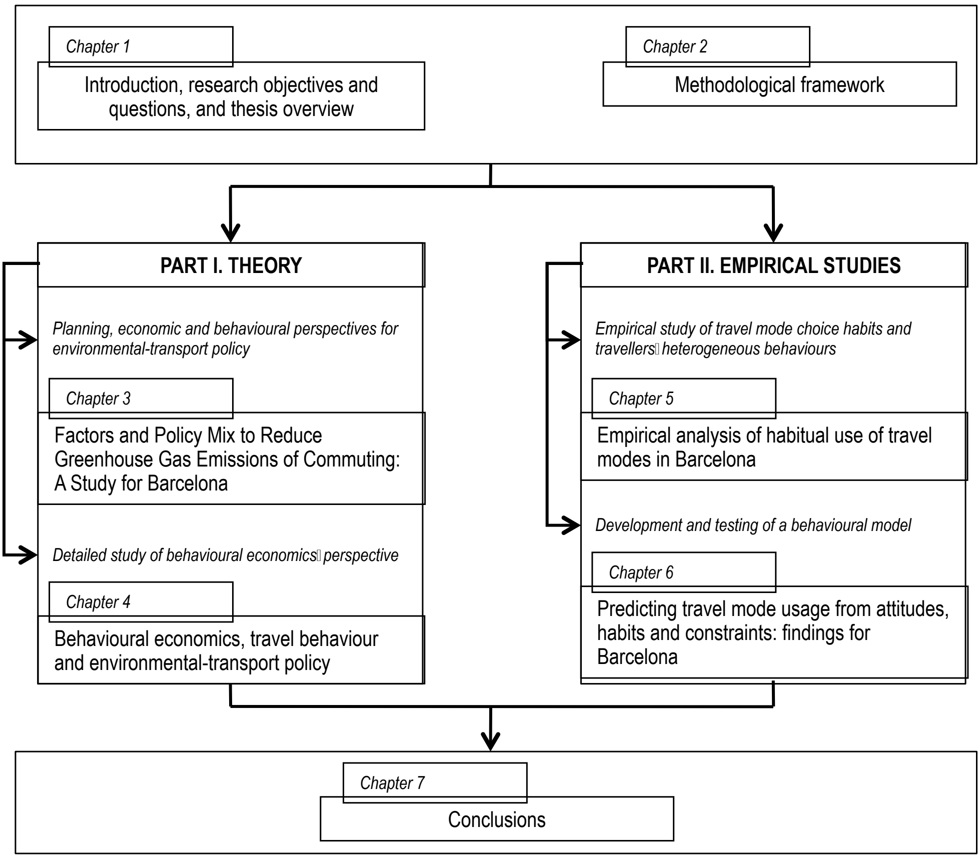

Figure 1.1. Structure of the Thesis.

2 Methodological framework

The methodologies and approaches used in this Thesis are described in reference to the division of the Thesis into two parts, one theoretical (Chapters 3 and 4) and one empirical (Chapters 5 and 6). The theoretical chapters 3 and 4 involved a literature review process consisting of a revision of published studies (i.e. articles), completed with insights from official reports and relevant books on the topic of travel behaviour and environmental policy for transport. Of course, not everything read has been referenced, but it has in some way or another contributed to the work.

Regarding the empirical studies that were carried out (Chapters 5 and 6), quantitative approaches were used in both cases involving the (multivariate) statistical analysis of the information collected from the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006, acronym in Catalan), a general mobility survey initiative of the Government of Catalonia and the Metropolitan Transport Authority (ATM, acronym in Catalan). Data from the EMQ 2006 is of the type of cross-sectional survey data, otherwise regarded as *correlational* data. The analysis of travel mode choice habits undertaken in Chapter 5 involved a classification analysis of a sample of travellers from the Barcelona Metropolitan Region (BMR), according to self-reported frequency of use of travel modes. In Chapter 6 we scaled up the level of complexity of the statistical techniques applied by using structural equation modelling (SEM) to empirically test the theoretical relations assumed in a behavioural model based on insights from the *ipsative theory of behaviour* (ITB) and the *theory of planned behaviour* (TPB) and the concept of 'habit'. The model aims to explain the variability in the use of private vehicles and public transport in the BMR. In addition, binary logistic regression analysis was used to estimate the probability that a person will chose to use public transport over a private vehicle, given certain determinants.

In what follows, we describe the main methodological approaches used. We explain the literature review process that was adopted, briefly present the study region, introduce the EMQ 2006 and discuss the statistical, multivariate analysis methods employed. Note that in this Section we only briefly review the underpinnings of the methods applied, while the specificitiesof the analyses carried out —data preparation, treatment and analysis— are described in the methodological section of the corresponding chapter.

2.1 Literature review process

The search for articles —the main source of information— involved three main strategies: (1) search by keywords on the internet (electronic search strategy), (2) scrutinising relevant journals (systematic search strategy), and (3) a snow-ball search strategy based on the cited bibliography of selected articles. Previously selected articles served to identify other compelling studies and most importantly to trace back to seminal articles and books. With these three search strategies a sufficiently large pool of articles was formed. Articles were then classified by theme and subtheme. This was an ongoing process resulting in the organization of the ideas and concepts dealt with in the present Thesis into three main lines, namely planning, economic and behavioural approaches to environmental-transport policy.

Electronic and systematic search strategies deserve more attention and may need a deeper explanation. The electronic strategy involved a search by keywords using the internet search engine Google Scholar and the scientific databases ScienceDirect and Scopus. This first approach to the literature was then complemented with a rather more systematic search for the latest published articles, which also served to follow up on key issues. A list of relevant peer review journals was elaborated from this. The selection of the journals was made based on where the articles found with the electronic search strategy had been published, the stated aims and scope of the journal, which had to be pertinent to the topic of travel behaviour and environmental policy for transport, and its impact factor. The latter gave us an idea of the quality of the journal and the significance of the issues treated in the articles published. Then, the selected journals were *scrutinised* from the most recent journal issues backwards. The articles were identified by their title, keywords and abstract.

Among the scientific journals scrutinised are: Transportation (Springer), Transportation Research Part A: Policy and Practice (ELSEVIER), Transportation Research Part D: Transport and Environment (ELSEVIER), Transportation Research

Part F: Traffic Psychology and Behaviour (ELSEVIER), Transport Policy (ELSEVIER), Journal of Transport Geography (ELSEVIER), Transportation Research Record (Journal of the Transportation Research Board), Transport Reviews (Taylor & Francis). Specific to the topic of behavioural theories and approaches are: Environment and Behaviour (SAGE journals), Journal of Environmental Psychology (ELSEVIER), and secondarily, Journal of Economic Psychology (ELSEVIER), Journal of Applied Social Psychology (Wiley Online Library). To study the case of the BMR, the journal of the Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers, was the main source of information consulted.

2.2 Study region

The BMR covers 10% of the Catalonian territory, involving close to 5 million inhabitants (about 70% of the Catalonian population). It is structured in two metropolitan rings that extend from the city of Barcelona outwards (see Figure 2.1). Barcelona and the first metropolitan ring are compact and diverse in land uses, while the second metropolitan ring comprises of seven large cities or metropolitan subcentres and their transport corridors and combines both rural and low-density residential uses. The public transport network of the BMR is radial, except within Barcelona city, and it shows some spatial deficiencies in access in new suburban residential and employment areas, as well as in rural areas, mainly within the second metropolitan ring. The connections by public transport between the metropolitan subcentres and the centre (Barcelona) are well established along seven corridor axes. Self-reported use of public transport is relatively large, all modes aggregated. However, 47.2% of the population still admit to making frequent use of private vehicles (40.8% car and 6.4% motorcycle), which can be reduced. Moreover, vehicle traffic is the principal source of GHG emissions in Barcelona, being responsible for 30-35% of total emissions for the period 1987-1996; only between 3.8 and 4.2% of the total CO_2 emissions from transportation in Barcelona originates from public transportation, even though this accounts for 55% of the total number of journeys made within the city (Baldasano et al. 1999). All in all, the BMR is a relevant case for studying travel patterns in relation to environmental-transport policy analysis.

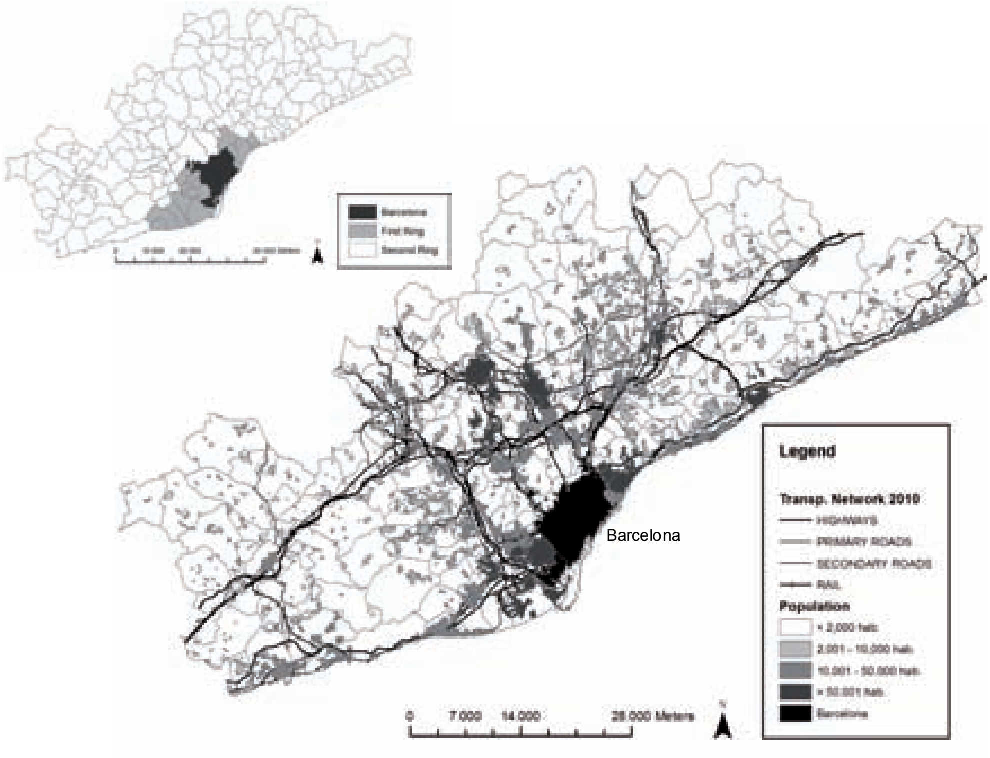

Figure 2.1. The Barcelona Metropolitan Region (BMR) with main features of the transport network, urbanised areas and populations of the municipalities; the small overview map shows the division of the BMR territory into Barcelona city and the two metropolitan rings (figure on top).

2.3 Data: Survey of Daily Mobility of Catalonia 2006 (EMQ 2006)

In both cases (empirical studies in Chapters 5 and 6), data are retrieved from the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006). The EMQ is a series of quinquennial general mobility surveys. At present it has only three editions 1996, 2001 and 2006. The edition for the year 2011 was not carried out due to budget constraints. The EMQ 2006 is, thus, the most recent set of data available from this series. The series has suffered methodological changes throughout these three editions that impede comparisons between the information collected. Travel information from editions 1996 and 2001 is based on a 1-week travel diary, whereas in the 2006 edition information refers to the day before the interview.

The EMQ 2006 involves, for the BMR, a total of 29,666 interviews (maximum error is 95% of ± 0.58%) held following computer-assisted telephone interviewing (CATI) methodology (ATM 2007). For the whole autonomous community of Catalonia, interviews completed totalled 106,091. The sample is representative of both territorial and socio-demographic grounds, a minimum of 800 interviews being held in each region; moreover, in those regions where there are municipalities of over 50,000 inhabitants, the number of interviews conducted was considerably higher.

The EMQ 2006 aims to describe the daily travel patterns and behaviour of the resident population of Catalonia over 4 years old, as well as to widen the understanding of people's travel determinants and perceptions of the transport system, in this case of the population over 16 years old. Accordingly, the dataset consists of two non-comparable data matrixes: one where the unit of study are the journeys made the day before the interview (i.e. objective information); and another where the unit of study is the individual (i.e. subjective information). This latter data matrix is the one used in the two empirical studies carried out in Chapters 5 and 6. The data collected includes people's self-reported use and valuation of travel modes —twelve travel modes, including walking, cycling, several urban and metropolitan public transport modes (urban and inter-urban buses, rail modes, and taxi), and two private modes (car and motorcycle)—, their reasons for choosing private or public transport modes, their average monthly expenditure on transport and use of travel information regarding traffic (users of private vehicles) or public transport services (users of public transport). Travel-related data is completed with socioeconomic and demographic data including driving licenses and private vehicle ownership.

As for the questionnaire used, it is structured in four different information blocks. The first block collected information about the household composition to ensure that a random selection of representative individuals was interviewed. The second block collected journey information (i.e. objective travel information not included in the data matrix used). The third block collected socioeconomic, demographic and other travel-related information of individuals (i.e. personal information). Finally, the fourth block of information collected individuals' perceptions and travel choice determinants (i.e. subjective travel-related information).

2.4 Classification analysis

In Chapter 5 classification techniques, namely multivariate cluster analysis, are used to analyse the complex phenomena of travel mode choice habits. In particular, we use cluster analysis to identify types of travellers from the BMR that differ from others in their modal habits. Cluster analysis is standard practice in market segmentation. The corollary for market segmentation is that consumers with similar needs and preferences can be grouped together so as to target them in the same manner (Wedel and Kamakura, 1998). Similarly, relatively homogeneous groups of travellers can be identified that need to be addressed through specific policies for effectiveness (Anable 2005; Jensen 1999; Krizek and El-Geneidy 2007).

Cluster procedures classify a sample of entities, in this case individuals, into a small number of mutually exclusive groups based on the similarities among the entities (Hair et al. 2009). That is, relative homogenous groups are formed that differ from the rest of groups. This approach allows the structuring of data in such a way that significant typologies are formed, according to the structuring variables (López-Roldán 1996). The main advantage of cluster classification is that it is an exploratory method, allowing the identification of occurring groups emerging from the data, in contrast to *a priori* chosen classifications. Even so, the researcher still has to make some substantive decisions based on their judgement and expertise (e.g., choosing the structuring variables and determining whether the groups extracted are compelling).

Cluster analysis involves at least three basic steps (Hair et al. 2009): first, the structuring variables have to be chosen. These have to reflect some form of similarity or association among the entities to determine the number of groups existing in the sample. Second, the clustering process is undertaken, whereby individuals are classified into relatively homogeneous groups, the clusters. Third, the clusters have to be profiled in order to determine their composition. We used bivariate analysis, namely crosstabs, for profiling the groups identified. Finally, a recommended fourth step is usually taken consisting of the validation of the cluster analysis. That is, testing whether the groups identified actually differ with regard to the proposed segmenting variables (i.e. behavioural variables of self-reported frequency of use of travel modes). Multivariate analysis of variance (MANOVA) was undertaken to assess mean group differences (i.e. behavioural differences).

2.5 Structural equation modelling (SEM)

In Chapter 6, structural equation modelling (SEM) is used to test the explanatory power of the theoretical model of behaviour proposed. The model should explain the variability in the use of private vehicles and of public transport in the BMR based on travellers' attitudes, constraints and habits. SEM procedures have been used since the 1980s in modelling travel behaviour, particularly modal choice in relation to attitudes, perceptions and intention, using both cross-sectional and panel or dynamic data (for a review see Golob 2003). SEM methods enable us to test complex theoretical relationships against data, in a highly intuitive manner, by means of graphical representations (i.e. path diagram). They are regarded as being flexible, in that the effects of several predictors or antecedents can be simultaneously estimated, unobserved latent variables representing theoretical concepts can be constructed from observed variables (i.e. indicators) and measurement errors can be estimated separately from the model's overall error (Chin 1998a).

The basic structure of a SEM model involves a measurement model representing the relationships between the latent variables and their indicators, and a structural model representing the relationships among the latent variables and the dependent (latent) variable. The measurement part of a SEM is essentially a factor analysis, while the structural part of the model is basically a regression analysis, but vastly more flexible in the types (and complexity) of theoretical interrelationships that may be tested (Iacobucci 2009). As such, SEM methods are said to combine a psychometric approach (factor analysis) with an econometric approach based on prediction (regressions) (Chin 1998b). The link between theory (latent variables) and data (indicators) (i.e. the measurement model) can be modelled as either reflective or formative, depending on the nature of these epistemic relationships (Roldán and Sánchez-Franco 2012). Reflective indicators share an underlying common factor and are therefore correlated. These do not identify any specific resource, but are a *reflection* of the theoretical (unobservable) construct to which they are linked. Formative indicators, on the contrary, are not necessarily correlated; they capture different underlying phenomena which together *form* the latent variable. Items are thus not interchangeable and so the elimination of one or more indicators implies omitting meaningful theoretical content.

There are two different, yet complementary, types of SEM methods, namely covariance-based SEM (CB-SEM) (Jöreskog 1978; Jöreskog 1982) and variance-based SEM or partial least squares (PLS-SEM) (Wold 1982). CB-SEM minimise discrepancy among the covariance matrix of the data and that which has been estimated by the model.

In other words, it reliably reproduces the sample covariances, which in turn implies making assumptions about data properties (normality and measurement scales), and epistemic relationships —links between theory (latent variables) and data (indicators); generally reflective scales are used. Formative scales can however be accommodated in CB-SEM, yet not in a straightforward manner (see MacKenzie et al. 2005; Williams et al. 2003). CB-SEM methods are adequate to test the empirical validity of relatively consolidated theory. On the contrary, PLS-SEM maximise the variance explained and are therefore focused on prediction. It is a rather exploratory method indicated to build up theory, while also allowing for theory confirmation (Chin 1998a). The PLS method does not make assumptions about data distributions (Bagozzi 1994; Fornell and Bookstein 1982) or sample sizes (Chin and Newsted 1999). Measurement scales can be ordinal and categorical, even binary (Falk and Miller 1992), and allow robust modelling of the indicators as either reflective or formative (Diamantopoulos 2011; Diamantopoulos and Winklhofer 2001). The underpinnings of PLS algorithms are described in Hair et al. (2011) and Tenenhaus et al. (2005). These characteristics of the PLS method makes it a rather more realistic approximation to what is encountered in social data (Fornell and Cha 1994; Hair et al. 2011). This is why, despite CB-SEM being the mainstream method, PLS-SEM methods are increasingly used. In our particular case, we apply the PLS-SEM method with the software SmartPLS version 2.0 (Ringle et al. 2005). This is justified upon the study objective (exploratory), the epistemic relation of data to theory (inclusion of formative indicators), the properties of the data (non-normal and highly skewed), the measurement development (involving categorical, binary variables), and the level of theoretical knowledge (Chin 1998a).

2.6 Binary logistic regression analysis

To complement the SEM analysis, a series of binary logistic regressions are carried out in Chapter 6. This time we model the choice between public transport and the private vehicle (binary choice). More particularly, we estimate the probability of choosing public transport modes over private ones, given certain choice antecedents. Note that this is a different question than the one analysed through SEM, which justifies the use of a different methodology. Logistic regression, or logit analysis, is similar to multiple regression analysis in that one or more independent variable is used to predict a single dependent variable. Logistic analysis is however specifically indicated when the dependent variable to predict is dichotomous (0/1; yes/no; private vehicle/public transport). Discriminant analysis would have also been adequate to this purpose, yet implies assumptions about the data that in our case are not met, namely that independent variables must follow a multivariate normal distribution and that the variance-covariance matrices of the independent variables in each group (i.e. private vehicle/public transport) should be equal. The logistic regression procedure requires fewer assumptions; it does not require the assumption of multivariate normality and moreover, it accommodates all types of independent variables (numeric and categorical) (Hair et al. 2009). This method thus better fulfils our needs.

From the regression coefficients (β) of the independent variables included in the model, we can directly estimate the probability that the individual *i* chooses option 1 = public transport. The general equation for the logistic function expressing the probability that the option in question is chosen as a function of several *k* explanatory variables (x_1, x_2, …, x_z), is:

$$P(Y_i = 1) = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}, \quad (1)$$

where α (i.e. the constant), β_1, β_2, …, β_k are the parameters of the model, estimated in our case using Wald's method (see Salas-Velasco 1996) with the option "Forward"; an option given by the statistic software SPSS. Wald's statistic enables us to contrast the null hypothesis that the independent variable does not explain the dependent variable. The option "Forward" is used to judge whether introducing a certain variable into the model will add a significant amount of information about the dependent variable.

Logistic regressions, namely binary choice models, are common practice in travel demand analysis (Ben-Akiva and Lerman 1985). It is assumed that the traveller associates a certain utility to each transport mode. The researcher ignores this utility, but it is implicit to the choice made by the traveller. Thus, as described in Popuri et al. (2011), let $U_{i,PT}$ be the utility that traveler *i* associates to public transport, and $U_{i,PV}$ the utility derived from private vehicles. The utility of public transport, $U_{i,PT}$, has a deterministic component $V_{i,TP}$, and a random error term $\varepsilon_{i,PT}$.

$$U_{i,PT} = V_{i,PT} + \varepsilon_{i,PT} \quad (2)$$

The deterministic component of the utility is given by the parameters of the model (i.e. the output of the logit analysis), as expressed in the following equation:

$$V_{i,PT} = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \qquad (3)$$

It is assumed that for the traveler *i* to choose public transport over the private vehicle, the utility associated to public transport has to be greater than that of the private vehicle, namely $U_{i,PT} > U_{i,PV}$. We only take into account the difference in utility, and assume $U_{i,PV} = 1$ and $U_{i,PV} = 0$. Reformulating, we then obtain:

$$\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon_{i,PT} > \varepsilon_{i,PV} \qquad (4)$$

The probability of traveler *i* choosing public transport is thus given by:

$$P_i(PT) = P(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon_{i,PT} > \varepsilon_{i,PV}) \qquad (5)$$

Since the error terms $\varepsilon_{i,PT}$ and $\varepsilon_{i,PV}$ are equally distributed, the functional form of the probability of traveler *i* choosing public transport is given by former Equation (1) expressed as:

$$P_i(PT) = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}, \qquad (1,6)$$

while the probability of traveller *i* choosing the private vehicle is:

$$P_i(PV) = \frac{1}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)} \qquad (7)$$

Part I
Theory

3 Factors and policy mix to reduce greenhouse gas emissions of commuting: A Study for Barcelona

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3.1 Introduction

The transport sector is almost entirely dependent on fossil fuels. It is the second largest sector producing global greenhouse gas (GHG) emissions and the second fastest growing sector of emissions in general, while future projections of emissions look dim (OECD 2008a). Policies targeting transport externalities, such as energy consumption and emissions, are often subject to rebound effects, notably increased use of vehicles that reduce their effectiveness (Rajan 2006; Rietveld 2006). The policy challenge is to formulate a combination of effective supply- and demand-side policies, technology-oriented solutions and physical planning. There is a clear need for understanding what a complete, effective policy package looks like as substantially reducing GHG emissions from transport is very difficult (Gilbert and Perl 2010; Hickman and Banister 2014).

This chapter will put the spotlight on commuting transport and try to obtain such a policy package on the basis of identified core factors of commuting. Commuting or the journey to work makes up an important part of transport. It should therefore be a target of climate policies that aim to reduce greenhouse gas emissions from transport. Commuting has long been an important target of transport policy and urban planning, because of its regular pattern, its close connection with congestion problems, and its association with people's choices about locations of work and housing (van de Covering and Schwanen 2006). Where people live influences their overall travel behaviour for extensive periods of time. In this chapter we use the term "commuting" to denote one-way journeys to job destinations. We concentrate on commuting at a regional scale and consider both intra- and intercity journeys. For the study of GHG emissions from commuting, we will focus on two aspects of commuting patterns and behaviour, namely commuting distance and transport mode choice. We give special attention to car use in view of its disproportional contribution to GHG emissions. In addition, the relationship between commuting distance, commuting time and transport mode is discussed. We find it advantageous to consider this relation since commuting distances, while relevant from a planning perspective, may be overlooked by travellers who may be more sensitive to variations in commuting time costs.

Many studies deal with the question concerning which factors underlie increased commuting distances and car usage. We review planning studies, economic studies, and studies from environmental and social psychology (i.e., behaviour studies). These three perspectives will be offered and from the insights gained we will identify a set of core factors, and then apply this to obtain a policy package for the Barcelona Metropolitan Region (BMR) in Catalonia (Spain). We do not consider here reducing carbon intensity of energy used for commuting since this has been analysed elsewhere (e.g., Chapman 2007; Ison and Ryley 2007; T&E 2006). In 2006, commuting made up 15.8% of the total number of journeys made within the BMR. In contrast to personal-purpose journeys (e.g., for shopping or daily leisure), commuting journeys usually involve relatively long distances, much time, and the use of motor vehicles (either public transport or private vehicles) (Miralles-Guasch 2011). In addition, commuting journeys are more scattered now and, thus, are not easily served by public transportation leading to an increase in the relative share of the use of the private vehicle. Changes in modal split and commuting distance have obvious repercussions in the amount of emissions. Vehicle traffic is the principal source of GHG emissions in Barcelona, being responsible for 30-35% of total emissions for the period 1987-1996; only between 3.8 and 4.2% of the total CO_2 emissions from transportation in Barcelona originates from public transportation, even though this accounts for 55% of the total number of journeys made within the city (Baldasano et al. 1999). All in all, the BMR is a relevant case for studying commuting patterns in relation to GHG emissions and environmental policy. Our contribution to the literature on commuting transport and its use of energy and related emissions is thus threefold: development of a framework based on the extensive literature on commuting and its factors; derivation of an environmental policy package addressing GHG emissions from commuting; and an application of these to Barcelona.

Similar studies to ours are found for large metropolitan areas, such as New

York and London (Hickman et al. 2009, 2010, 2013; Sperling and Gordon 2009). Hickman et al. (2013) mainly focus on reducing emissions from transport by investing in planning of, and infrastructure for, public transport in London and Oxfordshire metropolitan regions. Here we adopt a broader perspective, including a larger set of commuting determinants (factors) which allows us to derive a wider palette of policy options. Hickman et al. (2009, 2010) have a similar scope to ours, but focus on backcasting techniques, scenario-building and transport and carbon simulation models. Our study can be seen as complementary to these studies in that it aims to identify the full set of commuting factors (for the BMR). It should further be noted that the earlier studies do not deal specifically with commuting as we do, but instead address transport in general, including all personal journeys, freight transport and aviation.

The remainder of this chapter is structured as follows. Section 3.2 contains a literature review of the factors underlying commuting, and presents three distinct perspectives that offer a basis for policy design in the case study later on. Section 3.3 discusses general elements of a policy package for reducing GHG emissions of commuting. Section 3.4 presents the case study of the BMR. Section 3.5 concludes.

3.2 Commuting distance and transport mode: three perspectives

In subsequent subsections we identify the major factors underlying commuting based on a review of the literature. These factors include built environment (BE), transportation factors (TF), market factors (MF), socioeconomic factors (SE) and behavioural factors (BF). They are summarised in Table 3.1, while their relationship with the core factors of GHG emissions from commuting are depicted in Figure 3.1. It should be noted that these factors are not independent but some of their components may affect or correlate with those in others. In addition, a sixth factor "policy and regulation" can influence all of the factors. Together, the factors provide a framework to design a policy package to reduce GHG emissions from commuting (Section 3.3).

Table 3.1 combines the many suggestions found in the broad literature on commuting, which is reviewed in subsequent sub-sections. The table can thus be seen to provide a close to complete picture of all the factors that determine commuting. In view of the broadness and completeness of the framework, it is impossible to offer a fully quantified analysis approach as many factors defy quantification. As a result, we are forced to use a qualitative approach of analysis.

Table 3.1. Factors underlying commuting patterns.

Built environment (BE)	Transportation factors (TF)	Market factors (MF)	Socioeconomic factors (SE)	Behavioural factors (BF)
• Urban density (i.e., employment and residential densities) •Diversity of land uses (balance of jobs and houses) • Design of street and transport networks • Design attributes of the neighbourhood • Destination accessibility • Regional accessibility • Urban form • Distance or access to public transport (including infrastructure)	• Average travel time, reliability and punctuality (travel time variability), • Uncertainty about occurrence of unpredictable events (e.g., vehicle breakdown, accidents) • Level of service of public transport • Parking opportunities • Congestion (peak and off-peak periods)	• Labour market imperfections (search and moving costs, imperfect information about job offers and uncompensated commuting costs) • Housing market imperfections (search and transaction costs, regional/local price differentials) • Transport market imperfections (transport price and the cost of commuting affect both distance and mode)	• Age • Gender • Income • Level of education • Professional category • Occupational status • Household structure (dual-career, children)	• Self-selection bias • Activity patterns and lifestyle • Past behaviour and habits • Norms • Status seeking behaviour • Emotions

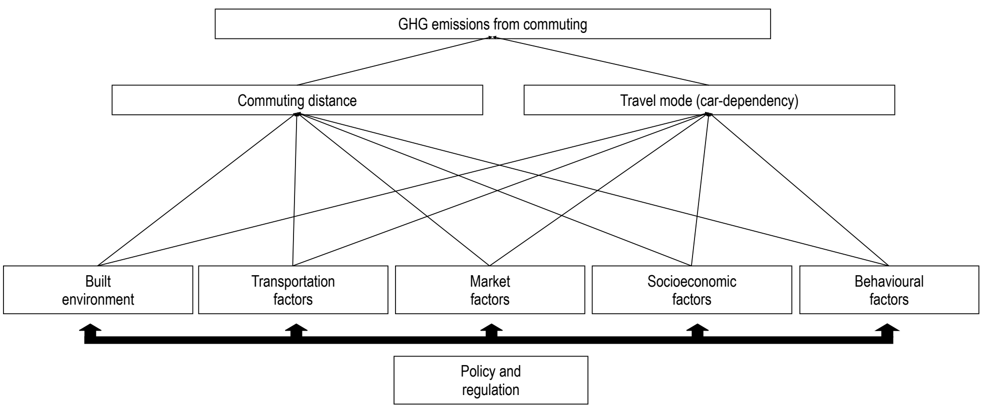

Figure 3.1. Multi-level relationship between core factors, commuting dimensions and GHG emissions.

3.2.1 Commuting distance *versus* time

Commuting distance and time are related through speed. Improvements in private vehicles and public transport have allowed commuters to travel longer distances at higher speeds within the same time (Metz 2004). Information about commuting distance is especially relevant from a planning perspective, while commuting time and time perception are more relevant to the individual and thus to understand their choices regarding commuting distances and transport modes. Average commuting times for many metropolitan areas have been rather constant over time, known as the "commuting time paradox" (van Ommeren and Rietveld 2005). This has led to the idea that an upper bound to commuting time may exist, that is, a time threshold below which workers are indifferent to commuting distances (Rouwendal 2004). This threshold is suggested to be about one hour for total daily travel. The results of Rouwendal and Meijer (2001) indicate that commuters may change their residence when commuting time exceeds one hour. An explanation for this one-hour budget time is competition between various uses of time during the day (Metz 2004; Mokhtarian and Salomon 2001). To compare, the average daily commuting time for EU15 and Spain is 37.5 minutes, while it is 48.8 minutes for the US, that means they all are below one hour (Stutzer and Frey 2008). The threshold may not just depend on the cost of commuting, but on other variables too, notably socioeconomic characteristics (e.g., income, employment status, and car ownership) and the spatial distribution of job offers around an individual's residential location (Mokhtarian and Chen 2004; Rouwendal 2004).

3.2.2 Three perspectives for policy: the planner, the economists and the behaviourist

Here we offer three perspectives on commuting that help us to organize the literature on factors of commuting. Moreover, these provide a clear basis for developing later, in the BMR case study, three distinct policy packages.

1. The planner

Planning studies focus on the provision of a supportive built environment. The aim is to indirectly influence commuters' travel behaviour through the alteration of the three dimensions of the built environment: land-use patterns, the transport system, and design features that are both functional and aesthetic (Handy 2004). Variations in commuting distance and travel mode choice are commonly related to changes in the built environment. In particular, increases in commuting distance are regarded to be due to dispersion and urban sprawl, which in turn intensifies commuters' car usage (Anderson et al. 1996). Sprawl is generally considered undesirable as it raises commuters' transport costs as well as the costs of transport supply (including infrastructure). Actual elements of the built environment affecting commuting distances and transport mode used for commuting have been extensively researched. Surveys are offered by Cervero and Kockelman's (1997), Ewing and Cervero (2001), Handy et al. (2002), Handy (2004), TRB (2005), and Ewing and Cervero (2010).[1] Seven "D factors" are brought about (Table 3.2).

[1] Ewing and Cervero (2001) included 14 studies, Handy et al. (2002) reported over 70 studies published during the 1990s, Handy (2004) reviewed 22 studies, TRB (2005) overlaps with Handy (2004) and other studies, and Ewing and Cervero (2010) revised over 200 studies from which, finally, 62 were used to undertake a formal meta-analysis.

Table 3.2. Features of the built environment influencing commuting behaviour.

Feature	Definition	Measurable indicators	Commuting distance and travel mode affected
Regional accessibility	Distribution of activities and transportation facilities across the region	Proximity to the CBD, rate of decline in density with distance from the CBD	Commuting distance, walking, car use
Urban density	Amount of activity concentrated in a given area	Population, dwelling units, employment, building floor area per unit of area	Commuting distance
Diversity of land uses	Number of different land uses and the degree to which they intermix	Entropy measures of diversity, index of dissimilarity, jobs-to-housing ratios	Commuting distance, walking, public transport use
Design of street and transport networks	Availability of alternative routes through the network	Density of intersections, street connectivity, sidewalk coverage, and continuity, etc.	Commuting distance, walking, public transport use, car use
Design attributes of the neighbourhood	Attractiveness and appeal, and other physical variables that differentiate pedestrian-oriented environments from car-oriented ones	Average street widths, number of trees on streets, presence of amenities, traffic intensity, safeness	Walking
Destination accessibility	Proximity of destinations (i.e., job accessibility)	Distance to journey destination, facilities reachable within a given distance or time	Commuting distance, walking, car use
Distance or access to public transport	Proximity to public transport stops/stations	Shortest street routes from homes/jobs to the nearest stop/station, density of routes of public transport, distance between stops, density of stations	Public transport use

Based on Handy et al. (2002), and making use of insights from Cervero and Kockelman (1997), Ewing and Cervero (2001, 2010), Handy et al. (2002), Handy (2004) and TRB (2005).

Note: CBD = central business district (where jobs are concentrated).

Urban form —the spatial arrangement of jobs, homes, and the transport network that connects them (infrastructure)— determines commuting distance. A distinction is made between: traditional monocentric forms, where jobs concentrate in the CBD, and commuting distances are theoretically minimal; and polycentric forms, where journeys are shorter for better regional and destination accessibility, higher density (especially at destination), and more intermixing of land uses. At a local scale, diversity of land uses (jobs-housing balance) has the greatest impact on commuting distance (Horner 2007). Transport mode choice depends on destination (job) accessibility, which has the strongest influence on car choice. Long distances act in favour of car usage and the opposite holds for "active commuting" (i.e., walking and cycling). Density and diversity variables have a substantially lower influence on car use. The second most important factor of modal choice is design features. The reason is that they favour more diversity of routes; mainly intersection density (grid pattern of street network) and street connectivity characteristics (i.e., directness of routes through the network and availability of route alternatives). For walking, other design characteristics like neighbourhood aesthetics, scenery and traffic turn out to be somewhat relevant, but less so than for "leisure walking". Public transport modalities like bus and rail depend very much on public transport accessibility.

A relevant issue in identifying the effects of the built environment on commuting decisions is the so-called self-selection bias. This denotes that commuters may anticipate their travel mode decisions —whether walking, cycling, public transport or driving a car— and choose a house location that matches them (Handy et al. 2005a; Handy and Mokhtarian 2005; Cao et al. 2002). The possibility of self-selection casts doubts on a firm causal relationship between the built environment and commuting behaviour, something that should have implications for transport and spatial planning (e.g., Giuliano 1991; Giuliano and Small 1993; Handy 2005; Handy et al. 2005a; Sohn 2005).

It is remarkable that similar urban forms show sharp differences in commuting patterns. Evidence for this is provided by empirical studies, especially those on "excess commuting". These highlight the crucial role of location choice, and the criteria that commuters employ to arrive at their decisions (Section 3.2.2, economic perspective). Næss (2009), however, argues that the existence of self-selection just stresses the importance of the built environment. In a study for Copenhagen, he provides empirical evidence that re-locating to live far from (or close to) the city centre has a positive (negative) impact on the use of motor modes after controlling for self-selection. This is attributable to differences in neighbourhood spatial features (typology), as well as journey-related choices, like engagement in activities, activity locations, route and travel mode choices. In addition, such location choices influence household commitments and attitudes towards the car. Findings like these still offer support for planning policies to create neighbourhood attributes that discourage undesirable transport choices.

2. The economist

The *economist* regards commuting as a costly activity without any value or utility in itself (Banister 2008). Workers should therefore be directed at minimising their commuting costs. In line with this, economic studies focus on an efficient spatial location of workers and economic activities. Initial research was limited to explaining transport and its relation with job and residence locations as a function of transport costs and housing prices, with decisions being constrained by income (or budget in the case of economic activities) (Alonso-Muth-Mills type of urban bid rent models). Households seek "the best value for money" (i.e., they are assumed to be rational —maximising their utility) which translates into the largest, best located, and cheapest houses (Wong 2002). Three trade-offs are expected: location *vs.* price, size *vs.* price and size *vs.* location.

This approach has its flaws. Individuals possess imperfect information about housing options which makes them rather choose "satisficing" options. A more extreme form of bounded rationality is that people show strong preferences for certain locations and dwelling types, regardless of how costly they are in terms of travel and commuting, notably in the case of detached houses near the countryside (Rouwendal and Meijer 2001). Strong differences exist in this respect between households with and without children. Individuals may evaluate elements other than commuting or job-residence location (e.g., aspects related to quality of life, such as environmental or neighbourhood amenities) (Feng 2008). Further, prices of transport do not reflect their external costs, and workers do not seem to be generally and fully compensated for increased commuting disutility in labour and housing markets (Stutzer and Frey 2008).

Subsequent studies acknowledge these limitations and explore constraints other than prices and income that prevent individuals from choosing optimally, such as coordination of choices in dual-career households and imperfect information (van Ommeren et al. 1998; van Ommeren 2000). Commuters express bounded rationality in their location choices, while information is costly and changing job or residence generates both pecuniary and non-pecuniary costs (Larsen et al. 2008). Van Ommeren and van der Straaten (2008) found that about 40% to 60% of daily commuting time (46 minutes; van Ommeren and Fosgerau 2009) is due to job search frictions, including imperfect information about job offers. Workers of high professional categories are most affected since job offers matching their qualifications are relatively scarce.

Generally household members change jobs more often than they change residences. Indeed, travellers are often reluctant to change housing location after a job relocation within the same metro region (Coulombel 2011). The reason is that relocating is costly and gains in job-residence distance are perceived to be small. House owners seem to be more reluctant to change their residential location than renters. This is partly due to considerably high taxes associated with buying a house, resulting in house owners facing higher moving costs than renters. Van Ommeren and van Leuvensteijn (2005) note that taxes on house purchasing, very common in OECD countries, reduced residential mobility of house-owners in The Netherlands by 50%; this is usually interpreted as the effect of transaction costs (i.e., moving costs from re-location) on the length of commute, which is generally found to be larger for owners than for renters (Larsen et al. 2008).

Models of transport mode choice assume that commuters choose the most convenient option based on the specific attributes of each mode (Handy 2004). Examples of such attributes are monetary and time costs (e.g., average travel time including in-vehicle time, waiting and time lost in transfers or parking), punctuality and reliability (travel time variability), uncertainty about unpredictable delays caused by, for instance, accidents and vehicle breakdowns, and comfort. However, in the particular case of the car, Gardner and Abraham (2007) find a systematic underestimation of car-related monetary costs, as well as a misconception of actual journey times for car and public transport. Modal choice is further studied as a function of people's socioeconomic profiles. Such studies often fail to capture all variability in travel mode choices (Anable 2005). Gender differences in modal choice, notably regarding car usage, are well recognised (e.g., Law 1999; Polk 2004); on average women use the car less than men. This difference, however, seems to be getting smaller; women, notably working mothers, are moving towards a level of car usage equal to that of men in countries like the USA and Australia (Brown et al. 2003; Dowling 2000). Behaviour with respect to age, which is largely connected to life-cycle variation in commuting behaviour (Ryley 2006), seems to differ between territorial spaces. For instance, elderly people from USA or north-European countries, like UK or The Netherlands, tend to make much use of the car, whereas in Spain they often walk or use public transport (bus) (see De Witte et al. 2013). Results for income and professional category seem to yield rather consistent results; high income and high professional categories are correlated with frequent car use (Lucas 2012).

3. The behaviourist

Transport studies on socio-psychological determinants of commuting behaviour focus mainly on travel mode choice. A notable share of driving does not respond to convenience, and for some drivers perceived barriers to modal change cannot be objectively measured, such as in terms of access or time and money costs (Goodwin 1995). As highlighted by Handy et al. (2005b), the distinction between driving by choice or necessity is not always clear, yet it is important for policy. For necessary car journeys, planners can explore ways of reducing journey distances and facilitate public transport usage. For driving by (voluntary) choice, policy design is more complicated since psychological bounds to the car are not easily broken and behavioural changes are not easily achieved in this case. Burnett and Hanson (1982) distinguish between three alternative types of travel behaviour: namely, habits that are not easy to change because individuals do not consider alternative options; "avoidance behaviour" —individuals preferring to deviate from more economically desirable (cheaper) and more feasible options; and constrained choices— institutional constraints prevent choosing individually desirable options.

A large number of behavioural theories and models have been put forward for transport studies, which encompass these insights and explore a wide range of modal choice determinants (e.g., Bamberg et al. 2007; Bamberg and Schmidt 2003; Carrus et al. 2008; Hunecke et al. 2001; Klöckner and Matthies 2004). Relevant factors analysed are habits (e.g., Triandis' theory of interpersonal behaviour), attitude, perceived social pressure (e.g., social (dis)approval of certain behaviour), perceived constraints (Ajzen's theory of planned behaviour), feelings and emotions (attached to driving, like of freedom, shame, guilt or pride) (e.g., Perugini and Bagozzi's model of goal-directed behaviour), and personal norms or moral obligations to behave in a certain (sustainable/ pro-social) way (e.g., Schwartz's norm activation model).

Particularly for commuting mode choice, habitual driving appears to be a key issue (Aarts et al. 1998; Gardner 2009). Commuting trips are repetitive and create routines that are difficult to break (i.e., habitual choices are taken unconsciously and information about alternatives is ignored), and that can be generalised across other travel contexts. For example, the habit of driving to work every morning can be generalised into making all morning journeys by car (Verplanken and Aarts 1999). In addition, Schwanen et al. (2012) argue that social pressure favouring car use may help reinforce or contribute to the formation of driving habits. Social influence and perceived constraints can also hamper conscious intentions to quit driving. Abrahamse et al. (2009) observe that leaving the car is a form of altruistic behaviour which may develop when personal norms (e.g., environmental concern) are strong enough and changing to alternatives to the car is perceived as easy and feasible. The formation of personal norms for public transport usage is influenced by negative feelings of guilt and social pressure (Bamberg et al. 2007; Carrus et al. 2008). Popuri et al. (2011) adds to these findings by noting that positive perceptions about public transport of friends and family contribute to preferences for public transport use. Indeed, studies by Steg (2003; 2005) suggest that car use for commuting is better explained by social and affective motives than by instrumental or functional motives (e.g., speed, flexibility, comfort, reliability, etc.). Males and young people give relatively more importance to symbolic and affective factors, for them the car expresses status and freedom and independence. Anable and Gatersleben (2005), however, show that instrumental attributes are more important in commuting while for leisure trips both instrumental and affective factors are equally valued.

3.3 Policy mix to reduce GHG emissions due to commuting

Based on the insights of Section 3.2, in what follows we suggest policies to reduce GHG emissions from commuting. We do not discuss here political feasibility, although we are well aware that policy does not have all degrees of freedom as it is deeply politicised. Policy measures are proposed in Table 3.3, derived from the framework. The design of the policy mix was inspired by Banister et al. (2000). Policy measures affect the two core transport mechanisms (i.e., targets in third set of columns): reduced commuting distances and promotion of a modal shift to sustainable modes. Most measures affect several factors simultaneously (fourth set of columns), even though they are designed in order to address (a) particular factor(s) specified in the first column. The fifth set of columns assesses various policy features including policy strategy, type of policy instrument, effect and time horizon.

Table 3.3. Suggested policies derived from the factors underlying commuting.

Main factor(s)	Policy measure	Targets		Factors[1]					Policy features	
		Journey distance	Travel mode	BE	TF	MF	SE	BF	Policy strategy[2]	Policy instrument[3]
BE	Internalisation of full transport costs in low-density building projects	*	*	**	*				PPM	P
	Prohibition of low-density building projects	*	*	**	*				PPM	C
	Changing the function of existing buildings at strategic sites with high accessibility – e.g., city centre and network nodes	*	*	**	*				PPM	C
BE/TF	Adaptation of the design of the public transport network to spatial developments and vice versa		*	**	**			*	SOP, PPM	I
	Provision of existing low-density residence/employment spaces with public transport		*	**	**			*	SOP, PPM	I
	Provision of park-and-ride facilities in stations close to low density residential areas		*	**	**			*	PPM, SOP	I
	Designation of environmental zones with limits on high-pollutant vehicles (e.g., city centres)		*	**	**			*	DOP, PPM	C
TF	Give public space to sustainable modes and promote street connectivity		*	*	**			*	SOP, PPM	I
	Speed limits in congested areas to lower pollution and make them less attractive, automatic speed control	*	*		**			*	PPM, DOP	C

Main factor(s)	Policy measure	Targets		Factors[1]					Policy features	
		Journey distance	Travel mode	BE	TF	MF	SE	BF	Policy strategy[2]	Policy instrument[3]
TF/MF	Variabilisation through increase of fuel tax + remove fixed road tax	*	*		**	**	*	*	DOP	P
	Congestion charges for rush hours or certain transport zones		*		**	**		*	DOP	P
	Parking charges and controls (e.g., in zones were driving is intense and that are well served by public transport, like city centres and certain business districts)		*		**	**		*	DOP	P,C
	Feebates on new cars dependent on emissions/ fuel consumption		*		**	**		*	DOP	P
	Concessionary fares for public transport based on social purposes (young, elders, and more generally low income groups) and economic incentives for public transport use to break-down car habits		*		**	**	*	**	DOP	P
MF	(Economic or social) incentives for those living close to their jobs	*	*	*		**	*	*	PPM	P
MF/TF /SE	Substitute taxes on owned housing by road taxes	*	*	*	**	**	**	*	PPM, DOP	P
MF/SE	Incentives to rent	*		*		**	**	*	PPM, DOP	P
MF/BF	Centralised (public) web-site to diffuse information about job offers	*	*	*	*	**		**	TEC, DOP	K
BE/SE	Build social housing at strategic sites with high accessibility —CBD, employment subcentres (if possible), and network nodes	*	*	**		*	**	*	PPM	C, I

Main factor(s)	Policy measure	Targets		Factors[1]					Policy features	
		Journey distance	Travel mode	BE	TF	MF	SE	BF	Policy strategy[2]	Policy instrument[3]
BF	(Injunctive) normative messages on transport externalities and sustainable modes	*	*					**	DOP	K
	Normative messages (descriptive or injunctive, depending on the case) about environmentally sustainable settlements	*	*					**	DOP	K
	Campaigns offering re-location solutions for dwellers	*						**	DOP	K
	Temporary road closures and withdrawal of parking spaces to break-down driving habits (e.g., in roads/zones where driving is intense and public transport alternatives exist)		*		*			**	DOP	I
	Temporary incentives for public transport (e.g., a free-period ticket) to create new habits of using public transport		*				*	**	DOP	P
	Innovative transport measures[4]		*		*			**	DOP, SOP	C, I, K
	Application of IT-systems to public transport systems to decrease uncertainty about reliability and waiting/transfer times		*		**			**	TEC	K
TF	Real time information on road congestion to divert traffic from congested roads		*		**	*		*	TEC	K
All factors affected	Public (and stimulating private) investments in R&D								TEC	K
	Computerized emission control via electronic sensors (monitoring)								TEC	K

Inspired by Banister et al. (2000).
Notes: The stars (*) mark means there is an impact of a given policy (second set of columns) on the two core aspects of commuting considered (targets in third set of columns) and the factors (fourth set of columns). A distinction is made between main factors (**) and other factors (*) being affected. (1) 'BE' (built environment), 'TF' (transportation factors), 'MF' (market factors), 'SE' ([individual] socioeconomic factors), 'BF' (behavioural factors), 'CF' (contextual factors) column titles relate to the specific factor affecting the three outlined targets. (2) 'DOP' (demand-oriented policies), 'SOP' (supply-oriented policies), 'TEC' (technology policies), 'PPM' (physical planning measures) column titles relate to the policy strategy. (3) 'P' (price-based instruments), 'C' (command-and-control measures), 'K' (knowledge, information, and moral suasion) and 'I' (infrastructure) indicate the type of policy instrument. (4) Individualised marketing, "deliberation intervention", car-sharing, car-clubs, car-pooling, PAYD, public transport traveller information systems, fuel-efficient driving, etc.

Policies affecting the built environment through changes in urban spatial structure can be used to concentrate population and economic activities in places already served (in terms of public transport, too) and with high intermixing of land uses (Nijkamp 1994). These measures mainly target commuting distance, but also stimulate modal shift. At the same time, limits are needed on the proliferation of low-density building projects. Two ways to avoid this are direct prohibition or increasing the costs to promoters for their construction.

The main policy measure aimed at correcting both spatial structure and transportation factors is the design or adaptation of the public transport network to spatial developments (while of course spatial developments might also adapt to, or be limited by, public transport networks). In this line, existing low-density residential and employment centres should be provided with alternatives to the private car (e.g., public transport and if not cost-effective, private collective transport that could be motivated by neighbours or firms themselves). These types of sites are big emitters and receivers of commuters, respectively. The purpose is, then, to facilitate modal shifts especially in those places and for those journeys that are car-oriented.

Main policy measures targeting transportation factors seek to increase the energy efficiency of vehicles, so as to reduce emissions per kilometre and local air pollution (e.g., by means of speed limits). Measures further intend to make driving undesirable and, thus, are mainly oriented to promote modal shift.

Other market measures target housing and labour market imperfections, namely searching and moving costs. They affect individual locational decisions and influence both commuting distance and modal split. A complementary measure is to provide affordable housing in strategic sites (i.e., CBD, sub-centres and network nodes). This is directed at low and middle income groups and young households, the groups having affordability problems with housing.

Behavioural factors are more difficult to tackle, mainly due to a lack of understanding of complex commuting behaviour. We propose measures aimed at raising awareness about transport externalities and promoting pro-environmental practices, as well as informing about the benefits of optimally choosing a location for living and working. Regarding the provision of information, Cialdini (2003, 2007) proposes to raise the effectiveness of the informative message by capturing people's normative concerns. This is using injunctive norms (perceptions about socially approved behaviours) when the intention is to change environmentally undesirable but socially extended behaviour, and descriptive norms (perceptions about behaviours socially extended) when pro-environmental behaviour is sufficiently extended.

For habitual car users, however, the provision of information may not be enough since drivers with strong habits are less responsive to new alternatives and new information. Proposed measures to alter habitual driving are changes in the structure of the physical environment, like temporary road closures or withdrawal of parking spaces (Brown et al. 2003; Fuji et al. 2001), so-called "deliberation intervention", which makes travellers more aware of their decision-making process, indicating clearly decision alternatives (Carrus et al. 2008), and monetary incentives to use alternatives to the car (Fujii and Kitamura 2003). These types of interventions promote the conscious re-thinking of travel mode options available. The effects of monetary incentives, however, should be monitored since crowding-out effects might occur (Gneezy and Rustichini 2000). In addition, so-called innovative transport measures can be considered, like individualised marketing, car-sharing, car-pooling and the formation of car clubs, as well as fuel-efficient driving and public transport traveller information (Banister et al. 2000).

Verhoef and van Wee (2000), propose to address the issue of car and status through feebates on new cars dependent on emissions/fuel consumption. In this case, feebate application is to vehicles for achieving increased fuel efficiency. The amount of the feebate applied to the purchase price of a vehicle is determined by the relative fuel efficiency of a vehicle; if the vehicle has higher fuel efficiency than average, it receives a rebate; if the fuel efficiency is lower, a fee is assessed (Davis et al. 1995). The feebate may vary in direct proportion to fuel consumption or emissions, the most straightforward design. Feebates can further be made fiscal-neutral (Verhoef and van Wee 2000).

Some of the measures included in the list deserve more attention and may need a deeper explanation. For instance, variabilisation through an increase of fuel taxes while removing fixed road taxes is proposed for several reasons. First, a fuel tax, when set sufficiently high, is one of the most effective measures to reduce emissions (see Sterner 2007). Second, pricing mechanisms increasing the variable costs of driving (i.e., fuel taxation, kilometre tax, road pricing, congestion charging, parking charges, insurance tax) have proven to be more effective than those raising fixed costs for owning a car (Dargay 2008). Third, factors like vehicle price, fuel consumption, size, reliability, and comfort affect car purchasing (i.e., vehicle type, fuel-efficient or less polluting vehicles) more than incentives like emission charges per kilometre (Dargay 2008). Such factors tend to be more important than environmental considerations.

Regulatory measures, such as emission standards, are not useful in reducing car use and emissions from actions like speeding, rapidly accelerating and cold starts (Banister et al. 2000; Proost and van Dender 2001). Standards may here achieve reductions in urban air pollution from motor vehicles (e.g., regulating fuel components and emissions from exhaust pipe engines, and ultimately from combustion engines), but limiting car usage is not their purpose and so only part of the actual emissions is affected by them.

Some reductions in fuel consumption will also be achieved by increased fuel efficiency. However, energy efficiency alone will not make a substantial difference in the short or medium term. Available technology has limitations and technological innovations will only be effective in the period after 2020 if a strong policy driving them is implemented now (Hickman and Banister 2007).

To correct housing market imperfections one can substitute house-moving taxes (also known as "transfer taxes") by road taxes as suggested by Larsen et al. (2008). They argued that empirical findings show that road pricing affects the location choice of households and firms by increasing travel expenditures. On the other hand, taxes on owned housing exert the opposite effect; they increase transaction costs and discourage households to relocate close to their jobs. Their suggested tax correction only holds for commuters who own their house as other road users do not face such a barrier in changing house location. Removing housing taxes, however, may have side-effects, such as mobilisation of capital investments into housing, and tax evasion by owners of multiple properties (including second residences). The removal of the tax should apply only to first residences and involve all members of the household registered within it. In this way, owners of multiple properties could not register their relatives as living in their second residences to skip paying housing taxes.

A well-known problem with taxes, and this applies to all economic incentives proposed here, is that they need to be set high enough to be effective. This may cause equity problems among different socioeconomic groups with the possible outcome of poor people being disproportionately affected (e.g., in the case of regressive taxes). Proost et al. (2002) suggest that the best way to deal with equity issues is via specific income supplements (e.g., bringing down distortionary taxes, such as labour taxes), rather than via reduced transport prices. This means using the net revenue from the transport sector to correct for spatial and social inequities. Another issue in implementing pricing mechanisms is that they are often subject to public rejection. However, acceptability can be raised by publicly explaining how revenues would be used (recycling to tax payers or investing).

Although we have proposed concessionary fares for public transport based on social purposes, these incentives should be independent from receiving net revenues from optimal pricing in the transport sector (Proost et al. 2002). Our support for incentives for public transport use is based on studies suggesting that changing the relative cost of the two modes (i.e., public and private) will influence personal transport choices (e.g., OECD 2008b).

3.4 Application to the Barcelona Metropolitan Region (BMR)

This section applies the set of factors identified in Section 3.2 and general policy insights of Section 3.3 to the case of the Barcelona Metropolitan Region (BMR). We have based our study of the BMR on the insights from empirical studies and official reports, which used primary data sources of general mobility surveys.[2] In some cases, data from the population census track were consulted as well (IDESCAT for several years).

An overview of the two aspects of commuting considered shows that in 2006 commuting made up 15.8% of the total number of journeys made within the BMR (the latter was equal to 2,528,365 one-way journeys to job destinations). Of these journeys 19.3% were made walking, 24.7% were made by public transport and 56.0% by private vehicle. Average commuting time (one-way journey) was 24.15 minutes.[3] Commuting distances are indirectly calculated (journey lengths were measured in minutes); in 2006 the proportion of population living and working in the same municipality was of 47.4% (Oliver-Frauca 2008).[4]

[2] Two main series of general surveys are available for the BMR, which include aspects of commuting behaviour, namely the Survey of living conditions and habits of the population of Catalonia (ECVHP, acronym in Catalan) and the Survey of Daily Mobility of Catalonia (EMQ, acronym in Catalan). While the latter is specific for daily travel behaviour, the former includes also other general aspects of travellers' lifestyles.

[3] Calculated from data in Survey of Daily Mobility of Catalonia 2006 (EMQ 2006).

[4] Estimating commuting distance from journey lengths has limitations, since the speed of commuting may be different depending on the travel mode chosen and traffic situation. However, general surveys do include information on the origin and destination of journeys, thereby facilitating accurate estimates of distance.

1. Built environment

The BMR has a large, diverse and compact centre (the municipality of Barcelona); an extremely dense first metropolitan ring formed of housing estates and industrial parks physically connected to Barcelona, with discontinuities in the form of agricultural land and peri-urban natural parks; and a second metropolitan ring comprising seven traditional satellite cities or sub-centres and their corridor areas, as well as an extensive area that combines both rural and low-density residential uses. The satellite cities were traditionally independent in terms of labour and services and have until recently been big attractors of population and employment. The region as a whole has a polycentric form in spite of dispersion trends (Trullén and Boix 2000; García-López and Muñiz-Olivera 2007; Garcia-Lopez 2010).Trends that promote commuting are the spatial segregation of economic sectors (i.e., zoning of tertiary, industrial and construction sectors), and a sharp decrease in the number of people that work in the municipality where they reside. Noteworthy is the proliferation of so-called "exclusionary spaces", suburban low density residential areas and industrial parks, mainly car-oriented (Cebollada and Miralles-Guasch 2010). Studies confirm that persons without access to a private vehicle, while living and working in these exclusionary spaces, can see their personal mobility compromised, with the result of being disadvantaged in the labour market (Cebollada and Miralles-Guasch 2008; Cebollada 2009; Miralles-Guasch 2010).

2. Transportation factors

Motorised modes, and especially private vehicles, dominate commuting trips within the BMR; the proportion of commuting trips made by motorised modes in 2006 was on average of 84.3% (52.7% private vehicles, 25.9% collective public transport, and 1.2% multimodal trips). In addition, data shows a decrease in non-motorised modes in favour of the private vehicle in the past two decades (the use of public transport remains almost unchanged) (Nel·lo 2010). When distance precludes walking or cycling to work, the choice between public and private transportation in the BMR is very much conditioned by territorial differences in accessibility to public transport services; (lack of) access to public transport. Accessibility decreases with distance to Barcelona city, the (public) transport network of the BMR is radial and has not yet accommodated the most recent dispersion trends taking place mainly in the Second metropolitan ring, which explains a spatial mismatch between its demand and supply. In addition, Matas (1991) and

Asensio (2002) identify quality and reliability of public transport services as further relevant factors. Private vehicle usage further increases with car access, namely with the number of vehicles in the household, and with access to a parking Oliver-Frauca (2010). About 77% of households have access to a car and 17% to a motorcycle in the BMR. The Second ring has a larger proportion of households with more than one car, related to houses here being larger and commonly including a garage. In Barcelona city the proportion of households without vehicle however is rising (from 29.3% in 2000 to 33.3% in 2006). Commuters with parking access at destination (job location) drive more (60% use the car) than those without parking (43.5% use the car). Only 9.7% of commuters with parking access use public transport versus 34.0% of commuters without parking using public transport.

3. Labour market factors

The incidence of temporary jobs is in the range 85.85% - 88.84% for the period 1998-2011 (IDESCAT 2012). Temporary workers are continuously engaged in the search for another job (Dolado et al. 2002), thus incurring higher job-searching costs (Kahn 2012). Moreover, workers with fixed-term contracts have lower salaries (Dolado et al. 2002), so they cannot afford housing in certain locations and may not be able to afford residential moving costs either. There is a low residential mobility for work purposes. With regard to workers' location adjustments, between the motives for residential movement declared among the population of the BMR in the *Survey of living conditions and habits of the population of Catalonia (2006)* (Alberich 2010), labour motives occupied the third position (9.0%), after motives such as housing/environment (44.0%) and family motives (38.5%). Ahn et al. (1999) and Antolín and Bover (1997) also report a very inelastic demand for mobility for working purposes when this implies a change of residence.

4. Housing market factors[5]

Housing prices increased 130% in the last two decades, mostly in the central city and First ring.[6] Variations in dwelling price and household income, throughout the region,

[5] When not indicated otherwise, information regarding the housing market has been taken from Donat's (2010).

[6] The evolution in housing prices by regime of tenure for Barcelona and other municipalities of the BMR is offered by the Catalan Department of Territorial Policy and Public Works (DPTOP in Catalan).

influence the spatial distribution of the population. 82% of householders are owners, but renting is still considered an option within the BMR; renters display a greater number of housing re-location which may favour reduced commuting distances. In the case of Catalonia, however, Artís et al. (2000) found that both house-owners and renters within the controlled rental market (i.e., having almost lifelong renting terms and thus paying very low rents) faced longer commuting lengths (measured in commuting time). In the case of owners, they note that for many households residential moving was not an option to relocate closer to their jobs since they face fixed moving costs that would more than offset the savings in commuting costs. Renters within the controlled rental market, in turn, would see an increase in their rental costs to an amount that would not be offset by savings in commuting costs.

Households' outlay on buying a house (i.e., average annual household expenditure allocated to pay the mortgage on the total income) increased by 26.7% in 2006, with respect to 2000, and varies territorially. Average outlay by households on mortgages[7] has mostly increased in the First ring, where housing prices are approaching those in Barcelona. Outlay in the First ring is now even higher than that of the Second ring, which traditionally encloses large residential areas with more expensive and larger dwellings, but also wealthier people. Traditionally, housing was the cheapest in the First ring and people living there had a low average income level. Barcelona, however, is still where the highest loans are paid, a direct consequence of increased housing prices due to the concentration of population. Housing affordability, measured by taking into account average income and housing prices by area, makes a family from Barcelona allocate 26.5% of its income to locate in this same municipality, 25.6% in the First ring, and just 23.7% in the Second ring. Therefore, housing affordability increases with distance to the region's core for both owners and renters. As a direct consequence, population growth has mainly taken place in small towns and new suburban settlements within the Second ring; between 1996 and 2010 population increased by 7.3% in Barcelona, 11.5% in the First Ring, and 39.6% in the Second Ring (ATM 2011). The social groups moving to small cities and towns from the Second ring are, generally, low income households with children, women, and young people.

[7] In the BMR, household spending on a mortgage is, on average, 26.6% of income. This amount increases to more than a third, if the entry and taxation costs are included (Donat 2010).

5. Transport market factors[8]

From 1990 to 2006, the average commuting time (one-way) in the BMR has changed from 22.5 to 24.6 minutes, an increase of 9.3%. This is despite improvements on the road network implemented between 1990 and 1995 (construction of the "Rondas" in Barcelona and other infrastructure), which temporarily reduced commuting time to 21.4 minutes in 1995 (Nel·lo 2010). Transport costs in time and money vary among the mode used and location of residence; both increase with distance to the CBD for those who use motorised modes. The former is connected to distance travelled and access (non-access) to public transport. In this respect, Trullén and Boix (2000) note that inequalities in the provision of transport infrastructures within the region make distinct areas show substantial commuting time differences for same number of kilometres travelled. A majority of commuting journeys made by private vehicles have a length of 15-30 minutes (48%), while those made by public transport exceed the 30 minutes (48%). On the other hand, average monthly expenditure in public transport is of €26, while for private vehicles it is about €100, of which 70% corresponds to expenses on fuel and the remaining 30% is split between parking and road toll expenses. Using the car is therefore on average quicker, but more expensive than using public transport. Asensio (2002) notes that rail modes, in particular the metro, are the closest substitute for the car since they incur similar monetary and in-vehicle time costs. Costs allocated to commuting vary with gender, age, professional level and income. Congestion further involves time losses for commuters in the BMR of 69% of the total commuting cost, reflecting a value of time of €7.57 per hour (Domínguez-Varela 2007). The time-distribution of mobility for commuting purposes shows three daily peak times: 7 to 9 am, 1 to 3 pm, and 5 to 6 pm; peaks of return journeys are less significant since journeys are more time-scattered (Miralles-Guasch and Oliver-Frauca 2008). During these peak times, traffic is presumably dense, while congestion is presumably at its highest. In 2008, in the BMR, the cost of congestion in terms of productivity loss was estimated at €311 million.

6. Socioeconomic factors

Travel behaviour differs by age, gender, occupation status, and professional category, with

[8] When not indicated otherwise, information regarding the transport market has been taken from Oliver-Frauca's (2010).

consequences for mobility purposes, commuting distances, and mode choice. General trends in the travel patterns of people, according to their socioeconomic individual attributes, in the BMR coincide with the findings of the literature on the issue (see Table 3.4). People within studying and working ages display a greater occupational mobility. Men also have greater occupational mobility and make a larger number of commuting journeys, whereas women tend to show a higher mobility for personal motives, and the same holds for those engaged in housework, the unemployed and retired segments of population. Gender differences have usually been attributed to variations in male and female roles. Commuting distance and time differ by gender. Workers belonging to high socio-professional categories drive more, while workers from low socio-professional strata are the ones that walk more to work. Workers belonging to higher socio-professional categories are still the social groups working closer to residence. Workers from lower socio-professional categories commute longer, on average; they form the social group showing greater tendency to work outside their municipality of residence.

Table 3.4. Commuting patterns for different individual socioeconomic attributes.

Commuting indicator	Age			Gender[1]		Professional category		
	18-24	25-44	45-64	Male	Female	Low	Medium	High
Commuting distance	there is no clear trend			+	-	++	+	-
Commuting time	++	+	--	-	+	++	+	-
Private vehicle use	--	++	+	++	-	-	+	++
Public transport use	++	+	-	-	++	++	+	-
Walking/cycling	+	-	++	-	++	++	-	+

Source: Based on Oliver-Frauca (2010). Data from *Survey of living conditions and habits of the population of Catalonia 2006* (ECVHP 2006, acronym in Catalan).

Notes: Signs ++, +, - and -- denote the relative magnitude of the indicator in the respective row for the group in the respective column. (1) Double sign reflects a gender difference larger than 15%.

7. Behavioural factors

These are probably the least studied of the factors for the BMR. Studies have mainly focused on individuals' preferences for location of residences and jobs, and commuting mode choice. 60.2% of households prefer to live in a single-family dwelling (Donat

2010). This is consistent with findings from Artís et al. (2000), dwelling characteristics being a significant factor of commuting in the BMR. Data are available on the motives for mode choice and the levels of satisfaction with the different transport modes. Nevertheless, the results do not allow for the extraction of categorical conclusions. Habitual car users seem to be more critical about public transport services and for them more satisfying transport modes are those reinforcing individuality (i.e., motorcycle, walking and cycling). The tram and *ferrocarril* train, which have fewer delays and are less crowded than other collective transport modes, are also among the most preferred modes. Regarding the awareness of environmental and transport externalities, 73.4% recognised co-existence with traffic problems (45.3% perceive them as severe or serious), while just 33.7% perceive severe air pollution and noise (Oliver-Frauca 2008).

8. Summary and policy lessons for the BMR

The analysis of factors undertaken reveals interdependencies that are of relevance to understand the particularities of the commuting behaviours and patterns in the BMR. A clear interaction exists between the built environment, market and socioeconomic factors (demographic movements). One interpretation is that population dispersion into small towns and newly constructed low-density residential areas —lacking adequate (public) transport infrastructure and services to accommodate such population growth— is featured by social groups with low incomes (i.e., young couples, women, etc.), which found affordable housing within these municipalities (Nel·lo 1995). However, in many cases their jobs are located in either the centre or the main employment sub-centres of the BMR, which stimulate car use. With this in mind, one might think that investment in public transport (infrastructure supply) could help correct for excess driving. However, behavioural factors, although comparatively less researched, seem to show a reinforcing pattern; habitual driving may be relevant in affecting perceptions about alternatives other than private vehicles, which in turn may compromise the effectiveness of investment efforts. In this vein, the possibility of self-selection bias (residential location-habitual transport mode) needs to be explored as well. Many more interactions can be linked in this way and policy suggestions can be derived in line with notions stressed in the literature on transport policy: integrated policy development and context-specific policies packaged to target all aspects of travel behaviour (e.g., Hickman et al. 2010).

Table 3.5 provides an example of how the measures can be combined and packaged to address the interaction between the factors described before. Policy packages (PP) in Table 3.5 are consistent with the three perspectives presented in Section 3.2, namely planning (PP1), economic (PP2) and behavioural (PP3). As a result, the packages differ in the type of instruments used. PP1 ("Planning") mainly includes planning/infrastructure and command-and-control instruments, PP2 ("Economic") includes price-based instruments, and PP3 ("Behavioural") includes a mixture of informative and price-based instruments.

Policy measures have been selected that address the main factors which stood out in the analysis of the BMR. In choosing a package of measures, attention was paid to avoid potential overlap and assure complementarities between policy measures. Policies reducing car use, for instance, require acceptable alternative transport modes and a favourable built environment. Synergies are expected among the different measures. Hickman et al. (2009) show that positive synergetic effects on emissions are to be expected between pricing measures raising the cost of driving considerably, and planning measures improving the coverage of the public transport network and facilitating relocation decisions. Only qualitative statements about impacts are feasible, as precise quantitative reductions of emissions due to a specific policy package are of course impossible to determine since the complex framework used for the analysis of the BMR cannot be completely quantified. Instead we propose something that might be called "adaptive policy": adjustments of specific measures (e.g., fuel tax) can be made through trial and error until an acceptable outcome that can be monitored is reached (like the level of GHG emissions). Two complementary measures are included, namely investment in R&D and monitoring of emissions, so as to allow for actual policy adaptation and assessment of synergies.

Table 3.5. An example of a policy package for the BMR.

Policy package	Policy measure	Effective-ness[1,2]	Efficiency[1]	Equity[3]	Implemen-tation costs[4]	Level of planning[6]
PP1: Planning (focus on BE, TF and SE)	Changing the function of existing buildings in strategic sites with high accessibility (e.g., city centre and network nodes)	+	0	0	++	M
	Build social housing in strategic sites with high accessibility – city centres, employment subcentres (if possible), and network nodes	+	0	+	+++	
	Adaptation of the radial design of the public transport network	+	0	+	+++	M
	Provision of existing low-density residential/ employment spaces, so-called “exclusionary spaces”, with public transport or travel plans	+/0	0	0	+++	R
	Provision of park-and-ride facilities in stations close to low density residential areas	+/0	0	+	++	R
	Give public space to sustainable modes and promote street connectivity (if possible) within cities	+/0	0	+/-	++	P
	Designation of environmental zones with limits on high-pollutant vehicles (e.g., city centres)	+	0	0	++	P
	Speed limits in congested areas to lower pollution and make driving less attractive (e.g., Barcelona Metropolitan Area) – automatic speed control	+	0	+	++	R
PP2: Economic (focus on BE, TF and SE)	Internalisation of *full* transport costs in low-density building projects	+	+	0	+	
	Variabilisation through increase of fuel tax + remove fixed road tax	+	+	-/0	+	
	Substitute moving taxes by geographically differentiated road taxes	+	+	0	+	
	(Economic or social) incentives for people to live closer to their jobs	-	-	0	+++	
	Centralised (public) web-site to diffuse *all* information about job offers (e.g., through the web-site of the Employment Service of Catalonia, SOC in Catalan)	+	+	0	++	
	Congestion charges during rush hours and within the central metropolitan area (Barcelona and First Ring)	+	+	-/0	++	
	Parking charges and controls (e.g., Barcelona city and other cities or city zones where driving is intense and which are well served by public transport, like city centres and business districts)	+/0	+	-	++	M
	Concessionary fares for public transport based on social purposes (young, elders, and more generally low income groups)	+	-	+	++	M

Policy package	Policy measure	Effective-ness[1,2]	Efficiency[1]	Equity[3]	Implemen-tation costs[4]	Level of planning[6]
PP3: Behavioural (focus on BF)	Campaigns offering re-location solutions for dwellers within empty flats in dense areas with mixed land uses	+/0	0	0	++	
	Application of IT-systems to public transport systems to decrease uncertainty about reliability and waiting and transfer times	+	0	0	++	R
	Temporary road closures and withdrawal of parking spaces to break down driving habits (e.g., in roads/zones where driving is intense and there are public transport alternatives for such routes/zones – Rondes in Barcelona and Nus de la Trinitat)	+	0	-/0	++	
	Monetary incentives for public transport (free-period ticket) to form habits of use of public transport	-	-	0	+++	
	(Injunctive) normative messages on transport externalities and sustainable transport modes	+	0	0	++	
	Descriptive normative messages about living in flats in dense areas with mixed land uses	+	0	0	++	
	Feebates on new cars dependent on emissions/fuel consumption	+	+	-/0	+	
	Innovative transport measures[5]	+/0	0	0	++	
Complementary measures	Public investments and stimulating private investments in R&D	+	0	0	+++	M
	Computerized emission control via electronic sensors (monitoring)	+	0	0	++	R

Inspired by Banister et al. (2000).

Notes: (1) + positive, - negative, 0 neutral or ambiguous. (2) Effectiveness is considered as reduction in GHG emissions and minimal rebound. (3) + is more equitable, - more inequitable (poor people disproportionately affected), 0 no change in equity. (4) + denotes small, ++ moderate, +++ large. (5) 'R' (realised), 'M' (implemented but in need of modification) and 'P' (planned) refer to policies included in planning for the BMR. (6) Individualised marketing, "deliberation intervention", car-sharing, car-clubs, car-pooling, PAYD, public transport traveller information systems, fuel-efficient driving, etc.

Policy measures are further assessed according to three ("e") criteria: effectiveness, efficiency and equity. Effectiveness was already assessed on the basis of the literature review in Section 3.3. Regarding economic efficiency (or cost-effectiveness), taxes or other price incentives are judged as positive (+), a subsidy as negative (-), and other measures as relatively neutral or ambiguous (0). A measure is considered inequitable (-) if poor people are disproportionately affected, it is considered equitable otherwise, and when no change in equity is expected, it is considered neutral or ambiguous (0). Implementation costs of measures are also considered. Planning measures like infrastructure supply and subsidies are considered to incur high implementation costs (+++), organisational or administrative instruments (e.g., designation of low-emission environmental-zones, centralised public web-site to diffuse job offers, or awareness campaigns) are assumed to incur medium costs (++), and command-and-control measures and taxes (e.g., increasing existing fuel taxes or feebates systems) are considered to incur relatively low implementation costs (+). These allow for a fair comparison between different measures. All measures in Table 3.3 were assessed in these terms and whenever overlapping or negative synergies existed between two measures, the final decision (i.e., which one to include) was taken based on how policies scored on these criteria. For instance, prohibition of low-density building projects and internalisation of full transport costs in low-density building projects overlap (same policy objective with same or similar effect, namely discouraging of low-density building projects). However, internalising the transport costs of low-density projects scored positively on economic efficiency, while prohibiting scored neutrally (0) (performance on the other criteria was similar). This latter option was hence discarded. Finally, we reviewed the current transport-policy agenda of the BMR, and compared it with our proposal (last column of Table 3.5 "Level of planning").

3.5 Conclusions

The relationship between commuting and GHG emissions is complex. There are many factors involved, which interact with one another. This poses a major challenge for effective policy targeting commuting-related emissions in urban areas. Both commuting distance and travel mode, especially car use, affect emissions. These aspects of commuting are relevant to climate policy, transportation policy and spatial planning. Empirical studies find an almost universal increasing trend in commuting lengths (mostly in distance), as well as a dominance of the private vehicle for commuting journeys. Commuting distance and travel mode choice are related to the built environment through urban form elements. However, when commuters choose location (i.e., residence and job locations) and mode of transport, they take into account a wider range of factors, as well as facing several constraints. Differences in behaviour exist between socioeconomic groups. In addition, studies note marked individual attitudes and preferences (including habits) for certain locations and modes, which deviate from rational behaviour and do not facilitate the effectiveness of policies.

We have identified five main factors of commuting, namely built environment characteristics, transportation factors, market factors, socioeconomic factors and behavioural factors, and within each of these a range of sub-factors. These factors have been examined for the case of Barcelona Metropolitan Region (BMR). We identified the influence of all five factors in explaining variations in commuting patterns and emissions from transport. We found that commuters face constraints when choosing locations, notably due to market imperfections in the labour and housing markets and related to, among others, high job-searching costs and high house moving costs. We identified variations in commuting behaviour for different socioeconomic groups, which correspond with those described in the literature. In addition, we observed contradictory commuting behaviours when analysing demographic trends; immigrants locate in central places with high accessibility to public transport, while locals move into less accessible small towns, thus increasing their commuting distances and car use. We further noticed that there is insufficient knowledge about the role that behavioural factors play in shaping commuting patterns through individuals' lifestyles, preferences, attitudes and habits in the BMR.

Specific public policies can be connected to all these factors. We analysed effective policies on the basis of the factors identified. This takes into account rebound effects in a proactive manner (i.e., anticipating undesirable effects and interactions). Essential for the case of the BMR are limiting spatial dispersion trends and providing adequately designed public transport services. The latter is already included within the political agenda of the BMR and is currently being implemented. As for the former, it seems that there is little willingness to restrain low-density building projects (both residential and business/industrial centres). A similar conclusion is reached by Hickman et al. (2013) for London and Oxfordshire metropolitan regions. A reduction in CO_2 emissions from transport to a level compatible with reasonable aspirations can be achieved through heavy investment (i.e., radical projects) in urban and transport planning. The political feasibility and affordability of such stringent investments are questionable, however, especially within a time horizon that is needed for rapidly controlling emissions. We did not examine political feasibility here, but it could well form part of a future step in research on the BMR. In addition, the effects of market imperfections on labour and housing markets need more attention as they complicate policy analysis; so far the role of these factors seems to have been completely overlooked in policy studies, design and implementation for the BMR. Possibly, corrections of these imperfections can further contribute to reducing GHG emissions from transport. Policy packages, of whatever type would have to include measures discouraging car usage. Measures increasing the costs of driving are effective and have low implementation costs. However, alternative strategies based on behavioural research can also be competitive in this sense. Generally, a reduction in journey distances seems feasible, while the use of private vehicles can be reduced through effective policy intervention. Of course, one has to expect policy limits to exist with regard to social groups with strong preferences for low-density sites and pro-car attitudes.

4 Behavioural economics, travel behaviour and environmental-transport policy

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4.1 Introduction

Key challenges in attaining sustainable urban travel behaviour include physical-infrastructural, technological and behavioural issues. There is an ever growing number of studies noting that a transition to sustainable mobility is unlikely if technological improvements and changes in the built environment are not combined with behavioural change (Hickman and Banister 2007; Chapman 2007; Rajan 2006; Steg and Vlek 2009). Many studies have tackled these issues focusing on particular policy strategies (e.g., physical planning and infrastructure supply, pollution standards, pricing mechanisms and information provision), but have in most cases assumed representative, rational agents. However, behaviour of travellers is heterogeneous while their preferences are inconsistent (Anable 2005; Barr et al. 2011). Moreover, socioeconomic factors are insufficient to explain observed differences in behaviour.

Transport reality is often better described by behavioural approaches. They have already received some attention in recent studies on travel behaviour. Two themes of behavioural economics are encountered in travel studies. One is bounded rationality, addressed mainly by applying Prospect Theory to travel time uncertainty and interpretations of expected travel time, which is relevant to valuation exercises in project appraisal, notably understanding WTP/WTA differences in estimating the value of time savings (Avineri and Bovy 2008; Batley 2007; van de Kaa 2005, 2006; Schwanen and Ettema 2009). Several empirical studies aim to improve demand management by using real-time information about travellers in transport networks (Avineri and Prashker 2003; van de Kaa 2008; Nakayama and Kitamura 2000). This is of importance to redistribute traffic and reduce congestion, which affects local air quality. Most of these studies adopt an experimental approach within controlled settings so that the effects of targeted factors can be analysed in isolation. Insights are then used to improve demand modelling.

A special issue within this theme of bounded rationality of travellers is that of habitual behaviour (Bamberg et al. 2003; Bamberg and Schmidt 2003; Gardner 2009; Klöckner and Matthies 2004; Thøgersen (2006); Verplanken et al. 1998). Habits reflect time-inconsistent preferences that lead to seeking immediate rewards. Most daily travel choices are largely habitual and automatic, involving low information processing (Verplanken et al. 1997). Habitual travel behaviour violates rational choice principles through the absence of a process of cognitive deliberation –involving preference formation, deliberate information processing and preference-based choice (Gärling et al. 2001).

The second theme is social preferences, which include altruism, fairness, norms, reputation and status seeking concerns. Social preferences have received most attention in studies explaining modal choice (Abrahamse et al. 2009; Anable and Gatersleben 2005; Johansson-Stenman and Martinsson 2006; Sohn and Yun 2009). There is a long history of applying social psychology to travel studies dealing with feelings of moral obligation, perceived social pressure and control beliefs.

In parallel, behavioural economics has recently seen much application to environmental economics. This has given rise to studies of sustainable consumption, voluntary cooperation in public goods like conservation of natural resources or recycling, environmental valuation, and the implications of these for environmental and climate policy (for surveys, see Brown and Hagen 2010; Gsottbauer and van den Bergh 2011; Jackson 2005; Shogren and Taylor 2008; and Venkatachalam 2008). These studies support the idea that explicitly accounting for behavioural biases due to both bounded rationality and social preferences, increases the understanding of complex environmentally-relevant behaviour, and so provides an improved basis for environmental policy design.

This chapter reviews empirical evidence on behavioural biases in travel choices (long- and short-term choices) and their implications for environmental-transport policy. Van de Kaa (2008) and Li and Hensher (2011) offer a review of applications of Prospect Theory to transport policy, while Avineri (2012) and Metcalfe and Dolan

(2012) offer broader surveys of the implications of bounded rationality and social preferences for travel behaviour and policy. However, none of these studies deals in detail with environmental policy issues related to transport, which is the focus of our review.

The remainder of this chapter is structured as follows. Section 4.2 offers a literature review of insights from behavioural economics that are applicable to travel behaviour. Section 4.3 discusses policy implications and provides guidelines for environmental-transport policy design. Section 4.4 concludes.

4.2 Behavioural economics and transport

4.2.1 Behavioural economics

Behavioural economics merges the fields of economics and psychology to provide a better understanding of choice behaviour (Camerer 1999; McFadden1999; Rabin 1998). Realistic behaviour of individuals is often not well captured in traditional models of economic policy. Deviations from rational agent behaviour are due to four factors: (1) imperfect information and individuals' limited computational abilities, (2) asymmetric valuation of gains and losses and probabilities weighted non-linearly, (3) time-inconsistent preferences, and (4) social preferences and self-identity concerns (Gsottbauer and van den Bergh 2011).

These deviations have particular consequences for behaviour. Implications of (1) are the use of heuristics and false associations or logical leaps due to mental shortcuts and calculation mistakes. Implications of (2) are: frames influencing choices, choice persistence or inertia, and risky choices when outcomes are framed as gains and conservative choices when outcomes are framed as losses. Implications of (3) are: hyperbolic discounting, i.e., overvaluation of the present over the future, myopic behaviour, self-control problems and habit formation due to positive rewards in the present. Implications of (4) are both limited self-interest (altruism and fairness) and inter-dependency of choices due to self-identity concerns. Biases create inconsistencies in behaviour that are generally classified under two broad categories, namely bounded rationality –(1) to (3)–, and social or other-regarding preferences –(4). Table 4.1 offers a summary of some of the various behavioural anomalies and systematic biases.

Table 4.1. Summary of concepts and insights from behavioural economics.

Bounded rationality and Prospect Theory	JUDGEMENT ERRORS: imperfect information, complexity and individuals' limited computational abilities; use of heuristics and judgement biases	Availability heuristic	Choices rely heavily on readily retrieved information from memory and little on background information.
		Affect heuristic	Choices are based on feelings and emotions, as well as on one's mood.
		Representati-veness heuristic	People tend to exaggerate the probability of occurrence of representative stereotyped events or outcomes.
		Anchoring and adjustment	People make an initial guessing of probabilities, based on substandard cues, and stick close to their initial guess. They ignore additional information that contradicts their initial hypothesis.
		Lexicographic preferences	Simplification of a decision choice set by focusing on only one (or few) attribute(s).
		Default bias	People choose the default option in a complex choice set, thus disregarding other alternatives' attributes or choice outcomes.
		Confirmatory bias (illusory correla-tion, hindsight bias, filtering)	People use information to justify their initial guesses and choices. They may "filter" information to such an end(*filtering effect*). In a similar way, people may assess past choices on the basis of new information they did not have when choices were made (*hindsight bias*).
		Mental accounting	People keep mental accounts for different expenses. This violates the fungibility property of money.
		Overconfidence, errors of application	Individuals tend to be overconfident about their capabilities and often do not apply their expert knowledge to common-problem solving (*error of application*). Overconfidence is further related to the *confirmatory bias.*
		Salience and vividness	Individuals weight extraordinary evidence disproportionately against the odds, even when information about actual probabilities is available.
	CHOICE UNDER RISK AND UNCERTAINTY: context-dependent preferences, alternatives framed as either gains or losses, and probabilities weighted non-linearly	Framing	The way a set of options, in a decision problem, is formulated (i.e., "framed") influences individuals' preferences.
		Loss aversion	Individuals have asymmetric preferences for gains and losses. People put a higher value on losses than on same-sized gains, and dislike to take (even) smal risks. In addition, people are *risk averse* over gains and *risk seeking* over losses.
		Endowment effect	Individuals are *loss averse* and value more the things they own than those do not. This effect can be immediate and arbitrary (i.e., recently owned things), though the longer the tenure, the higher the value assigned.
		Status quo effect	Individuals stick to their original choices (i.e., *status quo*), even if change would cause substantial improvement. This is a consequence of losses being disproportionately valued and the *endowment effect*.
		Certainty effect	People prefer certain over uncertain or probabilistic outcomes and so choice outcomes that are framed as sure losses lead to *risk seeking* behaviour (overestimation of low probability outcomes or rare events), while choice outcomes framed as sure gains lead to *risk aversive* behaviour (underestimation of high probability outcomes).
		Preference reversal	Individuals with stable, well-defined preferences can end up choosing an option that is not the one they value the most. Preference reversal can be induced by a change of the reference point or by the introduction of a decoy option into a set of options. The latter will tip the balance towards the non-decoy option, not chosen otherwise.

Bounded rationality and Prospect Theory	TIME-INCONSISTENT PREFERENCES AND SELF-CONTROL PROBLEMS: intertemporal choice and habit formation	Hyperbolic discounting, immediacy effect	People value present rewards much more highly than future gains. As a result, individuals sometimes make decisions which are not in their best long-term interest (i.e., myopic behaviour). This deviation partly explains *procrastination,* addictions and habitual behaviour.
		(Lack of) self-control	The "need" over the "will" or lack of self-control is explained by people valuing present gains much more than the future ones.
		Habits	Habits are automatic, non-deliberated responses formed through the repetition of a satisfactory course of action that is stored in memory. Habitual behaviour can be explained by having time-inconsistent preferences, but habits can also (positively) be seen as mental shortcuts or simplification heuristics that save costs of search, information processing and deliberating a decision.
Social preferences and self-identity concerns	SOCIAL PREFERENCES AND SELF-IDENTITY CONCERNS: limited self-interest and self-identity concerns	Fairness (equity, justice)	People dislike *unequal* allocations of goods.
		Altruism, 'warm glow'	People value the well-being of others. A distinction is made between "pure" *altruism* (i.e., when an action is taken in a generous way and without receiving anything in return) and "impure" *altruism* (i.e., when the action produces some sort of benefit to the altruistic individual; '*warm glow*' and *reputational altruism*). Altruism can further take the form of *(direct or indirect) reciprocal altruism.*
		Reciprocity	Individuals expect others to act in a similar way to how they act (e.g., expect to be treated well by a person they have treated well).
		Envy and retaliation	Willingness to sacrifice with the aim to hurt others who have been unfair to you or mistreated you, even if it comes at a high cost. This is a special case of *reciprocity*.
		Norms	People usually care about others' behaviour and seek to behave appropriately. Social and personal behaviour are guided by norms and rules, which are (often) developed socially. Social norms are injuctive (i.e., describing a socially accepted behaviour) or descriptive (i.e., a norm that describes an extended behaviour).
		Status, relative income, positional goods	Status denotes a social position often signalled by more wealth relative to others. The consumption of *positional goods* which show one's relative wealth (i.e., conspicuous consumption) is one way in which individuals derive status. Individuals further derive reputation from showing membership to high status, relevant reference groups.
		Role models and peer effects	Role models are "salient" members of relevant reference social groups (i.e., well positioned socially), which may influence the behaviour of those individuals who value becoming a member of such social group.

Notes: Table adapted from Gsottbauer and van den Bergh's (2011) classification of behavioural economic insights. Further insights retrieved from Ariely (2009), Camerer (1999), Cialdini (2003, 2007), Kahneman (2011), McFadden (1999), Rabin (1998), Shogren and Taylor (2008) and Tversky and Kahneman (1981).

Systematic behavioural biases have implications for policy design. Indeed, several authors have translated insights of behavioural economics into general policy rules. Notable examples are NUDGE (Thaler and Sunstein 2008), the seven principles from the NEF report (Dawnay and Shah 2005), and MINDSPACE (Metcalfe and Dolan 2012), the latter being focused on travel behaviour and transport policy. A difference between the study offered in this chapter and Metcalfe and Dolan (2012) is that we provide a more complete review of the set of travel choices (short- and long-term choices) and associated insights from behavioural economics which allow resulting lessons for environmental-transport policy.

4.2.2 Application of behavioural economics to transport

Travel choices can be distinguished into long-term and short-term choices (Table 4.2). A similar distinction is made in van de Kaa (2008). *Long-term choices* are not travel choices *per se*, but entail long-term commitments with strong determinants of daily travel behaviour, namely residential and employment locations and engagement with travel modes of the type of getting a driving license and car ownership. Such commitments have a lasting effect and constrain *short-term* or daily *choices.* Figure 4.1 offers a summary of the empirical evidence on behavioural biases in travel choices.

Table 4.2. Set of travel choices that individuals and households face.

Set of travel choices	
Long-term choices	*Short-term choices*
• Residential and employment location • Driving license • Car ownership and car purchasing	• Destination • Departure time • Route • Travel mode

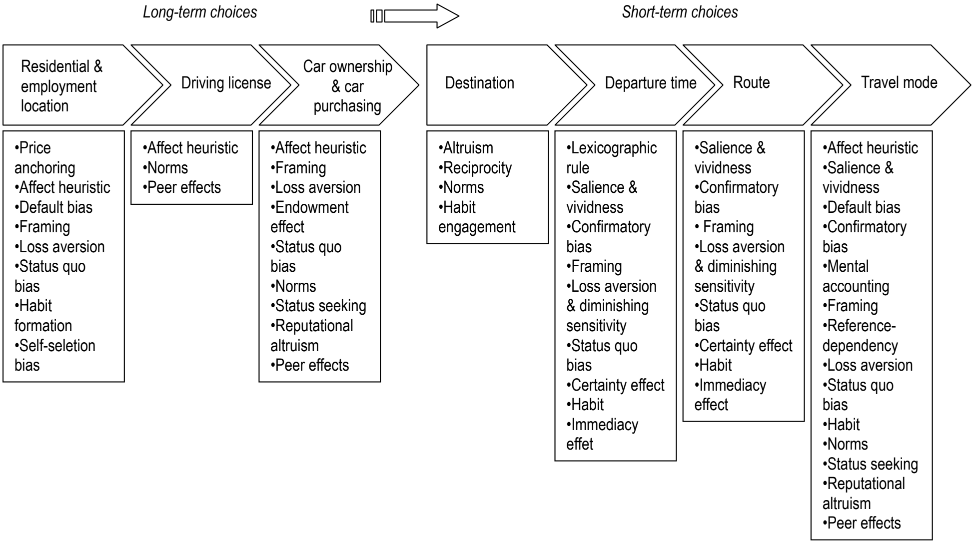

Figure 4.1. Behavioural biases and anomalies in short- and long-term travel choices.

4.2.2.1 Long-term choices

Travellers express bounded rationality in their location choices. They face imperfect information about job and residence offers, as well as incur both searching and transaction costs (pecuniary and non-pecuniary) that impede relocation and contribute to inertia (van Ommeren and Fosgerau 2009; van Ommeren and Leuvensteijn 2005; van Ommeren and van der Straaten 2008). However, the latter leads to the inefficient situation of having excess commuting (e.g., cross-commuting trips). Inertia in turn provides the stability necessary for habits to form and exist (Ouellette and Wood 1998). In choosing residence, the effect of price anchoring has been described in real estate market studies (Epley and Gilovich 2005). This effect is most clearly observed when people relocate to a new city, as they tend to go for the same price they were paying before, even when housing prices are lower in the new location (Ariely, 2009). Choices further depend on the way alternatives are presented, known as framing. Studies by Tversky and Kahneman (1991) and Axhausen et al. (2001) support the idea that in choosing a job or a house, households take their prior status as a reference and thus value alternatives and their attributes in a loss-aversive manner.

At the intersection of location choices and travel mode choices self-selection bias plays a role. Individuals may opt for car-oriented environments if they are inclined to drive, or choose pedestrian-oriented environments if they are committed to walking or cycling (Axhausen et al. 2001; Cao et al. 2002; Handy et al. 2005a; van Wee et al. 2002). Self-selection bias is found to have a greater effect in people who have relatively strong preferences for driving (Handy and Mokhtarian 2005).

Emotions, status and norms can encourage engagement with the car. Obtaining a driving license has a strong symbolic and emotional component, like a ritual of adulthood initiation (Haustein et al. 2009). These authors report a high importance of symbolism and affective socialization constructs in the formation of driving habits and positive personal norms about driving among adolescents. These constructs are learned from parents and peers who serve as role models.

Travellers commit themselves to particular travel behaviours through the ownership of cars and season-tickets for public transport; they accept a large one-off payment for low or zero marginal cost at the point of use (Simma and Axhausen 2001; 2003). Such commitments influence modal use to a greater extent than past behaviour. Studies moreover found high stability in car-ownership. There seems to be a greater resistance or *status quo* effect to change car ownership than to reduce the level of car usage (Brindle 2003). This may have to do with loss aversion and a related concept, namely the endowment effect. In addition, Ellaway et al. (2003) found that car access provides psychological and social benefits, such as mastery, self-esteem, and feelings of autonomy, protection and prestige, which public transport users do not derive from their transport modes. These benefits are associated with longevity and better health. Self-esteem depended on the type of car in the case of men but not women, while driving provided more benefits than being a passenger. Advertisement in mass media favours these positive associations affecting car purchasing. Bradsher (2002) notes that in the case of SUVs *versus* compact cars, marketing strategies have played a crucial role in making SUVs appealing to insecure, self-centred people, who want to appear frightening to others.

Houses and cars are both typical conspicuous goods that signal wealth (Hirsch 1976). Travellers show status seeking behaviour through the purchase of conspicuous goods and services as a way to signal reputation and social position. They further copy those relevant to them who seem successful. Car ownership, in fact, increases with income (Dargay 2001). Johansson-Stenman and Martinson (2006) found non-conscious concerns about self-image to be significant in car purchasing and related to the consumption of luxury cars signalling social position and wealth. They also found that subjects generally care about the environment, but not as much as they care for status. Interestingly, certain social subgroups derive reputation and status from showing environmental concern. In these cases owning a bike or a hybrid car may thus be a sign of status. Sexton and Sexton (2011) show that the willingness to pay for a Toyota Prius varies significantly with the environmental concerns of one's neighbours, which denotes conspicuous generosity or impure altruism. Indeed, other hybrid car models were not as effective as the Prius in communicating environmental concern. The Prius was found to be superior as a symbol of environmental concern, possibly because it was the first commercially successful hybrid car and because it has a design that is easily distinguished from other cars (see Maynard 2007).

4.2.2.2 Short-term choices

Probably the first decision to study should be whether to travel anyway. Travel is necessary for reaching destinations and to participate in daily activities. Some travelling may be difficult to avoid, like commuting, unlike other types like socially induced trips. Some socially induced trips (e.g., assisting someone going to a doctor or participating in joint activities) have been considered a form of altruistic behaviour which can be influenced by social norms and expectations that others will reciprocate (Goulias 2007; Goulias and Henson 2006).

Travel-activity patterns are organised around a small number of fixed activities or stops (Hanson and Huff 1982, 1988). Most short-term travel choices are repetitive and the result of daily routines, with fixed combinations of departure time, route choice and travel mode. Auto-commuters surveyed in Taiwan leave home at the same time 82% of the time and take the same route as the previous day 90% of the time (Jou et al. 2008). Most commuters are not likely to change their departure times and routes, suggesting that the commuters are very familiar with their commutes or that the commuting routes they take may be already the best routes. Repetitive trips to habitual activities stimulate automatic travel responses regarding mode choice (Aarts et al. 1998; Aarts and Dijksterhuis 2000). Habits are a key factor in modal choice and can be generalised across choice contexts (Gardner 2009). Travel mode habits lead to misperceptions about non-habitual modes (e.g., systematic underestimation of performance attributes like reliability and disregard of cost differences) (Anable and Gatersleben 2005). Strong travel mode habits moderate and even preclude the effect of deliberated intentions to change behaviour (Aarts and Dijksterhuis 2000). It seems that habits also moderate the effect of moral obligations to behave pro-environmentally (Klöckner et al. 2003; Klöckner and Matthies 2004). Indeed, Anable (2005) noticed that habitual car drivers do not feel any moral obligation to decrease their car use.

Reference-dependency, loss aversion and diminishing sensitivity, can explain departure time adjustments among commuters (Jou and Kitamura 2002; Jou et al. 2008; Senbil and Kitamura 2004). Travellers may have several reference points (e.g., earliest permissible arrival time, preferred arrival time, and starting time of work) and therefore early arrivals (i.e., gains) can still be valued negatively, even though late arrivals (i.e., losses) would certainly be valued (more) negatively. Jou and Kitamura (2002) noticed diminishing sensitivity to time gains: for example, the subjective value of gains of 0 to 5 minutes is higher than that of gains of 20 to 25 minutes. Hjort and Fosgerau (2012) moreover demonstrated that this diminishing sensitivity effect is stronger for travel expenses than for time costs, for both car trips and public transport trips. Travellers dislike uncertainty about travel time (i.e., travel time variability) more than they dislike long travel times (Bates et al. 2001; Noland and Polak 2002; Senna 1994). They are bad at computing probabilities, and so use simplification rules and are more inclined to reliable alternatives. For route choice, framed information about travel time distributions affected choices. Avinieri and Prashker (2004) found evidence of certainty effect (i.e., underweighting of high probabilities) due to risk aversion, and risk-seeking behaviour for choice settings implying low-probability, high-reward outcomes. In addition, de Palma and Picard (2005) found that absolute risk aversion is constant and larger for public transport users than for car users with regard to both expected travel time and travel time variability.

Reference-dependency and judgement errors can further explain suboptimal choices between bus lines, as well as the "waiting time paradox", according to which public transport users perceive that they always have to wait too long for the bus (Avineri 2004). For the case in which travellers are provided with information about headways, they may erroneously take the average waiting time (i.e., half the headway) as a reference and by setting such a low value as reference, additional waiting is usually framed as a loss. Bates et al. (2001) acknowledges that with regard to subjective perceptions of travel time variability or the reliability of different travel modes, there are relevant differences between the car and public transport. As he points out, in the latter case, the presence of a schedule involving potential waiting time or trip-duration favours establishing comparisons among the actual and the scheduled waiting/trip time, and so any discrepancy may be interpreted as unreliability, even though a certain delay might be constant, which would imply no variability. Hence, for advertised public transport services, reliability and punctuality (adherence to schedule) are closely related. Indeed, misconceptions about travel time costs (and systematic underestimation of car-related expenses) can explain choosing the car over public transport (Bonsall et al. 2004; Gardner and Abraham 2007). In addition, individuals with marked preferences for cars tend to use information on actual travel times to reinforce car choice and show travel mode persistence, namely undergo the "car effect" bias (Innocenti et al. 2013). Information on public transport schedules can lead to more use of public transport. Rietveld (2003) shows that the problem is not so much to inform public transport users, but how to frame the information provided so that biases connected to reference-dependency are minimised and public transport use is encouraged as a reliable means of transport. For example, as full reliability of schedule information cannot be guaranteed, providing information about probability distributions of arrivals or of travel times may be useful.

For particular choices, and under certain conditions, results from iterative tasks with immediate feedback, such as choices in transport contexts, are biased but go in the opposite direction of those predicted by Prospect Theory (i.e., one-shot tasks based on a full description of the choice problem); loss aversion is the only bias that appears robust in both iterative and one-shot tasks choice contexts (see Barron and Erev 2003). Under imperfect information travellers learn about travel time distributions from their experiences. Choices are repetitive and they get immediate feedback on actual travel time. However, their estimates about travel time distributions can be inaccurate in some cases (not leading to the best choices), for instance, if estimates are based on recent bad outcomes or small samples of outcomes, or if payoff distributions have large variances. The latter stimulates exploration (i.e., more random choices) and slows learning, thus, leading, on average, to more sub-optimal choices in the medium-term (see Erev and Barron 2005). Mahmassani and Srinivasan (2004) noted that subjects without reliable information overreacted to negative experiences, such as being stuck in traffic in the previous period, by switching more their departure times and routes in response. Recent events are more heavily weighted, while bad experiences are retained in memory for longer times, which reduce the probability that a risky choice is repeated but impede learning about the actual value of the alternative –the so-called “hot stove” effect (Denrell and March 2001). Avineri and Prashker (2005) found evidence of this payoff variability effect: in some cases increasing travel time variability of the route with the highest expected travel time could increase its perceived attractiveness, thus implying an underweighting of low probability outcomes.

Travel mode alternatives include other than utilitarian attributes, namely symbolic-affective and social ones. Anable and Gatersleben (2005) found that while utilitarian attributes are more important in explaining modal choice in commuting, for personal trips both utilitarian and affective factors are equally important. Steg (2005) notes that what best captures car use by young male commuters are emotions evoked by driving (notably, freedom, independence, comfort and apparent control), perceived social pressure favouring car use, and status seeking. The car is used by these commuters as a way of self-representation and to show membership to (i.e., imitate) relevant reference social groups. These feelings give the car a comparative advantage over public transport (Steg 2003; Steg and Gifford 2005). Whereas positive feelings ascribed to the car predict its use, negative ones like guilt and disappointment predict intentions to use public transport (Abrahamse et al. 2009; Carrus et al. 2008). Friends and family (i.e., relevant others), and a supportive social context, play a key role in transmitting the negative effects of car use and the positive ones of public transport, its reliability, lack of stress and possibility of undertaking a productive commute (i.e., working while travelling), which increase preferences for public transport use (Haustein et al. 2009; Murray et al. 2010; Popuri et al. 2011).

4.3 Lessons for environmental-transport policy

Here we discuss implications of the insights reviewed in Section 4.2 for environmental-transport policy. In doing so we distinguish between policy lessons that are connected to bounded rationality and to social preferences. Table 4.3 provides an overview and summary.

Table 4.3. Environmental-transport policy analyses for the set of long-term and short-term travel choices.

	Travellers' biases	Evidence from behavioural economics studies	Implications for environmental-transport policy
Bounded rationality, Prospect Theory and Time-inconsistent preferences	• Are emotional	Value both utilitarian and affective attributes of jobs, houses and travel modes (vehicles).	Positive emotions ascribed to the car favour car use and habit formation, and should be discouraged. Public transport use may be triggered through feelings of guilt and shame associated with car use, which, in turn, can be promoted by educating people to take responsibility for one's impact. Travellers with strong pro-environmental motivations are more prone to adopt (new) sustainable alternatives.
	• Stick to the *status quo* and choose the default option	Stick to current choices, particularly if they are socially accepted.	Green alternatives (e.g., electric and hybrid cars and compact housing without parking) can be presented as defaults. Opt-out defaults increase the probability that the green option is chosen. Defaults are more effective when travellers are unfamiliar with green alternatives.
	• Have separate mental accounts	Use separate accounts for fixed and variable costs of driving.	Increasing variable costs of driving has a greater effect than increasing fixed costs. The introduction of new pricing schemes can reduce the effect of mental accounts in controlling consumption.
	• Self-selection bias	Self-selection bias affecting location choices in favour of (private) travel modes.	Instruments can be designed that simultaneously discourage car use, while encouraging sustainable location choices. Land planning policies focusing on sustainability.
	• Make errors and misinterpret information	Errors regarding travel time and money costs that suggest a systematic bias towards the car, disregard information that does not match one's preference (confirmatory bias) or disregard information at all in the case of strong habits.	Providing information to redress misperceptions, something that would increase the likelihood of changes Removing barriers to information, and finding ways of presenting information that seems complex at first (e.g., information about probability distributions, energy efficiency and other emission-related concepts).
	• Learn about their travel context	Learning does not guarantee more optimal choices in the medium-term.	Feedback is a necessary learning tool and helps redress misperceptions. Overall, descriptive information about travel time distributions has positive effects, though inexperienced travellers benefit more from information than experienced ones. External provision of feedback/information about environmental performance is necessary
	• Overvalue recent, salient events	Retain bad experiences for longer times and weight heavily most recent events.	Information plays a crucial role during incident conditions (e.g., accidents, break-downs). Information needs to be detailed and accurate.

	Travellers' biases	Evidence from behavioural economics studies	Implications for environmental-transport policy
Bounded rationality, Prospect Theory and Time-inconsistent preferences	• Follow simple rules	Use of simplification heuristics (e.g., housing price anchors, affect heuristics, and lexicographic preference for the car or "car effect").	Descriptive information facilitates learning but may be too abstract sometimes, while prescriptive information has limited long-term effects but is easier to understand. Some general travel-related information can be framed in the form of simple rules.
	• Are guided by references and frames	Take previous status as a reference, value asymmetrically gains and losses relative to it, and respond to framed information showing loss aversion.	Choice outcomes can be framed as either g ains or losses to persuade travellers towards a desired choice. Negative frames have a relatively greater influence on behaviour (retained for longer times). Experience can diminish the effects of loss aversion and even increase the acceptability of policies that incur high personal losses and generate opposition (e.g., road pricing). Pricing mechanisms can be understood as giving "the right to pollute" instead of signalling that "the polluter pays", and regulations can be understood as taking away freedom of choice.
	• Are creatures of habit	Act moved by habits, which moderate the effects of norms and deliberated intentions to change behaviour, and lead to misperceptions about the performance of non-habitual travel modes.	Travellers with strong habits disregard information. Unsustainable habits can be "unfrozen" through interventions that induce conscious deliberation of current choices and alternatives. Habits break when there are life-changing events (job and residential relocations); travellers are more receptive to information during these moments. Sustainable travel habits can be encouraged through economic incentives. If habits create an undesired consumption externality optimal Pigouvian taxation needs to be adjusted.
Social preferences and self-identity concerns	• Take norms as mandates and follow relevant others	Are motivated to behave appropriately and fit within their social contexts, and care about what nearby people do and think.	Norms can encourage both pro-self and pro-environmental behaviours depending on the social context, and so it is necessary to create a social environment that favours sustainable travel alternatives. The effectiveness of information can be raised by capturing travellers' normative concerns; and injunctive and descriptive norms promote cooperation in social dilemmas. Social rewards and punishment (e.g., public disclosure) help raise contributions and induce voluntary changes. Pro-social and pro-environmental behaviours are positively correlated in cases where objectives line up. Providing information about others' environmentally relevant behaviour can encourage behaviour change. If norms create an undesired consumption externality, optimal Pigouvian taxation needs to be adjusted.
	• Seek status and care about self-image	Want to show their wealth and appear generous in front of others.	Reputation and status concerns can favour car use over public transport. Reputation and status concerns limit the effect of information about car alternatives in triggering change away from the car. Status-seeking behaviour creates a consumption externality and optimal Pigouvian taxation needs to be adjusted. Status seeking can be used to promote pro-environmental behaviour, particularly when green products cost more than their non-green counterparts. Status seeking behaviour and self-image concerns can lead to conspicuous generosity or impure altruism.

4.3.1 Bounded rationality

1. Travellers are emotional

Travellers are emotional and associate car use with positive affective feelings. Marketing and mass media have a high responsibility in promoting affective aspects of vehicles and hence publicising them might be prohibited or discouraged through taxation (see Avineri and Goodwin 2010). A different side of emotions is illustrated by observations that negative feelings of shame and guilt encourage public transport use (Bamberg et al. 2007; Carrrus et al. 2008). Public transport use may be promoted through the activation of pro-environmental values (Gärling et al. 2003; Lindenberg and Steg 2007). Such values are ascribed to responsibility and awareness about environmental impacts, which trigger feelings of moral obligation or personal norms to behave pro-environmentally. These result from internalising social norms that criticize car use (see also Section 4.2.1 about norms). Indeed, environmental and social values are positively correlated with one another in cases where environmental and social objectives go in the same direction (de Groot and Steg 2008). In this vein, Fujii (2006) recommends educating people to have a high level of environmental concern and a positive attitude towards frugality (i.e., to form strong personal norms) (see also de Young 1996). Results from O'Connor (2002) further show that people who can accurately identify the causes and risks of climate change are more prone to reduce emissions voluntarily and support strong policy initiatives. Education is thus crucial to such behaviour. However, for the concrete case of modal change, the effect of personal norms on behaviour is decreased when barriers are perceived, that is, when changing is seen as difficult or costly (Abrahamse et al. 2009; Tanner 1999).

2. Travellers stick to the status quo and choose the default option

*Travellers show a tendency to stick to the status quo. S*uch inertia can tip the balance towards polluting alternatives when presented as the mainstream or default option (e.g., gasoline and diesel cars, single housing and dwellings blocks with parking). A straightforward way to take advantage of default bias is presenting "green" alternatives as defaults. Defaults have proved to be effective in the case of adopting green electricity options as shown by Pichert and Katsikopoulos (2008), among others. Examples of green defaults in the context of transport are electric and hybrid cars, and compact housing without parking. Appropriately setting defaults could further encourage certain departure times and routes to alleviate congestion. Thaler and Sunstein (2008) argue that the effect of defaults could be reinforced if they are supported by norms and framed as the recommended action to take. In addition, opt-out defaults, i.e., when the passive response means sticking to the default, increase the probability that the (green) default option is chosen (Johnson and Goldstein 2003). Overall, policies need to be more stringent when polluting default effects in the market are strong (Carlsson and Johansson-Stenman 2012). Notwithstanding this, Löfgren et al. (2009) found that when individuals are familiar with green alternatives, and as long as costs of switching are low, individuals may actively take the environmental option. This result is encouraging as it means that an environmentally educated population can cooperate without further persuasion, even though defaults may be necessary to encourage early adoption.

3. Travellers have separate mental accounts

Travellers use different mental accounts for fixed and variable time costs and money expenses derived from transport. Studies suggest that to decrease car use, it may be more effective to increase variable expenses of driving than fixed ones (Dargay 2008). Thus, raising fuel prices and setting emission taxes per kilometre driven or road pricing schemes may be good policy alternatives to discourage car use. Travellers even differentiate between travel modes. One consequence of this is that the costs and expenses of driving are generally underestimated relative to those of using public transport, which creates a competitive disadvantage for alternatives to the car. Mental accounts influence product choice, in that accounts and budgets are used as self-control devices to avoid overconsumption, which is a positive trait, maintaining driving levels low once variable costs of driving have increased (e.g., through policy). However, Cheema and Soman (2006) found that for ambiguous expenses, this self-control mechanism may fail because these can be assigned to more than one account which often justifies spending. Thus, from a policy perspective it may be a better strategy to simply raise current fuel taxes, tolls, etc. rather than introducing new pricing schemes that might be ambiguous to travellers without previous experience with such schemes.

4. Self-selection bias

Travellers self-select residential locations favourable to their travel mode preferences. Self-selection related to car lovers may be a problem here. Hence, it may be important to design mechanisms that simultaneously discourage car use and encourage sustainable location choices. Næss (2009), however, argues that self-selection bias highlights the importance of location choices; that is, there is a remaining effect on modal choice of the location of a residence and the neighbourhood typology (i.e., favourable or not favourable to car use) after controlling for self-selection bias. These findings support land planning policies that design neighbourhoods with attributes that discourage positive attitudes of households to the car, and thus car ownership and use.

5. Travellers make errors and misinterpret information

Travellers make computing errors and may misinterpret the information provided. The common belief is that (better) information will decrease uncertainty and ease decision-making, so that travellers will make more optimal choices (i.e., choose the alternative yielding the highest payoff, whether minimising travel time, travel costs, or environmental impact). However, still there are barriers to information. Regarding information about expected travel time and the various measures of variability/reliability, it is unclear how people perceive mean-variance concepts and other characteristics of travel time distributions; most people are not familiar with the concept of variance (or standard deviation) (Bates et al. 2001; Noland and Polak 2002). Therefore, they may misunderstand the information provided about expected travel times and travel time variability (e.g., headways). Indeed, reference points are easily influenced by framing, yet are not completely understood by researchers, who think that may be endogenously set (see van Wee 2010). Larrick and Soll (2008) provide evidence that "miles per gallon" (MPG) as a measure of fuel efficiency may be misleading. The reason is that people rely on linear reasoning about MPG, which leads them to undervalue the benefits of small efficiency improvements on inefficient vehicles. In other words, people undervalue the benefits of replacing the most inefficient cars by new cars with higher MPGs and thus better performance in terms of fuel consumption (money savings) and carbon emissions. A simple change, such as using "gallons per mile" (GPM) instead, would allow consumers to understand exactly how much fuel they are using and, with additional information, how much carbon they are emitting. Regarding information about emissions, Coulter et al. (2008) investigated the role of carbon calculators in shaping people's understanding, attitudes and behaviours; participants could experiment with a range of carbon calculators, though. They noticed that most people have a limited understanding of emissions-related concepts and cannot well connect emissions with their own behaviour. Particularly, for the case of travel behaviour, a high resistance to change associated with perceptions about impossibility and inconvenience of changing to public transport (e.g., limited alternatives), reliability, time and costs being more important than environmental concerns, and blaming others. Waygood and Avineri (2012), on the other hand, found that framing emissions as relative to a carbon budget (i.e., as a quota), has the greatest impact in modal choice, compared to carbon mass, and tree- and earth-equivalent, which may result too abstract. The carbon-budget frame further activated normative concerns of subjects by providing a social reference point.

6. Information feedback affects learning by travellers

Information feedback affects learning by travellers. Many studies indicate that feedback of information is a necessary element in learning for travellers. Travellers already receive immediate feedback on actual travel times and trip expenses, especially in the case of public transport where they have to pay for a ticket, and to a lesser extent in the case of cars (because of fixed costs). However, the effect of information in travel contexts where travellers also learn through experience is limited. Several studies have investigated this issue for the case of travel time minimisation through route choice (Avineri and Prashker 2006; Ben-Elia et al. 2008; Selten et al. 2007). It seems that, initially, information about travel time distributions has positive effects —increases initial risk seeking behaviour, reduces initial exploration and increases between-subject differences—, but as travellers become more experienced, behaviour moves towards the predictions of the payoff variability effect (Ben-Elia et al. 2008). Inexperienced travellers thus benefit more from information than experienced ones (see also point *10* in this Section about habits). These results are further confirmed for travel mode choices, even in the more realistic case when information is costly (Denant-Boèmont and Petiot 2003). Travellers, however, do not get immediate feedback from their choices in terms of actual CO_2 emissions, which they do get in terms of actual travel times, etc. Learning is thus complicated, and external feedback/information is necessary. In the case of energy use at the household level, energy savings are achieved through both instantaneous direct feedback (i.e., meters; illustrate the impact of end-uses) and indirect feedback (i.e., billing; usually more suitable to observe the consequences of changing consumption) (Darby 2006). Emissions meters could be adapted for their installation into cars, but it is not immediately clear how all these insights about feedback and experience translate to information about emissions.

7. Travellers overvalue recent, salient events

Travellers tend to overvalue recent and extraordinary events. Learning may reduce travel uncertainty because travellers can adjust to recurrent congestion, but still unpredicted events happen (e.g., accidents, break-downs and occasional peaks in congestion). Under incident conditions, information plays a crucial role in redressing misperceptions (Chorus et al. 2006). The information provided needs to be of high quality, accurate, and tailored if possible, as people distrust erroneous information. Salient events entailing bad experiences are relatively easy to recall and reduce the probability of an alternative being chosen again (i.e., the "hot stove" effect). The latter impedes collecting additional information about the actual value such an alternative, which in the transport case would be the value of the travel alternative in the absence of extraordinary events altering the normal functioning of transport services. This is, when *a priori* information is not advanced. Hence, one may want to minimise the disturbances derived from incidents by providing high quality information, so that the choice is repeated.

8. Travellers follow simple rules

Travellers tend to follow simple rules. Travellers often make use of simplification heuristics and rules of thumb to ease decision making. Simple rules could be crafted to guide travellers towards making more sustainable choices. Long-term effects are limited for recommendations about departure time, route or when to use travel mode choices, if compared to the effects of descriptive information (Chorus et al. 2006). But, in some instances, simple rules prove very effective, as do simple protocols. In the transport context, safety recommendations to aid people behave adequately during traffic accidents save lives (Sweedler1995). Other examples from transport include general rules about car maintenance, such as oil change at 30,000 km or tyres when the height of the rubber drawing reaches the level of the indicator (then it is likely that the tread depth is approximately the legal limit of 1.6 mm). These rules are not accurate, but offer good guidance. Accordingly, some general information could be framed into simple rules. For instance, rules about what is an acceptable level of car use: do not take the car for trips that can be covered walking within 15 minutes (equivalent to a distance of less than

1.5 km). In addition, rules can be about when it is not advisable to acquire a car: consider not buying a car if its use is, on average, only required once a month, you will save money and energy. Rules can even be about location choices: the recommended job-housing distance to avoid unnecessary transport expenses is less than 5 km, equivalent to 1hour walking.

9. Travellers are guided by references and frames

Travellers are guided by references and frames and dislike losses. Choice outcomes can be framed as losses to persuade travellers towards a desired choice. Avinieri and Prashker (2004) showed how negatively framed information about travel time distributions could trigger route changes towards reliable routes. Avineri and Waygood (2013) further found that negative framing is actually more effective than positive framing in highlighting differences between travel modes in terms of associated CO_2 emissions. They compared sets of modes including bicycle, full car, and single occupancy of a SUV vehicle, and framed information on emissions as “lower” or “higher” to signal whether a travel mode was “better” or “worse”, respectively. However, learning can reduce loss aversion in view of uncertainty about travel time costs (Avineri and Prashker 2005; Ben-Elia et al. 2008). Consequently, loss frames may only be effective with inexperienced travellers. Indeed, findings from Schuitema et al. (2010) show that experiencing the benefits of policies during trial periods, particularly of a congestion charge, increase their acceptability. Loss aversion can affect the acceptance of a policy in that people may be insecure about how interventions affect their daily life in terms of personal losses (less car use and higher financial costs). Framing has other effects on how pricing mechanisms are understood. Nash (2006) investigates these effects on consumers, voters, business community, and environmental NGOs, and finds that pricing mechanisms can be understood as giving the “right to pollute”. This perception can lower their effectiveness. Accordingly, pricing mechanisms could be better framed as “penalties” to avoid such misinterpretation. In addition, this frame of “right to pollute” explains differences in opposition between pricing and regulation, with the latter being more opposed as it is perceived to restrict freedom of choice. This insight has implications on how to present some policies to both travellers and politicians to seek maximum acceptability, especially if policies are necessary.

10. Travellers are creatures of habit

Travellers are creatures of habit. Travellers with strong habits disregard travel information. Gärling and Axhausen (2003) argue that habits need to "unfreeze" to allow conscious deliberation of behaviour if change is to occur. Both Garvill et al. (2003) and Eriksson et al. (2008) notice positive and lasting results of so-called "deliberation intervention", where participants are induced to deliberate about alternatives to their habitual choices. The intervention was particularly successful for car users with a strong car habit and a strong moral motivation (or personal norm) to reduce personal car use. Deliberation can also be prompted through changes in the choice context. Verplanken et al. (2008) found for modal choices that residential relocations allow conscious renegotiation of past habits, activating pro-environmental intrinsic values that guide behaviour toward sustainable alternatives. Habits can also be broken and formed through financial incentives, with long-lasting effects (Charness and Gneezy 2008; Fujii and Kitamura 2003). Bamberg (2006) tested the synergic effects of these insights through an intervention carried out after residential relocation. This involved providing a 1-day free ticket and personally tailored information about public transport services. The intervention caused an increase in public transport use from 18% to 47%. Car use habits significantly decreased after relocation and behavioural changes took place for both habituals and non-habituals. Moreover, participants significantly changed their attitudes and beliefs about the feasibility and adequacy of using public transport. In this case, no crowding-out effects were described (see also Hunecke et al. 2001). Finally, some studies suggest that when habits create a negative environmental externality optimal taxation must be increased beyond the traditionally optimal (Pigouvian) level to make change possible (Fuhrer 2000; Leith et al. 2012; Löfgren and Nordblom 2006).

4.3.2 Social preferences and self-identity concerns

1. Travellers take norms as mandates and follow relevant others

Travellers take norms as mandates and follow relevant others. Most pro-environmental behaviours can be explained by peoples' motivation to behave appropriately and fit within their social contexts (Dawnay and Shah 2005; Lindenberg and Steg 2007). In this vein, Cialdini (2003, 2007) found that the effectiveness of informative messages can be raised by capturing various normative concerns: using injunctive norms (perceptions about socially approved behaviours) when the intention is to change an environmentally undesirable but socially extended behaviour; and using descriptive norms (perceptions about behaviours socially extended) to reinforce a pro-environmental behaviour that is sufficiently extended. The effect of norms on social dilemmas has been extensively researched. Quitting the car has frequently been regarded as a social dilemma; while driving a car (i.e., to defect) may be in the individual interest, less driving (i.e., to cooperate) is in our collective interest and makes all better off (Vlek 2000). Thøgersen (2008) tests and confirms the hypothesis that injunctive and descriptive norms interact synergistically to promote cooperation in social dilemmas about public goods. Biel and Thøgersen (2007) further review the application of norms in iterative dilemmas, such as travel decisions. They argue that what others do is likely to influence individual behaviour based on expectations about reciprocity and conditional cooperation. In this sense, Schulz et al. (2007) did notice a decrease in energy use when bills provided information on how energy efficient their neighbours were. An analogy in the transport context is provided by Gaker et al. (2010) who found, through an experiment, that information of peer compliance with pedestrian laws has a stronger influence on pedestrian safety behaviour than descriptive information (e.g., accident statistics or citation rates). Still some people may feel that their contribution is irrelevant compared to that of others, notably particular heavily-polluting industries (Lorenzoni et al. 2007). To free-ride is considered a violation of the equity norm. Violations of social norms in dilemmas are often responded to by sanctions. Social punishment and rewards encourage cooperation. Public disclosure is a form of social punishment that includes reputation concerns. It has proven effective with both individuals and firms (e.g., McKinely 2008). Examples applicable to transport include publicizing car or individuals' emissions and energy use, placing signals in pollutive cars, and labelling (Rand and Nowak 2009). Lastly, financial incentives affect moral obligations to behave pro-environmentally (i.e., personal norms) through so-called crowding out effects (Clark et al. 2003; Frey 1992; Frey and Oberholzer-Gee 1997). Heymen and Ariely (2004) found that in the absence of prices people's choices and efforts are guided by social principles, which are not sensitive to compensation, in contrast to monetary exchange in formal markets.

2. Travellers seek status and care about self-image

Travellers seek status and care about self-image. A travel mode such as the car is valued in both utilitarian (time and money costs) and social terms (reputation and status). The effect of information about car alternatives in triggering change is limited due to both drivers' preferences for reputation and status, and overconfidence in judging the costs of a modal option, which leads to biased choices (Chorus et al. 2006). Regarding overconfidence, note that car users tend to underestimate the cost of driving, while they overestimate the cost of public transport. Satisfied car users are even unlikely to bother to seek information regarding alternatives that they perceive to perform poorly. Indeed, information about modal alternatives to the car will only have an effect provided alternatives clearly outperform the car in terms of travel times, expenses (i.e., costs) and image, and costs of information acquiring and eventual adaptation (i.e., changing the choice with all its consequences). The presence of status-seeking behaviour means that the level of optimal correcting taxes for conspicuous goods that damage the environment needs to be raised (Howarth 1996). However, under status seeking prices may sometimes send the wrong message and so it may be more efficient to deal with status through income taxes (Aronsson and Johansson-Stenman 2008; Ireland 1998). An alternative for the context of transport is proposed by Verhoef and van Wee (2000), namely feebates on new cars dependent on emissions/fuel consumption. That is, the amount of the feebate is determined by the relative fuel efficiency of a vehicle; the fee is applied to more polluting cars, whereas less polluting cars receive the financial incentive (i.e., the rebate). An elaborate discussion of the effects of feebate schemes and design options is offered by de Haan et al. (2009), Mueller and de Haan (2009), and Peters et al. (2008). Status, however, does not depend only on material wealth but on social reputation. We have already discussed that some social groups derive utility from showing environmental concern. Linking these social preferences, namely status seeking and reputation, could alter behaviour in an environmentally favourable direction. Griskevicius et al. (2010) actually demonstrated that eliciting status motives can be an effective way to promote pro-environmental behavior. Status motives increased desire for green products (including hybrid or electric cars) when shopping in public (but not private) and when green products cost more (but not less) than non-green products, so that green products can simultaneously signal one's "caring" and "wealth". The experiment assessed different products and their green counterparts, including cars (traditional *versus* hybrid models). Environmental studies further point to "conspicuous generosity", namely the desire to appear generous in front of others, as a way to get people to cooperate in social dilemmas (Andreoni 1989; Andreoni and Petrie 2004; Alpizar et al. 2008).

4.4 Conclusions

Much of transport reality is better described by behavioural approaches than by rational agent models. Behavioural economics offers alternative and comprehensive answers to the questions of why people behave as they do and why it is so difficult to change travel behaviour. The literature gives evidence for the following stylized facts about bounded rationality, namely travellers are: (1) emotional, (2) stick to their *status quo* and choose the default option, (3) separate accounts to process costs of action, (4) self-select environments favourable to their preferences, (5) make errors and misinterpret information, (6) overvalue recent, salient events, (7) follow simple rules, (8) are guided by references and frames, (9) prefer certainty of outcomes, and (10) are creatures of habit. Concerning social preferences, travellers (11) take norms as mandates, (12) care about reputation, (13) seek status, and (14) follow relevant others.

These characteristics of travellers produce systematic biases in their behaviour that interfere at all stages of decision-making. Behavioural anomalies can be described either for long-term choices affecting day-to-day travel choices (residential and employment locations, owning a driving license and car purchasing), or short-term daily travel choices (destination or activity choice, departure time, route and travel mode choice). Behavioural deviations are a source of ineffectiveness in traditional environmental policy and so the recognition of them in policy design is highly recommendable. It even allows for testing types of instruments other than traditional ones, such as defaults, normative messages, deliberation interventions, and social punishment (public disclosure).

Policies to address bounded rationality involve penalising the promotion of positive feelings ascribed to driving, while encouraging negative ones of guilt and shame. Supportive norms and environmental education motivate people to behave pro-environmentally. Cooperation increases whenever people are able to identify the environmental impacts of their behaviour. In addition, green alternatives can be presented as the recommended default option. Regarding social preferences and self-identity concerns, supportive social environments seem to be crucial to encourage people to cooperate. Social pressure favouring green alternatives and behaviours can be very effective, since people mostly want to fit within their social contexts and appear generous.

Defectors can hence be punished through public disclosure. Peers and neighbours have a great influence on individuals' behaviour. Thus, green behaviours and attitudes of peers and neighbours can be published to provide a positive reinforcement and ease behavioural change. Finally, reputation and status concerns could work together through the promotion of social status over material wealth to favour sustainable alternatives. Marketing strategies could improve the social image of green alternatives and make them fashionable. Synergic effects can be obtained if role models became involved and people copied them.

Traditional policy instruments need to be adapted whenever systematic biases affect the effectiveness of measures. The effects of information in triggering behaviour change are limited when alternatives to the car do not outperform at utilitarian (time and money costs) and social levels (e.g., provide reputation and status). Providing accurate and reliable information, personalised if possible, during incidents is cost-effective and corrects misperceptions that can lower public transport use; public transport users show relatively higher degrees of risk aversion due to time losses than car users. Crafting messages in the form of simple rules may aid decision-making, while normative messages may increase the effectiveness of information provision by providing a socially acceptable behavioural reference. Furthermore, polluting alternatives can be discouraged through negative frames that focus on the environmental performance of alternatives. Framing can further affect the support for price-based mechanisms, which need to be presented as environmental penalties. For pricing mechanism entailing major opposition, such as road pricing schemes, trials can help increase their acceptability. Financial incentives can crowd-out intrinsic motivations to behave pro-environmentally but they seem to have a positive effect in the formation of sustainable habits. Travel mode habits can break when people relocate and, therefore, relocation might be facilitated through reducing relevant transaction costs. The presence of norms, habits and status seeking behaviour favouring polluting travel behaviour affect the size of any optimal corrective tax. In the case of status seeking, prices could send the wrong message anyway. In this case, correction could be considered through income taxation and feebates.

All in all, policy strategies need to be perceived as fair and just. Policies need to involve all actors (travellers, car producers, the automotive lobby, public authorities and the media sector) so that travellers feel that everyone is contributing and thus reciprocate.

Part II
Empirical studies

5 Empirical analysis of habitual use of travel modes in Barcelona

Adapted from:
Garcia-Sierra M, Miralles-Guasch C, Martínez-Melo M (2014) Empirical analysis of habitual use of travel modes in Barcelona. Transport Policy (Under review).

5.1 Introduction

It is widely believed, nowadays, that in order to be more effective, environmental transport policies need to better account for bounded rationality and heterogeneity of travellers (Anable 2005; van den Bergh et al. 2000; Jensen 1999; Krizek and El-Geneidy 2007; Steg and Vlek 2009). Findings suggest that different types or groups of travellers have different requirements that need to be addressed through specific policies, thus, implying that policies need to be adapted to meet the particularities of travellers. This contrasts with the notion of "average traveller" as supported by rational models of behaviour, and which is widely accepted in current transport policy design. With this in mind, being able to identify types of travellers that differ from others in terms of their personal characteristics, perceptions, beliefs, habits or other choice determinants, has relevant implications for policy design.

Habits are a key factor in modal choice and pose a real challenge to environmental-transport policy aimed at behavioural change with a view to creating more sustainable mobility (Eriksson et al. 2008). Habits are unconscious by definition and involve little information processing (Verplanken et al. 1997). For frequently repeated journeys, which entail a fair share of all daily mobility, travel mode habits are likely to become established and generalise. It is thus important to adapt policy to possible habitual behaviour. However, habits are not accounted for in current transport policy design, which is supported by rational models of behaviour (Carrus et al. 2008; Stern 2000).

Alternative behaviourally-based models used in the design of pro-environmental policy strategies also have a rational basis and are often confronted by the strength of habit-behaviour relationship. This is the case, for instance, of intention-behaviour models based on Ajzen's Theory of Planned Behaviour , largely applied in travel studies and environmental-transport policy design (Bamberg et al. 2003; Bamberg and Schmidt 2003; Thøgersen 2006). Evidence shows that strong travel mode habits moderate and even preclude the effect of deliberated intentions to change behaviour (Aarts and Dijksterhuis 2000a). However, as argued by Gardner (2009), habits and intentions coexist, but their relevance depends on the choice context. Thus, for familiar and repeated behaviour, actions tend to be automatic, namely habitual, while when confronted with unfamiliar situations, actions tend to be the result of consciously formed intentions (Aarts and Dijksterhuis 2000b; Lanken et al. 1994). Similarly, norm-based models used to explain pro-social and pro-environmental behaviour, like Schwartz's Norm-Activation Model, have also included habit in most cases. It seems that habits also moderate the effect of peoples' moral obligation to behave pro-environmentally, thus, limiting the effectiveness of normative instruments (Klöckner et al. 2003; Klöckner and Matthies 2004).

This chapter identifies types of travellers that differ in their travel mode habits. We do this for a sample of travellers from the Barcelona Metropolitan Region (BMR) in Spain, where 47.2% of the population reports making frequent use of private vehicles. As will be shown here, identifying relatively homogeneous groups of habitual users of private modes has relevant implications for policy design. We use self-reported frequency of use of travel modes for working days as the segmenting variables, since travel patterns on work days demonstrate stability, which is a pre-condition for habit formation (Gärling and Axhausen 2003; Schlich and Axhausen 2002). Additional theory-based controls for the habit construct are used; we control for choice context stability, use of travel information and habit generalisation. An analysis along these lines yields insights about the modal mix of travellers, namely the whole set of travel modes used. The latter is useful in identifying groups of "potential mode switchers", namely, travellers familiar with both private and public transport modes, who may be more easily convinced to refrain from driving. Data were retrieved from a general mobility survey, *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006). The resulting types were further completed with socioeconomic and demographic, territorial and other travel-related information of travellers integrating them.

The remainder of this chapter is as follows. Section 5.2 introduces the theoretical framework. Section 5.3 introduces the methodology. Section 5.4 presents the empirical analysis resulting in the seven behavioural types. Section 5.5 concludes.

5.2 Theoretical framework and previous research

5.2.1 Travel mode habits

Travel mode choice habit is defined as automatic, goal-directed behaviour (Aarts et al. 1998). Frequently repeated travel goals prompt automatic responses based on past choices archived in memory as satisfying. In this vein, it has been proposed that travel choices made out of habit are *script-based*. That is, the sequence of preference formation, deliberate information processing, preference-based choice, positive outcome, is stored in memory in the form of a script, and then only the final choice is retrieved, so that previous deliberation is no longer undertaken (Gärling et al. 2001). Accordingly, habits have also been considered a form of choice-making heuristic or mental short-cuts, since automatic responses are unconscious and non-deliberated, requiring little cognitive effort and low information processing.

Habitual choices rely on past behaviour and experience. However, habits and past behaviour are different concepts; all habits are based on past actions, but past actions are not necessarily habitual and may derive from the formation of repetitive deliberated intentions (Klöckner and Matthies 2004). The activation of the automatic response, the habitual response, is guided by contextual stimuli, so-called environmental cues. Habit formation requires actions, entailing positive outcomes (i.e., rewards), to be sufficiently repeated within stable contexts, where cues are present. Similar cues found in similar travel contexts facilitate habit generalisation when habits are strong enough; e.g., moving from commuting to work every morning to making all morning journeys by car (Gardner 2009). Overall, these characteristics of habit make them very difficult to change, but also predictable; qualities that are both challenging and attractive for environmental-transport policy.

5.2.2 Measuring habit and habit strength

Measuring habit and habit strength is difficult, due to its unconscious nature. Approximations to the measurement of modal choice habits have improved over time and we have tried to accommodate such improvements. Traditionally, past behaviour was considered an indicator for habit, and frequency of past behaviour an indicator for habit strength (Triandis 1977, 1980). Frequency of past behaviour can be directly asked through questionnaires within survey settings, or inferred from travel diaries. In what pertains to survey settings, Ouellette and Wood (1998) argue that frequency is most commonly measured through rating scales formulated as number of times that a given behaviour, like modal choice, has been repeated in the past. In this vein, providing a concrete and short temporal reference frame, such as “the past week”, increases the accuracy of the measurement. Alternatively, rating scales can use adverbs reflecting frequency, namely “often”, “sometimes”, “rarely”, as in our case.

Indicators of habit based on frequency of past behaviour are most extensively used. There are more sophisticated indicators based on the automaticity of responses, the level of information used by respondents, and the extent to which habit is generalised, but their measurement entails small samples within experimental settings (Verplanken and Orbell 2003). In this chapter, we opt for a mixed approach, namely, we use self-reported frequency of past behaviour as the main indicator, while also controlling for context stability, low use of travel information, and habit generalisation. In this way, we aim to increase the theoretical robustness of our main indicator.

5.2.3 Previous studies constructing typologies of travellers

Travel mode habits can be studied through the construction of typologies. This approach allows the structuring of data in such a way that significant types are formed (López-Roldán 1996). Identifying relatively homogeneous groups of habitual users of private modes has relevant implications for policy design. In this context, studies can be found that (1) classify individuals according to their habitual travel patterns, (2) classify individuals according to their travel patterns, specifically, in what refers to their level of use of travel modes and with an emphasis on travellers’ multimodality, and (3) classify individuals according to their attitudes towards travel modes, so as to obtain their psychographic profiles. All these studies retrieve information from data of surveys and travel diaries.

The first group are studies based on activity-travel approaches, which have long identified types of repetitive travel patterns. The underlying reason is the belief that daily travel patterns are largely habitual, particularly on work days, and that they can be connected to sociodemographic variables and other determinants of travel, such as spatial effects and choices of car ownership (Bayarma et al. 2007; Hanson and Huff 1986; Krizek 2006; Lin and Long 2008: Maat and Arentze 2003; Manaugh et al. 2010).

A second group of studies are those focusing on travellers’ multimodality.

Multimodality is considered a desirable behaviour from a sustainability perspective in contrast to car dependency and car habit. Accordingly, these studies research who multimodal people are, where they locate and how motivated unimodal car users are to change (Diana and Mokhtarian 2009; Nobis 2007). Noticeable findings include groups of youths and elders with higher degrees of multimodality, and that multimodality is associated with urban environments, namely, large cities where public transport is primarily used (Nobis 2007). Additionally, Diana and Mokhtarian (2009) found at least one group of car users, those *deprived* of alternatives, showing the desire to diversify its modal mix to include a larger use of public transport modes.

Finally, the third set of studies focuses on travellers' psychological profiles in terms of their attitudes, normative beliefs, worldviews and sometimes habits towards travel modes, which are then contrasted to sociodemographic variables (Anable 2005; Beirão and Sarsfield-Cabral 2008; Jensen 1999). These studies aim to identify groups of travellers showing positive attitudes towards public transport and that are motivated to change their car use. Anable (2005) identifies a group of habitual car drivers, *Complacent Car Addicts*, who do not feel any moral obligation to decrease their car use. It is noticeable that habits could not be captured by any other attitudinal construct.

5.3. Methodology

5.3.1 Study region[9]

The BMR covers 10% of the territory of Catalonia, involving close to 5M inhabitants (about 70% of the Catalan population). It is structured into two metropolitan rings that extend from the city of Barcelona outwards. Barcelona and the first metropolitan ring are compact and diverse in land uses, while the second metropolitan ring comprises seven large cities or metropolitan subcentres and their transport corridors, and combines both rural and low-density residential uses. The public transport network of the BMR is radial, except within Barcelona city, and it shows some spatial deficiencies in access in new suburban residential and employment areas, as well as in rural areas, mainly from the second metropolitan ring. The connections by public transport between the metropolitan subcentres and the centre (Barcelona) are well established along seven corridor axes. Self-reported use of public transport is relatively large, all modes

[9] A rather more detailed description of the BMR is offered in Chapter 3, Section 3.4.

aggregated. But, 47.2% of the population still reports making frequent use of private vehicles (40.8% car and 6.4% motorcycle), which could be reduced (Miralles-Guasch and Tulla-Pujol 2012).

5.3.2 Data and survey questionnaire

Data were retrieved from a general mobility survey, namely, *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006). The data set involves, for the BMR, a total of 29,666 interviews (maximum error is 95% of ± 0.58%) held following computer-assisted telephone interviewing (CATI) methodology (ATM 2007). The information collected includes people's use and valuation of travel modes, their motivations in choosing among private and public transport, average monthly expenditure on transport, and use of travel information. The EMQ 2006 assesses twelve travel modes, including walking, bicycle, several urban and metropolitan public transport modes (urban and inter-urban buses, rail modes, and taxi), and two private modes (car and motorcycle). Some public transport modes deserve further attention. There are two metropolitan rail services, namely RENFE Rodalies and FGC. RENFE Rodalies has more rail lines and covers a larger part of the territory, whereas FGC services have fewer lines and cover only two metropolitan corridors: south and west. In addition, there is a Tram service operating mainly within Barcelona but extending, both north and south, to some adjacent cities of the First metropolitan ring.

Three sets of variables from the questionnaire were selected in order to capture habit and habit strength, based on the theoretical insights reviewed in Section 5.2:

1. *Self-reported frequency of use of travel modes* was measured for all twelve travel modes using a rating scale involving the levels "often", "sometimes", and "never or almost never". Self-reported frequency of use "often" was used as an indicator of the cognitive construct habit. An additional variable was used to test the consistency of responses: frequency of use of private vehicles *versus* public transport.

2. *Journeys to work/education* are assumed to be made in relatively stable choice contexts, hence, more journeys made to work/education indicate more opportunities for habits to form and establish themselves. Two variables captured this: "Days going to work/education [day rate]", and "Times going from home to work/education [day rate]".

3. *Frequency of information request.* Four variables captured information use of both private and public transport users within a time frame of one year (12 months) before taking the questionnaire. Low use of travel information indicates automaticity of choice. Not requesting information or frequency of requesting information rated as "occasionally" was interpreted as an indication for low use of travel information, thus, signalling strong habit.

Additionally, if only one travel mode is clearly predominant in the modal mix of a group, this is interpreted as a sign of habit generalisation indicating strong habit.

Habit information is completed with socioeconomic and demographic, territorial, as well as other travel-related information. These other variables were used to subsequently characterise the types identified, and are:

4. *Socioeconomic and demographic.* Gender, age, occupied *vs.* non-occupied, level of education completed, and monthly household income.

5. *Territorial.* Municipality of residence according to its number of inhabitants, and corresponding metropolitan ring.

6. *Other travel-related variables.* Driving license, vehicle ownership, and monthly expenditure on transport, the latter including the taxi. Expenditure in private vehicles includes fuel expenses, fixed parking near home and other parking expenses, and road tolls.

5.3.3 Statistical analysis

Classification techniques, which could be of the multivariate type, allow reducing data (cases or variables) in a meaningful way. Cases (i.e., individuals) are classified into groups that are relatively homogeneous and heterogeneous, within and among themselves, respectively, according to a predefined set of variables: the structuring variables. We use cluster procedures to classify travellers according to their self-reported frequency of use of travel modes, so as to identify groups of travellers sharing similar travel mode habits. The nature of cluster classification procedures is exploratory, meaning, that its actual goal is to identify occurring groups emerging from the data, in contrast to forced, *a* *priori* chosen classifications. This is considered a positive trait of this procedure, in the sense that total reliance on researcher judgement is avoided.

We expect the seven behavioural types of travellers to differ in their modal behaviour. In accordance, multivariate analysis of variance (MANOVA) has been undertaken to assess between group differences in terms of behaviour and validate classification results.

In analysing the data, we have followed a sequential statistical process consisting of the following steps:

a. *Descriptive analysis.* Frequency analysis and correlation analysis based on the magnitude of Pearson's correlation coefficients of structuring variables, namely, self-reported frequency of use of travel modes.
b. *Cluster analysis.* Hierarchical cluster[10] (squared Euclidean distance, Ward agglomeration method) to determine K ($5 < K < 7$) and subsequent non-hierarchical cluster repetitions using k-means procedure (trials for 5, 6 and 7 clusters). K-means procedures are deterministic, meaning that each case is classified into only one cluster in a way that cases belonging to the same cluster share similar characteristics regarding the variables used to segment the sample. Moreover, within-group homogeneity and between-group heterogeneity are maximised through these procedures. Seven clusters provided the best discriminative result; 96.6% of the cases were satisfactorily classified within this solution (28,697 cases representing around 4M people of the overall population of BMR).[11] Of relevance is that in k-means procedures, repeated calculations introduce variations in the segmentation solution due to random components of the clustering algorithm (e.g., random starting points) (Dolnicar and Lazarevski 2009). This is a consequence of its exploratory nature and it may occur even when maintaining the same number of initial clusters. Hence, following Dolnicar and Lazarevski's (2009) recommendations on this matter, repetitions of the procedure were held in order to identify the most stable segments, namely those which were consistent across repetitions. These results further influenced the choice of the final cluster solution.

[10] Hierarchical cluster had to be performed on a subsample of 10% of the cases, a solution for large samples (Bieger and Laesser 2002).

[11] Determination criteria are not clear in this respect, and cluster solution is often chosen, based on heuristics (Shoemaker 1994; Frochot and Morrison 2001).

c. *Multivariate analysis of variance (MANOVA) and Bonferroni corrections*. Validation of the behavioural types extracted. Bartlett's test of sphericity was significant at a *p-value* < .001. Thus, a sufficient level of correlation between the twelve dependent variables of self-reported frequency of use of travel modes was found suggesting the appropriateness of a MANOVA. The Box's M value of 109912.12 was significant (*p-value* < .001); the assumption of homogeneity of covariance matrixes was not supported. This test is very sensitive to normal distributions and sample sizes, and the sample sizes differ for the seven groups. A statistically significant MANOVA effect was, however, obtained through Pillai's Trace = 2.681, F(72.273660) = 3069.84, significant at *p-value* < .001. This is probably the test that is the least sensitive to violations of homogeneity of covariance matrixes, and so we assume that the MANOVA result is robust. This result suggests that there would be one or more significant mean differences in modal behaviour across the different behavioural types extracted. The multivariate effect size was estimated at .447, implying that 44.7% of the variation was accounted for by the types extracted. The analysis was followed up by performing a series of one-way ANOVAs with the twelve variables of self-reported frequency of use of travel modes as dependent variables and the types extracted as the independent variable. The assumption of homogeneity of variances was tested for all twelve dependent variables through Levene's F tests, and was not met in any of the cases (*p-values* < .001). Variances were estimated and examined, and none of the largest standard deviations were greater than four times the size of the corresponding smallest, which suggests that the ANOVAs would be robust (Howell 2010). All of the ANOVAs were statistically significant (*p-values* < .001 for Welch and Brown-Forsythe's tests) suggesting that groups could be unique, in terms of their modal behaviour, and Bonferroni tests supported this finding. The effect sizes (i.e., partial η^2) of the twelve dependent variables ranged from .852 ("Car driver") to .037 ("Bicycle").[12] Effect sizes indicate the level of contribution of each variable in maximising dissimilarity between the groups. In this case, frequency of use of "Car driver" made the strongest contribution to differences amongst the seven behavioural types extracted. This was followed by frequency of use of "Metro",

[12] Effect sizes (partial η^2) for the dependent variables are as follows: .171 for walking; .439 for urban bus; .087 for interurban bus; .623 for metro; .525 for tram; .411 for metropolitan rail RENFE Rodalies; .135 for metropolitan rail FGC; .049 for long-distance rail; .047 for taxi; .852 for car driver; .065 for motorcycle driver; and .037 for bicycle.

"Tram", "Urban bus" and "RENFE Rodalies", which is consistent with the modal split of the BMR as described in our data.

d. *Bivariate analysis, crosstabs (with Chi-square and residuals tests):*
   1. To profile the types according to their self-reported frequency of use of travel modes. Frequency "often" is our habit indicator and primarily determined the profiles of the types. However, other modes chosen "sometimes" and "never or almost never" were also accounted for and played a key role in refining the profiles of the types, as well as providing an accurate picture of the complete modal mix of each type. Additional variables supporting habit measurement, namely, "Journeys to work/education" and "Frequency of information request", were also analysed in this manner.
   2. To analyse socioeconomic, demographic, territorial and other travel-related variables completing the profiles of the types.

The statistical process here undertaken is quite standard as can be inferred from the large number of travel studies implementing it for similar purposes to ours (e.g., Lanzendorf 2002; Hildebrand 2003; Schwanen and Dijst 2003; Anable 2005; Mohammadian and Zhang 2007).

5.4 Results

5.4.1 Descriptive analysis

We analysed the use made of travel modes by the population of the BMR, as described by the EMQ 2006. We first focussed on the self-reported frequencies of use of the different travel modes for the overall sample (Table 5.1), and then we analysed whether or not their use is correlated through Pearson's correlations (Table 5.2). A large majority of the population of the BMR, more than 70%, report walking "often" (Table 5.1). This places walking at the top of travel mode alternatives. The car is still the second most frequently used travel mode, used regularly by 40.8% of the population. Urban bus and metro are used by around 20% of the population. Other modes seem to be subsidiary, used "sometimes". Looking at the correlation matrix reveals an interesting pattern: the use of travel modes correlates within one another (Table 5.2). That is, travellers tend to combine several modes. However, the use of private modes is negatively correlated to that of public transport and walking.

Table 5.1. Frequencies of use of travel modes for the overall population of BMR. (%).

	Never or almost never	Sometimes	Often
1. Walking	7.9	18.9	73.2
2. Urban bus	55.3	26.1	18.6
3. Inter-urban bus	81.1	13.8	5.1
4. Metro	45.6	29.3	25.1
5. Tram	89.1	8.5	2.4
6. Metropolitan rail (RENFE Ro.)	60.6	28.7	10.7
7. Metropolitan rail (FGC)	71.7	20.6	7.7
8. Long-distance	89.1	9.9	1.0
9. Taxi	72.7	23.6	3.7
10. Car driver	46.1	13.1	40.8
11. Motorcycle driver	91.6	2.0	6.4
12. Bicycle	81.8	12.5	5.7

Table 5.2. Pearson's correlations.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Walking	1											
2. Urban bus	.16	1										
3. Inter-urban bus	.09	.20	1									
4. Metro	.19	.34	.14	1								
5. Tram	.06	.15	.12	.23	1							
6. Metropolitan rail (RENFE Ro.)	.14	.09	.17	.23	.09	1						
7. Metropolitan rail (FGC)	.10	.17	.09	.28	.09	.22	1					
8. Long-distance	.06	.10	.09	.15	.08	.21	.14	1				
9. Taxi	.02	.16	.03	.15	.06	.03	.10	.14	1			
10. Car driver	-.15	-.33	-.17	.19	-.07	-.06	-.08	-.07	-.12	1		
11. Motorcycle driver	-.11	-.13	-.06	-.08	-.03	-.03	-.03	-.01	-.00	.07	1	
12. Bicycle	.05	-.07	-.01	.03	.02	.09	.04	.04	-.01	.14	.11	1

5.4.2 Classification analysis and the profiles of the types

Classification analysis concluded with the seven cluster solution providing the best discriminative result, where the seven clusters extracted proved to be relatively stable (Table 5.3). This analysis has thus allowed us to pass from twelve to seven entities, each of which has a sufficiently large relative share, provided that the sample was indeed very large. The seven clusters extracted were then profiled into behavioural types in a subsequent stage of the analysis. The profiles of the types are based on frequency of use "often", indicating habit. Modes characterising each type are given by the mean values of the variables used to derive the clusters (Table 5.3). Only values that are significantly different compared to the overall distribution of the sample are considered for profiling. To this end, residuals were adjusted to ±1.96. We found significant differences between the seven groups regarding the frequency of use of the different travel modes (*p-values* < 0.001). Each of the types extracted has a unique behavioural profile, which was validated using MANOVA, including post-hoc analysis using Bonferroni corrections (results included in Table 5.3).

Table 5.3. Mean values of self-reported frequency of use of travel modes for each cluster (%).

	1. Urban public transport users (12.1%)	2. Car drivers (26.1%)	3. Commi-tted public transport users (5.1%)	4. Subur-ban public transport users (10.1%)	5. Motor-cycle enthusiasts (10.1%)	6. Potential mode switchers (17.3%)	7. Pedes-trians (15.8%)	Sample average (96.6%)
Metro	2,3,4,5,6,7	1,3,4,5,6,7	1,2,4,5,6,7	1,2,3,5,6,7	1,2,3,4,6,7	1,2,3,4,5,7	1,2,3,4,5,6	
(Habit) Often	**70.30**$^{++}$	0.00	**67.00**$^{++}$	**40.40**$^{+}$	18.30	**36.10**$^{+}$	0.00	25.10
Sometimes	28.60	8.90	29.10	**44.70**	41.10	**59.00**	13.10	29.30
Never or almost never	1.10	**91.10**	3.90	15.00	40.50	4.90	**86.90**	45.60
Tram	3,4,5,6,7	3,4,5,6,7	1,2,4,5,6,7	1,2,3,6	1,2,3,6,7*	1,2,3,4,5,7	1,2,3,5*,6	
(Habit) Often	0.00	0.20	**33.90**$^{++}$	0.10	0.30	1.80	0.60	2.40
Sometimes	1.90	2.60	**66.10**	5.60	6.40	**10.90**	4.10	8.50
Never or almost never	**98.10**	**97.20**	0.00	**94.20**	**93.30**	87.30	**95.30**	89.10
Metropolitan rail (RENFE Ro.)	2,3,4,5,6,7	1,3,4,5,6	1,2,4,5,7	1,2,3,5,6,7	1,2,3,4,6,7	1,2,4,5,7	1,3,4,5,6	
(Habit) Often	0.70	1.80	**13.70**$^{+}$	**59.60**$^{++}$	0.40	**16.10**$^{+}$	0.00	10.70
Sometimes	**30.20**	19.60	**45.10**	**40.20**	14.50	**42.80**	22.00	28.70
Never or almost never	**69.20**	**78.60**	41.20	0.20	**85.00**	41.10	**78.00**	60.60
Metropolitan rail (FGC)	2,5,6,7	1,3,4,6	2,5,6,7	2,5,6,7	1,3,4,6	1,2,3,4,5,7	1,3,4,6	
(Habit) Often	17.40	1.30	**14.50**$^{++}$	**15.20**$^{++}$	3.20	**11.40**$^{++}$	2.10	7.70
Sometimes	**29.90**	11.10	**36.30**	**31.30**	10.00	**32.00**	11.60	20.60
Never or almost never	52.70	**87.70**	49.30	53.50	**86.80**	56.70	**86.30**	71.70
Long-distance	2,3,4,5,7	1,3,4,6,7	1,2,4*,5,6,7	1,2,3*,5,6,7	1,3,4,6	2,3,4,5,7	1,2,3,4,6	
(Habit) Often	1.10	0.20	**2.30**$^{++}$	**3.50**$^{++}$	0.60	1.00	0.20	1.00
Sometimes	**13.00**	4.20	**20.50**	**21.10**	5.00	**13.00**	6.40	9.90
Never or almost never	85.90	**95.60**	77.20	75.30	**94.40**	86.00	**93.40**	89.10
Taxi	2,4,5,6,7	1,3,4,5,6,7	2,4,5,6,7	1,2,3,5*,6	1,2,3,4*,6*,7*	1,2,3,,5*,7	1,2,3,4,5*,6	
(Habit) Often	**7.20**$^{++}$	1.40	**5.80**$^{+}$	**4.50**$^{+}$	4.00	3.90	3.40	3.70
Sometimes	**35.80**	12.20	**37.00**	**26.90**	24.50	**28.10**	22.80	23.70
Never or almost never	57.00	**86.40**	57.20	68.60	71.40	68.00	**73.80**	72.70
Car driver	2,3,4,5,6,7	1,3,4,5,7	1,2,4,5,6,7	1,2,3,6,7	1,2,3,6,7	1,3,4,5,7	1,2,3,4,5,6	
(Habit) Often	0.70	**89.50**$^{++}$	**7.50**$^{+}$	0.00	0.00	**90.10**$^{++}$	0.00	40.80
Sometimes	**19.60**	10.50	**19.60**	**16.60**	**15.80**	9.90	9.70	13.10
Never or almost never	**79.70**	0.00	**72.90**	**83.30**	**84.20**	0.00	**90.30**	46.10

	1. Urban public transport users (12.1%)	2. Car drivers (26.1%)	3. Committed public transport users (5.1%)	4. Suburban public transport users (10.1%)	5. Motorcycle enthusiasts (10.1%)	6. Potential mode switchers (17.3%)	7. Pedestrians (15.8%)	Sample average (96.6%)
Motorcycle driver	2,4,5,6	1,3,4,5,6,7	2,4*,5,6	1,2,3*,5,6,7	1,2,3,4,6,7	1,2,3,4,5,7	2,4,5,6	
(Habit) Often	1.40	**8.80+**	1.90	3.30	**21.60++**	5.00	0.90	6.40
Sometimes	0.70	**3.80**	0.50	1.70	1.60	**2.50**	0.30	2.00
Never or almost never	**97.90**	87.50	**97.60**	**95.00**	76.80	**92.40**	**98.90**	91.60
Bicycle	2,3,4,6,7	1,5,6,7	1,5,6,7	1,5,6,7	2,3,4,6,7	1,2,3,4,5,7	1,2,3,4,5,6	
(Habit) Often	3.50	**6.10+**	7.10	**8.50++**	3.20	**7.70++**	1.70	5.70
Sometimes	7.50	**18.00**	12.60	12.90	6.40	**18.70**	3.20	12.50
Never or almost never	**89.00**	75.90	80.30	78.60	**90.40**	73.60	**95.10**	81.80

Notes: Clusters' relative shares are given in brackets under the captions. Number series for each mode indicate a significant difference among groups (ANOVA post hoc Bonferroni tests, *p-values* < .001). (*) *p-value* < .05. Figures in bold indicate a statistically significant difference compared to the overall distribution for the sample. (+) Traits characterising a given type. (++) Most prominent traits characterising a given type.

Table 5.4 presents a summarised view of the profiles of the types based on the results from the bivariate analysis of segmenting variables of clusters. *Urban public transport users* are users of the urban bus, the metro, and the taxi (as a secondary choice). All are urban modes present in large cities, mainly in Barcelona. Use of public transport is combined with frequent walking, and only "sometimes" using the car (19.60%). *Car drivers* constitute the largest group, formed of users of private vehicles. The main mode characterising this group is car driver (89.5%), but used in combination with frequent use of the motorcycle and the bicycle. *Committed public transport users* is a particular type making major use of public transport, while frequently using private motorised modes, though to a much lesser extent. Main public transport modes characterising this latter type are metro and tram, in combination with walking. With respect to *suburban public transport users*, these are metropolitan rail RENFE Rodalies, and secondarily interurban bus and metropolitan rail FGC. This group "sometimes" use private motorised transport modes, mainly the car. *Motorcycle enthusiasts* is formed by self-reported habitual users of motorcycles, who "sometimes" combine the use of this mode with walking (34.0%) and car (15.8%). *Potential mode switchers* is formed of travellers that make major use of the car (90.1%), but in combination with frequent use of public transport, predominantly *rail* modes: FGC, metro and RENFE Rodalies. *Potential mode switchers* are familiar with both private and public transport modes, which could be interpreted as being a relatively easy target group of behavioural change policies for sustainability. This group of travellers is, therefore, of great interest from a policy perspective. The *pedestrians* are habitual walkers (90.7%) who only "sometimes" use urban and inter-urban buses (43.8% and 17.8%, respectively). Other modes are excluded from their modal mix. They also represent a large share of the total sample. However, this share is narrower than what results from the descriptive analysis.

Table 5.4. Types' profiles according to the self-reported frequency of use of travel modes.

Cluster/Type[1]	Type profile
1. Urban public transport users (12.1%)	• Users of public transport modes. Main modes characterising this group are: urban bus, metro, and secondarily taxi. Use of public transport is combined with frequent walking. • "Sometimes" use private motorised transport modes; mainly the car.
2. Car drivers (26.1%)	• Users of (individual) private vehicles; car is their main mode, but combine it with frequent use of the motorcycle and the bicycle. • "Sometimes" walk. • "Never or almost never" make use of public transport modes.
3. Committed public transport users (5.1%)	• Users of a varied mix public transport modes; main public transport modes characterising this group are: metro and tram, and secondarily interurban bus, FGC and regional train. Use of public transport is combined with frequent walking and, to a lesser extent, with frequent use of the car.
4. Suburban public transport users (10.1%)	• Users of public transport modes. Main public transport modes characterising this group are: RENFE Rodalies, and secondarily interurban bus, FGC (and bicycle). Use of public transport is combined with frequent walking. • "Sometimes" use private motorised transport modes; mainly the car.
5. Motorcycle enthusiasts (10.1%)	• Habitual motorcycle drivers. • "Sometimes" walk or use the car. • "Never or almost never" make use of public transport modes.
6. Potential mode switchers (17.3%)	• Mainly "car driver(s)", but in combination with *rail* public transport, namely metro, FGC, and RENFE Rodalies. They also "often" walk and cycle. • Other public transport modes and taxi may be used "sometimes". • "Never or almost never" make use of the motorcycle.
7. Pedestrians (15.8%)	• Habitual pedestrians. • "Sometimes" use urban and interurban buses. • "Never or almost never" use private transport modes or public transport modes other than the bus.

Note: Clusters' relative shares are given in brackets.

Overall, we have identified two types or groups purely of users of private transport modes, namely *motorcycle enthusiasts* and *car drivers*. Both *potential mode switchers* and *committed public transport users* straddle two categories, namely, private transport users and public transport users, though they show opposite behaviour. *Potential mode switchers* are mainly users of private modes, while *committed public transport users* are for public transport. Together, the three types of users of private transport account for more than half the population, a fact that could not have been deduced from the descriptive analysis of the data. Purely public transport users involve two different groups: *urban public transport users* and *suburban public transport users*, which together with *committed public transport users* represent over one fourth of the overall population. A main characteristic of public transport users is the combination of frequent use of public transport with frequent walking. This is not surprising, provided the need to walk to stations/stops. Note that we have made a distinction between *urban* and *suburban* public transport users. Users from these two groups combine different public transport modes depending on their differential accessibility and, therefore, its differentiation into "urban" and "suburban". A further characteristic of these two types is their occasional (i.e., "sometimes") use of private modes, mainly the car. This marks a clear differentiation with *committed public transport users*.

The habit construct was measured through the self-reported frequency of use indicator "often", also used to profile the seven types. However, habits are rather more complex. They need stable contexts in order to form, and if strong enough they can be generalised. In addition, habitual users can be further identified by their use of travel information; low for habitual. In accordance, we have reinforced our habit indicator to capture this complexity through three theoretically-based controls: (1) journeys to work/education, indicating context stability; (2) low use of travel information, indicating automaticity of behaviour; and (3) unimodality, namely, only one travel mode predominating the modal mix, indicating habit generalisation. Bivariate analyses were undertaken and mean values of these variables are displayed in Table 5.5. The implications are readily readable: not all types identified can be referred to as displaying (strong) travel mode habits.

Table 5.5. Variables controlling for habit and habit strength constructs. Mean values (%).

	Urban public transport users	Car drivers	Commi-tted public transport users	Sub-urban public transport users	Motorcycle enthusiasts	Potential mode switchers	Pedes-trians	Sample average
- Familiar journeys (group average)								
Days going to work/education [week rate]	4.92	5.08	4.94	4.94	5.03	4.98	5.04	5.01
Times going from home to work/education [day rate]	2.34	2.54	2.37	2.27	2.45	2.37	2.55	2.43
- Information request[1] (%)								
Private vehicle (No)	**82.40**	63.80	**78.80**	**78.90**	**83.00**	57.30	**91.70**	73.90
Frequency (Private vehicle)								
Occasionally	**79.40**	69.00	72.60	**77.90**	64.40	67.40	**77.20**	70.40
1- 4 times month	14.10	20.60	20.30	14.60	**26.60**	**23.40**	17.90	20.70
> 4 times a month	6.50	**10.40**	7.20	7.50	9.00	9.20	4.90	8.90
Public transport (No)	71.20	**79.00**	65.30	62.90	**81.20**	60.80	**88.90**	74.20
Frequency (Public transport)								
Occasionally	75.50	**86.20**	71.30	73.60	80.50	74.50	**84.00**	78.00
1- 4 times month	18.30	11.80	**20.60**	**20.00**	15.80	**20.30**	12.30	17.20
> 4 timesa month	**6.20**	2.00	**8.00**	**6.40**	3.70	5.20	3.60	4.80

Notes: Figures in bold indicate a statistically significant difference compared to the overall distribution for the sample. (1) Refers to information requests made in the past 12 months.

We found significant differences between the seven groups for all these habit variables (*p-values* < 0.001). Concerning context stability, namely journeys to work/education, all groups seem to coincide in a working week of five days and around three journeys of home-work/education. The latter indicates highly stable travel contexts of more than 2 habitual journeys per day, thus providing a basis for habit formation. Regarding information requirements, responses given are consistent; i.e., those who asserted that they did not request information also reported an "occasional" frequency of information requests. Overall, use of information is low for all types, thus indicating that modal choices may be largely habitual, that is, automatically made. This may be challenging for the design of information campaigns attempting to either attract public transport users or discourage the use of private vehicles. Worth special mention is the group *potential mode switchers*. This group displays a relatively high use of information about public transport services (and also about private vehicles), which may be encouraging from a policy perspective. Habit generalisation condition, however, is only satisfied by two types, *motorcycle enthusiasts* and *pedestrians.* However, *car drivers* can be considered habitual car users if the unimodality condition is relaxed; this group has a very narrow modal mix of only three modes, where the car clearly predominates.

5.4.3 Characterisation of the types

We further analysed the behavioural types identified as socially-embedded groups. For this purpose we have considered other choice determinants, namely socioeconomic and demographic, territorial and other travel-related characteristics. There is evidence in the literature related to the BMR of all these variables correlating with behaviour (Cebollada and Miralles-Guasch 2008; Miralles-Guasch 2002). Thus it could well be that these types emerged from underlying structured social characterisations (Domínguez-Amorós and López-Roldán 1996). We investigated this hypothesis to prove or disprove it. Results from the bivariate analyses of these additional variables are displayed in Tables 5.6 (socio-demographics) and 5.7 (territorial and other travel). All of them were significantly related with the types extracted at a *p-value* < 0.001, hence indicating that all seven types had unique social profiles. That is, they are different travellers and different persons, as well.

Table 5.6. Socioeconomic and demographic characteristics of each type. Mean values (%).

	Urban public transport users	Car drivers	Commi-tted public transport users	Sub-urban public transport users	Motorcycle enthusiasts	Potential mode switchers	Pedes-trians	Sample average
Gender(Female)	**66.70**	33.60	**58.20**	**60.30**	**55.90**	37.40	**73.40**	51.40
Age								
16 to 29 years	**21.90**	17.10	**28.50**	**33.50**	**20.50**	**20.40**	7.80	19.40
30 to 64 years	57.00	**75.60**	53.70	51.20	46.50	**71.00**	45.50	60.80
More than 65 years	**21.10**	7.30	17.80	15.30	**33.00**	8.60	**46.70**	19.80
Level of education completed								
No education	5.00	2.20	4.40	5.50	**16.40**	1.50	**21.70**	7.50
Primary education	31.70	34.70	30.70	32.00	**39.80**	24.20	**51.20**	35.20
Secondary education	**37.30**	**40.40**	**39.80**	**40.10**	27.60	**38.50**	19.00	34.80
Higher education	**26.00**	22.60	**25.00**	22.40	16.10	**35.90**	8.00	22.50
Other	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10
Monthly household income								
<1.000€	**24.90**	9.40	22.50	**25.40**	**37.70**	8.40	**51.20**	22.80
1.000€ - 2.000€	**43.30**	**41.70**	**42.60**	**42.00**	34.90	39.10	34.20	39.60
2.000€ - 3.000€	21.10	**29.70**	21.00	21.40	18.30	**32.20**	10.00	23.60
3.000€ - 4.000€	6.30	**11.90**	8.90	7.80	5.80	**12.60**	3.00	8.80
4.000€ - 5.000€	2.60	**3.90**	3.60	1.80	2.30	**4.50**	0.80	3.00
> 5.000€	1.80	3.50	1.40	1.60	1.10	3.20	0.80	2.30
Individuals in the household (group average)	2.62	2.99	2.83	2.76	2.55	2.85	2.37	2.74
Occupied	48.50	**77.20**	46.60	47.90	42.30	**72.80**	24.30	55.90

Notes: Figures in bold indicate a statistically significant difference compared to the overall distribution for the sample. (1) Refers to current or previous professional status in the case of unemployed, retirees and pensioners.

Table 5.7. Territorial and other travel-related characteristics of each type. Mean values (%).

	Urban public transport users	Car drivers	Committed public transport users	Sub-urban public transport users	Motorcycle enthusiasts	Potential mode switchers	Pedes-trians	Sample average
Territorial								
Municipality size (inhab.)								
< 2,000	0.00	**1.30**	0.00	0.20	0.50	0.60	0.40	0.60
2,000 – 10,000	0.60	**13.60**	1.60	5.40	5.00	7.50	4.70	7.00
10,000 – 50,000	3.20	**29.10**	15.10	**24.70**	15.30	**22.30**	19.40	20.40
>50,000	23.20	**42.30**	29.20	**39.70**	36.00	37.10	**43.30**	37.50
Barcelona	**72.90**	13.60	**54.10**	29.90	**43.20**	32.40	32.30	34.40
Metropolitan ring								
Barcelona	**72.90**	13.70	**54.10**	30.00	**43.30**	32.50	32.40	34.50
Rest of first ring	20.60	21.80	**37.00**	**27.60**	**30.30**	**25.80**	23.10	24.90
Second ring	6.50	**64.60**	8.90	**42.30**	26.40	**41.70**	**44.50**	40.70
Other travel								
Driver license								
Motorcycle (Yes)	18.40	**44.10**	19.90	21.60	**31.00**	**38.90**	11.60	29.60
Moped (Yes)	8.50	**30.40**	9.80	10.40	**21.60**	**23.90**	5.90	18.40
Car (Yes)	47.20	**100.00**	50.30	41.10	41.20	**100.00**	30.10	67.00
Vehicle ownership								
Motorcycle/ moped (Yes)	7.90	**18.30**	8.30	15.40	**48.60**	12.30	8.70	16.80
Car (Yes)	61.80	**100.00**	67.10	57.30	58.20	**100.00**	58.40	86.09
Bicycle (Yes)	19.60	**37.30**	**30.00**	**32.60**	17.30	**39.00**	10.30	28.00
Monthly expenditure[1] (€) (group average)								
Private vehicle	67.32	117.92	74.73	57.02	54.30	103.02	52.96	101.61
Public transport	25.24	8.86	28.42	32.70	14.97	20.18	11.39	19.78
Public transport + taxi	33.65	15.09	37.63	38.58	20.83	26.23	16.44	25.95

Notes: Figures in bold indicate a statistically significant difference compared to the overall distribution for the sample. (1) Monthly expenditure is only accounted for modes used.

Gender differences are remarkable; women are associated in relatively greater measure with the use of public transport, while men are with private vehicles (Table 5.6). Income is associated with age, in that highest incomes are found for adults. We also expected monthly income to be indicative of travel modes used through transport expenses. Results show that groups of car users also belong to highest income ranges. Moreover, for car users there seems to be a minimum income threshold of between €1,000 and €2,000 per month. While the former result is not very remarkable, the latter is quite a finding. Income does not seem to be a constraint for motorcycle use.

Territorial variables analysed were consistent among themselves (Table 5.7). Territorial variables yielded results that were further consistent with the modal offer of public transport services within the BMR (see Section 3.2). Among residents from suburban areas, namely First and Second rings, the car has a greater share, especially for residents of both middle-sized and small towns. On the other hand, urban residents of Barcelona or of large cities from the First ring, tend to rely more heavily on public transport. Three variables referring to other travel-related characteristics of travellers were analysed (Table 5.7). Variables “driving license” and “vehicle ownership” reinforced classification results. Monthly expenditure on transport was, remarkably, higher for frequent users of the car and consistent with income, as expected.

Adding all pieces of information, *urban public transport users* type is most significantly formed of both young and elderly educated women, with a monthly income below €2,000 and, mainly, with no occupation. They are, to a large extent, residents of Barcelona, having no driving license or own vehicle. *Car drivers* are mainly adult men, with middle education (secondary school completed). Monthly income range is wide for this type, which encompasses relatively high incomes; almost all are employed. They are mostly suburban residents from small and medium-sized towns from the Second metropolitan ring, having driving license and own vehicle. Monthly expenditure on private transport is the highest, at around €120. *Committed public transport users* type is most significantly formed of young educated females, mostly unemployed. They are urban residents from Barcelona and other large cities from the First metropolitan ring. Their income range is €1,000-€2,000, and their expenditure on private transport is around €75 per month. *Suburban public transport users* are mostly young, females with no employment, holding secondary education. They are mostly suburban residents from medium-sized cities from the First and Second metropolitan rings, have no driving license and own a bicycle. *Motorcycle enthusiasts* type is most significantly formed of young females, with low educational level. Monthly income is relatively low for this type with no employment, living in Barcelona and other large cities from the First metropolitan ring; having a driving license and owning a motorcycle. *Potential mode switchers* are adult and young, educated men, and almost all are employed. Monthly incomes are the highest. Significant residential locations for this type are suburban medium-sized cities from both First and Second metropolitan rings, having driving licenses for car and motorcycle, and owning a car. Monthly expenditure on private transport is relatively high. Finally, the *pedestrians* type is most significantly formed of elderly females, with low educational level and low income (bellow €1,000 per month); mainly, unemployed and, presumably, retired. The most salient residential locations are large suburban cities from the Second metropolitan ring, having no driving license and not owning a vehicle, and their monthly expenditure on private transport is the lowest, at around €50.

5.5 Conclusions

As a central part of this chapter, a classification analysis has been performed on a sample of travellers from the BMR. The aim was to identify types of habitual users of private modes representing a policy challenge. Seven types were identified, according to the self-reported frequency of use of travel modes, namely *Urban public transport users*, *Car drivers*, *Committed public transport users*, *Suburban public transport users*, *Motorcycle enthusiasts, Potential mode switchers*, and *Pedestrians.* Data were retrieved from a general mobility survey, which guarantees close to full representation of the BMR population. The modal behaviour of the types was completed with socioeconomic and demographic, territorial and other travel-related information. In this way, well recognised determinants of travel mode choice could be connected to all the aforementioned. We found that the types extracted not only show unique modal behaviour, but have unique social profiles, which can to a large extent explain their modal choices and habits. Moreover, results offered a view of the modal split of the BMR, which could not be directly inferred from a merely descriptive analysis of the data.

From the types identified, those more challenging from a policy perspective are habitual users of the private vehicle: *motorcycle enthusiasts* and *car drivers. Motorcycle enthusiasts* show strong modal habits (i.e., satisfied all habit criteria). For this type, the design of specific policy strategies is necessary in order to break down the strong habit and form more sustainable habits. *Car drivers,* though, do not strictly satisfy a unimodality condition, making a disproportionately large use of the car, having a highly stable travel context, and making little use of travel information. They can thus be considered habitual car users. This behavioural type is, however, further constrained by its residential location and environment. Accordingly, policy measures targeting *car drivers* will most probably have to address such locational constraints, before dealing with car habit. *Suburban public transport users* also have to deal with accessibility constraints. Improvements in access to public transport services may therefore be cost-effective. *Potential mode switchers* and *committed public transport users* are both interesting groups from a policy perspective. They show opposite behaviour and personal profiles, thus supporting the idea that different types of travellers may need to be approached in different ways for the effectiveness of policies. *Potential mode switchers* are middle-aged, educated males living in suburban medium-sized cities and are mainly car users, while *committed public transport users* are young educated females living in large cities and, mainly, using public transport. *Potential mode switchers* can be considered a strategic target of policy measures aimed at behavioural change, since these travellers regularly use both private and public transport modes and make regular use of travel information.

The results from the present chapter provide a more accurate picture of travellers' daily modal behaviour, and this contributes toward advancing tailored interventions. The corollary is the presumption that types of travellers displaying differences in their daily use of travel modes, for differing motives, should be approached in different ways in order to increase policy effectiveness.

6 Travel mode usage from the perspective of attitudes, contraints and habits: A study of Barcelona

6.1 Introduction

Recent research has acknowledged that travellers' behaviour is a critical issue if we are to accomplish a more sustainable future for personal transport. Understanding travel mode usage and its choice determinants is critical to facilitating a change in behaviour, which could in turn contribute substantially to climate change mitigation. To this end, insights from two psychological theories are integrated here, namely the *ipsative theory of behaviour* (ITB) and the *theory of planned behaviour* (TPB). Additionally, we extend these by including the concept of habit. We argue that they are complementary and that their integration can shed light on the processes underlying travel mode use, specifically private vehicle usage and public transport usage. More specifically, we combine here the notions of attitude and perceived behavioural control from the TPB with those of subjective or *ipsative* constraints (including habits) and objective or situational constraints from the ITB.

We analyse the relative influence of these determinants of travel mode usage for journeys to places of work or of study (formal education). We do so for a sample of travellers from the Barcelona Metropolitan Region (BMR) in Spain. Two types of analyses are carried out. Firstly, we make use of structural equation modelling (SEM) procedures in order to explain self-reported frequency of use of private vehicles and of public transport. Secondly, we use binary logistic regression procedures to analyse under which circumstances (i.e., attitudes, constraints and private vehicle habits) people would be more prone to using public transport. Data were retrieved from the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006). The main objective of this general survey is to describe daily travel patterns of the resident population of the BMR (and Catalonia), as well as examining the subjective dimension of people's travel behaviour. The EMQ 2006 is an initiative of the Government of Catalonia in collaboration with the Metropolitan Transport Authority. As such, the EMQ is a real instrument for policy design, which has served to assist demand management and planning.

The remainder of the chapter is as follows. Section 6.2 reviews previous research on social psychology and travel mode choice, as well as introducing the conceptual model here proposed. Section 6.3 describes the methodology. Section 6.4 presents the results from the statistical analyses. Section 6.5 discusses the main findings. Finally, Section 6.6 summarises policy implications derived from these results.

6.2 Theory

6.2.1 Previous research on social psychology and travel mode choice

The *theory of planned behaviour* (TPB) is the theory from social psychology probably most applied in studies of travel mode choice (e.g., Bamberg and Schmidt 1998, 1999; Forward 1998). The conception of travel mode choice as being mainly a reasoned choice has undoubtedly favoured the success of the TPB, which assumes a conscious evaluation of the pros and cons of undertaking a certain behaviour, yet subject to social and perceived situational constraints. On the other hand, the predictive capacity of the *ipsative theory of behaviour* (ITB) in the case of travel mode choice has already been tested by Tanner (1999). Her results indicated that subjective constraints explained a significant amount of variance in behaviour, while objective situational constraints also helped to explain behaviour. Aside from the study of travel mode choice, both the TPB and the ITB have been successfully applied in other areas of environmentally-significant behaviour. The TPB has been applied to explain a myriad of environmental behaviours, such as recycling and composting (Taylor and Todd 1995); engaging with environmental organizations (Kaiser and Gutscher 2003; Staats 2003); or using unbleached paper, reducing the consumption of meat, and saving electricity and water at home (Harland et al. 1999). Meanwhile, the ITB has been used by Tanner et al. (2004) to explain green food-shopping behaviour.

Other social psychology-based theories and behavioural models have been applied in transport studies for travel mode usage and choice. These include Schwartz's *norm activation model* (NAM), Stern's *value-belief-norm theory* (VBN), Triandis' *theory of interpersonal behaviour* (TIB), and Perugini and Bagozzi's *model of goal-directed behaviour* (MGB) (e.g. Carrus et al. 2008; Klöckner and Matthies 2004; Oreg and Katz-Gerro 2006; Verplanken et al. 1994). Important antecedents of behaviour raised in these behavioural models are altruistic motives, namely personal norms or moral obligations to behave in a certain sustainable/pro-social way (NAM and VBN); and automatically-driven habitual behaviour and recalled emotions and desires (e.g., feelings of freedom attached to driving, but also of shame, guilt or pride when a behaviour involves a social punishment or reward) (TIB and MGB).

Many studies combining several theories tend to be integrated so as to increase the models' explanatory capacity and avoid what otherwise would be taking an inevitably partial approach to travel mode choice. In this vein, the TPB has often been integrated with the NAM (e.g., Abrahamse et al. 2009; Bamberg et al. 2007; Heath and Gifford 2002). Abrahamse et al. (2009) note however that car use for commuting was mostly explained by self-interest motives, namely variables reflecting individual outcomes (i.e., attitudes and perceived constraints), whereas the intention to reduce car use was mostly explained by morality concerns (personal norms). A meta-analytic review of findings from studies integrating TPB and NAM is offered in Bamberg and Möser (2007), who focus not just on explaining travel mode choice, but also recycling, water conservation, energy saving and green consumerism behaviours (see also the review offered by Kollmuss and Agyeman 2002). Similarly, the VBN is integrated with the TPB by Oreg and Katz-Gerro (2006) in order to explain three types of environmental behaviours, namely refraining from driving to cut down on air-pollution, recycling and environmental citizenship (e.g., participating in pro-environmental demonstrations, contributing funds for environmental causes). Their model was tested on samples from 27 countries accounting for cultural differences in the level of environmental awareness, and their results showed that environmental concern, perceived environmental threat, and perceived behavioural control (construct from the TPB), were all significantly related to the intention of making sacrifices for the environment, which in turn successfully explained the three types of pro-environmental behaviour.

Finally, this combinatory process has resulted in a search for a comprehensive and encompassing model to explain general environmental behaviour and travel mode choice and usage as a relevant example of environmental-significant behaviour. Efforts in this direction have been made by Klöckner and Blöbaum (2010), who propose the Comprehensive Action Determination Model (CADM). This model incorporates the main assumptions of the TPB, the NAM, the ITB and the concept of habit, and assumes that environmental behaviour is the result of intentional, normative, situational and habitual influences. The model was tested for travel mode choice behaviour and results showed that the predictive capacity of the CADM exceeded that of the TPB and NAM (even when these two theoretical models were combined). Notably, subjective and objective situational constraints were responsible for most of the variation in travel mode choice in the CADM, but intentions and habits also had a significant impact. Bamberg and Schmidt (2003) also presented a model that incorporated the TPB, NAM and TIB theoretical approaches. Results favoured insights from the TPB and the TIB; behavioural intention explained 45% of the variance on actual car-use and intention and habit together explained 51% of this variance. Personal norms, however, only explained 14%. In particular, the variable car use-habit from the Triandis model significantly increased the predictive power of the TPB. Moreover, after controlling for the effect of intention, the construct car use-habit had a significant and even stronger effect on behaviour.

6.2.2 The conceptual framework

The conceptual framework proposed here integrates the main concepts from the *ipsative theory of behaviour* (ITB), *the theory of planned behaviour* (TPB) and the theoretical concept of habit.

The *ipsative theory of behaviour* (ITB) (Frey 1988; Frey and Foppa 1986) conceives constraints as being the main determinants of behaviour. Two stages of decision making are distinguished. In the first stage, the possibility set relevant to the individual is determined on the basis of constraints and opportunities. In the second stage, the individual chooses among the alternatives that are still available to her. In the formation of a person's possibility set (i.e., the first stage of decision making), the ITB considers both the situational (or *objective*) and personal (or *subjective*) choice constraints. In accordance, two differing possibility sets are envisaged and a mismatch is assumed amongst them. One is the objective possibility set (OPS), which comprises of all the options available to an individual in a given choice context, and so it involves what can be *objectively* done. It is "transpersonal" in the sense that the options it contains can be recognised by anyone who is informed about the choice context. The other possibility set is the so-called ipsative possibility set (IPS), which is only meaningful for the person concerned. The IPS involves the options that for some reason are considered by that person. The IPS can be larger than the OPS and involve options that are far beyond one's possibilities, such as for a person showing overconfidence. On the contrary, the IPS can shrink and just contain a few options from the whole OPS. This might be the case for a person who is going through a self-coercive process that weakens her will (e.g., addictions), a person that is misinformed or puts little effort into gathering information, thus disregarding feasible alternatives. In particular, an "underextended" IPS can be the result of routinized or habitual behaviour (Tanner 1999). We stand to this proposition.

Lastly, and provided that there is more than one option left in the IPS, the person has to choose which action to undertake (i.e. the second stage of decision making). In choosing amongst the options left within the IPS is when Ajzen's *theory of planned behaviour* (TPB) (Ajzen 1985; 1991) becomes relevant for us. The TPB assumes self-conscious weighting of personal utility and costs subject to perceived constraints, namely perceived behavioural control and social pressure. It focuses on deliberated behaviour mediated by intention, where individuals carefully consider the available information and assess or evaluate the individual outcomes of behaviour. The intention to perform a certain behaviour is assumed to be formed as a result of three components: (1) personal attitude toward the behaviour, (2) social norms regarding the (dis)approval of the behaviour, and (3) feelings of being in control to undertake the behaviour (i.e., perceived choice constraints). The latter is operationalised through the construct *perceived behavioural control*, that refers to people's self-perception of their ability to perform the behaviour and which can directly influence behaviours requiring of resources or opportunities (Madden et al. 1992). This concept thus overlaps the notion of subjective constraints considered in the ITB. As a general case, it is assumed that the more favourable the attitude towards the behaviour, the more supportive the social environment, and the greater the perceived behavioural control, the stronger an individual's intention to perform the behaviour should be, and so most probably the behaviour will be enacted (Ajzen 1991).

The main limitation of the TPB model is in predicting repetitive behaviour, namely routines and automatically-driven habitual behaviour (see Conner and Armitage 1998). At a cognitive level, habits are contrary to intentions; habits are unconscious and habitual actions are unplanned, while intentions are consciously formed and the resulting course of action is deliberate and planned. Verplanken et al. (1994) and Aarts et al. (1998) showed that in the presence of strong travel mode habits, actual behaviour is not well predicted by assuming self-conscious attitudes and intentions. Instead, behavioural responses to the goal of travel are automatically activated (i.e., unconsciously and with little mental effort) (Aarts and Dijksterhuis' 2000a,b). Studies on travel mode choice have repeatedly exposed that for familiar journeys (e.g., commuting journeys), habits dominate travel mode choice (e.g., Davidov 2007; Gardner 2009; Gärling et al. 2001), creating intention-behaviour inconsistencies that are systematic (Fuji and Gärling 2003). As a result, past behaviour and habit are often included as an extension of the TPB in models for travel mode choice (e.g., Bamberg et al. 2003; Carrus et al. 2008; Chen and Chao 2011; Eriksson et al. 2008; Klöckner and Blöbaum 2010; Thøgersen 2006).

Figure 6.1 shows a schematic view of how the ITB, the TPB and the concept of habit can be integrated at a theoretical level.

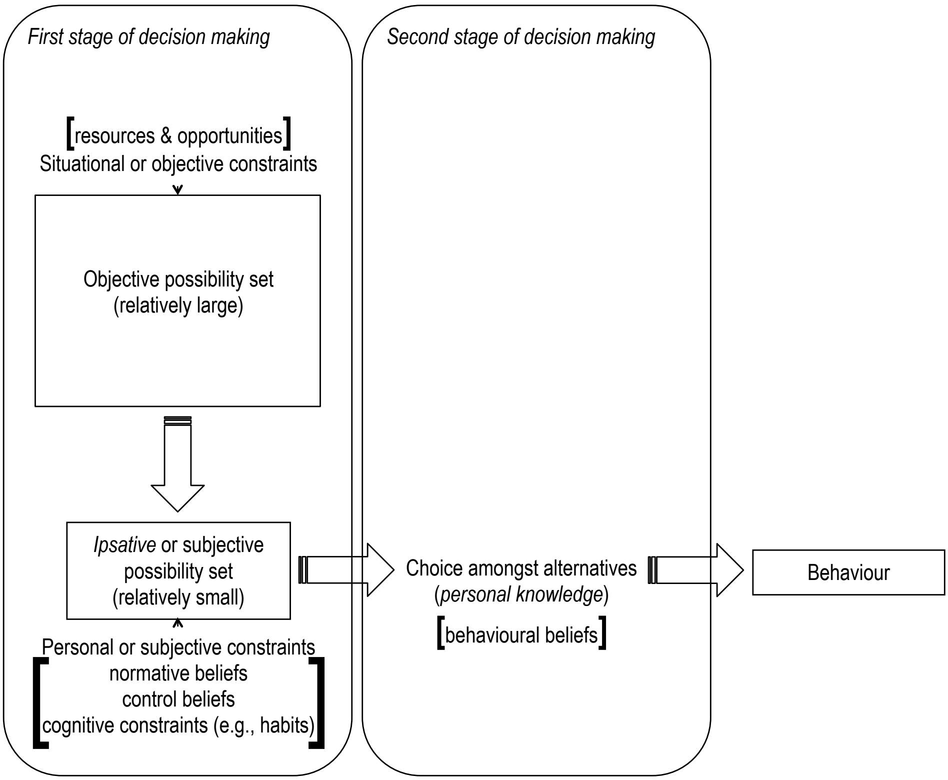

Figure 6.1. Schematic view of the integration of ITB, TPB and habits in this study.

6.2.3 The present study

The present study takes into account the influence of attitude, habit and perceived and actual choice constraints on travel mode usage. In doing so, we aim to contribute to the discussion about the determinants of travel mode choice and usage in order to inform policy. We first briefly discuss each of the theoretical constructs studied and then present the conceptual model proposed.

1. Perceived choice attributes and attitude

Attitudes are formed as a result of a reasoned evaluation or appraisal of the behaviour, and are related to individual outcomes (Ajzen 1991). Antecedents of attitudes are salient *behavioural beliefs*, which people hold about the attributes of the object of the behaviour. Beliefs about attributes are based on both past experience and the opinions of others, and only those which are salient to the person in question ultimately determine behaviour. The attributes assessed are specific to the behaviour and are valued either positively or negatively depending on the expected behavioural outcome; positive if favourable consequences are expected or negative otherwise. Figure 6.2 presents a schematic view of the process by which attitudes are formed. It is worth mentioning that the construct attitude as conceived in the TPB involves evaluative judgements only (i.e., perceived costs and benefits of enacting certain behaviour), but not affective ones (i.e., feelings). Affective judgements, if added to extend the TPB, are normally conceptualised separately (e.g., Bamberg and Schmidt 2003; Carrus et al. 2008).

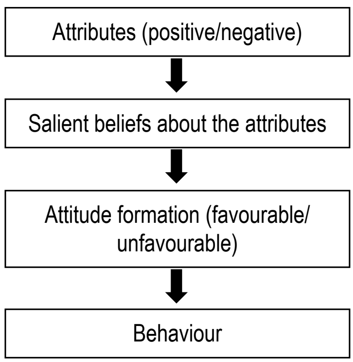

Figure 6.2. Schematic view of the formation of the *attitude* construct.

Attitudes can be measured by means of a global measure —directly asking whether the behaviour is perceived to be good/bad, pleasant/unpleasant—, or through a belief-based index. In this index the strength of each salient behavioural belief is multiplied by the person's subjective evaluation of the respective belief's attribute. The construct *attitude* is directly proportional to the sum of the products across all salient beliefs. Belief-based measures have the advantage that evaluating each attribute separately forces careful consideration, and so individuals tend to provide a relatively more reasoned answer in this manner than when they have to provide a global estimate of their general attitude. Indeed, general measures of attitude have poor correlations with attitude estimates obtained through belief-based measurements (i.e., belief-based indices).

According to Ajzen's TPB, the effect of attitudes on behaviour is mediated by intentions. However, several studies (e.g., Bentler and Speckart 1979) have stated that attitudes have a direct and significant effect on behaviour, including more recent studies that specifically deal with travel mode choice and usage (e.g., Gärling et al. 2001; Thøgersen 2006).

Overall, a positive attitude towards a certain travel mode is assumed to have a favourable impact on its usage. The perceived attributes of travel modes contribute to the formation of such positive attitude. Instrumental attributes that refer to the convenience of using a certain travel mode for its functionality, like quickness, cost, comfort, flexibility, reliability or environmental impact, all form the construct attitude (e.g., Bamberg and Schmidt 1999; Chen and Chao 2011). Here we opted for a belief-based measure of attitude. Respondents were asked how quick, convenient, safe, cheap and comfortable they thought the travel mode they used was. Other non-utilitarian attributes of travel modes include affective ones, namely positive feelings or emotions attached to driving (e.g., freedom and arousal). For commuting journeys, these may be relevant to certain segments of the population, notably (young) men (Pooley and Turnbull 2000; Steg 2005), though instrumental attributes might be relatively more important overall (Anable and Gatersleben 2005).

2. Habits

Conceptually, habits are complex processes. Travel mode choice habits are goal-directed, script-based processes. That is, when the goal to travel somewhere automatically drives past choices stored in memory, no assessment of the alternatives takes place and so decision-making involves little effort and information processing (Gärling et al. 2001; Triandis 1977; Verplanken et al. 1997). It is difficult to measure an unconscious process. Sophisticated script-based indexes have been developed, e.g., response-frequency measure (RFM) (Verplanken et al. 1994) and self-report habit index (SRHI) (Verplanken and Orbell 2003). Notwithstanding, habit is most commonly measured through self-reported frequency of past behaviour in survey-based research (Ouellette and Wood 1998). So far, research has shown correlation between script-based indexes and self-report measures of travel mode choice frequency.

The concept of habit is often integrated into models based on the TPB in order to account for non-deliberated, automatic behaviour based on past actions and routines. There are several ways in which habits are modelled. Notably, habits are conceived to have a direct effect on behaviour (e.g., Verplanken and Aarts 1999), but also to exert an indirect (i.e., moderating) effect on attitude-behaviour relation (e.g., Gardner 2009). That is, an individual's assessment of non-habitual modes can be biased in favour of their habitual mode. Both direct and moderating effects of habits have been jointly tested and support has been found for each of these paths (e.g., Verplanken et al. 1994). A third option is proposed by Gärling et al. (2001), namely that a positive attitude towards a certain travel mode causes frequent choices which in turn lead to script-based travel mode choice. This conceptualisation corresponds to a mediating effect of frequency of past behaviour (see Baron and Kenny 1986). Here we test the hypothesis of a direct effect of habits on behaviour and choice of transport means.

3. Perceived choice constraints

In the TPB, perceived choice constraints are conceptualised upon the constructs social or subjective norms and *perceived behavioural control* (PBC). Social norms refer to (normative) beliefs concerning the extent to which those persons relevant to the individual (dis)approve certain behaviour. Social norms were not measured in the survey we use here, and so will not be discussed any further. We are however aware of the limitations this can impose on our models. PCB, on the other hand, refers to the perceived easiness or difficulty of performing certain behaviour. As such, antecedents of PCB are so-called control beliefs about the presence or absence of requisite resources and opportunities necessary to perform the behaviour (Ajzen 1991). As in the case of *attitude*, each control belief is multiplied by its perceived power to preclude the behaviour, and the construct PCB is directly proportional to the sum of the products across the salient control beliefs. PCB construct comprises of obstacles that can be both real (*objective*) and imaginary (*subjective*).

The ITB does differentiate between objective and subjective constraints, while adding personal or self-imposed constraints to the list. Objective constraints refer to obstacles that are objectively true, subjective constraints involve the obstacles the individual *believes* to be objectively true, and personal constraints are obstacles that the individual consciously or unconsciously takes to apply to herself, and which ultimately affect her behaviour (Frey and Foppa 1986). Personal constraints can differ from subjective ones because individuals might systematically misperceive or even deny the knowledge they have. As such, the ITB recognises the existence of systematic biases like those derived from habits, which may lead to underestimating feasible alternatives and disregarding relevant information. The constraints considered in the ITB involve resources —income and relative prices, time, and physical and mental limited abilities—, infrastructure and technology (including communication systems), personal values, social norms as conceived in the TPB and self-imposed constraints.

In this chapter we propose two separate models, one for those who report making a greater use of private vehicles for journeys to work or to a formal place of study ("users of private vehicles"), and one for those who report making a greater use of public transport ("users of public transport"). For users of private vehicles it can be assumed that they are not facing any specific constraints regarding the usage of private transport. The same can be inferred for users of public transport. In particular, they were asked about the unavailability or inadequacy of the alternative. The novelty hence lies in the fact that constraints are modelled with respect to the alternative (i.e., non-chosen mode). As in the case of *attitudes*, we use a belief-based measure of PCB. We measured whether users of private vehicles perceived that they did not have an alternative of public transport and whether public transport alternatives were less frequent or involved many transfers —inadequacy of existent alternatives. Users of public transport responded to whether they perceived difficulties to travel by private means due to problems parking or traffic congestion.

4. Actual choice constraints

Actual or objective constraints are also modelled with respect to the alternative. For users of private vehicles we take into account objective situational constraints preventing access to public transport. These were measured indirectly by means of two variables regarding residence location, namely municipality size and metropolitan ring. The previous gives us a sense of the level of service that can be expected, whereas the latter provides a measure of the distance to Barcelona city (i.e., the region's core), where the public transport network is denser. Please note that the public transport network of the BMR is markedly radial with a vast majority of lines starting and ending in Barcelona. It is assumed that the smaller the municipality of residence is and the further it is located from Barcelona, the lower the access to public transport services is. In the case of public transport users, the actual constraint was imposed by the availability of a vehicle, namely by the variable vehicle ownership. Similar measures of actual constraints are used by Tanner (1999).

5. Behaviour

Two analyses are undertaken in this chapter. We use structural equation modelling (SEM) procedures in order to explain self-reported frequency of use of both private vehicles and public transport. This is captured by the number of journeys made by private vehicles (or public transport) to the place of work or study (weekdays), divided by the total number of all reported commuting journeys (weekdays). This ratio serves as the first behavioural indicator. Secondly, we use binary logistic regression procedures to analyse the relative influence of attitudinal and constraint choice-determinants and private vehicle-habit in choosing public transport over the private vehicle. This binary variable is the second behavioural indicator used.

6. The conceptual model

In this study we make use of a general mobility survey, namely the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006, acronym in Catalan). As such, we had to adapt the conceptual model to what was available in the data, while subject to the precondition that the model had to be sustained by theory and previous research. The advantage however is clear, namely as the models presented here are based on data from a real instrument for policy design. Moreover, using a general survey avoids problems of sample size and sample representativeness. The disadvantage is however in the restrictions of the variables measured, which force the harmonisation of data and theory into a simple but comprehensive model (Figure 6.3). In this sense, models' limitations can be interpreted as the result of the narrow view of determinants contemplated in actual policy design based on insights from general mobility surveys. This is not to be understood as a criticism of general surveys, but as an invitation to reflect on the potentialities and limitations of these instruments for policy design. We recognise that in carrying out a general survey one does not have all degrees of freedom to ask about everything (e.g., the number of questions asked is restricted by the duration of interviews).

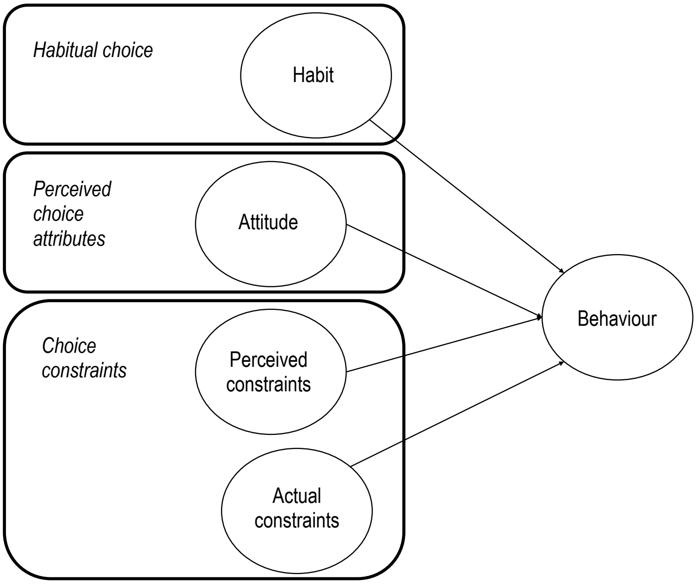

Figure 6.3. Conceptual model.

The causal relations assumed are depicted in the model shown in Figure 6.3 and their formulation as hypotheses is as follows:

Hypothesis 1. Past behaviour and habit have a direct and positive effect on modal behaviour.

Hypothesis 2. Attitude towards travel mode has a direct and positive effect on modal behaviour.

Hypothesis 3. Perceived constraints on the use of an alternative travel mode have a direct and positive effect on modal behaviour.

Hypothesis 4. Actual constraints impeding the use of an alternative travel mode have a direct and positive effect on modal behaviour.

6.3 Methodology

6.3.1 Samples

Data were retrieved from the *Survey of Daily Mobility of Catalonia 2006* (EMQ 2006).[13] The main objective of this general survey is to describe the daily travel patterns of the resident population of the BMR (and Catalonia), as well as to examine the subjective dimension of people's travel behaviour. In this chapter we used the subjective information referred to the individual's valuation of travel modes, as well as the factors they considered in choosing between private and public transport means.

Three subsamples were extracted from the original data matrix for the three statistical analyses carried out (i.e., two SEMs and one logistic regression analysis). The actual process of formation of the three subsamples is depicted in Figure 6.4. Here we first describe the sociodemographics of the original sample and then we provide a detailed explanation of how the subsamples were created, while also describing their sociodemographics. The original sample consisted of 51.2% females (48.8% males) (N = 45,184). The age of the respondents is divided into three segments: 16 to 29 years (22.2%), 30 to 64 years (58.7%), and more than 65 years (19.1%). Regarding their professional situation, 54.1% are occupied and of those who are unoccupied, 9.8% are students. 34.2% live in Barcelona city, 24.8% live in other municipalities within the first metropolitan ring, and 41% live in the second metropolitan ring. Out of those not living in Barcelona city, 37.6% live in cities of more than 50,000 inhabitants. 68.1% have a driver's license and 59.2% own a vehicle (either a car or a motorcycle, or both). 39.9% reported making a greater use of private vehicles for journeys to work or study (formal education), and for those in other professional situations (e.g., unemployed or retired), their behaviour refers to journeys made on a weekday. 34.1% reported making a greater use of public transport (same question), as for the rest, 3.8% use them both equally (private vehicle and public transport), and 22.1% does not use either of them.

[13] For brevity, the information regarding the EMQ 2006 can be consulted in Chapter 2, Methodological framework.

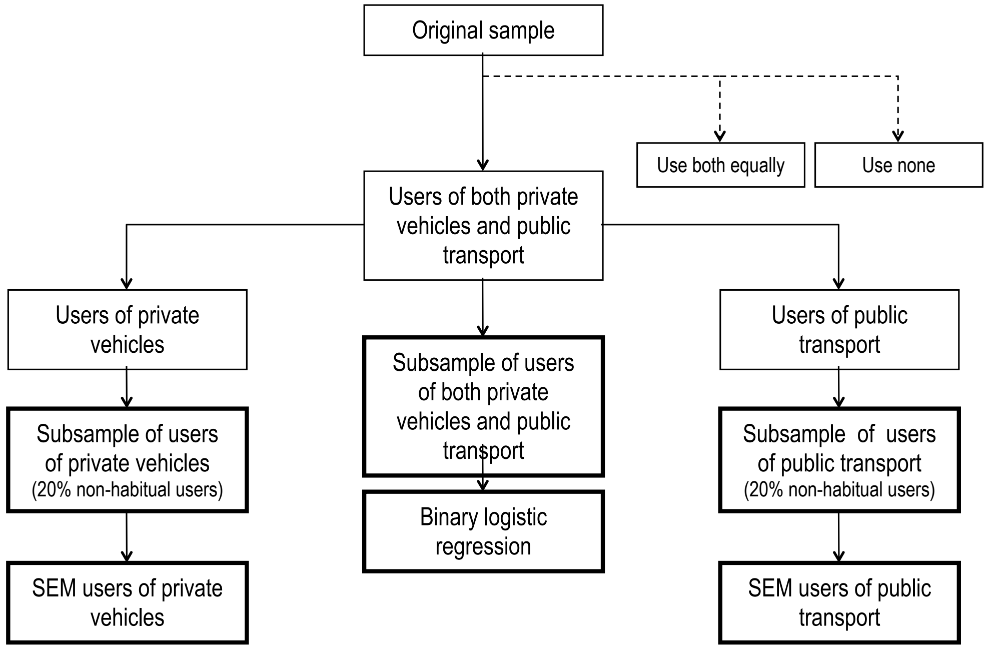

Figure 6.4. Schematic view of the formation of the three subsamples.

The answer to this latter question segmented the sample into either "users of private vehicles" or "users of public transport". Figure 6.5 offers a schematic view of this part of the questionnaire. Nine factors from a closed list were assessed by either users of private vehicles or of public transport; the lists provided were not the exact same, yet some parallelisms amongst them can be established that allow us to compare several factors in the lists. Only those reporting a greater use of private vehicles were questioned about the importance of the factors in choosing the motorcycle/car as their habitual travel mode instead of public transport. The same procedure (but inverted) was followed with those reporting a greater use of public transport modes: rail (three rail modes), metro, tram, and bus.

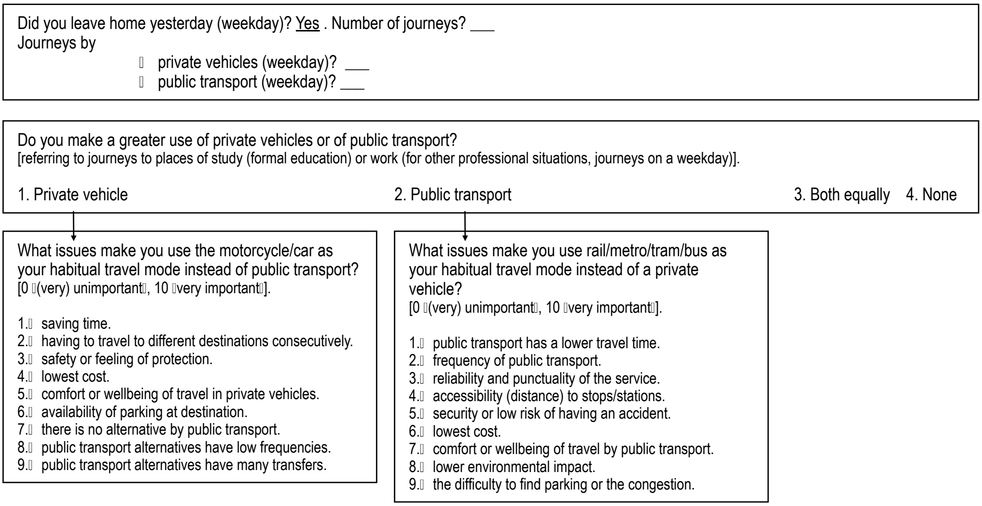

Figure 6.5. Schematic view of the central part of the questionnaire referring to the factors assessed by either users of private vehicles or users of public transport.
Source: Adapted from ATM (2007).

1. Subsamples for the SEM analyses

For SEM analyses we modelled the use of private vehicles separately from the use of public transport (Figure 6.4). As such, we worked with two separate subsamples, one formed by "users of private vehicles" and one formed by "users of public transport". In creating these two subsamples, we replicated the exact same process, and so for brevity we will just describe the steps taken to extract the subsample of users of private vehicles. Firstly, from the original sample, we selected the cases reporting a greater use of private vehicles. Then, the cases with missing values on any of the variables of interest were eliminated. Lastly, a subsample was formed. Cases were randomly selected, yet ensuring 20% of occasional users of private vehicles (habit indicator based on frequency of use of private vehicles "sometimes") (N = 2,500). The minimum of 20% of occasional users was necessary in order to measure the effect of habits; otherwise the Bootstrapping test would fail (i.e., singular sample). Regarding the sociodemographics of the two subsamples, these are briefly described below.

a. Subsample of users of private vehicles

33.5% of respondents are women. 20% are aged between 16 to 29 years, 74.5% are between 30 to 64 years, and 5.5% are of more than 65 years. 75.7% are occupied and 4.9% are students (unoccupied). 20% live in Barcelona, 22% in the rest of first metropolitan ring, and 58% in the second metropolitan ring. 38.8% live in cities of more than 50,000 inhabitants (i.e., other than Barcelona). 100% have a driver license and 100% own a vehicle (car/motorcycle).

b. Subsample of users of public transport

58.9% of respondents are women. 25.5% are between 16 and 29 years old, 52.2% between 30 and 64, and 22.2% are older than 65. 44.7% are occupied and 14.6% are students (unoccupied). 55.5% live in Barcelona, 29.9% in the rest of first metropolitan ring, and 14.6% in the second metropolitan ring. 31.2% live in cities of more than 50,000 inhabitants (i.e., other than Barcelona). 52.7% have a driver license and 36.6% own a vehicle (car/motorcycle).

2. Subsample for the binary logistic analysis

In the logistic analyses, users of private vehicles and public transport are studied together. We only analysed comparable variables present in the two lists, namely those determinants referred to by using the exact same wording in the two lists or that regard to the same underlying idea. Accordingly, we first selected, from the original sample, individuals or cases reporting a greater use of both private vehicles and of public transport (N = 21,645). The resulting subsample is composed of 51.1%women. 22.8% of all respondents are aged between 16 to 29 years old, 62.8% are between 30 to 64 years old, and 14.4% are older than 65. 59.4% are occupied and 9.4% of the unoccupied are students. 26.4% live in Barcelona, 31.8% in other municipalities within the rest of the first metropolitan ring, and 41.8% live in the second metropolitan ring. Of those living in municipalities other than Barcelona city, 38.5% live in cities of more than 50,000 inhabitants. 74.6% have a drivers license and 66.3% own a vehicle (car/motorcycle). 56.6% reported making a greater use of private vehicles, while 43.4% make a greater use of public transport.

Table 6.1 presents a summarised view of the sociodemographics of the original sample and the three subsamples used in the statistical analyses. Note that the subsamples are reminiscent of the (corresponding) original sample.

Table 6.1. Socio-demographic profiles of the original sample and subsamples. (%)

	EMQ 2006 (original)	EMQ 2006 (original)		SEM subsample		Logit subsample
		Users private vehicles	Users public transport	Users private vehicles	Users public transport	
Gender (Female)	51.20	37.40	60.70	33.50	58.90	51.10
Age						
16 to 29 years	22.20	22.30	26.70	20.00	25.50	22.80
30 to 64 years	58.70	71.00	51.00	74.50	52.20	62.80
More than 65 years	19.10	6.70	22.30	5.50	22.20	14.40
Professional situation						
Occupied	54.10	74.70	43.40	75.70	44.70	59.40
Student	9.80	5.70	15.40	4.90	14.60	9.40
Metropolitan ring						
Barcelona	34.20	20.10	52.30	20.00	55.50	26.40
Rest of first ring	24.80	22.60	26.80	22.00	29.90	31.80
Second ring	41.00	57.30	20.90	58.00	14.60	41.80
Living in cities other than Barcelona (>50,000 hab.)	37.60	39.50	32.80	38.80	31.20	38.50
Driver license	68.10	92.60	52.60	100.00	52.70	74.60
Vehicle ownership	59.20	90.10	36.80	100.00	36.60	66.30

6.3.2 Model variables

The questionnaire of the EMQ 2006 examined the following variables of interest which, in turn, were used as indicators of the latent variables in the SEM models (Table 6.2). An extensive review of studies was undertaken in order to assess currently used indicators for the latent variables modelled (see the Appendix, Section A6.1). The selection of determinants or antecedents used in the logistic regression is presented afterwards (Table 6.3). We have only relied on comparable variables, namely relating to those determinants or antecedents that were measured using exactly the same wording or that regard the same underlying idea. Whenever it was necessary, the scores given were inverted. This is further indicated in Table 6.3.

Table 6.2. Variables for the SEM analysis.

Latent variable/Question/Scale/Items	
a. Users of private vehicles (Model 1)	
- Private vehicle-habit (PV-HAB)	
How often do you use the car/motorcycle? 0 “Sometimes”, 1 “Often (Habit)”	
- Attitude toward private vehicles (ATT) (5 items)	
What issues make you use the motorcycle/car as your habitual travel mode instead of public transport? [referred to commuting journeys and journeys to study (formal education), for other professional situations refers to journey made on weekdays] Likert-type scale 0 “(very) unimportant”, 10 “very important”	
bb1 Quick	…saving time
bb2 Convenient	…having to travel to different destinations consecutively
bb3 Safe	…safety or feeling of protection
bb4 Cheap	…lowest cost
bb5 Comfortable	…comfort or wellbeing of travel in private vehicles
- Perceived constraints, no alternative or inadequate (NOA) (3 items)	
NOA1 No PT alternative	…there is no alternative by public transport
NOA2 PT (low) frequency	…public transport alternatives have low frequencies
NOA3 PT many transfers	…public transport alternatives have many transfers
- Actual constraints, residence location (RES) (2 item)	
Municipality of residence?	
SIZE Municipality size	1 “Barcelona”, 2 “> 50,000 hab.”, 3 “10,000-50,000 hab.”, 4 “< 10,000 hab.”
RING Metropolitan ring	1 “Barcelona”, 2 “Rest of first ring”, 3 “Second ring”
b. Users of public transport (Model 2)	
- Public transport-habit (PT-HAB)	
How often do you use the rail/metro/tram/bus? 0 “Sometimes”, 1 “Often (Habit)”	
- Attitude toward public transport (ATT) (6 items)	
What issues make you use rail/metro/tram/bus as your habitual travel mode instead of a private vehicle? [referred to commuting journeys and journeys to study (formal education), for other professional situations refers to journey made on weekdays] Likert-type scale 0 “(very) unimportant”, 10 “very important”	
bb1 Quick	…public transport has a lower travel time
bb2 Convenient	formed from the variables: bb21 “…frequency of public transport”, bb2$_2$ “…reliability and punctuality of the service”, and bb2$_3$ “…accessibility (distance) to stops/stations”
bb3 Safe	…security or low risk of having an accident
bb4 Cheap	…lowest cost
bb5 Comfortable	…comfort or wellbeing of travel by public transport
bb6 Environment	…lower environmental impact
- Perceived constraints, no alternative or inadequate (NOA) (1 item)	
NOA1 No parking or congestion	…the difficulty to find parking or the congestion
- Actual constraints, car ownership (CAR) (1 item)	
Own a car/motorcycle?	0 “Yes”, 1 “No”
- Behaviour, self-reported use of X [private vehicles/public transport] (Models 1 and 2) (USE)	
Ratio-indicator number of journeys made by X [private vehicles/public transport] (weekday), divided by the total number of all reported journeys (weekday)	

Table 6.3. Comparable variables used in the binary logistic regression analysis.

Items/Question/Scale[1]	
- Attitude (Models 1 and 2)	
Quickness	PV: …saving time
	PT: …public transport has a lower travel time
Frequency	PV: …public transport alternatives have low frequencies (inverted scale)
	PT: …frequency of public transport
Safety	PV: …safety or feeling of protection
	PT: …security or low risk of having an accident
Cheapness	PV: …lowest cost
	PT: …lowest cost
Comfort	PV: …comfort or wellbeing
	PT: …comfort or wellbeing
- Constraints (Models 3 and 4)	
PT-access[2]	PV: …there is no alternative by public transport
	PT: …accessibility (distance) to stops/stations
Municipality size	Municipality of residence? 1 “Barcelona”, 2 “>50,000 hab.”, 3 “10,000-50,000 hab.”, 4 “<10,000 hab.”
Metropolitan ring	Municipality of residence? 1 “Barcelona”, 2 “Rest of first ring”, 3 “Second ring”
- Private vehicle-habit (Models 2 and 4)	
PV-habit	How often do you use X [private vehicles/public transport]? 0 “Never or almost never”, 1 “Sometimes”, 2 “Often (Habit)”
- Behaviour, binary variable (dependent variable in all models)	
	Do you make a greater use of private vehicles or of public transport? [referred to commuting journeys and journeys to study (formal education), for other professional situations refers to journey made on weekdays] 0 “private vehicles”, 1 “public transport”

Note: (1) “PV” stands for users of private vehicles; “PT” stands for users of public transport. (2) “PT-access” stands for access to public transport.

6.3.3 SEM analysis

Structural equation modelling (SEM) methods are used to test the antecedents of travel mode usage as given by the ratio-indicator “number of commuting journeys made by mode *X* [private vehicle or public transport] (weekdays)/total number of all reported commuting journeys (weekdays)”; i.e., the first behavioural indicator. SEM procedures have been used since the 1980s in modelling travel behaviour, particularly modal choice in relation to attitudes, perceptions and intention (for a review see Golob 2003). SEM methods allow testing complex theoretical relationships against data, in a highly intuitive manner, by means of graphical representations (i.e., path diagram). They are regarded as being flexible, in that the effects of several predictors or antecedents can be simultaneously estimated, unobserved latent variables representing theoretical concepts can be constructed from observed variables (i.e., indicators), and measurement errors can be estimated separately from the model's overall error (Chin 1998a). These characteristics of SEM methods provide them with a comparative advantage with respect to other predictive methods, such as multivariate regression analysis. The basic structure of a SEM model involves a measurement model representing the relationships between the latent variables and their indicators, and a structural model representing the relationships between the latent variables and the dependent variable or construct.

For the SEM analyses we use partial least squares (PLS) with the software SmartPLS 2.0 (Ringle et al. 2005). PLS method, also referred to as the variance-based SEM method, maximise the variance explained in the dependent variable and are therefore adequate for prediction (Wold 1982). It is a rather exploratory method indicated to build up theory, while also allowing for theory confirmation (Chin 1998a). The PLS method does not make assumptions about data distributions (Bagozzi 1994; Fornell and Bookstein 1982) or sample sizes (Chin and Newsted 1999). Measurement scales can be ordinal and categorical, even binary (Falk and Miller 1992), and allow robust modelling of the indicators as either reflective or formative (Diamantopoulos 2011; Diamantopoulos and Winklhofer 2001). The underpinnings of PLS algorithms are described in Hair et al. (2011) and Tenenhaus et al. (2005). The choice of the PLS-SEM method in this study is justified on the basis of our exploratory objective. Besides, we count with non-normal data, highly skewed and with problems of kurtosis, and necessitate modelling formative and reflective measures, as well as single-measured latent variables (Hair et al. 2011; Henseler et al. 2009; Tenenhaus et al. 2005). Moreover, some items were measured using binary categorical scales (Miles and Snow 1978). In this regard, binary single-item indicators "habit" and "car ownership" were only used to measure independent or exogenous latent variables (Henseler 2010; Henseler et al. 2009).

Recently, a great deal of studies offering guidelines and illustrative examples of how to perform, interpret and report results from a PLS-SEM analysis have appeared (e.g., Chin 1998a). Some of them are regarded to be specific for a certain research field, e.g., Peng and Lai (2012) for operations management, Hair et al. (2012a) and Shook et al. (2004) for strategic management, Hair et al. (2012b) for marketing, and Roldán and Sánchez-Franco (2012) for information systems. However, much of the information in these studies about the theoretical underpinnings of PLS-SEM analysis, and the necessary steps to adequately assess the measurement and structural models, is of a general scope. We have considered those recommendations in applying the PLS method, while following the indications in handbooks for PLS (e.g., Hair et al. 2014; Vinzi et al. 2010). Yet, whenever additional information is in order, this is provided in the results section (Section 6.4).

It is worth mentioning that the latent variable *attitude* is modelled as formative, based on the criteria developed by MacKenzie et al. (2005). Accordingly, we considered the nature of the epistemic relationship between the latent variable (theory) and the observable variables (data), namely the direction of causality (causal indicators *versus* effect indicators), and the (low) correlations amongst the observable variables. It is made clear from MacKenzie's et al. (2005) example on "job satisfaction" that we face a similar case with the attitude measurement (see also the example in Mathieson et al. 2001). That is, the indicators considered, namely "quick", "convenient", "safe", "cheap" and "comfortable", are distinct valuable facets or attributes of travel modes, which together determine a person's overall *attitude* towards certain travel mode (causal indicators). Note that similar studies have modelled this same relationship as reflective (e.g., Bamberg and Schmidt 1999; Chen and Chao 2011). Nevertheless, the reflective approximation would be rather questionable. Indeed, Cohen et al. (1990) reported several studies where formative indicators were erroneously modelled as being reflective in models that were estimated through CB-SEM. The implications of modelling a formative measure are as follows: (a) observable variables have one dimension and are not interchangeable —items cannot be eliminated without compromising the full meaning of the latent construct—, and (b) the error term is estimated for the latent variable, not for the measurements. In addition, formative indicators should represent a census of potential salient behavioural or attitudinal beliefs. With this in mind, an extensive review of studies was undertaken in order to assess currently used indicators of *attitude* towards travel modes (see the Appendix, Section A6.1). Likewise, the list of motives included in the EMQ 2006 questionnaire is based on the knowledge acquired in previous editions (ATM 2007).

6.3.4 Binary logistic regression analysis

In order to complement the SEM analysis, a series of binary logistic regressions are carried out. This time we estimate the probability that a person ends up being a user of public transport or a user of the private vehicle, given certain determinants. In particular, we analyse under which circumstances people would be more prone to using public transport. Note that this is a different question than the one analysed through SEM, which justifies the use of a different methodology. We took as the dependent variable whether travellers reported making a greater use of private vehicles or of public transport (second indicator of behaviour, binary choice). Logistic regression, or logit analysis, is similar to multivariate regression analysis in that one or more independent variables, also referred to as explanatory variables, are used to predict a single dependent variable. Logistic regression is however specifically indicated when the dependent variable to predict is dichotomous, namely binary (e.g., 0/1; yes/no; private vehicle/public transport). In addition, logistic regression procedure does not require the assumption that multivariate normality should be met and, moreover, can accommodate all types of independent variables (numeric and categorical) (Hair et al. 2009).

From the regression coefficients (β) of the independent variables included in the model, we can directly estimate the probability that the individual i chooses option 1 = public transport. The general equation for the logistic function expressing the probability that the option in question (Y_i = 1) is chosen as a function of several k independent variables (x_1, x_2, …, x_z), is:

$$P(Y_i = 1) = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)},$$

where α (i.e., the constant), β_1, β_2, …, β_k are the parameters of the model, estimated in our case using Wald's method (see Salas-Velasco 1996) with the option "Forward"; option given by the statistic software SPSS. Wald's statistic allows us to contrast the null hypothesis that the independent variable does not explain the dependent variable. The option "Forward" is used to judge whether introducing a certain variable into the model will add a significant amount of information about the dependent variable.

Four logistic regressions were carried out. First, we regressed the explanatory variables "quickness", "frequency" "safety", "cheapness" and "comfort"; i.e., the attitudinal variables. Then, we included the variable "PV-habit" (i.e., private vehicle-habit) to the variables in this first model. In model 3, we regressed the constraint variables "PT-access" and the proxies for the level of public transport service "municipality size" and "metropolitan ring". In model 4, the variable PV-habit was added to the variables in model 3.

6.4 Results

6.4.1 Structural models

Two structural models were estimated. Model 1 was estimated for users of private vehicles, while model 2 was estimated for users of public transport. These are used to test the hypotheses in the conceptual model (Section 6.2) and to assess the model explanatory capacity. The two models were estimated through partial least squares (PLS) using the software SmartPLS version 2.0. In what follows we report the results for models 1 and 2.

1. SEM users of private vehicles (Model 1)

The measurement model (outer model) includes both reflective and formatively measured constructs, as well as single-item measurements. The criteria to assess reflective and formative constructs are different (MacKenzie et al. 2005), hence we evaluate them separately. With regards to the reflective constructs NOA, RES and USE, item loadings and corresponding t-values (in brackets) are shown in Figure 6.6, while composite reliability, Cronbachs' alpha, and average variance extracted (AVE) indices are shown in Table 6.4. Standardized item loadings are all greater than 0.70 and significant (t-values > 1.96) (Carmines and Zeller 1979), indicating the adequacy of the indicators proposed to represent each latent construct (i.e., individual item reliability is adequate).[14] Construct reliability, as measured by the indices composite reliability and Cronbachs' Alpha, is also adequate (Table 6.4). Values of composite reliability are greater than 0.70 in the two cases (NOA and RES constructs). The value of the Cronbachs' Alpha for the construct NOA is slightly lower than 0.70. However, Hair et al. (2012a) note that composite reliability is generally considered the more appropriate criterion to establish internal consistency reliability as compared to Cronbach's Alpha. PLS-SEM algorithm emphasizes indicators with strong reliability levels more. Thus, Cronbach's Alpha is generally perceived as a lower bound of reliability whereas composite reliability is the upper bound.

[14] Individual item loadings over 0.7 imply the item explained about 50% of the variance in the underlying latent variable (Chin 1999).

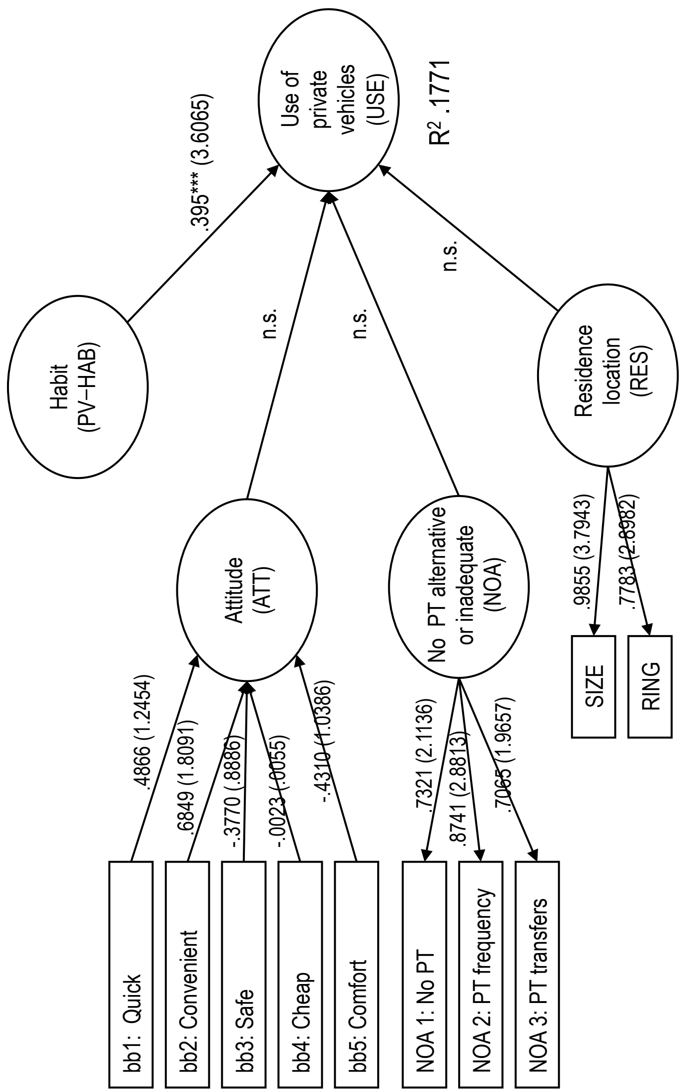

Figure 6.6. Structural model for users of private vehicles (Model 1).

Table 6.4. Measurement model results of reflective constructs only, construct reliability and convergent validity.

Construct	Composite Reliability	Cronbachs' Alpha	AVE
NOA	.8167	.6680	.5997
RES	.8803	.7956	.7885
USE	N.A.	N.A.	N.A.

Notes: AVE stands for average variance explained; N.A. stands for not available. Note that reflective construct "USE" is measured by means of a single item, and so reliability indices and AVE are 1.

Convergent validity of constructs is satisfied; AVE values are greater than 0.50 (Fornell and Larcker 1981). Discriminant validity criteria are also met (Tables 6.5 and 6.6). This is achieved both via the comparison of the square root of AVE *vs*. correlations (Table 6.5) and cross-loadings (Table 6.6). Note that the square root of corresponding AVEs (diagonal elements in bold in Table 6.5) are greater than the related inter-construct correlations (off-diagonal elements in Table 6.5) in the construct correlation matrix, thus indicating adequate discriminant validity for all of the reflective constructs.

Table 6.5. Constructs' correlation matrix, discriminant validity.

Construct	ATT	HAB	NOA	RES	USE
ATT	–				
HAB	.1479	–			
NOA	.1397	.1011	**.7744**		
RES	-.0191	.0257	.1096	**.8880**	
USE	.1402	.4082	.0497	.0709	–

Notes: Diagonal elements (in bold) are the square root of the average variance explained (i.e., AVE). Off-diagonal elements are the correlations among the constructs. For discriminant validity to be satisfied, diagonal elements should be larger than off-diagonal elements.

Table 6.6. Outer model loadings and cross loadings (reflective constructs only).

Indicators	NOA	RES	USE
NOA1	**.7321**	.1319	.0339
NOA2	.8741	.1210	.0481
NOA3	**.7065**	-.0198	.0305
RES1	.0703	**.7783**	.0213
RES2	.1121	**.9855**	.0790
USE	.0497	.0709	**1**

Notes: An indicator should load more strongly on their own construct than on other latent constructs. Similarly, each construct should load more strongly on the indicators that are assigned to it than on other items.

Regarding the formative construct *attitude* towards private vehicles, the formation of this composite construct involves five observable variables, namely "quick", "convenient", "safe", "cheap", and "comfortable", well supported by literature and previous studies (Anable and Gatersleben 2005; Bamberg and Schmidt 1998, 1999; Chen and Chao 2011; Steg 2003, 2005). Assessment results of individual formative indicators, namely item weights and its significance and collinearity diagnosis, are shown in Table 6.7. Item weights inform about the contribution of each formative indicator to its respective composite construct (Chin 1998a), which enables us to rank indicators according to their contribution. A level of significance of at least 0.05 suggests that a formative indicator is relevant for the construction of the composite latent construct (Urbach and Ahlemann 2010). In this vein, items only making a small contribution to the explained variance in the formative construct can be dropped. Nevertheless, the decision to eliminate a certain indicator should be ultimately based on theoretical grounds (Hair et al. 2014). Only the indicator "bb4 Cheap" has a t-value lower than 0.05, yet its elimination is discouraged by theory. Values of variance inflation factor (VIF) statistic are lower than 3.3, indicating that multicollinearity among indicators is not severe (Diamantopoulos and Siguaw 2006; Roberts and Thatcher 2009). In this respect, Belsley (1991) proposed a rather more exhaustive diagnosis of collinearity involving the analysis of condition indices and variance proportions. The highest condition index has a value of 5.1620, way below the suggested maximum of 30 for high multicollinearity problems.

Table 6.7. Measurement model results (formative constructs only).

Indicator	Outer weights	t-value (Bootstrap)	VIF
bb1: Quick	.4866 n.s.	1.2454	1.163
bb2: Convenient	.6849*	1.8091	1.141
bb3: Safe	-.3770 n.s.	.8886	1.130
bb4: Cheap	-.0023 n.s.	.0055	1.088
bb5: Comfortable	-.4310 n.s.	1.0386	1.141

Note: (*) p-value < 0.1; (**) p-value < 0.05; (n.s.) not significant [based on t(499), two-tailed test where t(0.1; 499) = 1.648; t(0.05; 499) = 1.965; t(0.01; 499) = 2.586; t(0.001; 499) = 3.310].

At the construct level, the evaluation of formatively measured constructs involves the assessment of external and nomological validity and discriminant validity. We were unable to assess external and nomological validity, yet the combination of indicators used to measure the composite latent construct *attitude*, as well as the construct *PV–habit*, are well supported by previous studies (see the Appendix, Section A6.1). In what refers to external validity, the research design of the EMQ 2006 survey does not include additional reflective indicators that could capture the essence of the *attitude* construct so as to estimate a two-block redundancy model (i.e., MIMIC model) (Chin 2010; Diamantopoulos and Winklhofer 2001). As for discriminant validity, Urbach and Ahlemann (2010) propose to assess it by means of inter-construct correlations. Correlations between the composite latent constructs *attitude* and *PV–habit* and all other constructs are lower than 0.7 (Table 6.5), indicating that the constructs differ sufficiently from one another.

Regarding the assessment of the structural model (inner model), in PLS to assess the quality of a model we rely on the measurement of the model's predictive capacity (R^2). This is because PLS algorithm maximises the variance explained by the dependent variable. In other words, it focuses on minimising the discrepancies between the actual and predicted values of the dependent variable. The R^2 is of 0.1771 (Figure 6.6). According to Falk and Miller (1992) the minimum recommended value of R^2 is 0.10, although there are other more demanding positions (e.g., Chin 1988a). The sign, magnitude and significance of the path coefficients are shown in Tables 6.8 and 6.9. Note that hypothesis 3 (H3) is not supported; the algebraic sign is contrary to what was assumed (second column Tables 6.8 and 6.9) (Urbach and Ahlemann 2010). Bootstrapping was used to assess the precision of PLS estimates (i.e., standard errors and t-statistics, and percentile 95% confidence interval). It is a non-parametric test involving repeated random sampling with replacement from the original sample to create a bootstrap sample (Hair et al. 2011). We used bootstrapping n = 5,000 subsamples to generate standard errors and t-statistics, and percentile bootstrap 95% confidence interval (Hair et al. 2011; Henseler et al. 2009). The results from the t-statistics and 95% confidence interval tests coincide; only one path is significant, namely hypothesis 2 (H2), while the rest are not supported —are not significant (Table 6.8) and their confidence intervals include zeros (Table 6.9).

Table 6.8. Structural model results (baseline model).

Hypothesis	Suggested effect	Path coefficient	t-value (Bootstrap)	Support
H1: ATT > USE	+	.0843 n.s.	.6755	No
H2: PV–HAB > USE	+	.3950***	3.6065	Yes
H3: NOA > USE	–	-.0089 n.s.	.0737	No
H4: RES > USE	+	.0633 n.s.	.5840	No

Note: (*) p-value <.05; (**) p-value <.01; (***); p-value <.001; (n.s.) not significant [based on t(4999), one-tailed t Student test where t(0.05; 4999) = 1.645; t(0.01; 4999) = 2.327; t(0.001; 4999) = 3.092].

Table 6.9. Structural model results using percentile bootstrap 95% confidence interval, n = 5,000 subsamples (baseline model).

			95% confidence interval (Bootstrap)		
Hypothesis	Suggested effect	Path coefficient	Lower	Upper	Support
H1: ATT > USE	+	.0843	-.2097	.3395	No
H2: PV–HAB > USE	+	.3950	.1405	.5712	Yes
H3: NOA > USE	–	-.0089	-.2291	.2063	No
H4: RES > USE	+	.0633	-.1678	.2374	No

Table 6.10 shows the amount of variance explained by each determinant of behaviour, as well as the predictive relevance of the model as measured by Stone-Geisser's Q^2 test. Note that the construct PV-HAB explains as much as 16.12% of the variation in the use of private vehicles. The effect size (f^2 = 0.1842) and q^2 index (q^2 = 0.1825) for this construct were also estimated. The effect size (f^2) assesses whether an exogenous variable has a substantial effect on the dependent construct by considering changes in the R^2 (Cohen 1988). In other words, it informs about the relative impact of a particular exogenous variable (i.e., antecedent) on the dependent latent variable. It can be calculated as $f^2 = (R^2_{\text{included}} - R^2_{\text{excluded}})/(1 - R^2_{\text{included}})$. Values of 0.02, 0.15 and 0.35 are considered low, medium and large effect, respectively. It follows that PV-HAB has a medium effect of 0.18 on the dependent construct USE. Finally, Stone-Geisser's cross-validated redundancy Q^2 test allows assessing the model predictive validity. This test indicates how well observed values are reproduced by the model and its parameter estimates (Roldán and Sánchez-Franco 2012). A value of Q^2 greater than 0 suggests

that the model has predictive relevance. Similarly to the f^2 test, the Q^2 test allows the assessment of the predictive relevance of an exogenous variable to the model by means of the q^2 index, $q^2 = (Q^2_{included} - Q^2_{excluded})/(1- Q^2_{included})$. Again, values of 0.02, 0.15, and 0.35 indicate small, medium, or large predictive relevance, respectively. Accordingly, PV-HAB has a medium predictive relevance.

Table 6.10. Effects on endogenous variables (baseline model).

Variable and hypothesis	R^2	Q^2	Direct effect	Correlation	Variance explained	f^2	q^2
USE	.1771	.1761					
H1: ATT > USE			.0843	.1402	1.18%		
H2: PV–HAB > USE			.3950	.4082	16.12%	.1842	.1825
H3: NOA > USE			-.0089	.0497	-.04%		
H4: RES > USE			.0633	.0709	.45%		

2. SEM users of public transport (Model 2)

We first assess the measurement model (outer model). A reflexive scale was used to form the latent variable "bb2 Convenient". This variable involves the indicators "bb21 Frequency", "bb22 Reliability" and "bb23 PT-access", which show relatively higher correlations thus indicating that these indicators could be a reflection of an underlying common factor. In this case they would be interchangeable. In order to determine the actual number dimensions of a construct, Lévy (2003) recommends performing an exploratory factor analysis (EFA). The EFA undertaken by the ATM (2007) confirmed our intuition that these indicators form the unidimensional factor "convenient" referred to public transport. This latent variable, in turn, captures a unique aspect of travellers' attitude toward public transport, which is why we measured it by means of a formative scale.

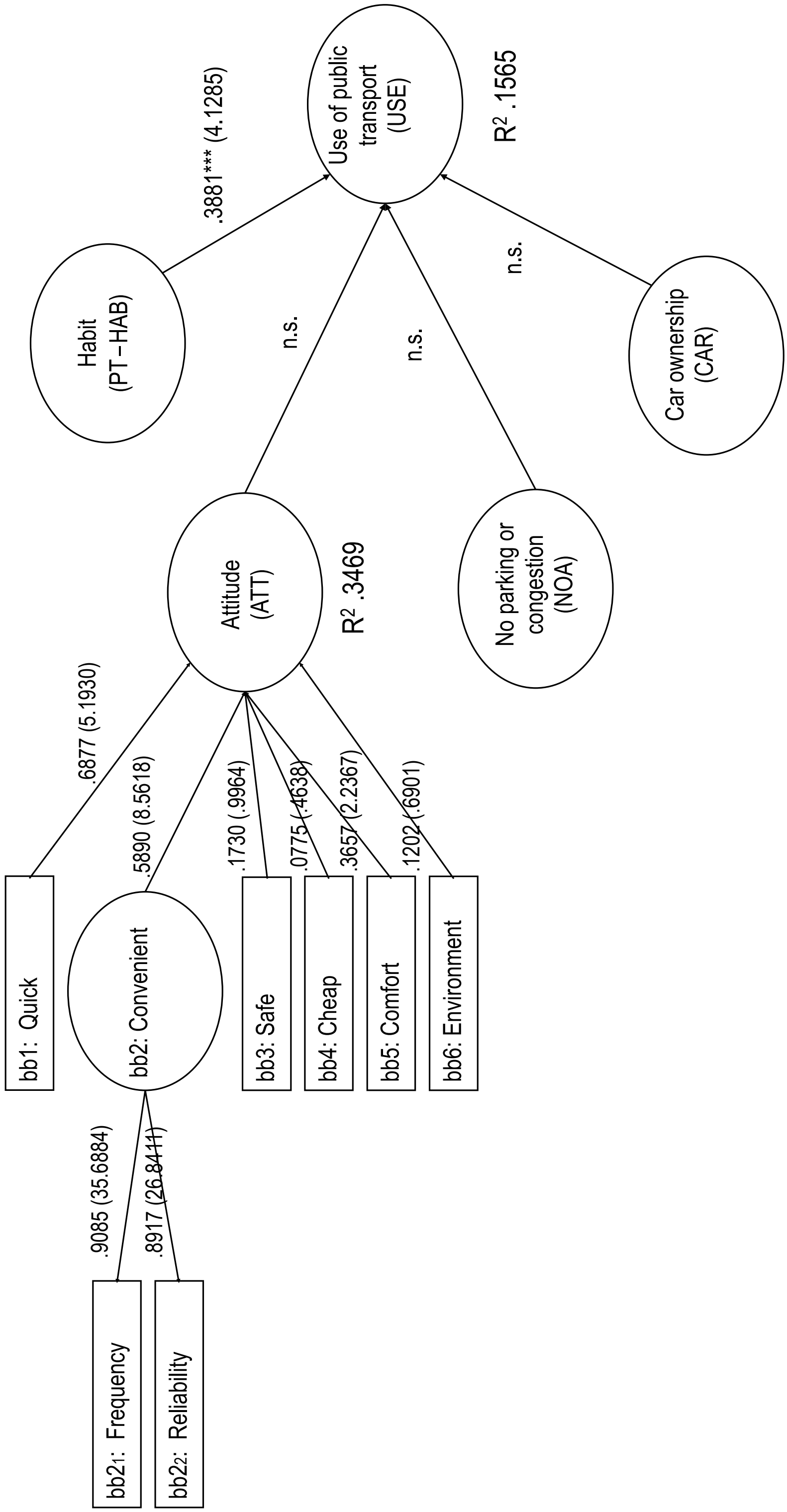

Figure 6.7. Structural model for users of public transport (Model 2)

The indicator “bb23 PT-access” had a standardized loading (λ) lower than 0.7. The model was thus re-specified to improve its convergence, namely the problematic indicator was eliminated (Anderson and Gerbing 1988). Standardized loadings of indicators “bb21 Frequency” and “bb22 Reliability” are greater than 0.7; individual items reliability are adequate (Figure 6.7). Composite reliability and Cronbachs’ Alpha are also greater than 0.7 (Table 6.11). Convergent validity is achieved through an average variance explained (AVE) of 0.8 (way larger than the recommended value of 0.5). Lastly, discriminant validity is met for the four reflective constructs —bb2 “Convenient”, NOA, CAR and USE— through both the comparison of the square root of the AVEs with inter-construct correlations (Table 6.12) and cross-loadings (Table 6.13). With regards to the formative construct “attitude” (ATT), item weights, their significance and collinearity diagnosis, are shown in Table 6.14. All indicators that have a level of significance greater than 0.05 are relevant for the construction of the composite latent variable, while values of variance inflation factor (VIF) statistic are lower than 3.3, indicating multicollinearity among indicators is not severe. Moreover, the highest condition index has a value of 5.0610.

Table 6.11. Measurement model results of reflective constructs only, construct reliability and convergent validity.

Construct	Composite Reliability	Cronbachs’ Alpha	AVE
bb2 Convenient	.8952	.7661	.8102
NOA	N.A.	N.A.	N.A.
USE	N.A.	N.A.	N.A.

Notes: AVE stands for average variance explained; N.A. stands for not available. Note that reflective constructs “NOA” and “USE” are measured by means of a single item, and so reliability indices and AVE are 1.

Table 6.12. Constructs’ correlation matrix, discriminant validity.

	bb2	ATT	HAB	NOA	CAR	USE
bb2	**.9001**					
ATT	.5890	–				
HAB	-.0090	-.0406	–			
NOA	.1590	.2646	.1294	–		
CAR	.0144	.0115	-.0633	-.3136	–	
USE	-.0395	-.0310	.3930	.0763	-.0198	–

Notes: Diagonal element (in bold) is the square root of the average variance explained (i.e., AVE). Off-diagonal elements are the correlations among the constructs. For discriminant validity to be satisfied, diagonal elements should be larger than off-diagonal elements.

Table 6.13. Outer model loadings and cross loadings (reflective constructs only).

	bb2	NOA	CAR	USE
bb2₁	**.9085**	.1525	.0064	-.0196
bb2₂	**.8917**	.1330	.0201	-.0527
HAB	-.0090	.1294	-.0633	.393
NOA	.1590	**1**	-.3136	.0763
CAR	.0144	-.3136	**1**	-.0198
USE	-.0395	.0763	-.0198	**1**

Table 6.14. Measurement model results (formative constructs only).

Indicator	Outer weights	t-value (Bootstrap)	VIF
bb1: Quick	.6877***	5.1930	1.113
bb3: Safe	.1730 n.s.	.9964	1.315
bb4: Cheap	.0775 n.s.	.4638	1.265
bb5: Comfortable	.3657*	2.2367	1.191
bb6: Environment	.1202 n.s.	.6901	1.341

Notes: (*) p-value < 0.05; (**) p-value < 0.01; (***) p-value < 0.001; (n.s.) not significant [based on t(499), two-tailed test where t(0.05; 499) = 1.965; t(0.01; 499) = 2.586; t(0.001; 499) = 3.310].

Figure 6.7 shows the variance explained by the model (R^2 = 0.1565) and the path coefficients (i.e., structural model or inner model assessment). The t-statistics were estimated using bootstrapping (500 subsamples and one-tailed t-distribution). Two paths are significant, namely hypothesis 1 and 3 (H1, H3) (Table 6.15). Percentile bootstrap, 95% confidence interval using 5,000 subsamples confirms this result (Table 6.16); support is found for H1 and H3. Variance explained (R^2) are 0.3469 and 0.1565 for constructs "attitude" (ATT) and "use of public transport" (USE) (Table 6.17), which can be considered to be low (Chin 1998a). Notwithstanding, Stone-Geisser's cross-validated redundancy Q^2 confirms the model predictive relevance (i.e., $Q^2 > 0$). Note that PT-HAB alone explains as much as 15.25% of the variance in the dependent construct USE. The relative impact (f^2 = 0.1736) and predictive relevance (q^2 = 0.1748) of this construct are further estimated, and a medium effect is found for both estimates.

Table 6.15. Structural model results (baseline model).

Hypothesis	Suggested effect	Path coefficients	t-value (Bootstrap)	Support
H1: bb2 > ATT	+	.5890***	8.5618	Yes
H2: ATT > USE	–	-.0256 n.s.	.2281	No
H3: HAB > USE	+	.3881***	4.1285	Yes
H4: NOA > USE	+	.0382 n.s.	.3692	No
H5: CAR > USE	+	.0170 n.s.	.1709	No

Note: (*) p-value <.05; (**) p-value <.01; (***); p-value <.001; (n.s.) not significant [based on t(4999), one-tailed t Student test where t(0.05; 4999) = 1.645; t(0.01; 4999) = 2.327; t(0.001; 4999) = 3.092].

Table 6.16. Structural model results using percentile bootstrap 95% confidence interval, n = 5,000 subsamples (baseline model).

Hypothesis	Suggested effect	Path coefficients	95% confidence interval (Bootstrap)		Support
			Lower	Upper	
H1: bb2 > ATT	+	.5890	.4691	.7425	Yes
H2: ATT > USE	–	-.0256	-.2518	.1887	No
H3: HAB > USE	+	.3881	.1923	.5582	Yes
H4: NOA > USE	+	.0382	-.1677	.2397	No
H5: CAR > USE	+	.0170	-.1797	.2138	No

Table 6.17. Effects on endogenous variables (baseline model).

Variable and hypothesis	R^2	Q^2	Direct effect	Correlation	Variance explained	f^2	q^2
ATT	.3469	.1122					
H1: bb2 > ATT			.5890	.5890	34.69%		
USE	.1565	.1563					
H0: bb2 > USE			-.0151	-.0395	.06%		
H2: ATT > USE			-.0256	-.0310	.08%		
H3: HAB > USE			.3881	.3930	15.25%	.1736	.1748
H4: NOA > USE			.0382	.0763	.29%		
H5: CAR > USE			.0170	-.0198	-.03%		

6.4.2 Probabilistic analysis of public transport usage

Here we examine the determinants in choosing public transport modes over private ones. This is given by the probability that an individual considers herself as making a relatively greater use of public transport. The results of the four logistic regressions undertaken are shown in Tables 6.18 and 6.19. All explanatory variables are statistically significant. Regarding the multicollinearity analysis, variance inflation factors (VIFs) are lower than 3.3 for all variables included and all models estimated.

Table 6.18. Binary logistic regressions of behavioural beliefs, control belief and actual constraints, and PV-habit.

							C.I. 95% Exp. (*B*)	
	N	*B*	S.E. *B*	Wald	*p-value*	Exp. (*B*)	Lower	Upper
Model 1	19,856							
Quickness		-.078	.004	368.10	.000	.925	.917	.932
Frequency		.013	.004	11.81	.001	1.014	1.006	1.021
Safety		.103	.004	574.31	.000	1.109	1.100	1.118
Cheapness		.206	.004	2188.89	.000	1.229	1.218	1.239
Comfort		-.138	.004	1030.30	.000	.871	.864	.879
Constant		-.079	.034	5.31	.021	.924		
Model 2	19,856							
Quickness		-.066	.007	85.09	.000	.936	.923	.949
Frequency		.014	.007	4.33	.038	1.014	1.001	1.028
Safety		.111	.008	213.91	.000	1.117	1.101	1.134
Cheapness		.243	.008	1010.98	.000	1.275	1.256	1.294
Comfort		-.148	.007	389.81	.000	.862	.850	.875
PV-habit		-3.465	.052	4368.82	.000	.031	.028	.035
Constant		4.586	.106	1869.28	.000	98.140		
Model 3	19,953							
PT-access		.041	.004	123.56	.000	1.042	1.035	1.050
Municipality size		-.312	.025	149.81	.000	.732	.696	.770
Metropolitan ring		-.760	.029	673.67	.000	.468	.442	.495
Constant		1.937	.051	1456.19	.000	6.940		
Model 4	19,953							
PT-access		.031	.006	24.10	.000	1.032	1.019	1.045
Municipality size		-.169	.046	13.62	.000	.845	.77 2	.924
Metropolitan ring		-.760	.053	206.31	.000	.468	.422	.519
PV-habit		-.342	.049	4622.38	.000	.035	.032	.039
Constant		6.382	.126	2572.44	.000	591.164		

Table 6.19. Model fit of binary logistic regressions.

	χ^2	*p-value*	Cox–Snell R^2	Nagelkerke R^2	Correctly classified
Model 1	4486.77	.000	.202	.270	67.49%
Model 2	18793.23	.000	.612	.817	91.40%
Model 3	3485.60	.000	.160	.214	69.78%
Model 4	17929.72	.000	.593	.792	90.86%

6.5 Discussion and concluding remarks

In this chapter a conceptual model was created that combined the main insights from the *ipsative theory of behaviour* (ITB) and the *theory of planned behaviour* (TPB) with the concept of *habit*. The model accounted for individuals' attitude and habit, perceived choice constraints —namely the perception of not having an adequate modal alternative—, and actual constraints —objective situational constraints limiting the use of alternatives. On the basis of the ITB, two stages in decision making were envisaged. In the first stage people's possibility set is determined as a result of the many constraints faced. This process may reduce the set of alternatives considered by the individual to just one, as in the case of individuals showing strong travel mode habits. In the second stage, provided that there are more than one alternative left in the possibility set, individuals weigh the remaining alternatives on the basis of salient beliefs about their attributes —i.e., attitude formation.

The conceptual model proposed was sustained by both the theory and the EMQ 2006 data. In other words, it reflected how transport mode usage was conceptualised in the EMQ 2006. The model was tested separately for users of private vehicles (model 1) and users of public transport means (model 2). These models explained around 18% and 16% of the variance in the use of transport modes, private vehicles and public transport respectively. Results showed in both cases (model 1 and model 2) that *habit* was the single significant predictor of the variability in modes usage, accounting for around 16% of the variance in private vehicle usage and 15% of public transport usage. Other behavioural antecedents (attitude, perceived and actual constraints) were non-significant. Several explanations were already anticipated.

The relative effect of attitude and constraints on behaviour varies across behaviours and situations (Ajzen 1991, 2002). For repetitive commuting journeys, which entail the performance of automatically-driven habitual actions, it is expected that self-conscious attitudes play a minor role in predicting current behaviour. In a similar study to that of ours, but based on panel data, Thøgersen (2006) estimated the relative effect on public transport use for commuting and daily shopping journeys of attitudes, perceptions about the adequacy of public transportation to cover one's transport needs, and car ownership. He found that the influence of these variables is greatly attenuated when past behaviour is accounted for, and that past behaviour, driven by habitual (automatic) processes, is indeed a stronger predictor of current behaviour than any other antecedent. In our case, this effect may have been strengthened by the fact that we pre-selected users of private vehicles and of public transport that had already stated making a large use of these travel modes (i.e., users with strong habits). Yet, several studies report that no attitude-behaviour relation existed when travel mode habit was strong (Verplanken et al. 1998; Garvill et al. 2003; Eriksson et al. 2008). Nevertheless, the overall result is sustained by the conceptual model proposed in that individuals showing strong travel mode habits would only consider their habitual option, and hence modal alternatives would not even be assessed.

In regards to the effect of constraints on behaviour, note that in the EMQ 2006 self-reported perceived constraints were provided for non-chosen modes. There is a risk of endogeneity when constructing latent variables for non-chosen modes. Johansson et al. (2006) argue that an individual's opinion of non-chosen modes can be biased in favour of their chosen mode. In this vein, it is recognized that in surveys people tend to justify their behaviour and this generates inconsistent responses that can be attributed to the so-called "response bias" (Fuji and Gärling 2003). That is, people are prone to giving responses that excuse themselves. These issues might have contributed to the non-significant effect obtained from the latent variables reflecting people perceived constraints.

The latent variable *attitude* was estimated by means of the formative indicators "quick", "convenient", "safe", "cheap", and "comfortable". Formative or causal measurement scales allow us to rank indicators according to their contribution (i.e., item weights) to the formation of the construct. As such, causal claims can be inferred. Private vehicle users mostly valued positive traits of vehicles "convenience" and "quickness". Convenience unfolds a desire for autonomy and control expressed by the possibility to chain (unplanned) journeys. Comfort, however, had an unexpected negative impact on attitude. The monetary costs of driving, clearly a disadvantage of private vehicles, are undervalued, which is in line with findings from qualitative studies reporting a systematic underestimation of driving expenses (Gardner and Abraham 2007). Yet, most fixed costs for private vehicles (e.g., purchase costs, repairs and maintenance, road taxes, traffic fines) remain as "sunk" costs not accounted for when deciding a travel mode. This has obvious implications for pricing policies over car-related costs. First, raising the fixed costs of driving will most probably have little effect on discouraging private vehicle usage. Secondly, and for variable driving costs, either price increases are substantial or most likely they will go unnoticed. Regarding public transport use, "quickness", "convenience" and "comfort" mostly contributed to a positive attitude (in descendent order). Actually, "convenience" related to the frequency and reliability of public transport. That is, a high quality service where you do not have to wait for too long and without unexpected delays. Environmental concern had a modest, yet positive influence on attitude.

In addition, a series of binary logistic regressions were performed. This time we examined the determinants in choosing public transport modes over private ones (binary choice). Note that in this case we are not analysing travellers' actual behaviour, but rather their underlying intention to use public transport. This distinction is fairly important since intention and behaviour tend to only be correlated on a low-to-medium level (see the discussion in Fujii and Gärling 2003). At the same time, the strength of the relationships "attitude-intention" and "perceived constraints-intention" is stronger than that of "attitude-behaviour" and "perceived constraints-behaviour" (Ajzen 1991). We first regressed salient behavioural beliefs —"quickness", "frequency", "safety", "cheapness" and "comfort"—, and then habit for the private vehicle (PV-habit) was added. All predictors were significant in both cases (*p-values* < .05). It was found that behavioural beliefs alone could explain 27% of the variance in the dependent variable, while adding up PV-habit raised variance explained up to 82%. Driving habits, thus, have a significant and highly substantial negative effect on the probability of choosing public transport. Note that in this case, and contrary to the SEM results, attitudinal beliefs do entail predicting. It was found that travellers who care about "cheapness" and "safety" and consider "frequency" acceptable, are more prone to choosing public transport, whereas those valuing "quickness" and "comfort" and who have strong driving habits are more likely to choose private transport. Regarding the influence of constraints (models 3 and 4), salient constraints —"access to public transport" (PT-access), and the proxies for the level of public transport service "municipality size" and "metropolitan ring"—, explained around 21% of the variance in the dependent variable. Adding up PV-habit again raised variance explained up to 80%. "Metropolitan ring" had the greatest, and yet negative impact. It provides a measure of the distance to Barcelona city (denser public transport network). The size of the municipality of residence, which indirectly measured the level of service of public transport, also had a negative effect. These results confirm our suspicion that that the smaller the municipality of residence and the farther it is located from Barcelona, the lower the probability of using public transport is.

In conclusion, habits play a major role in explaining both actual usage of public transport modes for commuting purposes, as well as the probability of choosing public transport, which is strongly diminished by the presence of driving habits. In view of this result, in the next Section we discuss policy implications and suggest measures to both break unsustainable driving habits and to form new sustainable ones.

6.6 Policy recommendations

The results obtained from the analyses suggest that there is a need to address the habitual use of private vehicles. We therefore end this chapter by listing a series of interventions to break-down and form new habits (Table 6.20). The first come in two types: (1) those inducing deliberation, namely increasing awareness of travel mode choice (i.e., so-called "deliberation intervention"), and (2) those interrupting the automatic activation of habits through changes in the choice context (e.g., altering transport infrastructures, or offering financial incentives such as free-period tickets to try out public transport means). Interventions to form new travel habits include the provision of tailored information and feedback, and interventions creating new automatisms through goal setting —a plea for commitment and the formation of implementation intentions.

Table 6.20. Policy recommendations to break-down habits and form new ones.

Interventions to break-down habits
• Deliberation intervention
• Changes in the infrastructure (e.g., temporary road closures and withdrawal of parking spaces)
• Economic incentives (e.g., free-period ticket)
Interventions to form new habits
• Provision of tailored information and feedback
• Use of commitment devices (plea for commitment and goal setting)
• Form an implementation intention

Deliberation intervention aims to induce reasoning, that is, bring behaviour in line with attitudes and intentions. These interventions consist of self-monitoring one's own travel, usually by means of travel diaries (Verplanken et al. 1998). This forces the traveller to think about the circumstances in which the behaviour is executed. The basic premise is thus that assessing one's own travel interrupts habit. Some degree of success has been achieved. Garvill et al. (2003), for instance, noticed a temporary reduction in car-use within the experimental group, notably for car users with strong driving habits. The reason for this is that people with strong driving habits make most journeys by car, and thus it is relatively easier for them to substitute some car journeys. Notwithstanding, an increase in reasoning could not be confirmed. That is, no change in either "attitude-behaviour" or "habit-behaviour" relationships was observed. On the other hand, interventions disrupting the choice context, such as temporary road closures (Fujii et al. 2001) and the withdrawal of parking spaces (Brown et al. 2003), necessarily force a change of travel mode. In these two cases behavioural change was effectively achieved. Moreover, public transport usage was maintained because the tryout experience resulted satisfactory and so the negative perceptions held about public transport were shifted. The corollary is a simple one; *if you try it and like it, you'll probably repeat it*. This same logic underlies interventions involving financial incentives in the form of a free-period ticket to use public transport. Fujii and Kitamura (2003) achieved long-lasting effects through an intervention consisting of a one-month free bus ticket. Results showed that attitudes towards buses were more positive after the tryout and that the frequency of bus use increased, even one month after the intervention period. Moreover, a decrease in car habit was observed after the intervention. Motivation to reduce car use (i.e., personal norm) was important too (Verplanken et al. 2008). Indeed, the observed interaction between the effect of the financial incentive and that of strong personal norms is additive (Hunecke et al. 2001).

Once driving habits are interrupted, the objective is to encourage public transport usage and ultimately to avoid relapses. The provision of tailored information about public transport can help raise awareness about compelling alternatives to the car. Yet, effects on behaviour should not be expected as a result of the provision of information alone (Tertoolen et al. 1998). Both establishing a goal commitment and forming an implementation intention contribute to changing behaviour and help to avoid relapses. These two instruments are very powerful because they both operate through the formation of automatisms. By committing to a goal, people automatically feel obliged to comply to it so as to be (and to appear) consistent with their stated intention (Cialdini 1993). This reduces the effort of undertaking the new action. Even if people make goal commitments, the distance between goal setting and goal attainment is often large (Gollwitzer 1990). The formation of implementation intentions, that is, establishing a concrete plan of action specifying where, when and how actions leading to goal attainment will be carried out, provides a means to meet the commitment satisfactorily. In essence, implementation intentions are about feeling in control (Gärling and Fujii 2002), and ultimately, forming unconscious associations between the context of choice and the desired goal response (i.e., actually forming new habits). Yet, implementation intentions have the form of "When situation *x* arises, I will perform response *y*!" (Gollwitzer 1999:494).

Usually interventions to form new habits are preceded by interventions to break-down past habits. Positive results have been noticed from interventions combining financial incentives (i.e., free-period ticket) with tailored information. Notably, Bamberg (2006) reported an increase in public transport use from 18% to 47%. Matties et al. (2006), on the other hand, combined a free-period ticket with a plea for commitment that they actually will tryout public transport. The influence of personal norm (i.e., the moral motivation to change) was also measured. The overall effects of the intervention were few. Yet, the incentive interrupted the habitual response and did have a direct effect on behaviour, while the motivation to change was strengthened by the commitment. That is, only those who had a strong moral motivation to change car use and who had committed to doing so still used public transport 23 weeks after the intervention. Bamberg's (2000) intervention combined goal commitment, namely to tryout (just once) a special public transport offer, with stimulating subjects to form an implementation intention. Results showed that implementation intentions significantly increased the probability that the subject would try out the special offer. Finally, Eriksson et al. (2008) noticed positive and lasting results of so-called "deliberation intervention" in combination with commitment and the formation of an implementation intention. The effectiveness of deliberation intervention was raised by commitment and implementation intention, and the intervention was particularly successful for car users with a strong car habit and a strong moral motivation (or personal norm) to reduce personal car use.

In summary, some degree of success has been achieved by means of just one intervention. Yet, what seems to work best is combining several complementary interventions. Notably, combining interventions with different functions favours the creation of synergic effects (i.e., merging interventions which break-down habits with those that form new ones). Long-lasting effects on behaviour are achieved by interventions that encourage tryouts and form new automatisms. Tailored information can ease the process of changing the established behaviour, although radical or lasting changes should not be expected as a result of information provision alone. Finally, those who respond better to interventions are people with strong habits and strong motivations to change their current behaviour. A great deal of studies discuss ways to motivate people to perform sustainable behaviours, such as refraining from driving (e.g., de Groot and Steg 2008; Fujii 2006; Lindenberg and Steg 2007; O'Connor 2002; de Young 1996).

Appendix

A6.1 Indicators for the latent variables

An extensive review of studies was undertaken in order to assess currently used indicators for the latent variables of interest (Table A6.1).

Table A6.1. Studies and currently used indicators for the latent variables of interest.

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Abrahamse et al. (2009)	TPB & NAM	• *Attitude (toward car use)* (7 items alike in total): like driving to work, driving to work allows a flexible schedule, etc. (agreement–disagreement). • *Perceived constraints (PBC over car use reduction)* (4 items): reduce car use/use alternatives possible (yes–no/difficult–easy). • *Behaviour (car use for commuting)*: Self-reported percentage of commuting journeys by car (typical commute).	Hierarchical regression analyses	Car commuters
Bamberg et al. (2007)	TPB & NAM	• *Attitude (toward public transport use)* (2 items): use public transport instead of the car for daily journeys (bad–good/ unpleasant–pleasant). • *Perceived constraints (PBC over public transport use)* (2 items): use public transport instead of the car (daily routes) (impossible–possible). Use public transport next weeks (daily journeys) (unsure–sure). • *Habit (past public transport use):* same behavioural indicators. • *Behaviour (public transport use)* (3 items): self-reported public transport use, ratio number of trips by public transport/total number of trips (one 1-day mobility-diary & three 14-day mobility diaries of all trips conducted at least 2 times a week). Self-reported frequency of use (last 4 weeks) (always–never).	SEM	(Typical) daily journeys
Bamberg & Möser (2007)	TPB & NAM + 'moral' feelings	Meta-analysis of 46 studies (period 1995–2006) about proenvironmental behaviour (e.g., travel mode choice, recycling, water conservation, energy saving, green consumerism). TPB and NAM constructs operationalised as described in the theories (include attitude, PBC and behaviour).	Meta-analytic SEM	Meta-analysis of 46 studies

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Bamberg & Schmidt (1999)	TPB	• *Attitude (toward travel modes, bus usage in particular)*: *Behavioural beliefs* (5 items) include bus (car/bicycle) commute to campus next time (1) cheap, (2) quick, (3) comfortable, (4) without stress, (5) flexible (likely–unlikely). *Attitude* (2 items) includes take the bus (use my car/bicycle) next time (bad–good/unpleasant–pleasant). • *Perceived constraints (PBC over travel modes, bus usage in particular)*: *Control beliefs* (4 items) include next time I go to campus will (1) be good bus connection, (2) know schedule, (3) have car access (4) distance will not prevent bike use (likely–unlikely). *PBC* (2 items) includes bus (car/bicycle) commute to campus next time (easy–difficult), freedom to take the bus (my car/bicycle) commute to campus next time (high–low). • *Actual constraints (over bus usage)*: analysis of the objective infrastructural conditions (students perceived public transport as slow, inflexible, uncomfortable, expensive, and as more stressful than the car or bike). • *Behaviour (travel mode use)*: self-reported travel mode (first commuting journey apartment–campus).	SEM	Panel study, students, commuting journeys
Carrus et al. (2008)	MGB (TPB + "habit" & anticipated emotions & desire)	• *Attitude* (8 items): use public transportation instead of the car for daily commute (good–bad/ unpleasant–pleasant/appropriate–inappropriate/right–wrong/ pleasant–unpleasant/boring–funny/ harmful–beneficial/useful–useless). • *Perceived constraints (PBC)* (2 items): use public transportation instead of the car for daily commute (difficult–easy/complicated–simple). • *Habit:* self-reported frequency of use public transportation instead of the car to commute (last 2 weeks) (never–always). • *Behaviour*: not measured, instead *behavioural intentions* (unlikely–likely/undecided–decided).	Multiple regression & SEM	
Chen & Chao (2011)	TPB + "habit" & TAM	• *Attitude* (*toward public transport)* (7 items): take the KMRT to commute next time (1) cheap, (2) fast, (3) comfortable,	SEM	Students, commuting journeys

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Chen & Chao (2011)	TPB + "habit" & TAM	(4) convenient, (5) safe, (6) good, (7) pleasant (disagree–agree). • *Perceived constraints (PBC over public transport use)* (2 items): take the KMRT easy/ high freedom (disagree–agree). • *Habit:* self-reported frequency of use of the motorcycle/car to commute (1-week), average number of days (1–5 days). • *Behaviour*: not measured in this study, instead s*witching intention toward public transport* strong/ high likelihood/make an effort.	SEM	Students, commuting journeys
Eriksson et al. (2008)	"Habit" & personal norm	• *Habit:* self-report index of habit strength (SRHI) (12 items). • *Behaviour*: (change) number of car trips (passenger/driver).	Regression model	
Gardner (2009)	TPB (intention) *vs.* "habit"	• *Actual constraints*: respondents with car access (preceding week). • *Habit:* self-report index of habit strength (SRHI). • *Behaviour*: self-reported public transport use, ratio number of trips by public transport/total number of commuting trips to campus (preceding week).	Multiple regression	Prospective design (2 surveys 1 week difference)
Harland et al. (1999)	TPB & NAM	• *Attitude* (*toward using alternatives to the car)*: (negative–positive). • *Perceived constraints (PCB over using alternatives to the car)*: possibility (next 6 months) (likely–unlikely). • *Habit (using alternatives to the car):* self-reported frequency (past 6 months) (never–always). • *Behaviour (using alternatives to the car)*: self-reported behaviour.	Hierarchical Regression Analyses	Self-administered survey, general population (intervention)
Heath & Gifford (2002)	TPB & NAM	• *Attitude (toward bus usage)*: *Behavioural beliefs* (6 items) include (1) costs, (2) convenience, (3) travel time, (4) comfort, (5) flexible schedule, (6) take control over one's time (unimportant–important). *Attitude* (1 item) includes like taking the bus (driving) to campus (disagree–agree). • *Perceived constraints (PCB over bus usage)*: *Control beliefs* (2 items) include live near a good bus route, know the bus schedule not (facilitating–facilitating). *PCB* (1 item) includes difficulty using the bus to commute to	Hierarchical Regression	Longitudinal approach (2 surveys, namely before & after), university students, commuting journeys (intervention)

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Heath & Gifford (2002	TPB & NAM	campus (difficult–easy). *[Subjective probabilities of behavioural and control beliefs were further measured.]* • *Behaviour*: self-reported percentage of occasions students took the bus to commute to campus, compared to other modes (previous 10 school days).	Hierarchical Regression	Longitudinal approach (2 surveys, namely before & after), university students, commuting journeys (intervention)
Johansson et al. (2006)	General attitudes & personality traits	• *General attitude (other areas of daily life)* (5 latent variables constructed): (1) comfort, (2) convenience, (3) flexibility, based on attitudinal indicator variables. (4) safety and (5) environmental concern, based on behavioural indicator variables (i.e., recycling behaviours and "safe" driving). •*Actual constraints (commuting Stockholm–Uppsala)*: only three different modes realistic (car, train and bus) and no usage restrictions. • *Behaviour (travel mode choice, car vs. public transport)*: self-reported travel mode.	SEM + multinomial probit	Self-administered survey, commuters between Stockholm and Uppsala (Sweden)
Klöckner & Blöbaum (2010)	TPB + "habit", NAM & ITB	• *Attitude*: not measured, instead *intention* to use public transport instead of the car for frequent journeys university/ shopping/leisure/ work (next 7 days) (disagree–agree). • *Perceived constraints (PCB over using public transport instead of the car)* (2 items): forced to use the car for frequent trips/difficult for frequent trips (disagree–agree). •*Actual constraints*: car access (never–always). • *Habit:* (1) response frequency measure (RFM) (5 items), (2) self report habit index (SRHI) (6 items). • *Behaviour (car use)*: self-reported car use, ratio trips by car/ total number of trips, 4 frequent trips recorded (university, most frequent shopping location, most frequent leisure activity, work) (1-week online logbook).	SEM	Students, four frequent journeys
Klöckner & Matthies (2004)	NAM & "habit"	• *Habit (car use):* response frequency measure (RFM) (5 items). "Car" and "motorbike" counted as "car". • *Behaviour*: self-reported public transport use, ratio commuting trips by public transport/ total number of commuting trips by car and public transport (4-weeks logbook).	Binary logistic regression	Commuting journeys

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Oreg & Katz-Gerro (2006)	TPB & VBN + "postmate-rialism" & "harmony"	• *Attitude (toward the environment)*: environmental concern (2 items), perceived threat of air pollution by cars to them-selves/their families (2 items) (not dangerous–dangerous). • *Perceived constraints (PCB over the environment)* (2 items): (1) difficulty to do much about the environment, (2) no point in doing what I can for the environment unless others do (disagree–agree). • *Behaviour (proenvironmental behaviour)*: self-reported frequency in which respondents cut back on driving a car for environmental reasons (never–always). Other behaviour analysed include recycling and environmental citizenship.	SEM	International Social Survey Programme (ISSP) [includes Spain (N = 958)]
Popuri et al. (2011)	Attitudes	• *Attitude (toward public transport)* (23 statements condensed into 6 factors): (1) need for reliable and stress-free commute, (2) need for privacy and comfort, (3) dynamic work schedule and complexity of trips, (4) tolerance to walking and waiting, (5) attitude to importance of public transportation, (6) perceived safety. •*Actual constraints: level of service* includes travel times (in-vehicle and out-of-vehicle time) and costs (public transport fare and car operating cost) for public transport and car (5 items). *Car access* includes number of vehicles in HH, number of workers in HH (2 items). *City-to-city commuter* and *suburb-to-city commuter*. • *Behaviour (public transport choice)*: self-reported travel mode (1=public transport, 0=car).	Binary logistic regression	General survey, commuting journeys
Steg (2005) (Study 2)	TPB & others	• *Attitude (toward car use)*: *instrumental motives* (16 items) include commuting by car during rush hours (1) cheap, (2) comfortable, (3) easy, (4) environmentally friendly, (5) fast, (6) independent, (7) private and (8) safe (unlikely–likely/not important–important). For each aspect, scores on both likelihood and importance were averaged. Other motives analysed involve symbolic and affective motives. • *Behaviour (car use)*: self-reported car use, ratio number of commuting trips by car/commuting trips.	Multiple Regression Analysis	car commuters use during rush hours

Author	Behavioural theory/ies[1]	Constructs of interest	Method	Sample details
Tanner (1999)	ITB & others	• *Perceived constraints (factors impeding to reduce driving frequency)* (7 items): (1) need to transport material, (2) reduced time budget, (3) inconvenience, (4) low frequency of public transport, (5) transfers necessary with public transport, (6) cost, (7) colleagues opinion, apply no/yes. Scores combined in an index of number of perceived behavioural barriers. •*Actual constraints (driving frequency)* (3 items): (1) residence location (rural/urban), (2) income, (3) age. • *Behaviour (index of driving frequency)*: self-reported travel mode use for commuting, shopping, leisure travel. Car and motorcycle options (driver/passenger) were processed into an index of driving frequency.	Multiple regression analyses	Commuting, shopping and leisure journeys
Thøgersen (2006)	TPB + “habit”	• *Attitude (toward public transport use)* (3 item): taking the bus/train to work/shopping (meaningful–meaningless/right–wrong/beneficial–harmful). • *Perceived constraints (PBC over public transport use)*: how do you usually go to work/shopping, would it be possible to take bus/train to work/shopping (yes–no) (2 items). Scores processed into a three-point index. •*Actual constraints*: car ownership. • *Habit(public transport use):* self-reported behaviour in previous survey waves. • *Behaviour (public transport use):* self-reported frequency of use to (1) commute, (2) shop (never–always).	SEM	panel survey, commuting and shopping journeys

A6.2 Descriptive analysis

Pearson's correlations for the variables included in the SEM analysis, model 1 (Table A6.2) and model 2 (Table A6.4), and the logistic models (Table A6.6). In addition, means, standard deviations, skewness and kurtosis estimates and standard errors for the variables included in the SEM analysis are shown in Table A6.3 (model 1) and Table A6.5 (model 2).

Table A6.2. Pearson's correlations (Model 1, users of private vehicles).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. PV-USE[1]	1											
2. Quick	.08**	1										
3. Convenient	.10**	.31**	1									
4. Safe	-.05*	,13**	.16**	1								
5. Cheap	.01.	.21**	.15**	.20**	1							
6. Comfort	-.04*	.21**	.20**	.29**	.13**	1						
7. PV-Habit	.41**	.11**	.13**	-.03	.00	.01	1					
8. No PT alternative	.03	.04	.06**	.04*	-.02	-.10**	.07**	1				
9. PT (low) frequency	.05*	.17**	.10**	.08**	.06**	.05*	.09**	.45**	1			
10. PT many transfers	.03	.23**	.20**	.13**	.09**	.14**	.07**	.30**	.46**	1		
11. Municipality size	.08**	-.04*	.01	.00	-.07**	-.01	.03	.13**	.13**	-.02	1	
12. Metropolitan ring	.02	-.06**	.01	.02	-.05*	.00	-.01	.10**	.07**	-.02	.66**	1

Note: (**) correlation significant at p-value < 0.01, (*) correlation significant at p-value < 0.05.

Table A6.3. Means, standard deviations, skewness and kurtosis (Model 1, users of private vehicles).

	Mean	Stand. deviation	Skewness	*S.E.* Skewness	Kurtosis	*S.E.* Kurtosis
1. PV-USE[1]	.72	.38	-.975*	.049	-.646*	.098
2. Quick	6.11	4.17	-.632*	.049	-1.364*	.098
3. Convenient	5.64	4.16	-.466*	.049	-1.531*	.098
4. Safe	2.45	3.74	.984*	.049	-.829*	.098
5. Cheap	1.77	3.37	1.494*	.049	.473*	.098
6. Comfort	5.35	4.16	-.358*	.049	-1.620*	.098
7. Habit-PV[2]	.80	.40	-1.501*	.049	.253*	.098
8. No PT alternative	5.65	4.34	-.387*	.049	-1.645*	.098
9. PT (low) frequency	4.95	4.25	-.145*	.049	-1.742*	.098
10. PT many transfers	3.84	4.19	.309*	.049	-1.698*	.098
11. Municipality size[3]	2.50	.92	.103*	.049	-.821*	.098
12. Metropolitan ring[4]	2,45	0,72	-.904*	.049	-.536*	.098

Notes: (*) significant at *p-value* < 0.05. (1) Mean value of the variable "PV-USE" is expressed in 1%. (2) The variable "PV-Habit" is categorical and refers to self-reported frequency of use of private vehicles (0 = "never or almost never", 1 = "sometimes", 2 = "often"). (3) Municipality size is also categorical (1 = "Barcelona", 2 = "> 50,000 hab.", 3 = "10,000-50,000 hab.", 4 = "< 10,000 hab."). (4) Metropolitan ring is categorical (1 = "Barcelona", 2 = "Rest of first ring", 3 = "Second ring"). (*N* = 2,500).

Table A6.4. Pearson's correlations (Model 2, users of public transport).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. PT-USE	1											
2. Quick	-.02	1										
3. PT frequency	-.02	.49**	1									
4. Reliability and punctuality	-.05**	.42**	.62**	1								
5. Distance stops/stations	.03	.31**	.37**	.36**	1							
6. Safe	.04*	.22**	.28**	.27**	.32**	1						
7. Cheap	-.01	.19**	.22**	.22**	.24**	.35**	1					
8. Comfort	-.08**	.24**	.32**	.35**	.26**	.31**	.27**	1				
9.Environment	.02	.24**	.27**	.25**	.28**	.40**	.39**	.28**	1			
10. PT-Habit	.39**	-.01	.03	-.05*	.07**	.01	.01	-.10**	.03	1		
11. No parking or congestion	.08**	.16**	.15**	.13**	.20**	.26**	.24**	.14**	.36**	.13**	1	
12. Vehicle ownership	-.02	.05*	.01	.02	.00	-.01	-.10**	.01	-.10**	-.06**	-.31**	1

Note: (**) correlation significant at *p-value* < 0.01, (*) correlation significant at *p-value* < 0.05.

Table A6.5. Means, standard deviations, skewness and kurtosis (Model 2, users of public transport).

	M	SD	Skewness	*S.E. Skewness*	Kurtosis	*S.E. Kurtosis*
1. USE PT[1]	.53	.42	-.121*	.049	-1.635*	.098
2. Quick	5.49	4.05	-.452*	.049	-1.514*	.098
3. PT frequency	5.24	4.00	-.378*	.049	-1.573*	.098
4. Reliability and punctuality	5.16	4.03	-.336*	.049	-1.613*	.098
5. Distance stops/stations	5.46	3.92	-.483*	.049	-1.440*	.098
6. Safe	4.18	4.20	.118*	.049	-1.808*	.098
7. Cheap	4.53	4.14	-.032	.049	-1.761*	.098
8. Comfort	4.09	4.04	.122*	.049	-1.739*	.098
9. Environment	5.21	4.16	-.310*	.049	-1.671*	.098
10. PT-Habit[2]	.80	0.40	-1.501*	.049	.253*	.098
11. No parking or congestion	6.07	4.24	-.598*	.049	-1.443*	.098
12. Vehicle ownership[3]	.64	.48	-.580*	.049	-1.665*	.098

Notes: (*) significant at *p-value* < 0.05. (1) Mean value of the variable "PT-USE" is expressed in 1%. (2) The variable "PT-Habit" is categorical and refers to self-reported frequency of use of private vehicles (0 = "never or almost never", 1 = "sometimes", 2 = "often"). (3) The variable "Vehicle ownership" is also categorical (0 = "yes", 1 = "no"). (*N* = 2,500).

Table A6.6. Pearson's correlations (logit models 1 and 2).

	1.	2.	3.	4.	5.	6.
1. Greater use PV *vs.* PT[1]	1					
2. Quickness	-.11**	1				
3. Safety	.20**	.14**	1			
4. Cheapness	.35**	.14**	.31**	1		
5. Comfort	-.16**	.23**	.26**	.14**	1	
6. PV-Habit[2]	-.83**	.10**	-.15**	-.26**	.13**	1

Note: (**) correlation significant at *p-value* < 0.01.

Table A6.7. Pearson's correlations (logit models 3 and 4).

	1.	2.	3.	4.	5.
1. Greater use PV *vs.* PT	1				
2. PT-access	.13**	1			
3. Municipality size	-.36**	-.14**	1		
4. Metropolitan ring	-.39**	-.13**	.76**	1	
5. PV-habit	-.83**	-.11**	.31**	.34**	1

Note: (**) correlation significant at *p-value* < 0.01.

7 Conclusions

This Thesis evolves around the fundamental question of how to reach transport sustainability by changing daily travel behaviour. For this purpose, different perspectives were taken to shed light on the antecedents of travel choices and behaviour (with a focus on travel mode choices and commuting transport in general) in order to inform the design of effective environmental policy for transport. For this purpose a practical vision was kept and the theoretical insights gained were applied to, and contrasted with, the case study of the Barcelona Metropolitan Region (BMR).

The Thesis includes two theoretical chapters looking at travel behaviour antecedents through three different, yet complementary, lenses; planning, economic and behavioural, developing a conceptual framework and informing policy. In addition, two empirical chapters include a classification analysis and the development and testing of a behavioural model of travel mode choices.

Chapter 3 provided the framework for the rest of the Thesis. As such, a broad review was offered that covered insights from planning, economic and behavioural studies, studying determinants of soaring unsustainable travel and commuting behaviour. Travel behaviour cannot be explained on the basis of urban form features and spatial planning only. Economic studies identify socioeconomic factors to explain transportation choices. Furthermore, for choices that deviate from economic rationality, behavioural approaches can provide alternative explanations. Insights gained were organised in a framework that reflected the relation GHG emissions-commuting-underlying factors. The framework allowed for the analysis of the Barcelona Metropolitan Region (BMR) case study and the subsequent development of a policy strategy. The framework consisted of the two core aspects of commuting patterns— increased commuting distances and car usage— driven by five underlying factors —built-up environment, transportation factors, market factors, socioeconomic factors and behavioural factors. Factors that stood out in the BMR analysis involve a combination of constraints including accessibility, or a lack of accessibility, to adequate public transport in certain low-density areas (planning obstacles), increasing housing prices in the region's centre (Barcelona) and surroundings (in the rest of the first metropolitan ring), limited information about permanent job and housing offers and high relocating costs (economic obstacles), as well as marked individual preferences for certain low-density locations and the car (including car habits), which deviate from rational behaviour (behavioural obstacles). Specific planning, economic and behavioural strategies were connected to these factors and combined into three distinct policy packages. Together, these policy packages provided an integral strategy aimed at containing dispersion, discouraging driving, improving access to public transport alternatives and breaking-down driving habits. This involves (1) taxing low-density building projects (both residential and business/industrial) in order to internalize the associated environmental cost of increased driving, (2) facilitating relocation for living and working close by and in well communicated areas, (3) investing in public transport (mainly expanding the network), (4) increasing driving costs (economic and social), and (5) dealing with traveller's bounded rationality regarding workplace and residence location choices as well as travel mode choices. It was found that behavioural aspects of travellers are comparatively less researched in general and in particular within the BMR. This is particularly true with regards to biased workplace and residence location choices, pro-car attitudes and driving habits and since these behavioural aspects can undermine the effectiveness of any policy effort, further research is encouraged.

Consequently, in *Chapter 4* the relevance of insights from behavioural economics to the study of travel behaviour was analysed. It was argued that travel behaviour and transport choices in general are often better described by behavioural approaches as most daily travel-related choices are made under uncertainty and travellers are particularly prone to social and self-identity concerns. The chapter offers a review summarizing empirical evidence on biased travel choices due to bounded rationality and social preferences and ends with relevant policy implications. It takes into account biases towards both long-term travel-related choices —residential and employment location, owning a driving license and car purchasing— and short-term or daily travel choices — choice of destination, departure time, route and travel mode. Results show that travellers are prone to the so-called affect heuristics, they tend to stick to their choices, they incur mental accounting, they self-select residential locations that favour their travel mode preferences and they are bad at computation and misinterpret information, overvaluing recent, pertinent events. Moreover, learning does not guarantee more optimal choices in the medium-term; instead, travellers tend to fall into routines and habits when it comes to their daily travel behaviour. Nevertheless, travellers are generous and caring (i.e. altruists), or at least appear so in front of others as they comply with social norms and gain reputation from this. These systematic deviations from rational behaviour can alter the effectiveness of traditional environmental policy focused on travel behaviour change. It is suggested to rely more on new types of policies being able to account for this irrational behaviour, such as policy defaults, normative messages, policy frames (e.g., which frames for pricing mechanisms are more compelling, "environmental penalties" *versus* the "right to pollute"), and social punishment (e.g., through the usage of public disclosure). Besides new types of instruments, it is also proposed to revise the optimal size of environmental correcting taxes in particular in the presence of polluting habits, norms and status-seeking behaviour.

Chapter 5 dealt with heterogeneous travel behaviour based on travel mode choice habits. Most daily journeys are repetitive and habits are a key factor in modal choice. Cluster procedures were used to classify travellers from the BMR according to self-reported frequency of use of travel modes. This frequency-based indicator of habit was improved to capture habit complexity through the addition of several theoretically-based criteria. In particular, three criteria were imposed, namely high choice context stability, little use of travel information and habit generalisation. Modal profiles were completed with socioeconomic, demographic and other travel-related information so as to trace the origin of habits in widely recognised determinants of travel mode choice. Data were retrieved from a general mobility survey to ensure that the types extracted were representative of the population of the BMR. This straightforward approach resulted in the identification of seven relevant types of travellers exhibiting significant differences in their modal behaviour and habits. Of these seven types, habitual users of the motorcycle or *Motorcycle enthusiasts* and habitual users of the car or *Car drivers* require specific policy interventions to support sustainable driving habits. A third type, namely *Potential mode switchers*, can be considered a relatively easy target for environmental-transport policies; they are mainly car users who are also familiar with public transport. This chapter highlights those groups' specific requirements and can thus support the design of policies tailored to their specific needs.

Lastly, in *Chapter 6*, in order to theoretically and empirically test the relative influence of several antecedents of travel mode choice and usage, a conceptual model was proposed that integrated the insights gained in previous chapters. This model combined the main concepts from the *ipsative theory of behaviour* (ITB) and the *theory of planned behaviour* (TPB) with the notion of *habit*. It accounted for people's current preferred mode of transport (i.e. attitudes) and the constraints hampering the use of alternatives (i.e. more sustainable modes), namely actual and perceived choice constraints and habits. The model was tested on a sample of travellers in the BMR using the data from the general mobility survey EMQ 2006. Structural equation modelling (SEM) and binary logistic regression procedures were both used to test the formulated hypotheses, as well as the models' explanatory capacity. It was found that habit alone explained as much as 16% of the variance in private vehicle usage and 15% in public transport usage. Other antecedents examined (i.e. attitude and actual and perceived choice constraints) turned out to be non-significant. In view of this result, policy implications were discussed. In particular, recommendations were made on how to break down unsustainable driving habits and promote public transport usage. The former can be achieved by making people more conscious of their (unconscious) travel choices. This means persuading travellers to deliberate over alternatives to their habitual choices, so-called "deliberation intervention". Deliberation can also be promoted by changing the context in which choices are made, for instance, through temporary road closures or withdrawal of parking spaces. Alternatively, unsustainable habits can be broken using financial incentives. For example, policies involving the provision of a free-period ticket to try out public transport can be effective in achieving long-lasting modal changes. Tailored information can ease the process of changing the established behaviour, although radical or lasting changes should not be expected as a result of information provision alone. Instead, it is more effective to encourage people to design a plan to comply with their newly formed intentions.

Overall, the chapters composing this Thesis have covered a wide range of determinants or antecedents of travel behaviour. Some were studied at a theoretical level, while others could be empirically tested and together they encompassed a wide range of travel-related choices. Various constraints hindering more sustainable choices were also analysed; actual constraints forcing increased journey distances or limiting access to alternatives to the private vehicle (i.e. urban form obstacles) and for which strategic planning solutions are required; and perceived situational constraints for which solutions are trickier and behavioural instruments may be more compelling. Furthermore, habits were studied in depth given their relevance to daily travel behaviour and particularly to travel mode choices. The insights gained served to derive implications for policy, as well as to provide guidance for the design of new and context-specific instruments. The study of these antecedents further involved revising several alternative behavioural models and their underlying assumptions. As such, a fairly complete view of how to induce a change in daily travel behaviour to make it more sustainable was offered.

In what follows, a summarised view of the concluding remarks is provided for each chapter in bullet point form:

Chapter 3

- Planning and economic policies support those who want to drive less, as well as those who are constrained by income. Yet, policy limits exist for social groups with pro-car attitudes and strong preferences for low-density sites.
- Behavioural policies aimed at changing the attitudes and habits of *pro-car* user groups can be very effective in discouraging unsustainable driving.

Chapter 4

- Behavioural research highlights a wide range of behavioural biases interfering at all stages of decision-making concerning travel-related choices.
- Policy needs to account for those biases and design alternative instruments.

Chapter 5

- Classification procedures are useful to identify targetable transport user groups with special policy requirements (e.g., habitual users of private vehicles); while specific interventions required are relatively intensive and personalised.

Chapter 6

- Past travel behaviour and habits have the greatest influence on people's daily travel behaviour in the BMR.
- Policy interventions to break unsustainable driving habits and to form new, sustainable ones are necessary.

From these remarks, and from the previous discussion, several lines for future research can be drawn.

1. Transport user groups displaying strong pro-car attitudes are largely unaffected by traditional policy interventions. Some work has been done to assess the effectiveness of psychological strategies *versus* traditional ones in other areas of environmental research (e.g., recycling), but further research is necessary in the particular case of travel behaviour.
2. Habits are a key factor in travel mode choice. So far, a systematic research of interventions to dissolve and form habits has not been undertaken. This step is necessary in order to contrast the relative effectiveness of different policy interventions.
3. The subjective part of mobility is not well captured in general mobility surveys. Given the relevance of people's perceptions, attitudes, normative and self-image concerns, habits and environmental or altruistic motives, it is a challenge for the design of such surveys to include all of these factors.
4. In the particular case of the BMR, these behavioural issues are just starting to be considered. There are thus promising opportunities to build context-specific knowledge in this direction. Notably, experimental research is missing.
5. Finally, political feasibility and affordability of proposed policy measures is missing. Further research should address these issues.

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References

Aarts H, Dijksterhuis A (2000a) Habits as knowledge structures: Automaticity in goal-directed behavior. Journal of Personality and Social Psychology 78:53–63.

Aarts H, Dijksterhuis AP (2000b) The automatic activation of goal-directed behaviour: the case of travel habit. Journal of Environmental Psychology 20:75–82.

Aarts H, Verplanken B and van Knippenberg A (1998) Predicting behavior from actions in the past: repeated decision making or a matter of habit? Journal of Applied Social Psychology 28(15):1355–1374.

Abrahamse W, Steg L, Gifford R, Vlek C (2009) Factors influencing car use for commuting and the intention to reduce it: A question of self-interest or morality? Transportation Research Part F 12:317–324.

Abrahamse W, Steg L, Vlek C, Rothengatter T (2007) The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. Journal of Environmental Psychology 27:265–276.

Ahn N, De La Rica S, Ugidos A. 1999. Willignes to move for work and unemployment duration in Spain. Economica 66:335–357.

Ajzen I (1985) From intentions to actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann, (Eds.), Action control: From cognition to behaviour, (pp. 11−39). Heidelberg, Springer Series in Social Psychology.

Ajzen I (1991) The Theory of Planned Behavior. Organizational Behavior and Human Decision Processes 50:179−211.

Ajzen I (2002) Residual effects of past on later behavior: Habituation and reasoned action perspectives. Personality and Social Psychology Review 6(2):107−122.

Alberich J (2010) L'ús de l'espai. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB). Papers 51:28–43.

Alpizar F, Carlsson F, Johansson-Stenman O (2008) Anonymity, reciprocity, and conformity: Evidence from voluntary contributions to a national park in Costa Rica. Journal of Public Economics 92(5-6):1047–1060.

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

Anable J, Gatersleben B (2005) All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. Transportation Research Part A 39:163–181.

Anderson JC, Gerbing DW (1988) Structural equation modelling in practice: A review and recommended two-step approach. Psychological Bulletin 103(3):411−423.

Anderson WP, Kanaroglou PS, Miller EJ (1996) Urban form, energy and the environment: A review of issues, evidence and policy. Urban Studies 33(1):7−35.

Andreoni J (1989) Giving with impure altruism: Applications to charity and Ricardian equivalence. Journal of Political Economy 97, 1447–1458.

Andreoni J, Petrie R (2004) Public goods experiments without confidentiality: A glimpse into fund-raising. Journal of Public Economics 88:1605–1623.

Antolín P, Bover O (1997) Regional migration in Spain: The effect of personal characteristics and of unemployment, wage and house price differentials using pooled cross-section. Oxford Bulletin of Economics and Statistics 59(2):215–235.

Ariely D (2009) Predictability irrational: The hidden forces that shape our decisions. United States (US), Harper-Collins Publishers.

Aronsson T, Johansson-Stenman O (2008) When the Joneses' consumption hurts: Optimal public good provision and nonlinear income taxation. Journal of Public Economics 92:986–997.

Artís M, Romaní J, Suriñach J (2000) Determinants of individual commuting in Catalonia, 1986–91: Theory and empirical evidence. Urban Studies 37(8):1431–1450.

Asensio J (2002) Transport mode choice by commuters to Barcelona's CBD. Urban Studies 39(10):1881–1895.

ATM (2007) EMQ 2006 de la Regió Metropolitana de Barcelona: Dimensió subjectiva de la mobilitat. Retrieved from http://www.atm.cat/web/ca/veure.php?pdf=ca/_dir_EMQ_rmb/02_DIMENSIO_SUBJECTIVA&h=770.

ATM (2011) Vuitè informe de seguiment del PDI 2001-2010 (April 2011). Retrieved from http://www.atm.cat/web/pdf/ca/_dir_pdi/8e_informe_seguimentPDI/files/8e_informe_seguimentpdi.pdf.

Avineri E (2004) A Cumulative Prospect Theory approach to passengers behavior modeling: Waiting Time Paradox revisited. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 8(4):195–204.

Avineri E (2012) On the use and potential of behavioural economics from the perspective of transport and climate change. Journal of Transport Geography 24:512–521.

Avineri E, Bovy P (2008) Identification of parameters for a prospect theory model for travel choice analysis. Transportation Research Record 2082:141–147.

Avineri E, Goodwin P (2010) Individual behaviour change: Evidence in transport and public health. Project Report. Department for Transport, London. University of the West of England. Bristol, UK.

Avineri E, Prashker J (2004) Violations of Expected Utility Theory in Route-Choice Stated Preferences: Certainty Effect and Inflation for Small Probabilities. Transportation Research Record 1894:222–229.

Avineri E, Prashker JN (2003) Sensitivity to Uncertainty: Need for a Paradigm Shift. Transportation Research Record 1854/2003:90–98.

Avineri E, Prashker JN (2005) Sensitivity to travel time variability: Travelers learning perspective. Transportation Research Part C 13:157–183.

Avineri E, Prashker JN (2006) The impact of travel time information on travelers' learning under uncertainty. Transportation 33:393–408.

Avineri E, Waygood EOD (2013) Applying valence framing to enhance the effect of information on transport-related carbon dioxide emissions. Transportation Research Part A 48:31–38.

Axhausen KW, Scott DM, König A, Jürgens C (2001) Locations, commitments and activity spaces. Paper presented at the Survive Workshop, Bonn, December 2001.

Bagozzi RP (1994) Structural equation models in marketing research: Basic principles. Principles of Marketing Research 3(1):7–385.

Baldasano JM, Soriano C, Boada L. 1999. Emission inventory for greenhouse gases in the city of Barcelona, 1987-1996. Atmospheric Environment 33:3765–3775.

Bamberg S (2000) The promotion of new behavior by forming an implementation intention: Results of a field experiment in the domain of travel mode choice. Journal of Applied Social Psychology 30(9):1903−1922.

Bamberg S (2006) Is a residential relocation a good opportunity to change people's travel behavior? Results from a theory-driven intervention study. Environment and Behavior 38(6):820−840.

Bamberg S, Ajzen I, Schmidt P (2003) Choice of travel mode in the Theory of Planned Behavior: The roles of past behavior, habit, and reasoned action. Basic and Applied Social Psychology 25(3):175−187.

Bamberg S, Fujii S, Friman M, Gärling T (2011) Behaviour theory and soft transport policy measures. Transport Policy 18:228–235.

Bamberg S, Hunecke M, Blöbaum A (2007) Social context, personal norms and the use of public transportation: Two field studies. Journal of Environmental Psychology 27:190–203.

Bamberg S, Möser G (2007) Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. Journal of Environmental Psychology 27:14–25.

Bamberg S, Schmidt P (1998) Changing travel-mode choice as rational choice: Results from a longitudinal intervention study. Rationality and Society 10(2):223−252.

Bamberg S, Schmidt P (1999) Regulating transport: Behavioural changes in the field. Journal of Consumer Policy 22:479–509.

Bamberg S, Schmidt S (2003) Incentives, morality or habit? Predicting students' car use for university routes with the models of Ajzen, Schwartz and Triandis. Environment and Behavior 35:264–285.

Banister D (2008) The sustainable mobility paradigm. Transport Policy 15:73–80.

Banister D, Stead D, Steen P, Åkerman J, Dreborg K, Nijkamp P, Schleicher-Tappeser R (2000) European transport policy and sustainable mobility. London/New York, Spon Press, Taylor & Francis Group.

Baron RM, Kenny DA (1986) The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 51:1173–1182.

Barr S, Shaw G, Coles T (2011) Times for (Un)sustainability? Challenges and opportunities for developing behaviour change policy. A case-study of consumers at home and away. Global Environmental Change 21:1234–1244.

Barron G, Erev I (2003) Small feedback-based decisions and their limited correspondence to description-based decisions. Journal of Behavioral Decision Making 16:215–233.

Batley R (2007) Marginal valuations of travel time and scheduling, and the reliability premium. Transportation Research Part E 43:387–408.

Bayarma A, Kitamura R, Susilo YO (2007) Recurrence of daily travel patterns: stochastic process approach to multiday travel behavior. Transportation Research Record 2021:55–63.

Beirão G, Sarsfield-Cabral JA (2007) Understanding attitudes towards public transport and private car: A qualitative study. Transport Policy 14(6):478–489.

Belsley DA (1991) Conditioning diagnostics: Collinearity and weak data in regression, New York (NJ), John Wiley & Sons.

Ben-Akiva ME, Lerman SR (1985) Discrete choice analysis: Theory and applications to travel demand. Cambridge (MA), MIT Press.

Ben-Elia E, Erev I, Shiftan Y (2008) The combined effect of information and experience on drivers' route-choice behaviour. Transportation 35:165–177.

Bentler PM, Speckart G (1979) Models of attitude-behavior relations. Psychological Review 86:452-464.

Bieger T, Laesser C (2002) Market segmentation by motivation: The case of Switzerland. Journal of Travel Research 41:68−76.

Biel A, Thøgersen J (2007) Activation of social norms in social dilemmas: A review of the evidence and reflections on the implications for environmental behaviour. Journal of Economic Psychology 28:93–112.

Bonsall, P., Firmin, P. and Beale, J. (2004). Perception of modal attributes: how accurate and how susceptible to change? Paper presented at the 83rd meeting of the Transportation Research Board, Washington D.C.

Bradsher K (2002) High and Mighty: SUVs – The world's most dangerous vehicles and how they got that way. New York (NY), Public Affairs.

Brindle R (2003) Kicking the habit (Part 2): What are the real options for reducing 'car-dependence'? Road and Transport Research 12(4):34–40.

Brown BB, Werner CM, Kim N (2003) Personal and contextual factors supporting the switch to transit use: Evaluating a natural transit intervention. Analyses of Social Issues and Public Policy 3(1):139−160.

Brown G, Hagen DA (2010) Behavioural economics and the environment. Environmental and Resource Economics 46:139–146.

Burnett KP, Hanson S. 1982. The analysis of travel as an example of complex human behaviour in spatially constrained situations: Definition and measurement issues. Transportation Research Part A 16(2):87–102.

Button KJ (1993) Transport Economics (2nd Ed.). Aldershot (UK) & Vermont (USA), Edward Elgar.

Camerer C (1999) Behavioural economics: Reunifying psychology and economics. Proceedings of the National Academy of Sciences USA 96:10575-10577.

Cao XJ, Mokhtarian PL, Handy SL (2002) Examining the impacts of residential self-selection on travel behavior: Methodologies and empirical findings. Research Report CTS 08-24. Minneapolis: Center for Transportation Studies.

Carlsson F, Johansson-Stenman O (2012) Behavioral Economics and Environmental Policy. Annual Review of Resource Economics 4:75–3.

Carmines EG, Zeller RA (1979) Reliability and validity assessment. N. 07-017, Sage University Paper Series on Quantitative Applications in the Social Sciences. Beverly Hills, Sage.

Carrus G, Passafaro P, Bonnes M (2008) Emotions, habits and rational choices in ecological behaviours: The case of recycling and use of public transportation. Journal of Environmental Psychology 28:51–62.

Cebollada A (2009) Mobility and labour market exclusion in the Barcelona Metropolitan Region. Journal of Transport Geography 17:226–233.

Cebollada A, Miralles-Guasch C (2008) La estructura social de la movilidad cotidiana: el caso de los polígonos industriales. Anales de Geografía 28(2):63–83.

Cebollada A, Miralles-Guasch C (2010) La movilidad en la Región Metropolitana de Barcelona: Entre los nuevos retos y las viejas prácticas. Finisterra 45 (90):33–47.

Cervero R, Kockleman K (1997) Travel demand and the 3Ds: density, diversity, and design. Transportation Research Part D 2(3):199–219.

Chapman L (2007) Transport and climate change: A review. Journal of Transport Geography 15:354-367.

Charness G, Gneezy U (2008) Incentives to exercise. Econometrica 77(3):909–931.

Cheema A, Soman D (2006) Malleable mental accounting: the effect of flexibility on the justification of attractive spending and consumption decisions. Journal of Consumer Psychology 16(1):33–44.

Chen CF, Chao WH (2011) Habitual or reasoned? Using the theory of planned behavior, technology acceptance model, and habit to examine switching intentions toward public transit. Transportation Research Part F 14:128–137.

Chin WW (1998a) The partial least squares approach to structural equation modeling. In G.A. Marcoulides (Ed.), Modern methods for business research. Lawrence Erlbaum Associates, Mahwah (NJ), pp. 295–336.

Chin WW (1998b) Issues and opinion on structural equation modelling. Management Information Systems Quarterly 22(1):7–15.

Chin WW (2010) How to write up and report PLS analyses. In Esposito Vinzi, V., Chin, W.W., Henseler, J., & Wang, H. (Eds.), Handbook of partial least squares: Concepts, methods and applications (pp. 655–690), Berlin Heidelberg, Springer-Verlag.

Chin WW, Newsted PR (1999) Structural equation modeling analysis with small samples using partial least squares. In: R.H. Hoyle (Ed.), Statistical strategies for small sample research, (pp. 307–342), Thousand Oaks, Sage.

Chorus CG, Molin EJE, van Wee GP (2006) Travel Information as an instrument to change car-drivers' travel choices: a literature review. European Journal of Transport and Infrastructure Research, 6(4), 335-364.

Cialdini R (1993) Influence: The psychology of persuasion (Revised Edition). New York (NY), Harper Collins.

Cialdini RB (2003) Crafting normative messages to protect the environment. Current Directions in Psychological Science 12:105–109.

Cialdini RB (2007) Descriptive social norms as underappreciated sources of social control. Psychometrika 72(2):263–268.

Clark CF, Kotchen MJ, Moore MR (2003) Internal and external influences on pro-environmental behavior: Participation in a green electricity program. Journal of Environmental Psychology 23:237–246.

Cohen J (1988) Statistical power analysis for the behavioral sciences (2nd Ed.). Hillsdale (NJ), Erlbaum.

Cohen P, Cohen J, Teresi J, Marchi M, Velez CN (1990) Problems in the measurement of latent variables in structural equations causal models. Applied Psychological Measurement 14(2):183−196.

Conner M, Armitage CJ (1998) Extending the Theory of Planned Behavior: A review and avenues for further research. Journal of Applied Social Psychology 28(15):1429–1464.

Coulombel N (2011) Residential Choice and Household Behavior: State of the Art. SustainCity Working Paper, 2.2a, ENS Cachan.

Coulter A, Clegg S, Lyons G, Chatterton T, Musselwhite C (2008) Exploring public attitudes to person carbon dioxide emissions information. Technical Report. Government Department of Transport. University of the West of England. Bristol, UK.

Darby S (2006) The Effectiveness of Feedback on Energy Consumption. A Review for DEFRA on the Literature on Metering, Billing and Direct Displays. Retrieved from http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf.

Dargay J (2008) Personal transport choice. OECD Journal, General Papers, OECD Publishing 8(2):59–93.

Dargay JM (2001) The effect of income on car ownership: evidence of asymmetry. Transportation Research Part A: Policy and Practice 35(9):807–821.

Davidov E (2007) Explaining habits in a new context the case of travel-mode choice. Rationality and Society 19:315−334.

Davis WB, Levine MD, Train K (1995) Effects of feebates on vehicle fuel economy, carbon dioxide emissions and consumer surplus. U.S. Department of Energy, Office of Policy, Washington DC.

Dawnay E, Shah H (2005) Behavioural economics: Seven principles for policy-makers. New Economics Foundation (NEF), London.

de Groot JIM, Steg L (2008) Biospheric value orientations significant behavior: How to measure egoistic, altruistic, and value orientations to explain beliefs related to environmental. Environment and Behavior 40(3):330–354.

de Haan P, Mueller MG, Scholz RW (2009) How much do incentives affect car purchase? Agent-based microsimulation of consumerchoice of new cars — Part II: Forecasting effects of feebates based on energy-efficiency. Energy Policy 37:1083–1094.

de Palma A, Picard N (2005) Route choice decision under travel time uncertainty. Transportation Research Part A 39:295–324.

De Witte A, Hollevoet J, Dobruszkes F, Hubert M, Macharis C (2013) Linking modal choice to motility: A comprehensive review. Transportation Research Part A 49:329–341.

de Young R (1996) Some Psychological Aspects of Reduced Consumption Behavior: The Role of Intrinsic Satisfaction and Competence Motivation. Environment and Behavior 28:358–409.

Denant-Boèmont L, Petiot R (2003) Information value and sequential decision-making in a transport setting: an experimental study. Transportation Research Part B 37:365–386.

Denrell J, March JG (2001) Adaptation as information restriction: The hot stove effect. Organization Science 12(5):523– 538.

Diamantopoulos A (2011) Incorporating formative measures into covariance-based structural equation models. MIS Quarterly 35(2):335−358.

Diamantopoulos A, Siguaw JA (2006) Formative versus reflective indicators in organizational measure development: A comparison and empirical illustration. British Journal of Management 17(4):263–282.

Diamantopoulos A, Winklhofer HM (2001) Index construction with formative indicators: An alternative to scale development. Journal of Marketing Research 38(2):269–277.

Diana M, Mokhtarian PL (2009) Desire to change one's multimodality and its relationship to the use of different transport means. Transportation Research Part F 12:107–119.

Dolado JJ, García-Serrano C, Jimeno JF (2002) Drawing lessons from the boom of temporary jobs in Spain. The Economic Journal 112:F270–F295.

Dominguez-Amorós M, López-Roldán P (1996) La construcció de tipologies: procés i tècniques d'anàlisi de dades. Papers 48:31–39.

Domínguez-Varela A (2007) Análisis de la Congestión en Áreas Metropolitanas: Aplicación al caso de Barcelona. Dissertation, Universitat Politècnica de Catalunya.

Donat C (2010) L'habitatge a la Regió Metropolitana de Barcelona, 1995-2006. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers 51:44–60.

Dowling R (2000) Cultures of mothering and car use in suburban Sydney: A preliminary investigation. Geoforum 31:345−353.

Ellaway A, Macintyre S, Hiscock R, Kearns (2003) A In the driving seat: Psychosocial benefits from private motor vehicle transport compared to public transport. Transportation Research Part F 6:217–231.

Epley N, Gilovich T (2005) When effortful thinking influences judgmental anchoring: differential effects of forewarning and incentives on self-generated and externally provided anchors. Journal of Behavioral Decision Making 18(3):199–212.

Erev I, Barron G (2005) On adaptation, maximization, and reinforcement learning among cognitive strategies. Psychological Review 112(4):912–931.

Eriksson L, Garvill J, Nordlund AM (2008) Interrupting habitual car use: The importance of car habit strength and moral motivation for personal car use reduction. Transportation Research Part F 11:10–23.

Ewing R, Cervero R (2001) Travel and the built environment: A synthesis. Transportation Research Record 1780:87–114.

Ewing R, Cervero R (2010) Travel and the built environment. Journal of the American Planning Association 76(3):265–294.

Falk RF, Miller NB (1992) A primer for soft modeling. The University of Akron Press, Akron (OH).

Feng NgCh (2008) Commuting distances in a household location choice model with amenities. Journal of Urban Economics 63:116–129.

Festinger L (1957) A Theory of Cognitive Dissonance. Stanford (CA), Stanford University Press.

Fornell C, Bookstein FL (1982) A comparative analysis of two structural equation models: Lisrel and PLS applied to market data. In C. Fornell (Ed.), A second generation of multivariate analysis (Vol. 1, pp. 289–324). New York (NY), Praeger.

Fornell C, Cha J (1994) Partial least squares. In R. Bagozzi (Ed.), Advanced methods of marketing, (pp. 52–78). Cambridge, Blackwell.

Fornell C, Larcker DF (1981) Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 18:39–50.

Forward SE (1998) Behavioural factors affecting modal choice: ADONIS. Swedish National Road and Transport Research Institute (VTI), Sweden.

Fosgerau M, Hjorth K, Brems C, Fukuda D (2008) Travel time variability: Definition and valuation. DTU Transport, Lyngby, Denmark.

Freedman DA (1991) Statistical models and shoe leather. Sociological Methodology 21:291−313.

Frey B, Oberholzer-Gee F (1997) The costs of price incentives: An empirical analysis of motivation crowding out. The American Economic Review 87:746–55.

Frey BS (1988) Ipsative and objective limits to human behaviour. Journal of Behavioral Economics 17(4):229–248.

Frey BS (1992) Pricing and regulating affect environmental ethics. Environmental and Resource Economics 2(4):399–414.

Frey BS, Foppa K (1986) Human behavior: Possibilities explain action. Journal of Economic Psychology 7:137−160.

Frochot I, Morrison AM (2001) Benefit segmentation: a review of its applications to travel and tourism research. Journal of Travel & Tourism Marketing 9(4):21-45.

Fuhrer JC (2000) Habit Formation in Consumption and Its Implications for Monetary-Policy Models. The American Economic Review 90(3):367–390.

Fujii S (2006) Environmental concern, attitude toward frugality, and ease of behaviour as determinants of pro-environmental behavior intentions. Journal of Environmental Psychology 26:262–268.

Fujii S, Gärling T (2003) Application of attitude theory for improved predictive accuracy of stated preference methods in travel demand analysis. Transportation Research Part A 37:389–402.

Fujii S, Gärling T, Kitamura R (2001) Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural change on cooperation in a real-life social dilemma. Environment and Behavior 33(6):796−808.

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

Gaker D, Zheng Y, Walker J (2010) Experimental economics in transportation: Focus on social influences and provision of information. Transportation Research Record 2156:47–55.

Garcia-Lopez MA (2010) Population Suburbanization in Barcelona, 1991–2005: Is its Spatial Structure Changing? Journal of Housing Economics 19:119–132.

García-López MA, Muñiz-Olivera I (2007) ¿Policentrismo o dispersión? Una aproximación desde la Nueva Economía Urbana. Investigaciones Regionales 11:25-43.

Gardner B (2009) Modelling motivation and habit in stable travel mode contexts. Transportation Research Part F 12(1):68–76.

Gardner GT, Abraham C (2007) What drives car use? A grounded theory analysis of commuters' reasons for driving. Transportation Research Part F 10:187–200.

Gärling T, Axhausen KW (2003) Introduction: Habitual travel choice. Transportation 30:1–11.

Gärling T, Fujii S (2002) Structural equation modelling of determinants of planning. Scandinavian Journal of Psychology 43:1−8.

Gärling T, Fujii S, Boe O (2001) Empirical tests of a model of determinants of script-based driving choice. Transportation Research Part F 4(2):89–102.

Gärling T, Fujii S, Gärling A, Jakobsson C (2003) Moderating effects of social value orientation on determinants of pro-environmental behavior intention. Journal of Environmental Psychology 23:1–9.

Garvill J, Marell A, Nordlund A (2003) Effects of increased awareness on choice of travel mode. Transportation 30:63–79.

Gilbert R, Perl A (2010) Transport Revolutions: Moving People and Freight Without Oil. Philadelphia, New Society.

Giuliano G (1991) Is jobs-housing balance a transportation issue? Transportation Research Record 1305:305–312.

Giuliano G, Small KA (1993) Is the journey to work explained by urban structure? Urban Studies 30(9):1485–1500.

Gneezy U, Rustichini A (2000) Pay enough or don't pay at all. The Quarterly Journal of Economics 115(3):791–810.

Gollwitzer PM (1990) Action phases and mind-sets. In E.T. Higgins & R.M. Sorrentino (Eds.), Handbook of motivation and cognition (Vol. 2, pp. 53-92). New York, Guilford.

Gollwitzer PM (1999) Implementation intentions: Strong effects of simple plans. American Psychological Association 54(7):493−503.

Golob TF (2003) Structural equation modeling for travel behavior research. Transportation Research Part B 37:1–25.

Goodwin P (1995) Car dependence. Transport Policy 2(3):151–152.

Goulias KG (2007) Companionship and altruism in daily activity time allocation and travel by men and women in the same households. Earlier Faculty Research, University of California Transportation Center, UC Berkeley. Retrieved from http://escholarship.org/uc/item/7d44668g.

Goulias KG, Henson KM (2006) On altruists and egoists in activity participation and travel: who are they and do they live together? Transportation 33:447–462.

Griskevicius V, Tybur JM, van den Bergh B (2010) Going green to be seen: status, reputation, and conspicuous conservation. Journal of Personality and Social Psychology 98:392–404.

Gsottbauer E, van den Bergh JCJM (2011) Environmental policy theory given bounded rationality and other-regarding preferences. Environmental and Resource Economics 49:263–304.

Gsottbauer E, van den Bergh JCJM (2013) Bounded rationality and social interaction in negotiating a climate agreement. International Environmental Agreements: Politics, Law and Economics 13(3):225−249.

Hair JF, Black WC, BJ Babin, Anderson RE (Eds.) (2009) Multivariate data analysis (7th Ed.), Englewood Cliffs (NJ), Prentice Hall.

Hair JF, Hult GTM, Ringle CM, Sarstedt M (2014) A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM), Thousand Oaks, Sage.

Hair JF, Ringle CM, Sarstedt M (2011) PLS-SEM: Indeed a Silver Bullet Journal of Marketing Theory and Practice 19(2):139–151.

Hair JF, Sarstedt M, Pieper TM, Ringle CM (2012a) The use of partial least squares structural equation modeling in strategic management research: A review of past practices and recommendations for future applications. Long Range Planning 45:320−340.

Hair JF, Sarstedt M, Ringle CM, Mena JA (2012b) An assessment of the use of partial least squares structural equation modeling in marketing research. Journal of the Academy of Marketing Science 40(3):414−433.

Handy S (2004) Critical assessment of the literature on the relationships among transportation, land use, and physical activity. In: TRB Special Report 282 (2005): Does the built environment influence physical activity? Examining the evidence. Washington, Transportation Research Board.

Handy S (2005) Smart growth and the transportation-land use connection: What does the research tell us? International Regional Science Review 28(2):146–167.

Handy S, Cao X, Mokhtarian P (2005a) Correlation or causality between the built environment and travel behavior? Evidence from Northern California. Transportation Research Part D 10(6):427–444.

Handy S, Mokhtarian P (2005) Which comes first: the neighborhood or the walking? University of California Transportation Center, ACCESS 26:16-21.

Handy S, Weston L, Mokhtarian PL (2005b) Driving by choice or necessity? Transportation Research Part A 39:183–203.

Handy SL, Boarnet MG, Ewing R, Killingsworth RE (2002) How the built environment affects physical activity: Views from urban planning. American Journal of Preventive Medicine 23(2):64–73.

Hanson S, Huff J (1986) Classification issues in the analysis of complex travel behaviour. Transportation 13:271−293.

Hanson S, Huff JO (1982) Assessing day-to-day variability in complex travel patterns. Transportation Research Record 891:18–24.

Hanson S, Huff JO (1988) Systematic variability in repetitious travel. Transportation 15(1/2):111–135.

Harland P, Staats H, Wilke HAM (1999) Explaining proenvironmental intention and behavior by personal norms and the theory of planned behavior. Journal of Applied Social Psychology 29(12):2505–2528.

Haustein S, Klöckner CA, Blöbaum A (2009) Car use of young adults: The role of travel socialization. Transportation Research Part F 12:168–178.

Heath Y, Gifford R (2002) Extending the theory of planned behaviour: Predicting the use of public transportation. Journal of Applied Social Psychology 32:2154–2185.

Henseler J (2010) On the convergence of the partial least squares path modeling algorithm. Computational Statistics 25(1):107−120.

Henseler J, Ringle CM, Sinkovics RR (2009) The use of partial least squares path modeling in international marketing. Advances in International Marketing 20:277−320.

Heymen J, Ariely D (2004) Effort for payment: a tale of two markets. Psychological Science 15(11):787–793.

Hickman R, Ashiru O, Banister D (2009) Achieving carbon efficient transport: Backcasting from London, Transportation Research Record 2139:172−182.

Hickman R, Ashiru O, Banister D (2010) Transport and climate change: Simulating the options for carbon reduction in London. Transport Policy 17:110–125.

Hickman R, Banister D (2007) Looking over the horizon: Transport and reduced CO2 emissions in the UK by 2030. Transport Policy 14(5):377–387.

Hickman R, Banister D (2007) Looking over the horizon: Transport and reduced CO_2 emissions in the UK by 2030. Transport Policy 14:377–387.

Hickman R, Banister D (2014) Transport, climate change and the city. Abingdon, Routledge.

Hickman R, Hall P, Banister D (2013) Planning more for sustainable mobility. Journal of Transport Geography 33:210–219.

Hirsch F (1976) The social limits to growth. Cambridge, Harvard University Press.

Hjorth K, Fosgerau M (2012) Using prospect theory to investigate the low marginal value of travel time for small time changes. Transportation Research Part B 46(8):917–932.

Horner MW (2007) A multi-scale analysis of urban form and commuting change in a small metropolitan area (1990–2000). The Annals of Regional Science 41(2):315−332.

Howarth RB (1996) Status effects and environmental externalities. Ecological Economics 16:25–34.

Hunecke M, Blöbaum A, Matthies E, Höger R (2001) Responsibility and environment: Ecological norm orientation and external factors in the domain of travel mode choice behaviour. Environment and Behavior 33(6):830−852.

Iacobucci D (2009) Everything you always wanted to know about SEM (structural equations modeling) but were afraid to ask. Journal of Consumer Psychology 19:673–680.

IDESCAT (2012) Territori, Banc d'estadístiques de municipis i comarques. Retrieved from http://www.idescat.cat/territ/BasicTerr?TC=5&V0=4&V3=779&V4=780&ALLINFO=TRUE&PARENT=25&CTX=B&V1=1&VOK=Confirmar.

Innocenti A, Lattarulo P, Pazienza MG (2013) Car stickiness: Heuristics and biases in travel choice. Transport Policy 25:158–168.

Ireland N (1998) Status seeking, income taxation and efficiency. Journal of Public Economics 70:99–113.

Ison S, Ryley T (2007) Options for sustainable mobility. Engineering Sustainability 160(ES1):27–33.

Jackson T (2005) Motivating sustainable consumption: a review of evidence on consumer behaviour and behavioural change. Report Sustainable Development Research Network, Surrey.

Jensen M (1999) Passion and heart in transport — a sociological analysis on transport behaviour. Transport Policy 6:19–33.

Johansson MV, Heldt T, Johansson P (2006) The effects of attitudes and personality traits on mode choice. Transportation Research Part A 40:507–525.

Johansson O (1997) Optimal Pigovian taxes under altruism. Land Economics 73:297–308.

Johansson-Stenman O, Martinsson P (2006) Honestly, why are you driving a BMW? Journal of Economic Behavior and Organization 60:129–146.

Johnson EJ, Goldstein D (2003) Do Defaults Save Lives? Science 302(5649):1338–1339.

Jöreskog KG (1978) Structural analysis of covariance and correlation matrices. Psychometrika 43(4):443−477.

Jöreskog KG (1982) The LISREL approach to causal model-building in the social sciences. In: H. Wold, K.G. Jöreskog (Eds.), Systems under indirect observation, Part I, (pp. 81−100). Amsterdam, North-Holland.

Jou R, Kitamura R (2002) Commuter departure time choice: A reference point approach. Proceedings EWGT, Paper presented at the 13th Conference of the EWGT. Retrieved from http://www.iasi.cnr.it/ewgt/13conference/26_jou.pdf.

Jou RC, Kitamura R, Weng MC, Chen CC (2008) Dynamic commuter departure time choice under uncertainty. Transportation Research Part A 42:774–783.

Kahn LM (2012) Temporary jobs and job search effort in Europe. Labour Economics 19:113–128.

Kahneman D (2011) Thinking, fast and slow. London, Penguin Books.

Kahneman D, Tversky A (1979) Prospect Theory: An analysis of decision under risk. Econometrica XLVII:263–291.

Kaiser FG, Gutscher H (2003) The proposition of a general version of the theory of planned behaviour (TPB): predicting ecological behaviour. Journal of Applied Social Psychology, 33, 586–603.

Kitamura R (1988) An evaluation of activity-based travel analysis. Transportation 15:9−34.

Klöckner CA, Blöbaum A (2010) A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. Journal of Environmental Psychology 30:574−586.

Klöckner CA, Matthies E (2004) How habits interfere with norm-directed behaviour: A normative decision-making model for travel mode choice. Journal of Environmental Psychology 24(3):319–327.

Klöckner CA, Matthies E, Hunecke M (2003) Problems of operationalizing habits and integrating habits in normative decision-making models. Journal of Applied Social Psychology 33:396–417.

Knetsch J (1997) Evaluation and environmental policies: Recent behavioural findings and further implications. In Sustainability and Global Environmental Policy: New Perspectives, ed. A. Dragun and K. Jakobsson. Cheltenham (UK), Edward Elgar Publishing.

Kollmuss A, Agyeman J (2002) Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environmental Education Research 8(3):239−260.

Krizek KJ (2006) Lifestyles, residential location decisions, and pedestrian and transit activity. Transportation Research Record 1981:171–178.

Krizek KJ, El-Geneidy A (2007) Segmenting preferences and habits of transit users and non-users. Journal of Public Transportation, 10(3):71−94.

Larrick RP, Soll JB (2008) The MPG Illusion. Science 320: 1593–1594.

Larsen MM, Pilegaard N, van Ommeren J (2008) Congestion and residential moving behaviour. Regional Science and Urban Economics 38:378–387.

Law R (1999) Beyond "women and transport": Towards new geographies of gender and daily mobility. Progress in Human Geography 23(4):567–588.

Leith C, Moldovan I, Rossi R (2012) Optimal monetary policy in a New Keynesian model with habits in consumption. Review of Economic Dynamics 15:416–435.

Lévy JPM (2003) Modelización y análisis con ecuaciones estructurales. In J.P. Lévy Mangin & J. Varela Mallou (Eds.), Análisis multivariante para las ciencias sociales, Capítulo 17, (pp. 768-810), Madrid, Pearson.

Li Z, Hensher D (2011) Prospect Theoretic Contributions in Understanding Traveller Behaviour: A Review and Some Comments. Transport Reviews 31:97−115.

Lindenberg S, Steg L (2007) Normative, gain and hedonic goal frames guiding environmental behaviour. Journal of Social Issues 63(1):117–137.

Löfgren Å, Martinsson P, Hennlock M, Sterner T (2009) Does experience eliminate the effect of a default option? A field experiment on CO_2-offsetting for air transport. Working papers in economics no. 391. Department of Economics, Göteborg University.

Löfgren A, Nordblom K (2006) The importance of habit formation for environmental taxation. Working papers in economics no. 204. Department of Economics, Göteborg University.

López-Roldán P (1996) La construcción de tipologias: metodologia de análisis. Papers 48: 9–29.

Lorenzoni I, Nicholson-Cole S, Whitmarsh L (2007) Barriers perceived to engaging with climate, change among the UK public and their policy implications. Global Environmental Change 17:445–459.

Lucas K (2012) Transport and social exclusion: Where are we now? Transport Policy 20:105–113.

MacKenzie SB, Podsakoff PM, Jarvis CB (2005) The problem of measurement model misspecification in behavioral and organizational research and some recommended solutions. Journal of Applied Psychology 90(4):710−730.

Madden TJ, Scholder Ellen P, Ajzen I (1992) A comparison of the Theory of Planned Behavior and the Theory of Reasoned Action. Personality and Social Psychology Bulletin 18(1):3−9.

Mahmassani HS, Srinivasan KK (2004) Experiments with route and departure time choices of commuters under real-time information: heuristics and adjustment processes. In: Schreckenberg M and Selten R (eds.) Human behavior and traffic networks. Bonn, Germany, Springer Publishers.

Matas A (1991) La demanda de transporte urbano: Un análisis de las elasticidades y valoraciones del tiempo. Investigaciones Económicas 15(2):249–267.

Mathieson K, Peacock E, Chin WW (2001) Extending the technology acceptance model: The influence of perceived user resources. ACM SigMIS Database 32(3):86−112.

Matthies E, Klöckner CA, Preißner CL (2006) Applying a modified moral decision making model to change habitual car use: How can commitment be effective? Applied Psychology 55(1):91–106.

Maynard M (2007) Say 'hybrid' and many people will hear 'Prius'. The New York Times, July 4. Retrieved from http://www.nytimes.com.

McFadden D (1999) Rationality for Economists? Journal of Risk and Uncertainty, 19(1–3):73–105.

McKinely JC (2008) Champion cyclist and now champion guzzler of Austin water. The New York Times. Retrieved from http://www.nytimes.com/2008/08/16/us/16lance.html?_r=0.

Metcalfe R, Dolan P (2012) Behavioural economics and its implications for transport. Journal of Transport Geography 24:503–511.

Metz D (2004) Travel time—variable or constant? Journal of Transport Economics and Policy 38(3):333–344.

Miles R, Snow C (1978) Organizational Strategy, Structure and Process. New York (NY), McGraw-Hill.

Miralles-Guasch C (2002) Ciudad y Transporte: el Binomio Imperfecto. Barcelona, Ariel.

Miralles-Guasch C (2010) Dones, mobilitat, temps i ciutats. Quaderns de l'Institut 14, Institut Català de les Dones. Generalitat de Catalunya.

Miralles-Guasch C (2011) Dinámicas metropolitanas y tiempos de la movilidad: la Región Metropolitana de Barcelona, como ejemplo. Anales de Geografía 31(1):125–145.

Miralles-Guasch C, Oliver-Frauca L (2008) La mobilitat quotidiana a la Regió Metropolitana de Barcelona. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers 48:12–27.

Miralles-Guasch C, Tulla-Pujol AF (2012) La región metropolitana de Barcelona. Dinámicas territoriales recientes. Boletín de la Asociación de Geógrafos Españoles 58:299–318

Mokhtarian PL, Chen C (2004) TTB or not TTB, that is the question: A review and analysis of the empirical literature on travel time (and money) budgets. Transportation Research Part A 38:643–675.

Mokhtarian PL, Salomon I (2001) How derived is the demand for travel? Some conceptual and measurement considerations. Transportation Research Part A 35:695–719.

Mokhtarian PL, Salomon I, Redmond LS (2001) Understanding the demand for travel: it's not purely 'derived'. Innovation 14(4):355–380.

Muñiz I, Galindo A, García MA (2003) Cubic spline population density functions and satellite city delimitation: The case of Barcelona, Urban Studies 40(7):1303−1321.

Murray SJ, Walton D, Thomas JA (2010) Attitudes towards public transport in New Zealand. Transportation 37:915–929.

Næss P (2009) Residential self-selection and appropriate control variables in land use: Travel studies. Transport Reviews 29(3):293–324.

Nakayama S, Kitamura R (2000) Route Choice Model with Inductive Learning. Transportation Research Record 1725:63–70.

Nash J (2006) Framing effects and regulatory choice: The case of environmental regulation. Notre Dame Law Review 82(313):355–369.

Nel·lo O (1995) Dinàmiques territorials i mobilitat urbana en la Regió Metropolitana de Barcelona. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers 24:9–37.

Nel·lo O (2010) Les dinàmiques territorials a la Regió Metropolitana de Barcelona (1986-2006): hipòtesis interpretatives. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers 51:16–27.

Nijkamp P (1994) Roads Towards Environmentally Sustainable Transport. Transportation Research Part A 28A(4):261-271.

Nobis C (2007) Multimodality: Facets and causes of sustainable mobility behavior. Transportation Research Record 2010:35–44.

O'Connor RE, Bord RJ, Yarnal B, Wiefek N (2002) Who wants to reduce greenhouse gas emissions? Social Science Quarterly 83:1–17.

OECD (2008a) OECD Environmental Outlook to 2030. OECD Online publications. Retrieved from http://www.oecd-ilibrary.org/environment/oecd-environmental-outlook-to-2030_9789264040519-en.

OECD (2008b) Environmental policy and household behavioural change - Personal transport choices observer article. OECD, Project on Household Behaviour and Environmental Policy 2008. Retrieved from http://www.oecd.org/dataoecd/12/47/47234513.pdf.

Oliver-Frauca L (2010) La mobilitat i el transport. Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB), Papers 51:62–84.

Oreg S, Katz-Gerro T (2006) Predicting proenvironmental behavior cross-nationally: Values, the Theory of Planned Behavior, and Value-Belief-Norm Theory. Environment and Behavior 38:462− 483.

Ouellette JA, Wood W (1998) Habit and intention in everyday life: The multiple processes by which past behavior predicts future behavior. Psychological Bulletin 124(1):54–74.

Peng DX, Lai F (2012) Using partial least squares in operations management research: A practical guideline and summary of past research. Journal of Operations Management 30:467–480.

Perugini M, Bagozzi RP (2001) The role of desires and anticipated emotions in goal-directed behaviours: Broadening and deepening the Theory of Planned Behaviour. British Journal of Social Psychology 40:79–98.

Perugini M, Bagozzi RP (2004) The distinction between desires and intentions. European Journal of Social Psychology 34:69–84.

Peters A, Mueller MG, de Haan P, Scholz RW (2008) Feebates promoting energy-efficient cars: Design options to address more consumers and possible counteracting effects. Energy Policy 36:1355–1365.

Pichert D, Katsikopoulos KV (2008) Green defaults: information presentation and pro-environmental behaviour. Journal of Environmental Psychology 28:63–73.

Polk M (2004) The influence of gender on daily car use and on willingness to reduce car use in Sweden. Journal of Transport Geography 12(3):185–195.

Pooley CJ, Turnbull J (2000) Modal choice and modal change: the journey to work in Britain since 1890. Journal of Transport Geography 8:11−24.

Popuri Y, Proussaloglou K, Ayvalik C, Koppelman F, Lee A (2011) A Importance of traveler attitudes in the choice of public transportation to work: findings from the Regional Transportation Authority Attitudinal Survey. Transportation 38:643–661.

Proost S, van Dender K (2001) The welfare impacts of alternative policies to address atmospheric pollution in urban road transport. Regional Science and Urban Economics 31:383–411.

Proost S, van Dender K, Courcelle C, De Borger B, Peirson J, Sharp D, Vickerman R, Gibbons E, O'Mahony M, Heaney Q, van den Bergh J, Verhoef E (2002) How large is the gap between present and efficient transport prices in Europe? Transport Policy 9:41–57.

Rabin M (1998) Psychology and economics. Journal of Economic Literature 36(1):11-46.

Rajan SC (2006) Climate change dilemma: technology, social change or both? An examination of long-term transport policy choices in the United States. Energy Policy 34:664-679.

Rand D, Nowak M (2009) How reputation could save the Earth. New Scientist 2734:28–29.

Rietveld P (2003) Valuation of travel time and traveller information in multimodal personal travel under uncertainty. Tinbergen Institute Discussion Paper TI 2003-036/3.

Rietveld P (2006) Transport and environment. In: Tietemberg, T. (ed) The International Yearbook of Environmental and Resource Economics 2006/2007. Cheltenham (UK), Edward Elgar.

Ringle CM, Wende S, Will A (2005) SmartPLS 2.0. Hamburg. Downloaded from www.smartpls.de.

Roberts N, Thatcher JB (2009) Conceptualizing and testing formative constructs: Tutorial and annoted example. The Data Base for Advances in Information Systems, 40(3):9–39.

Roldán JL, Sánchez-Franco MJ (2012) Variance-based structural equation modeling: Guidelines for using partial least squares in information systems research. In M. Mora, O. Gelman, A. Steenkamp, M.S. Raisinghani (Eds.), Research methodologies, innovations and philosophies in software systems engineering and information systems, (pp. 193– 221). Hershey (PA), IGI Global.

Rouwendal J (2004) Search theory and commuting behavior. Growth Change 35(3):391–418.

Rouwendal J, Meijer E (2001) Preferences for housing, jobs, and commuting: A mixed logit analysis. Journal of Regional Science 41(3):475–505.

Ryley T (2006) Use of non-motorised modes and life stage in Edinburgh. Journal of Transport Geography, 14(5), 367–375.

Salas Velasco M (1996) La regresión logística: Una aplicación a la demanda de estudios universitarios. Estadística Española 38(141):193−217.

Schuitema G, Steg L, Forward S (2010) Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. Transportation Research Part A 44:99–109.

Schultz PW, Nolan JM, Cialdini RB, Goldsten NJ, Giskevicius V (2007) The constructive, destructive, and reconstructive power of social norms. Psychological Science 18:429–434.

Schwanen T, Banister D, Anable J (2012) Rethinking habits and their role in behaviour change: The case of low-carbon mobility. Journal of Transport Geography 24:522–532.

Schwanen T, Ettema D (2009) Coping with unreliable transportation when collecting children: Examining parents' behavior with cumulative prospect theory. Transportation Research Part A 43(5):511–525.

Selten R, Chmura T, Pitz T, Kubec S, Schreckenberg M (2007) Commuters route choice behaviour. Games and Economic Behavior 58:394–406.

Senbil M, Kitamura R (2004) Reference points in commuter departure time choice: A prospect theoretic test of alternative decision frames. Journal of Intelligent Transportation Systems 8:19–31.

Senna L (1994) The influence of travel time variability on the value of time. Transportation 21: 203–228.

Sexton SE, Sexton AL (2011) Conspicuous conservation: The Prius effect and willingness to pay for environmental bona fides. Working Paper. University of California, Berkley.

Shoemaker S (1994) Segmenting the U.S. travel market according to benefits realized. Journal of Travel Research 32:8−21.

Shogren JF, Taylor LO (2008) On behavioral-environmental economics. Review of Environmental Economics and Policy 2(1):26–44.

Shook CL, Ketchen DJ, Hult GTM, Kacmar KM (2004) An assessment of the use of structural equation modeling in strategic management research. Strategic Management Journal 25(4):397–404.

Simma A, Axhausen KW (2001) Structures of commitment in mode use: A comparison of Switzerland, Germany and Great Britain. Transport Policy 8(3):279–288.

Simma A, Axhausen KW (2003) Commitments and modal usage: An analysis of German and Dutch panels. Transportation Research Record 1854:22–31.

Small KA, Verhoef ET (2007) The economics of urban transportation. London & New York, Routledge.

Sohn J (2005) Are commuting patterns a good indicator of urban spatial structure? Journal of Transport Geography 13:306–317.

Sohn K, Yun J (2009) Separation of car-dependent commuters from normal-choice riders in mode-choice analysis. Transportation 36:423–436.

Sperling D, Gordon D (2009) Two billion cars: Driving toward sustainability New York. New York (NY), Oxford University Press.

Staats H (2003) Understanding pro-environmental attitudes and behaviour: An analysis and review of research based on the Theory of Planned Behaviour. In M. Bonnes, T. Lee, M. Bonaiuto (Eds.) Psychological Theories for Environmental Issues, (pp. 171–201). Aldershot, Ashgate.

Steg L (2003) Can public transport compete with the private car? IATSS Research 27(2):27–35.

Steg L (2005) Car use: Lust and must. Instrumental, symbolic and affective motives for car use. Transportation Research Part A 39:147–162.

Steg L, Gifford R (2005) Sustainable transportation and quality of life. Journal of Transport Geography 13:59–69.

Steg L, Vlek C (2009) Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology 29:309–317.

Steg L, Vlek C, Slotegraaf G (2001) Instrumental-reasoned and symbolic-affective motives for using a motor car. Transportation Research Part F 4(3):151–169.

Stern PC (1999) Information, incentives, and proenvironmental consumer behaviour. Journal of Consumer Policy 22:461–478.

Stern PC (2000) New environmental theories: Toward a coherent theory of environmentally significant behavior. Journal of Social Issues 56(3):407–424.

Sterner T (2007) Fuel taxes: An important instrument for climate policy. Energy Policy 35:3194–3202.

Stradling SG, Meadows ML, Beatty S (2000) Helping drivers out of their cars: Integrating transport policy and social psychology for sustainable change. Transport Policy 7:207−215.

Stutzer A, Frey BS (2008) Stress that doesn't pay: The commuting paradox. Scandinavian Journal of Economics 110(2):339–366.

Sweedler BM (1995) Safety recommendations: The engine that drives change. Safety Science 19(2–3):295–307.

T&E (2006) How clean is your car brand? The car industry's commitment to the EU to reduce CO_2 emissions: A brand-by-brand progress report. T&E – European Federation for Transport and Environment, Brussels, Belgium.

Tanner C (1999) Constraints on environmental behaviour. Journal of Environmental Psychology 19:145−157.

Tanner C, Kaiser FG, Wölfing-Kast S (2004) Contextual conditions of ecological consumerism: A food-purchasing survey. Environment and Behavior 36(1):94−111.

Taylor S, Todd P (1995) An integrated model of waste management behaviour: A test of household recycling and composting intentions. Environment and Behavior 27:603−630.

Tenenhaus M, Vinzi VE, Chatelin YM, Lauro C (2005) PLS path modeling. Computational Statistics & Data Analysis 48:159–205.

Tertoolen G, van Kreveld D, Verstraten B (1998) Psychological resistance against attempts to reduce private car use. Transportation Research Part A 32(3):171−181.

Thaler RH, Sunstein CR (2008) Nudge: Improving decisions about health, wealth and happiness. New Haven & London, Yale University Press.

Thøgersen J (2006) Understanding repetitive travel mode choices in a stable context: A panel study approach. Transportation Research Part A 40:621–638.

Thøgersen J (2008) Social norms and cooperation in real-life social dilemmas. Journal of Economic Psychology 29:458–472.

TRB (2005) TRB Special Report 282: Does the built environment influence physical activity? Transportation Research Board, Washington.

Triandis HC (1977) Interpersonal Behaviour. Monterey (CA), Brook/Cole.

Triandis HC (1980) Values, attitudes, and interpersonal behavior. In H. Howe & M. Page (Eds.) Nebraska symposium on motivation 1979, (pp. 195–295). Lincoln (NE), University of Nebraska Press.

Trullén J, Boix R (2000) Policentrismo y redes de ciudades en la Región Metropolitana de Barcelona. Draft paper, Universitat Autònoma de Barcelona.

Tversky A, Kahneman D (1981) The framing of decisions and the psychology of choice. Science 211(4481):453–458.

Tversky A, Kahneman D (1991) Loss aversion in riskless choice: a reference-dependent model. The Quarterly Journal of Economics 106:1039–1061.

Urbach N, Ahlemann F (2010) Structural equation modeling in information systems research using partial least squares. Journal of Information Technology Theory and Application, 11(2):5–40.

van de Coevering P, Schwanen T (2006) Re-evaluation of urban form on travel patterns in Europe and North-America. Transport Policy 13:229–239.

van de Kaa EJ (2005) Heuristic judgement, prospect theory and stated preference surveys aimed to elicit the value of travel time. European Transport Conference 2005, Strasbourg.

van de Kaa EJ (2006) Assessment of the value of travel time from stated choice surveys: the impact of lexicographic answering. European Transport Conference 2006, Strasbourg.

van de Kaa EJ (2008) Extended prospect theory. Findings on choice behaviour from economics and the behavioural sciences and their relevance for travel behaviour. T2008/11, TRAIL Thesis Series, The Netherlands.

van den Bergh JCJM, Ferrer-i-Carbonell A, Munda G (2000) Alternative models of individual behaviour and implications for environmental policy. Ecological Economics 32:43–61.

van Exel NJA (2011) Behavioural economic perspectives on inertia in travel decision making. Doctoral Dissertation, Vrije Universiteit Amsterdam, The Netherlands.

van Ommeren J, Fosgerau M (2009) Workers' marginal costs of commuting. Journal of Urban Economics 65:38-47.

van Ommeren J, Rietveld P (2005) The commuting time paradox. Journal of Urban Economics 58:437–454.

van Ommeren J, van Leuvensteijn M (2005) New evidence of the effect of transaction costs on residential mobility. Journal of Regional Science 45(4):681-702.

van Ommeren JN (2000) Commuting and relocation of jobs and residences. United Kingdom, Ashgate Publishing Limited.

van Ommeren JN, Rietveld P, Nijkamp P (1998) Spatial moving behaviour of two-earner households. Journal of Regional Science 38:23–41.

van Ommeren JN, van der Straaten JW (2008) The effect of search imperfections on commuting behaviour: Evidence from employed and self-employed workers. Regional Science and Urban Economics 38:127-147.

van Wee B (2010) Prospect theory and travel behaviour: a Personal Reflection Based on a Seminar. EJTIR 10(4): 385–394.

van Wee B, Holwerda H, van Baren R (2002) Preferences for Modes, Residential Location and Travel Behaviour: the Relevance for Land-Use Impacts on Mobility. EJTIR 2(3/4):305–316.

Venkatachalam L (2008) Behavioral economics for environmental policy. Ecological Economics 67:640–645.

Verhoef E T, van Wee B (2000) Car ownership and status. Tinbergen Institute Discussion Paper TI 2000-076/3.

Verplanken B, Aarts H (1999) Habit, attitude, and planned behaviour: Is habit an empty construct or an interesting case of goal-directed automaticity? European Review of Social Psychology 10(1):101–134.

Verplanken B, Aarts H, van Knippenberg A, Knippenberg C (1994) Attitude versus general habit: Antecedents of travel mode choice. Journal of Applied Social Psychology 24:285–300.

Verplanken B, Aarts H, van Knippenberg A, Moonen A (1998) Habit versus planned behaviour: A field experiment. British Journal of Social Psychology 37:111−128.

Verplanken B, Aarts H, van Knippenberg AD (1997) Habit, information acquisition, and the process of making travel mode choices. European Journal of Social Psychology 27:539−560.

Verplanken B, Orbell S (2003) Reflections on past behavior: A self-report index of habit strength. Journal of Applied Social Psychology 33:1313–1330.

Verplanken B, Walker I, Davis A, Jurasek M (2008) Context change and travel mode choice: Combining the habit discontinuity and self-activation hypotheses. Journal of Environmental Psychology 28:121–127.

Vinzi VE, Chin WW, Henseler J, Wang H (Eds.) (2010) Handbook of partial least squares: Concepts, methods and applications. Springer-Verlag, Berlin, Heidelberg.

Vlek C (2000) Essential psychology for environmental policy making. International Journal of Psychology 35(2):153–167.

Waygood E, Avineri E (2012) Transportation carbon emission information: The effect of format on behavioural intention. In 2012 IATBR Conference, Toronto, Canada.

Wedel M, Kamakura WA (1999) Market segmentation: conceptual and methodological foundations (2nd Ed.). Boston, Kluwer Academic Publishers.

Williams LJ, Edwards JR, Vandenberg RJ (2003) Recent advances in causal modeling methods for organizational and management research. Journal of Management 29(6):903–936.

Wold H (1982) Soft modeling: The basic design and some extensions. In: K.G. Jöreskog, H. Wold (Eds.), Systems under indirect observations: Causality, structure, prediction, Part 2, (pp. 1–54). Amsterdam, North-Holland.

Wong GKM (2002) A conceptual model of the household's housing decision-making process: The economic perspective. Rurds 14(3):217–234.