



Linking modal choice to motility: A comprehensive review



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ABSTRACT

Modal choice is determined by a whole range of factors that are interrelated to a larger or smaller extent. It is often the result of a very compound choice process that can take place consciously or unconsciously and that includes objective as well as subjective determinants. Despite its significance in our daily life, there is no uniform way to define and analyze the concept of modal choice. The aim of this review is to fill this gap by elaborating a common modal choice definition and by providing a comprehensive review on the concept of modal choice through linking it to Kaufmann's motility concept. By doing so, this review will not only contribute to an improved knowledge on different modal choice determinants and their interdependencies, but can also assist to the understanding and modeling of modal choice decisions. The review can therefore help increasing the effectiveness of policy measures taken by environmental, urban and transport policy makers.

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1. Introduction

The need for mobility is of growing importance in our daily lives. A typical day consists of a chain of activities, often located at different places. This has created a rising demand for mobility. In most cases, the car is the indisputable dominant transport mode used to fulfill this need, which leads to negative side-effects (not only for the environment, but also for the economy and society) that cannot be ignored in mobility policies and planning. A growing awareness of the rising mobility needs and its accompanying effects has opened the debate on how to manage our current and future mobility in a more sustainable way (Banister, 2008; Schwanen et al., 2011). In order to take adequate policy measures to guide our mobility towards a more sustainable one, a deeper understanding of the actual travel behavior of people and their modal choices is necessary (Bhat, 1998). Although there have been many studies which focus on modal choice, there is no uniformity in the definitions and the methodologies used to study this concept. Modal choice is a very complex decision process, determined by a wide range of factors stemming from different disciplines (economy, sociology, geography and psychology). Usually, the epistemological basis of modal choice research highly depends on the practices and objectives of the research teams investigating it. This allows for alternative theoretical reflections, but also complicates things, as the research approach will have an impact on the research outcomes.

The aim of this review is to gain a deeper understanding of the notion of modal choice with emphasis on how modal choice can be defined and on the determinants that can play a role in the modal choice decision process. In order to do so, we adopt a multi-disciplinary point of view where we link modal choice to Kaufmann's motility concept (Kaufmann,

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2002), as this allows incorporating the cross-fertilization between different research fields. This results in elaborating a multi-disciplinary definition on modal choice, which is then used as a basis for building a comprehensive framework for structuring and discussing the modal choice determinants analyzed in the context of this review. The discussion of determinants is based on a descriptive analysis of the determinants studied and found significant in the modal choice papers we reviewed. A statistical analysis is not envisaged in this review paper but will be performed at a later stage, when the framework will be used to guide a more in-depth modal choice analysis of the National Household Travel Survey of Belgium. This review provides a multi-disciplinary structured insight into the influence of modal choice determinants and can therefore assist in improving the knowledge on modal choice decisions and its modeling, which in turn will help increasing the effectiveness of measures taken by environmental, urban and transport policy makers.

The outline of this review is as follows: first, the search strategy for the literature review will be explained and the key research questions will be lined out. After that, attention will be paid to different approaches that can be used to study modal choice, which will lead to the formulation of a multi-disciplinary definition of modal choice. Based on this definition, we then elaborate a multi-disciplinary framework that will be used as a frame to structure and discuss the determinants of modal choice. After that, the most important trends and interdependencies between these determinants will be discussed. Finally, we will draw conclusions and make recommendations for future modal choice research.

2. Search strategy

For this review, we take into consideration all types of research (modeling, empirical, surveys, etc.) concerning passenger travel behavior with emphasis on modal choice. With this review we seek to address the following questions:

- How is modal choice defined?
- Which factors determine modal choice?
- How do these factors determine modal choice?

Our data collection strategy is mostly based on a computerized search. Articles were mainly retrieved by tracking cited references and by tracking e-catalogues. The review mainly covers the last two decades. Several sources were used to search for literature; these included the web-based search tools (V-spaces and Article database, e-sources) and the VUBIS library e-catalogue from the university library of VUB (Vrije Universiteit Brussel). In addition, also ordinary web-search robots (e.g. Google Scholar) were used to track cited references and to find publication titles for further lookup at the university library. The search was conducted in 2010 from March until August, using the search term 'modal choice' on the search robots. From the resulting output, the relevant hits were filtered out for further analysis. Articles were then screened on their relevance with regard to modal choice definition and determinants. Finally, this resulted in 76 articles retained for further analysis and processed for this review. It is important to mention that the review focuses on modal choice for daily and regular trips made at local or regional level and that the processed articles mainly cover developed, rich countries, which is determining for the focus of the findings and discussion. Table 1 summarizes the main features of the studies examined, based on region, journey type and transport modes considered.

As far as the region is concerned, a large part of the studies are related to Europe (40 out of 76) and a smaller part to the USA (9 out of 76). In 21 of the reviewed papers the modal choice studies were performed in other regions, mainly Canada, Australia, New Zealand and Japan. In the remaining 6 papers, the study region was not specified. Regarding journey type, 14 of the 76 modal choice papers deal with home-work commute trips and 5 study other journey types (e.g. business trips, leisure trips, etc.). In many of the papers (40 out of 76,) several journey types are studied at the same time. In 17 out of 76 cases, the journey type considered was not specified. Finally, with regard to the transport modes investigated almost half of the papers (35 out of 76) include car, public transport as well as active modes. 29 papers only confront car use against public transport use, 5 articles consider other combinations and in 7 studies the transport modes examined were not specified.

3. Modal choice definition

Although no common definition on modal choice was found while reviewing the selected articles, in many studies, a definition can be derived from the nature of the determinants studied. As such, the approach used to study modal choice

Table 1

Summary table of the main features of the studies examined based on region, journey type and transport modes considered (PT = public transport).

Region	#	Journey type	#	Transport modes	#
USA	9	Home-work commute	14	Car/PT	29
Europe	40	Other (business, leisure, etc.)	5	Car/PT/Active modes	35
Other	21	Combination of types	40	Other	5
Not specified	6	Not specified	17	Not specified	7
Total	76	Total	76	Total	76

strongly depends on the objectives of the research teams investigating it. Based on the specific focus used to analyze the complex process of modal choice in the reviewed articles, three major approaches can be distinguished: a rationalist approach, a socio-geographical approach and a socio-psychological approach.

The rationalist approach can be seen as the mainstream approach to study modal choice following the assumption that travellers take decisions based on utility maximization attained by minimizing travel time and costs (Shen et al., 2009). This microeconomic approach implies that individuals behave perfectly rational dealing with all kinds of available information. In this approach, a person confronted with different alternatives will act rational and select the alternative with the highest utility. The determinants studied in these researches are mostly associated with travel time and costs, leading to modal choice definitions based on objective and rational components only. The socio-geographical approach explicitly introduces a spatial component into the modal choice decision process and starts from the activity schedule of individuals or households to explain modal choice (Bhat and Singh, 2000; Axhausen, 2002; Meister et al., 2005; Cirillo and Axhausen, 2002). This approach treats the demand for travel as a derived demand, where people are presumed to travel not for the sake of it, but in order to pursue activities distributed in space and time. Introducing time and space into the modal choice decision process leads to the inclusion of a spatial component in the modal choice definitions. The socio-psychological approach aims at explaining modal choice by the study of attitudes of individuals with regard to the available transport means. The concepts of intentions and habits are important elements in this approach. Already in the seventies, Lovelock (1975) pointed out that modal choice is also determined by psychological variables. Many researchers postulate that modal choice should not only be studied based on objective measurements, but should also take into account subjective aspects (e.g. Fyrhi and Hjorthol, 2009; Kajita et al., 2004; Lang et al., 2011; Hine and Scott, 2000; Bamberg et al., 2003; Van Acker et al., 2010). Therefore, a realistic framework of modal choice should not only consider economic aspects, but also factors from transport geography and social psychology.

Kaufmann et al. (2004) incorporate this cross-fertilization between different fields in the concept of 'motility', which they define as 'the capacity of entities to be mobile in social and geographic space, or as the way in which entities access and appropriate the capacity for socio-spatial mobility according to their circumstances'. The three basic elements of motility are access, competences and appropriation, which are linked to the economic, social, cultural and political structures within which mobility takes place. Access refers to the range of mobility options and is limited by contextual circumstances; competences include the skills and abilities to be aware of and make use of access; appropriation refers to how entities perceive their own access and competences and how they react upon them. Depending on the circumstances and context, entities have different access, competences and appropriation, meaning that they have diverse motility options at their disposal.

Inspired by this multi-disciplinary approach and the 'motility' concept, we propose to define modal choice as the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors. Transport alternatives can refer to one single mode, but also to a combination of travel modes (motorized as well as non-motorized). The socio-demographic and spatial factors determine the possibilities with respect to mobility, while the socio-psychological factors influence how these possibilities are acted upon. This influence can be reasoned as a result of perceptions, society values and norms, personal attitudes and preferences, or unreasoned resulting from habits.

4. Modal choice determinants

Building further upon our modal choice definition, the framework used for the identification and structuring of modal choice determinants should be based on a multi-disciplinary approach where economics, transport geography, and social psychology come together. From this basic thought, we elaborated the conceptual framework presented in Fig. 1. On the outside circle, the framework distinguishes 3 types of determinants constituting the options to make a modal choice. These indicators can be socio-demographic, journey characteristic or space-related. The connection between each of these determinant types represents the possible interrelations and dependencies that may occur among them. Together they encompass the access and competences described in the motility concept. The second circle represents the influence of socio-psychological or subjective factors, like habits, perceptions, experiences, etc. These factors are determining for how the possibilities shaped in the first circle are acted upon. In the motility approach, they are referred to as appropriation factors. Modal choice is then positioned in the middle as the result of the interactions between the socio-demographic, journey characteristic and spatial indicators combined with the influence of subjective indicators. The aim of this framework is to provide a comprehensible and useable way to structure modal choice determinants to allow for a better understanding of the complex concept of modal choice. In this paper, the framework is used to structure the wide range of modal choice determinants resulting from the review analysis. It is useful at this moment to point out that our list of 26 determinants is not exhaustive as we focus on those commonly studied or analyzed in the articles we reviewed.

In order to get an idea of the importance of these determinants in the modal choice decision, we not only identify the determinants taken into consideration in the different papers, but we also verify in a descriptive way in how many of the cases each determinant has been labeled as a significant contributor to the modal choice decision. This results in the classification shown in Fig. 2, where the horizontal axis is an indicator of whether a determinant is commonly studied as it represents the ratio of the number of papers including a certain determinant against the total number of papers reviewed. Car availability, for instance, is mentioned as a determinant in 36 of the 76 reviewed papers, which corresponds to 47% on the

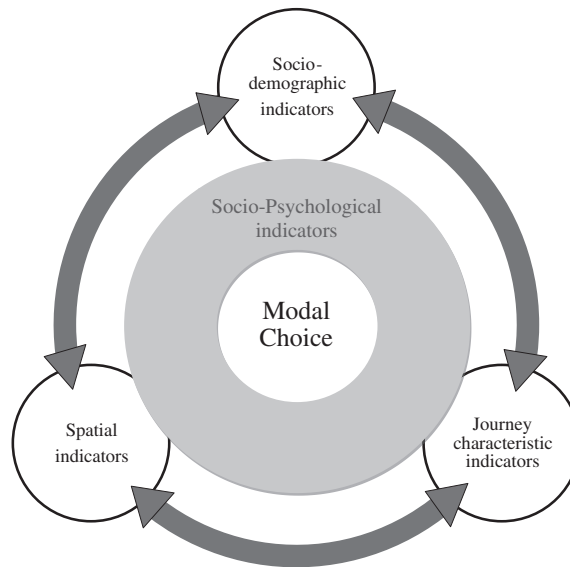


Fig. 1. Framework for structuring modal choice determinants.

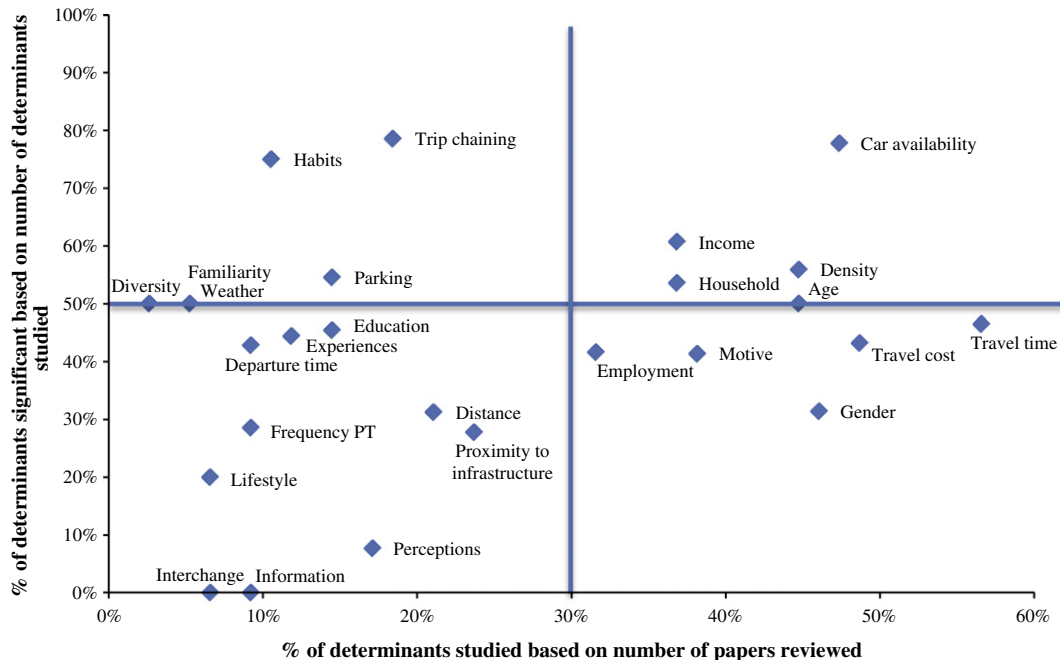


Fig. 2. Classification of modal choice determinants based on the review analysis.

horizontal axis. The vertical axis indicates whether a determinant is frequently recognized as significant. This is expressed as the ratio of the number of times a determinant is found significant against the number of times a determinant is studied. For car availability this ratio stands at 78%, as car availability has been found significant in 28 of the 36 papers where it has been studied. Based on this representation, we can classify the determinants roughly into four groups: those rarely studied and infrequently found significant (such as interchange, information, lifestyle, perceptions, etc.), those rarely studied and frequently found significant (such as habits, trip chaining, parking, etc.), the ones often studied and rarely found significant (such as gender, employment, motive, etc.) and usually found significant (such as car availability, income, density, household type, etc.). It appears that objective and straightforward determinants, like socio-demographic characteristics (age, gender, employment, income, etc.) and car availability, are more frequently studied compared to subjective and more complex ones, like familiarity, trip chaining, lifestyle, etc. Nonetheless, some of these appear to be understudied as they tend to have a significant influence on the modal choice decision (e.g. trip chaining, habits, etc.).

In the following sections, each of the determinants will be described separately. In order to structure them we use the multi-disciplinary framework that distinguishes between socio-demographic indicators (Section 4.1), spatial indicators (Section 4.2), journey characteristic indicators (Section 4.3) and socio-psychological indicators (Section 4.4).

4.1. Socio-demographic indicators

The first group of determinants consists of socio-demographic indicators, which shape the individual situation of the traveler as well as part of his/her social interactions. This group entails the following determinants: age, gender, education, occupation, income, household composition and household car ownership.

4.1.1. Age

Age, at the same time, determines the social status of the individual, which increases with age, and the physical ability to travel, which tends to decline as people grow older. In literature, there seems to be no real consensus on the impact of age on modal choice. Some studies found that older people tend to use public transport more often (Bhat, 1998; Cirillo and Axhausen, 2006; de Palma and Rochat, 2000), while others state that car use increases together with age (Nurul Habib et al., 2009; Pucher and Renne, 2003, 2005; Kim and Ulfarsson, 2008). According to Schwanen et al. (2001) it is not so much age, but rather car ownership that is determining for the modal choice for all age categories. According to our classification, age is found to be a significant determinant of modal choice in about half of the cases.

4.1.2. Gender

No real consensus about the role of gender in modal choice can be found in the consulted literature. Some studies report that women are more likely to use the car because of the higher proportion of household errands in combination with their home-work commutes which makes public transport less convenient (Brown et al., 2003). Other studies report that men are more likely to use the car while women are more dependent on public transport (Bhat, 1998; Limtanakool et al., 2006; O'Fallon et al., 2004; Schwanen et al., 2001). It appears that the interdependency between gender and other factors, like household composition, employment status, etc. is more determining for decisions on transport modes than gender itself. Although gender is quite often studied in the papers we reviewed compared to other determinants, it is only found significant in 31% of the cases considered.

4.1.3. Education

Education determines occupation, income and social status on one side and influences the development of organizational competences on the other side. For education too, no consent was found in literature. According to Pickery (2005) higher educated people are more likely to have higher income levels and as a result they are more prone to use the car to go to work. This is denied by other authors like Limtanakool et al. (2006) and Schwanen et al. (2001) who state that higher educated people use public transport more frequently for commuting than the car. Here also, it is the interdependency with other determinants like occupation, household size, etc. that determines modal choice, rather than education level itself. In our overview, education is classified as a determinant that is not often studied, and found significant in 45% of the papers where education is investigated.

4.1.4. Occupation

Employment is related to income and car ownership. Next to the type of occupation and job characteristics of workers, also the company's mobility policy has an influence on the modal choice of their employees, especially for commuting trips (De Witte et al., 2008; Bastin and Dobruszkes, 2006). Cervero (2002) reports that full-time workers are more likely inclined to use transit due to the acquisition of transit travel passes. Part-time workers and self-employed people are more likely to drive and less likely to walk (Nurul Habib et al., 2009; O'Fallon et al., 2004) and single workers are prone to use public transport more often for commuting (Limtanakool et al., 2006). Employment also has an impact on modal choice for shopping trips in a way that employed individuals are more likely to use the drive alone mode for shopping compared to unemployed individuals (Bhat, 1998). Although our modal choice paper review reveals that employment is more often studied compared to most determinants, it is only found significant in 42% of the cases considered.

4.1.5. Income

According to our overview of determinants, income is classified among the more important determinants of modal choice. It is studied in 37% of the reviewed papers and found significant in 61% of those papers. Several studies indeed agree that modal choice is income related (Lyons et al., 2002; Bresson et al., 2004; Dargay, 2007; Paulley et al., 2004; Schafer, 2000). Moreover, income entertains a positive relationship with car use and an inverse relationship with public transit use (Goodwin et al., 2004a; Hensher and Rose, 2007; Vasconcellos, 2005; Pucher and Renne, 2003, 2005). Choosing a solo-auto mode over shared-riding or transit is more likely among higher income levels (Bhat, 1997). Lower incomes tend to be more influenced by the price of transport, which stimulates their mobility decisions according to this criterion (Hine and Scott, 2000). People of lower income level face severe restrictions to travel because of less access to cars and lower mobility levels (Vasconcellos, 2005). Although many authors confirm the positive relationship between income and car ownership (and hence car use), some of them criticize this by stating that income does not seem to affect modal choice for business journeys

(Limtanakool et al., 2006) and that rising wealth is not necessarily associated with increases in automobile dependency (Kenworthy and Laube, 1996). According to the latter, car dependency is also determined by economic constraints and strong physical planning policies that favor non-auto modes. One could thus, for further improvement of understanding the factors influencing modal choice, correlate rising income with modal choice determining factors like density and other spatial characteristics.

4.1.6. Household composition

Based on our review analysis, household composition is positioned in the quadrant composed of the determinants more frequently studied and more often found significant. It is studied in 37% of the papers reviewed and indicated as significant in more than half of them (54%). The composition of the household has an impact on the number of cars available as well as on the organizational skills of the household members. In general it is found in literature that as the size of a household increases, there is a higher probability of travelling by car (Cirillo and Axhausen, 2002; de Palma and Rochat, 2000). Especially the presence of children increases the utility of car use, which has a significant negative impact on public transport use in turn (Limtanakool et al., 2006; Cirillo and Axhausen, 2006).

4.1.7. Car availability

Car availability is a very important determinant influencing modal choice. According to our overview, it is one of the determinants being studied more often, and is found to have a significant influence on modal choice in 78% of the cases where it was studied. The probability of selecting a car for travel increases with increasing amount of cars per driver in a household (Cirillo and Axhausen, 2002; Kenworthy and Laube, 1996; Limtanakool et al., 2006; Goodwin et al., 2004b). Residing in a zero-car household is strongly related with transit dependency (Cervero, 2002). As the ratio of the number of vehicles available to workers in a household increases, there is less competition for cars among household members and consequently a lower tendency to use the shared-ride mode and an even lower likelihood of using public transport or soft modes (Bhat, 1997; Nurul Habib et al., 2009). De Witte et al. (2008) found in their analysis that the odds of train use in comparison to car use decrease by 52% for commuting trips for each unit increase in number of cars and by 96.6% when commuters can make use of a company car. O'Fallon et al. (2004) confirm that having a company car influences the commuting modal choice in favor of the car.

4.2. Spatial indicators

The spatial indicators are elements characterizing the spatial environment in which the journey and thus modal choice takes place, such as density, diversity, public transport availability and parking.

4.2.1. Density

In this paper, density is considered as the ratio inhabitants/built-up area. In our categorization, we find density in the right upper quadrant, as it is not only more often studied (45%) but also more regularly identified as a significant factor in explaining the use of certain transport modes (56%) compared to other determinants. According to Kenworthy and Laube (1996) density is indeed a key determinant in modal choice: the balance between public transport use and private transport use is strongly related to urban density in a way that high densities tend to be associated with lower average trip distances for all modes, improved public transport and enhanced possibility of walking and cycling. For those who do not own a private car, urbanization is even more significant in their modal choice, where public transport mainly competes with walking and cycling (Schwanen et al., 2001). Urban areas (higher density) are usually better served with public transport than rural areas (lower density). One can conclude that public transport is more used in high density areas compared to lower ones (Camagni et al., 2002; Limtanakool et al., 2006). The urban location of a household has a positive effect on the use of public transport (Cirillo and Axhausen, 2006).

4.2.2. Diversity

Diversity can be seen as a mixed land-use in terms of a diverse pattern of residence, commerce, institutions, green space, industry and transport infrastructure accommodated by the neighborhood. According to Cervero (2002) land-use mixtures at both origin and destination side lower the probability of driving alone or ride-sharing in contrast of taking public transport, and vice versa. In their study on Brussels, Bastin and Dobruszkes (2006) found that the use of car is lower when people go to work in offices located close to main rail stations. Diversity is not often included in the modal choice research papers we reviewed, but appears to be significant half the time it is included.

4.2.3. Proximity to infrastructure and services

Proximity to infrastructure refers to the availability of road networks and of public transport infrastructure. Based on our review analysis, proximity to infrastructure is classified among the determinants getting less attention and being less often identified as significant. It is closely related to other spatial characteristics like density and diversity, both at the origin and destination side of the trip. According to Limtanakool et al. (2006), the availability of a public transport-stop increases public transport use, although for the modal choice decision the proximity to a public transport-stop at the destination side is of greater importance and determining than at the origin side. The supply of public transport is generally measured by the

distance to public transport stops of a certain quality level, which has a direct influence on public transport use (Hensher, 2008; Rietveld, 2000). If there is no or insufficient public transport available for only one trip in a longer trip chain, no public transport will be used for the entire chain and those trips will generally be done by car (Van de Walle and Steenberghen, 2006). Kenworthy and Laube (1996) mention that auto use increases significantly with increasing road availability.

4.2.4. Frequency of public transport

Frequency plays a crucial role in public transport availability and usage and as a result influences modal choice. Efficiency and frequency are mainly related to city density and to population size. In big metropolitan areas, well-organized public transport networks are generally available. Higher frequencies increase the comparative efficiency of public transport with respect to the other transport modes and by that also the share of public transport (Camagni et al., 2002). Higher frequencies also make the trips less unpredictable while perceived time would be shorter. Poor public transport services, on the other hand, lead to lower public transport use (Vasconcellos, 2005). Movements with public transport within cities are in function of its frequency, whereas intercity movements are dependent on arrival times (Cascetta and Papola, 2003). Based on our review analysis, frequency of public transport is getting less attention and is less often identified as significant compared to other determinants.

4.2.5. Parking

The availability of parking has an important impact on modal choice, especially in highly dense areas (Kajita et al., 2004). People are stimulated to use their car (irrespective of whether it is quicker or not than public transport) when they are guaranteed of having a (free) parking space at work (Kenworthy and Laube, 1996; Kaufmann, 2002; Ye et al., 2007; Vasconcellos, 2005; O'Fallon et al., 2004). Brown et al. (2003) conclude that lowering the parking lots will raise the use of transit in relation to car use. Although parking is found to have a significant influence on modal choice in more than half (55%) of the papers where it has been studied, the number of times it was investigated is rather low (only in 14% of all the papers reviewed).

4.3. Journey characteristic indicators

The third group consists of journey characteristic indicators, which are elements peculiar to the trip under consideration. These elements encompass motive, distance, travel time, travel cost, departure time, trip chaining, weather circumstances, information and interchange.

4.3.1. Travel motive

Travel motive is closely linked to travel need, which stands at the origin of mobility demands and is therefore an important determinant of modal choice. Literature research gives an insight in the main travel motives being commuting, business or leisure. Pucher and Renne (2003) and Fyrhi and Hjortol (2009) indicate that for commuting trips the share of public transport is consistently higher than for other travel motives. According to Limtanakool et al. (2006) and O'Fallon et al. (2004), private car use is very prominent for a business traveller. In their study on short home-based trips Kim and Ulfarsson (2008) found that non-automobile modes are more frequently used for school trips. Also for short social/recreational trips, the softer modes (walk and bike) are primarily used (Pucher and Renne, 2003). In contrast, Kim and Ulfarsson (2008) suggest that picking-up/dropping-off and shopping are strongly related to automobile use. For longer leisure trips, the car appears to be the most typical mode (Fyrhi and Hjortol, 2009; Van de Walle and Steenberghen, 2006). Although motive is quite often studied in the papers we reviewed compared to other determinants, it is only found significant in 41% of the cases considered.

4.3.2. Distance

Distance influences modal choice in a way that for longer distances, faster travel modes will be preferred. In Brussels, for example, the car is the dominant transport mode for commuting distances up to 30 km (Pickery, 2005). Beyond this distance, train use becomes more likely for the home-work commute (De Witte et al., 2008). This is due to the fact that the train becomes more performing and hence more competitive for longer distances and because of socio-geographical aspects as Brussels' suburbs are mainly rich with people living according to the Kaufmann's so-called 'Californian way of live' (Kaufmann, 2000). Rietveld (2000) focused in his study on the access and exit modes when making a multimodal journey. For the home end (access mode) he found that walking is the dominant mode up to 1.2 km, biking for distances between 1.2 km and 3.7 km and public transport for distances higher than 3.7 km. For the activity end (exit mode), walking appeared to be dominant up to 2.2 km and public transport from 2.2 km. Distance, travel time and travel cost are directly related to each other. The longer the distance, the longer the travel time and the more it will cost. Based on our review analysis, distance is classified among the determinants getting less attention and being less often identified as significant.

4.3.3. Travel time

Travel time is an important determinant of modal choice (Bhat, 1997; Van de Walle and Steenberghen, 2006) and can be valued differently depending on the travel motive. Transit options often involve longer walking distances (Brown et al., 2003) and higher public transport travel times reduce the use of it (Vasconcellos, 2005). Travellers also seem to be more

sensitive to out-of-vehicle travel time than in-vehicle travel time (Bhat, 1998). Although travel time is studied the most in the papers we reviewed compared to other determinants, it is only found significant in 47% of the cases considered.

4.3.4. Travel cost

Travel cost also play a role in modal choice (Kajita et al., 2004; Bhat, 1997). Consumers are sensitive to changes in price, but the extent depends on several factors, like the purpose of the trip (Annema, 2002; Litman, 2004). If a public transport pass is owned, public transport use will increase (Kim and Ulfarsson, 2008; Last and Manz, 2003) and car use will be lower (Ye et al., 2007). Nevertheless, public transport use is particularly sensitive to increases in public transport fares (Vega and Reynolds-Feighan, 2009; Vasconcellos, 2005). The more it costs to commute by transit relative to driving alone, the more people are likely to solo-commute (Cervero, 2002). However, studies about improving public transport indicate that only a limited share of car drivers would want public transport to be made less expensive in order to use it (Mackett, 2003; De Witte et al., 2008). Although our modal choice paper review reveals that travel cost is more often studied compared to most determinants, it is only found significant in 43% of the cases considered.

4.3.5. Departure time

The trip timing, with regard to the departure time, is interconnected with modal choice. Public transport is less attractive during off-peak due to lower service levels whereas car is more attractive during off-peak due to lower traffic congestion (Nurul Habib et al., 2009). This is where departure time determines the access to certain transport modes. Departure time is also related to travel motive and the necessity of the trip, which is determining for the organizational possibilities of an individual or household. For home-work and home-school trips for instance, people are obliged to move during peak hours. For public transport this implies higher frequencies but at the same time lower comfort. For less stringent activities, like leisure activities, people are more likely to have the opportunity to depart outside peak hours to enjoy more comfort and convenience with the transport mode of their choice. In our overview, departure time is classified as a determinant that is not often studied, and only found significant in 43% of the papers where it was investigated.

4.3.6. Trip chaining

Trip chains are more complex compared to simple trips where there are no intermediate stops between the origin and destination. According to Nurul Habib et al. (2009), modal choice is determined by all trips in the chain, except if the first trip is a work trip, then this trip is determining for modal choice. In a recent study of Currie and Delbosc (2011), public transport chains were generally found to be more complex than those undertaken by car, explaining why car is usually favored when making trip chains. O'Fallon et al. (2004) report that car use is increased because of multiple destinations when having to drop off children. Krygsman et al. (2007) found that modal choice is interrelated with the choice of included intermediate activities on a home-work tour. Before and after work intermediate activities are correlated negatively to public transport use, while private transport modes have a positive impact on inserting intermediate activities before or after the main tour. It can thus be concluded that trip chaining has an impact on modal choice in a way that complex trip chains tend to be more car oriented and the more complex the chain, the less likely public transport is used (Van de Walle and Steenberghen, 2006; Ye et al., 2007). Although trip chaining is found to have a significant influence on modal choice in almost 80% of the papers where it has been studied, the number of times it was investigated is rather low (only in 18% of all the papers reviewed).

4.3.7. Weather conditions

Changes in weather conditions impact modal choice in a way that it determines the access to different travel modes, especially when it concerns non-motorized ones. Summer activities done by cycling will mainly shift to walking in winter (Fyrhi and Hjorthol, 2009). Goodwin et al. (2004b) indicate that over 20% of the employees change their main travel mode in summer. According to Kim and Ulfarsson (2008) cycling may not be a good alternative in bad weather conditions. Weather conditions are not often included in the modal choice research papers we reviewed, but appear to be significant in 50% of the cases where they are studied.

4.3.8. Information

In general, travellers do not want to spend too much time and effort on their modal choice decision. Research by Kenyon and Lyons (2003) found that information about alternative modes is rarely consulted as a result of which travellers can be unaware of possible modal alternatives for their journeys. Up-to-date and easy access information is particularly important for public transport use, where information is an important indicator of public transport quality (Grotenhuis et al., 2007). Information can also relate to the congestion and delay on roads and on how this information is distributed among people. Congested areas can cause stress for people, but this stress can reduce when information about the delays is given (Dijst et al., 2002). Based on our review of modal choice papers, information is classified as a determinant not frequently studied and not often found significant.

4.3.9. Interchange

Interchanges are linked to the use of different transport modes (e.g. train plus underground) or of different networks that complement each other (e.g. two different bus operators in a same city). They are also a consequence of how transit networks are designed (e.g. suburban lines going to the city centre or only to a peripheral underground station) (Dobruszkes et al.,

2011; Litman, 2008; Wardman and Hine, 2000). Access to (transit) modes is determined by the skills to deal with interchange. According to De Witte et al. (2008) the second most important reason for car users to use their car is a bad public transport connection. There is a general resistance among people to interchange (Hine and Scott, 2000) and it is found that a limited supply of integrated public transport modes reduces the use of it (Vasconcellos, 2005). In our classification, interchange is surprisingly found in the corner of determinants that are not frequently studied and also not often labeled as significant.

4.4. Socio-psychological indicators

The group of socio-psychological determinants bundles the factors that influence how an individual acts upon the options created by the previous groups of determinants. This group entails rather subjective components like experiences, familiarity, lifestyle, habits and perceptions.

4.4.1. Experiences

A positive or negative experience in the past will determine the modal choice process in the present. Also, network experiences can influence modal choice. The higher the user's road network experience, based on the length of time the user has used the main route to go to work, the higher the probability of using a private transport mode to go to work (de Palma and Rochat, 2000). This is why some studies propose to give users experiences of a real-life situation, an experience that could potentially lead to modify mode decisions (Brown et al., 2003; Fujii et al., 2001; Heath and Gifford, 2002). In our overview, experience is classified as a determinant that is not often studied, and only found significant in 44% of the papers where it was investigated.

4.4.2. Familiarity

Experience can lead to familiarity. Familiarity is related to the knowledge users have developed of the various means of travel at their disposal, which facilitates the use of the considered means of travel. De Witte et al. (2006) found that students' use of public transport in Brussels was significantly influenced by familiarity with regard to the public transport system and the city where their trips take place. Higher familiarity with the entire transport system reduces barriers for using alternative modes (Last and Manz, 2003). The use of public transport in the past may give people the skills and confidence to do so in the future (Brown et al., 2003). Familiarity is not often included in the modal choice researches we investigated, but appears to be significant half of the time it is considered.

4.4.3. Lifestyle

An individual's lifestyle choices are determining for his/her social status, which is in turn determining for his/her access to different travel modes. Lifestyle choices include decisions on education and occupation, which are both related to income and car ownership. Higher educated people are more likely to have higher income levels and to use the car to go to work (Pickery, 2005). According to the view of Scheiner and Holz-Rau (2007), individual lifestyles play an important role in determining travel modes, however, Van Acker et al. (2010) postulate that the influence of objective socio-economic (like age, gender, employment, etc.) characteristics exceeds the influence of subjective lifestyles. In our classification, lifestyle is found in the corner of determinants that are not frequently studied and also not often labeled as significant.

4.4.4. Habits

Habits can influence the interpretation of access and skills, in a way that transport users will put little cognitive effort in exploring the attributes of the different alternatives at disposal. Strong habit travellers use less compensatory choice rules than weak habit participants (Verplanken et al., 1997); their travel decision is only based on a fraction of the information available. Switching to other travel modes requires learning new routines. The way in which users have experienced a certain travel mode will help them appreciating a particular travel means and will play a decisive role in their modal choice. Although habits are found to have a significant influence on modal choice in almost 75% of the papers where it has been studied, the number of times it was investigated is rather low (11%).

4.4.5. Perceptions

The perception of individuals with respect to the different means of travel is of importance in the modal choice decision. Van Acker et al. (2010) mention that preferences are based on attitudes and perceptions. According to Goodwin et al. (2004b) quality perception is determined by the person's own history. Also travel time and travel cost can be perceived differently for alternative transport modes. With regard to travel times, time spent on public transport is perceived worse than time spent in a car. Transit wait time is perceived even more time-consuming than transit travelling time (Nurul Habib et al., 2009). This is confirmed by Kaufmann (2002) who states that the alleged slowness of public transport is not just a question of the amount of time, but also a question of how this time is experienced. Journey times by car are usually seriously underestimated while journey times by public transport are often overestimated, resulting in transit generally to be perceived more negatively compared to car. As far as costs are concerned, the assessment of car costs is often subjective: the costs of a car are often underestimated compared to the price of public transport for the same journey (Frenay, 1994; De Witte et al., 2008; Innocenti et al., 2009). In general, the traveller mainly considers out-of-pocket costs when making a transport decision. The

higher the fraction of true overall costs payable at point-of-use, the more present they will be in the modal choice decision. Once the car purchase decision is made and the annual fixed costs are paid, people are likely to use their car for most trips as the remaining marginal costs related to car use are relatively low. Public transport users, on the other hand, can buy single tickets or travel passes to pay for their journeys. When they are paying for their ticket at point-of-use, they are much more aware of the actual cost of their journey. The variation in modes of payment and the resulting difference in price perception have an impact on travel behavior and modal choice (European Commission, 1996). In our classification, perception is found in the corner of determinants that are not frequently studied and also not often labeled as significant.

5. Discussion: trends and interdependencies

Based on this review of modal choice determinants and their impact, some general tendencies can be derived. A first outcome is that at the origin of a modal choice process, one finds a travel need or motive. Usually four travel motives can be distinguished: home-work commuting, home-school commuting, business and leisure. Next to travel motive, car ownership is a key determinant of modal choice in a way that when a car is available, it will be used to travel. Kaufmann (2000) showed that a significant share of studied populations cannot choose their mode, either because they have no car or because they are not served by public transport. In zero-car households there is usually a greater dependency on public transport, regardless of whether this is forced or not. Given the increased availability of cars in households over the last decades, the car is a dominant travel mode for all travel motives. Nevertheless, for commuting to work the share of public transport is considerably higher than for the other travel motives.

Besides travel motive and car ownership, a wide range of different factors influence modal choice to a larger or smaller extent (Fig. 3). In many cases, these determinants are mutually affecting each other, explaining the many links between the different determinants. For instance, there is a positive relationship between income and car use and an inverse relationship with public transport use. Car use is then further influenced by parking facilities, both at the origin and destination side, which is especially the case in highly dense areas where parking spaces are scarce. Furthermore, income is related to employment, which is one of the factors determining lifestyle decisions. Employment affects the availability of a car indirectly through income, but for the commuting modal choice the mobility policy pursued by the company also plays a role. Employees are more likely inclined to use public transport when their company provides (or partially reimburse) transit passes. In any ways, earlier lifestyle decisions on education, occupation and housing will determine the access to different transport modes nowadays.

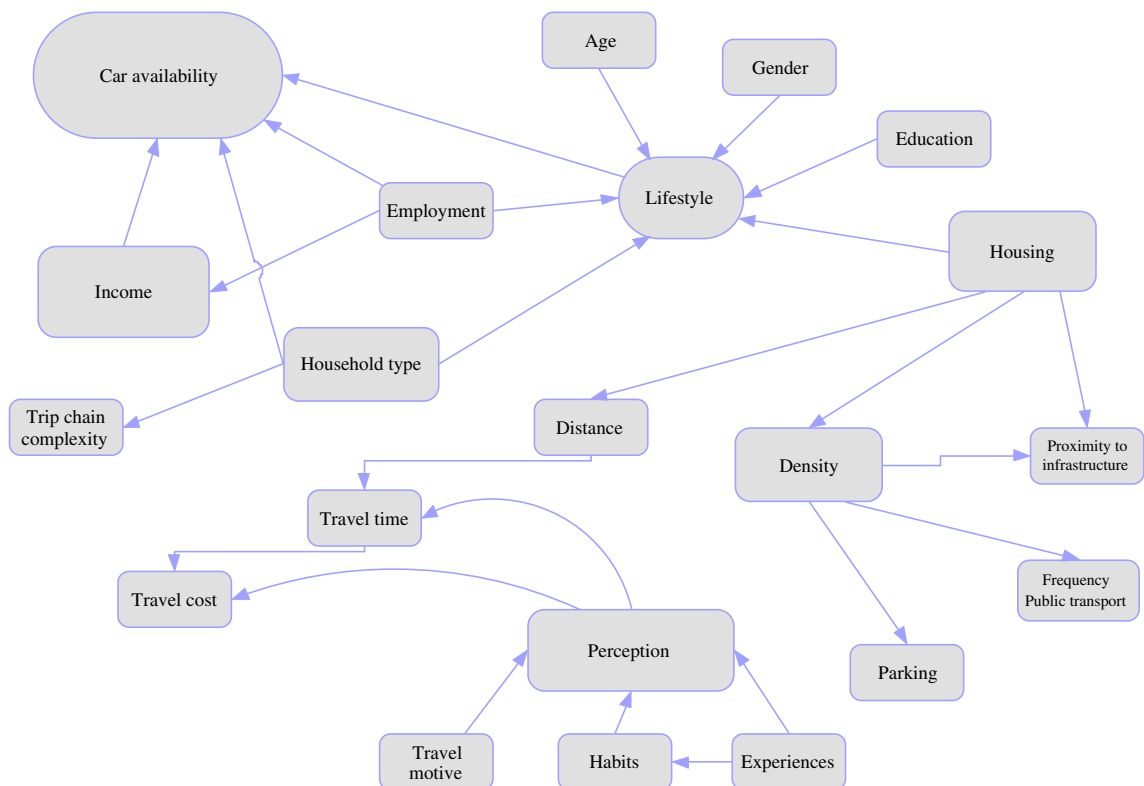


Fig. 3. Visualisation of modal choice determinant interdependencies.

In addition, the lifestyle decision or constraints on housing are determining for the space in which the modal choice decision has to be made. This is where density acts as a determinant of modal choice. It appears that higher density levels go together with improved public transport availability, which stimulates public transport use in turn. This indicates a link between density on one side and public transport frequency and availability on the other side. Public transport frequency is higher in metropolitan areas and as far as proximity to infrastructure is concerned, dependency on car use will be higher when there is no or insufficient public transport available. This impact is even stronger where extensive road networks are available.

The housing decision also influences trip characteristics like distance, travel time and travel cost, which are interdependent and determining for modal choice. Travel cost depends on travel time, which in turn depends on travel distance. In general, the car is the dominant mode and is even used for short distances that could easily be covered by walking or cycling. As far as travel time is concerned, one could conclude that travel time is related to spatial and temporal aspects where individual perception and experiences of different travel modes and value of travel time significantly influence modal choice, and where travel motive cannot be ignored. People tend to choose the fastest transport mode and although it is not always the case in reality, they often think that it is the car. In addition, when looking at the travel costs, it appears that public transport is more sensitive to changes in travel cost compared to the car.

Socio-demographic determinants like age, gender, education and household composition are related directly to lifestyle and indirectly to car ownership. Regarding the impact of age on modal choice, there is no consensus in literature, especially when it comes to older people. Some studies indicate that elderly are more relying on public transport, while others state that car use increases with age. It appears however that senior's modal choice is greatly influenced by car ownership. Also for gender, there is no real consensus in literature on its impact on modal choice. Some studies indicate that women are more likely to rely on the car because they have to run household errands or have to drop off/pick up children, while other studies state the opposite, because men are more prone to need a car for their work. As far as education is concerned, a reasoning followed by several authors is that higher education levels lead to higher incomes and consequently increases the likeliness of car use. In contrast, some authors state that public transport is more frequently used for commuting among higher educated people. Finally, household composition determines modal choices by influencing the number of cars available in the household and the complexity of trips being made within the household. The number of cars increases with household size, while the complexity and the number of trip chains grows with the presence of children. More cars available and higher trip complexity increases the likeliness of car use in turn. This indicates that household composition is also linked to trip chaining. The more complex these chains, the less likely public transport is used.

Regarding the socio-psychological impact, it appears that strong habits reduce the effort that will be put into exploring alternative modes, regardless of the access and competences of the traveller, while perceptions are determining for the way an individual assesses his/her own access and competences towards different modal options. In general, car use is perceived more positive compared to public transport in terms of freedom, independence, speed and price. Also protection and prestige play a role in how car use is perceived.

6. Conclusions and recommendations

A profound understanding of travel behavior in general and of modal choice in particular is indispensable to take adequate policy measures to guide our mobility towards a more sustainable one. Although travel behavior and modal choice have been studied for many years, our review demonstrates that there is no uniformity in the definitions and the methodologies applied to study the concept of modal choice. Usually, the definition used and the determinants included in the study depend on the research perspectives and goals of the research team. This has the benefit that different theoretical reflections can be made, but it also makes things more complex, as the selected approach will have an impact on the research findings. In a more classical view, the focus lies on rational and economic factors; a broader view already includes objective spatial components; whereas a multi-disciplinary view also considers subjective factors stemming from psychology to expand the objective view handled in rational and socio-geographical approaches.

Inspired by our aspiration to approach modal choice from a multi-disciplinary perspective, we propose a common definition where modal choice is defined as 'the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors'. We should point out that although this concept is called modal choice, in reality this choice can be limited due to objective or subjective circumstances. With regard to the objective context, the choice can be limited by the access a person has to travel modes. If there is only one option, the person does not really have a choice. As far as the subjective context is concerned, the choice can be the result of a reasoned decision process based on perceptions, attitudes and preferences, but can also result from unreasoned behavior based on habits. Therefore, it is appropriate to stress that although the term 'modal choice' is applied, the decision to use a certain transport mode is not always the result of a choice in the strict meaning of the word.

As far as the modal choice determinants are concerned, this review indisputably shows that there are a whole range of factors determining modal choice and that these factors are interrelated to a larger or smaller extent. In order to contribute to an improved knowledge on the different modal choice determinants and their interdependencies, a multi-disciplinary framework was elaborated to structure the variety of determinants stemming from different disciplines. Modal choice is

often the result of a very compound choice process that can take place consciously or unconsciously and that includes objective as well as subjective determinants, each requiring a different approach. Objective determinants can typically be identified quantitatively, while subjective ones are rather qualitative. Usually, more attention is paid to objective factors as they can be measured more easily. The proposed framework allows for assessing objective determinants influenced by subjective determinants like habits and experiences. It might very well be that the objective accessibility of a certain transport mode is high, but that this transport mode is not considered as a modal choice option by the traveller because he/she perceives the subjective accessibility as low. It is therefore vital to stress the importance of taking the subjective component into account when studying modal choice decisions. As such, the presented concept can assist policy makers towards setting up more sustainable transport systems by taking into account the variety of influencing factors. It is worthwhile to mention that in a next stage, this multi-disciplinary framework will be tested and valorized in a forthcoming application, where it will be applied to study the modal choice of people travelling to, in and from the Brussels Capital Region based on data available from the National Survey on the daily mobility of the Belgian population (BELDAM). In this stage, we will also try to determine the importance of and correlations between the determinants gathered in this review.

We can conclude that modal choice is clearly a complex and multifaceted concept. Due to this complexity, researchers tend to simplify their research methods and adjust their approaches to the specific situation they want to investigate. A regularly used simplification is that modal choice is measured in terms of a main or principal transport mode, which is usually the one used to cover the largest distance of the journey. This unimodal approach allows gaining insight in the multifaceted concept of modal choice, but neglects the occurrence of trip chains and multimodality, which have grown to be more important in our daily mobility as people strive for more efficient ways to join their activities throughout the day. Furthermore, the considerable importance of trip chaining and the overexposure of main travel modes also result in an underestimation of access and exit modes, which are typically 'soft or active modes' (walking and cycling). Another example of simplification concerns the aggregation of modes. When assessing car use against the use of public transport, many researches join multiple forms of public transport together in a single mode, although train and bus for instance can be very different. It is worth highlighting that this working method is usually inspired by modeling reasons rather than ideological ones. Nevertheless, mobility actors should be aware of the research simplifications and its repercussions when using the results of these simplistic models and predictions as a basis for studies and plans on mobility. In addition, the lack of harmonization in definition and analysis of modal choice makes it difficult or even impossible to compare modal choice data, both longitudinal (in time) and cross-sectional (between cities, regions or countries). Especially nowadays, when the detrimental impacts of our growing mobility needs and the accompanying modal choices are irrefutably present, the need for harmonization of travel surveys, definitions and methodologies becomes more urgent in order to be able to tackle these issues from a larger perspective and on a broader scale.

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