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What influences transport mode choice for commuting in the Vienna city region?

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List of Abbreviations

AIC	Akaike-Information-Criterion
BIC	Bayesian-Information-Criterion
CURB	The COVID-19 pandemic as a disruptive force for urbanisation – research project based in the SUUREG research group of ISR at ÖAW
EU	European Union
FRC	Functional Road Class
FWF	Austrian Science Fund
GIP	Graphenintegrationsplattform Österreich
ISR	Institute for Urban and Regional Research at the ÖAW
ÖAW / OeAW	Austrian Academy of Sciences
OD-pairs	Origin and destination of one trip
PGIS	Participatory GIS
PPGIS	Public Participation GIS
SGI	Services of general interest
SGEI	Services of general economic interest
SSGI	Social services of general interest
SUUREG	Working group Sustainable Urban Regions at ISR
TTB	Travel Time Budget
TOD	Transit-Oriented-Development
VGI	Volunteered geographic information
ZMR	Zentrales Melderegister | Central residents register

Abstract

The climate crisis has made it necessary to reorganise various areas of daily life. One of these areas is the mobility sector. To drive forward the transformation of the mobility sector, the aim must be to shift the necessary journeys to environmentally friendly means of transport in line with the principle of avoid – shift – improve. In order to make the transformation in this area not only ecologically but also socially sustainable and just, a transition phase is required that initiates the transition from the current heavily car-based mobility sector to other modes of transport. To make a corresponding change in behaviour as smooth as possible, the question arises regarding possible influencing factors on people's decision-making behaviour when choosing a means of transport. As part of this master's thesis, an extensive list of potential factors for transport mode choice is compiled from the existing literature and the transport mode choice is modelled based on selected factors, which partly stem from a PPGIS-survey, using multinomial logistic regression for the city of Vienna and the district of Mödling to show significant impacting factors on the mode choice in the study population. The results show an influence of sociodemographic and spatial and urban planning elements on the choice of transport mode and, in combination with the literature review, there is both a need for further research and scope for intervention for stakeholders and policymakers in this area.

Kurzfassung (German Abstract)

Aus der Klimakrise ergibt sich die Notwendigkeit, verschiedene Bereiche des täglichen Lebens umzugestalten. Einer dieser Bereiche ist der Mobilitätssektor. Um die Transformation des Mobilitätssektors voranzutreiben, ist nach dem Prinzip Vermeiden – Verlagern – Verbessern eine Verlagerung der notwendigen Wege auf umweltfreundliche Verkehrsmittel anzustreben. Um die Transformation in diesem Bereich nicht nur ökologisch, sondern auch sozial nachhaltig und gerecht zu gestalten, bedarf es einer Übergangsphase, die den Übergang, vom heute noch stark am Auto orientierten Mobilitätssektor, zu anderen Verkehrsmitteln einleitet. Damit eine entsprechende Verhaltensänderung möglichst reibungslos zu gestalten, stellt sich die Frage nach möglichen Einflussfaktoren auf das Entscheidungsverhalten der Menschen bei der Verkehrsmittelwahl. Im Rahmen dieser Masterarbeit wird aus der bestehenden Literatur eine umfangreiche Liste von potenziellen Faktoren für die Verkehrsmittelwahl erarbeitet und aus ausgewählten Faktoren, die zum Teil in einer PPGIS-Studie erhoben wurden, ein Modell mittels multinomialer logistischer Regression für die Stadt Wien und den Bezirk Mödling erstellt und damit für die Stichprobe signifikante Faktoren der Verkehrsmittelwahl herausgearbeitet. Die Ergebnisse zeigen einen Einfluss von soziodemografischen und raum- und stadtplanerischen Elementen auf die Verkehrsmittelwahl und in Kombination mit der Literaturrecherche ergeben sich sowohl weiterer Forschungsbedarf als auch Interventionsspielraum für Akteure in diesem Bereich.

1 Introduction

1.1 Problem statement and objective

The mobility sector is undergoing a large transformation process (Wolking, 2021). As societal macro-changes and challenges arise, the mobility sector is pressured to adapt itself to these developments. These macro changes and challenges include the climate crisis, the urbanisation, digitalisation, demographic change and rising individualism (Nuhn & Hesse, 2006; Wolking, 2021). Each of these changes and challenges bear opportunities and risks for the mobility sector, for example, the internet and digitalisation have the potential to mitigate some of the negative effects traffic has on the environment as video meetings can mitigate the need to travel to meet in person, it can also stimulate traffic through e.g. a rise in online shopping and the connected delivery of parcels (Nuhn & Hesse, 2006).

The historical development of cities and suburbs have left their mark on the mobility sector. The mostly car-oriented suburbs as a relic of the 1960s to 1970s have to undergo a larger shift in their mobility form to mitigate the high car usage and shift to more environmentally friendly transport modes. The idea that the built environment could be a proxy for the transport mode choice has arisen from a critical view on the car-centric neighbourhoods (Ramezani et al., 2021). In addition, planning paradigms like the transit-oriented development as part of the new urbanism in the US (Chapter 2.3.4) or the compact city in Europe (Chapter 2.3.5) have arisen in the late 20th century. They focus on the compactness of the city and the integration of city- and mobility planning (Chapter 2.3). Both planning concepts aim to revert / hinder the car-oriented development on a regional scale by designing the built environment to determine the mobility and not the other way around (Calthorpe, 2011; De Vos & Witlox, 2013).

The integrated city- and mobility planning can be considered part of the solution to tackle the climate crisis as in an integrated approach different mobility styles are emphasised (Priebs, 2019). In the last years an ongoing discussion about the mobility transition ("Verkehrswende") was held in Germany and to a lesser extent in Austria. This emphasises not only the necessity to change the mobility sector drastically, but also the relevance of the topic has been acknowledged in the society. This discussion is mostly held under the impression of the climate crisis and the large share of greenhouse gas emissions the mobility sector produces (Wolking, 2021). In Austria, the transport sector is the largest contributor to greenhouse gas emissions, with 44.8% of total greenhouse gas emissions in 2023 (Umweltbundesamt, 2025). This gives the mobility sector a decisive role in the fight against climate change. The European Commission has issued white papers on the effect of the mobility sector on the climate crisis and possible solutions. These documents only pay limited attention to the connection of the built environment and the mobility sector

(European Commission, 2001, 2011 cited in De Vos & Witlox, 2013). With the European Green Deal, the European Union aims to make the transport sector climate neutral until 2050 which emphasises the need to change the transport behaviour (DESTATIS - Statistisches Bundesamt, n.d.).

This ultimately makes the transport mode choice and the underlying factors for the decision a relevant question for the transformation of the mobility sector. A possible solution can be found in urbanism, which combined with a denser settlement and a fitting mobility system seems to be a suitable solution for many issues regarding the climate crisis and other issues of the urban society (Calthorpe, 2011).

The transport mode choice for regular trips like commuting can make a larger impact in terms of the reduction of greenhouse gas emissions. Commuting trips can make a large share of trips in general as shown by the 2013/2014 mobility panel "Österreich unterwegs", which shows 26% of all trips between Monday and Friday in Austria (24% in Vienna) were for the purpose of commuting between home and work. This is the largest share under the different trip purposes. From the trips to the workplace, 65.2% were made using the car, while 20.2% were made in the public transport, 6.6% with the bike and 7.6% by foot (Federal Ministry of Transport, Innovation and Technology (BMVIT), 2016). This underlines the necessity to look at commuting trips and proves them to be an inevitable part of the city-regional mobility behaviour (Chen et al., 2023).

A change in the mobility behaviour on commuting trips can thereby lead to a reduction in emitted greenhouse gas emissions. One changing variable in the mobility behaviour is the mode shift of the model avoid - shift – improve which is part of the Austrian mobility master plan 2030 (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), 2021). As the shift of the chosen transport mode can change the emitted greenhouse gas emissions, it is necessary to investigate the decision-making process of the transport mode. Chen et al. (2023) have mentioned the built environment as a significantly impacting factor on commuting behaviours. Additionally, other factors must be mentioned for the mode choice of the (commuting) trip. Jang & Ko (2019) mention in that context, that the optimal commuting time, in terms of commuter satisfaction, is not zero, which shows there is seemingly a psychological need to differentiate between home and work locations. This leads to the question, what influences the transport mode choice if a psychological necessity for the commuting trip persists. As the mode choice is a complex decision process an exhaustive list of variables determining it and the collection of corresponding data has been challenging (Cevero, 2002 cited in Chakrabati, 2016).

The extent to which mobility patterns and the influences on them are perceived can be differentiated according to the factors, as citywide, regional or local factors may be involved in the decision-making process. Another often used scale in this context is the neighbourhood. The neighbourhood scale has been part of the discussions for good housing standards since 1938, where many qualities like the modern development of neighbourhoods

are already mentioned (Davies, 1938 cited in Khosravi et al., 2016). Under the premise of similar accessibility of transport options a local scale in the form of neighbourhoods makes sense. It allows for a planning scale with a larger emphasis on active mobility and, if principles of the public mobility idea (Chapter 2.1) are implemented, can enhance peoples' chances for opportunities. Some planning concepts are also based on the neighbourhood scale as a minimal basic building block of the integrated city and mobility approach, like the transit-oriented-development (Calthorpe, 2011; Chapter 2.3.4) the X-minute city approach (Logan et al., 2022), or the city of short distances (Wittwer & Berger, 2021).

1.2 Research questions & structure of the thesis

As the title of this master's thesis suggests, the focus points are the influencing factors on the transport mode choice in the Vienna city-region. This is underlined by the main research question: "***Which individual, neighbourhood and city level variables could explain the transport mode choice on commuting trips in the Vienna city region?"*** The main research question emphasises the different scales on which factors determining the transport mode choice could be found.

The following chapter presents main planning models of the integrated city- and transport planning as well as models and theoretical frameworks of the decision-making process. This lays the foundation for the general understanding of transport mode choice. Chapter 3 provides additional information on the used methods as well as the study area for this master's thesis.

To answer the research question, it is divided into two supplemental research questions. The first one "***What could influence travel mode choices?"*** is answered through extensive literature review. The second supplemental research question ***"What could influence the transport mode choice for commuting trips in the Vienna city-region?"*** is answered through a multinomial logistical regression based on PPGIS, statistical and geospatial data, which was chosen based on the literature review. Chapter 4 provides the results of these analytical steps, whereby chapter 4.1 focusses on the first supplemental research question and the subsequent chapters 4.2 to 4.4 focus on the second supplemental research question.

In the last chapter, chapter 5, the results of the answers to the supplemental research questions are concluded and discussed and used to answer the main research question. In addition, the limitations as well as possible areas for further research and policy implications are given.

2 Models and theories

The following chapter links the main topic of this master's thesis to the relevant context and emphasises links to relevant adjacent concepts and theories. This provides a basis for the understanding of the thesis as well as the foundation for the further analysis. At first, a definition about the three main terms mobility, transport, and traffic (Chapter 2.1) will be given. Then the concept of mobility will be linked to the European concept of the services of general interest (Chapter 2.2) to embed the topic in the discord as well as show the relevance of SGI related factors for the mobility sector. Afterwards an extended look is given towards integrated city- & mobility planning (Chapter 2.3) within this scope the city-regional-scale (Chapter 2.3.2), and key planning paradigms (Chapter 2.3.3 – 2.3.5) will be presented. Finally, the chapter focusses on different behavioural approaches to explain decision-making processes and thereby give anchor points for the understanding of the transport mode choice (Chapter 2.4).

2.1 Definitions: transport – traffic - mobility

All three terms are used within the scope of transport geography but have to some extent different meanings and ideas behind them. These definitions focus on the transport geographic implications of the terms and exclude the usage of the terms in other areas (e.g.: digital infrastructure).

Transport

Transport is the ability to bring goods or people from one place to another while crossing a spatial distance with a certain transport mode (Krieger, 2018). This connects transport inherently to the spatial dimension. The connection can also be seen in related terms like public transport which is used as an umbrella term for different transport modes which are open to the public and can be used against a (small) transport fee. This includes not only the typical form of e.g. buses, light rail, rail services, but could also include forms of demand-oriented transport such as e.g. taxi services (Schiefelbusch, 2018). Public transport as well as transport in general are thereby focussed on providing accessibility to different spatially separated locations (Calthorpe, 2011).

Traffic

Traffic describes the actual movement of the goods that are transported (Götz, 2014) and has a major descriptive power for transport planners as which the quality and the improvement of the transport system were defined by a rise in the vehicle-miles driven or the vehicle speed (Litman, 2003; Chapter 2.4.2). Traffic is thereby prone to a very functional, efficient and rational look on the transport system (Götz, 2014). The focus of the traffic perspective in terms of modes is focussed on the car as other transport modes do not contribute much to the vehicle-miles driven and are comparably slow. This leads to a car-

centric development and evaluation of traffic, land-use and service level. Determinants like for example congestion level, available parking spots, vehicle registrations or drivers' licences are often used to measure traffic (Litman, 2003). Traffic is in this form an aggregate of realised individual mobility patterns (Lenz, 2018; Chapter 2.4.2).

Mobility

Mobility stems from the general idea of being moveable. This does not necessarily involve spatial movement as also cognitive movement can be part of mobility (Götz, 2014). In terms of transport geography mobility is linked to opportunities, or to be precise opportunities to realise social participation and to fulfil vital needs. A better mobility is thereby, in contrast to the above-mentioned traffic, conceptualised by a rise in the opportunities or an increase in the individual capacity to fulfil their needs. This is not necessarily linked to a certain transport mode as all transport modes have the chance to enhance the individual capacity (Calthrope 2011; Daubitz, 2021; Lenz, 2018; Litman, 2003; Nuhn & Hesse, 2006; Wittwer & Berger, 2021).

A rise in opportunities can happen with an increase in for example the vehicle-miles travelled, but it can also be completely decoupled from the need to change places. Some ideas that foster this form of decoupling include the usage of digital media to foster opportunities (Lenz, 2018; Nuhn & Hesse, 2006) as well as a focus on spatially close relationships, whereby these correlate with short geographical distances between the opportunities (Calthorpe, 2011; Schwedes, 2021b). It is however unclear if the usage of digital media really substitutes traffic or if it even fosters traffic in other ways (e.g.: more traffic due to online shopping) (Lenz, 2018; Nuhn & Hesse, 2006).

The idea of close geographical relationships implies that the need to travel can be mitigated in the efficient design of neighbourhoods. This goes along with the reduction of traffic, but not the reduction of movement or opportunities, as a goal for the transformation of the mobility sector (Calthrope, 2011; Wittwer & Berger, 2021).

Public Mobility as a concept fosters this idea of close relationships as well as the look on all three sustainability dimensions. In contrast to traffic the ecological and social aspect are put next to the economical view (Becker, 2019 cited in Schwedes, 2021b; Lenz, 2018). The balancing of the three dimensions and treating them as equally important is the ambitious premise of public mobility. This also implies the necessity to evaluate forms of cost in all three dimensions (e.g.: negative environmental consequences, economical costs and social participation) (Daubitz, 2021 & Nuhn & Hesse, 2006; Schwedes, 2021b; Stöglehner, 2023).

The positive ecological effect, of designing neighbourhoods in a way that mitigates the need for travel, can also be very positive for the social participation of the people. This can be provided within short distances and barrier-free for most of the population (Schwedes, 2021b). This shows that within the main idea of public mobility the ecological and social aspects are not contradictory but rather push in the same direction (Brocchi, 2019 cited in

Schwedes 2021b). With this understanding, public mobility can be the gateway to social participation of the whole society as well as lower the societal costs, due to higher rates of active mobility on shorter distances and the mitigation of traffic. This in turn makes public mobility economically viable (Schwedes, 2021b).

2.2 Mobility in the context of services of general interest

Services of General Interest (SGI) are a concept which is most prominently used in the policymaking of the European Union (EU). It's an umbrella term for universal services which should be provided to every EU-citizen. Whereby it is not defined what services specifically and how these services should be provided. This leaves it open to each member state to define which SGIs should be provided by the state via tax money or by the market (Humer et al., 2015).

SGIs cover different areas of daily life, e.g.: energy supply, public transport, culture and communication, broadcasting and social services (European Economic and Social Committee (EESC), n.d.). These different parts are structured into three main subcategories of SGI: services of general economic interest (SGEI), social services of general interest (SSGI) and non-economic services. SGEI and SSGI are affected by European legislation, while non-economic services, which include police and justice, are not affected by specific European legislation (European Union - Directorate-General for Communication, n.d.).

In the German-speaking countries, the term '*Daseinsvorsorge*' is more broadly used. These terms are not necessarily the same but have a considerable overlap (Welti, 2005 cited in Millstein, 2018). Schwedes (2021) has added to the discourse that if there is to be a reformulation of '*Daseinsvorsorge*', it should include a new understanding of public mobility. This opens the transport sector as well as planners to a broader dimension of mobility options. This would also include a redefinition of the role of the state from a provisioner of '*Daseinsvorsorge*' to a provider of guidelines for the private provision of these services (Schoch, 2008 cited in Schwedes, 2021b & Schwedes, 2021b; Stöglehner, 2020).

This idea is based on the criticism of the currently typical "minimum principle" of public transport, in which only a basic service must be provided within most regions (Wolking, 2021). This hampers the options for transforming the transport sector to the necessary extent regarding the climate change and other challenges (Chapter 1.1).

Public transport is therefore part of a general base of services that different levels of legislation consider important for the welfare state. This idea is to some extent contested, as there are advocates for a broadening of the term public transport to public mobility. Public mobility, as presented in Chapter 2.1, can be understood as a part of the services of general interest which can be seen more as a fundamental right then a funding as it is the case for public transport (Hill, 1996 cited in Schwedes, 2021b; Priebs, 2019). The concept of public

mobility can be seen for example in the planning paradigm of the Transit-Oriented-Development (TOD) (Chapter 2.3.4).

2.3 Integrated city- and mobility planning

In contrast to the general approach of transport geography, which prioritizes objective, quantifiable factors as a planning basis, the integrated city- & mobility planning adds the subjective perspectives of individuals as well as the neighbourhood level as a new scale. The look on these additional features gives new impressions and can enrich the current planning scheme to get a more in-depth look into transport mode choice. This approach therefore falls into accordance with the concept of public mobility (Chapter 2.1) (Boussauw et al., 2010; Calthorpe, 2011; Hoor, 2021; Priebs, 2019).

From a historical perspective, city-development has often been linked with accessibility planning, especially with the transport mode(s) which have been prevalent in the time frame the development has happened (e.g.: car-oriented-development in the mid-20th century, transit-oriented-developments in the early 21st century) (Calthorpe, 2011). In the 1980s, new approaches to the integration of settlement and transport planning were adopted in the US and Europe. In the USA, the principle of new urbanism has gained significant traction, while in Europe, the concept of the compact city has been a prominent topic of discussion (Schwanen & Mokhtarian, 2004). These developments present an opportunity, following the functional division at the beginning of the 20th century, to (re-)integrate the workplace into residential areas, given that the shift in work patterns, away from factories and towards office-based roles, has become a standard feature of the modern working landscape (Calthorpe, 2011).

2.3.1 What "new" does the integrated city- & transport planning bring to the table?

Integrated city- and transport planning shifts the focus to a much more human centred approach with a large emphasis on mobility as a basis (Boussauw et al.,2010 ;Calthorpe, 2011; Schwedes, 2021b). As discussed before (Chapter 2.1) public mobility as a concept allows for the mitigation of trips through a higher accessibility of opportunities for an individual. Especially regarding emission-intensive travel forms a shift in the chosen transport mode can maybe be induced by bringing amenities closer to the home (Calthrope, 2011; Priebs, 2019; Schwedes, 2021b). The emphasis on the mixture of different transport modes, according to the public mobility approach, seems necessary in terms of the need for a sustainable change in the transport sector (see Chapter 1.1) (Priebs, 2019). To achieve these goals integrated city- & transport planning strives to be more interdisciplinary oriented (Kutter, 2005 cited in Schwedes, 2021b). This approach includes for example sociology, gender studies, political science, health- and environmental planning, spatial planning and geography as well as the more technical disciplines of cartography, traffic planning and computer science (Schwedes, 2021b).

Commuting as an issue has not originated within transport planning; rather, it has primarily developed within the city planning of the 20th century, where transport planning was a step or two behind (Schwedes, 2021b). Dominant planning paradigms of that time, like the car-oriented city have led to a rise of distances between places and congestion. To tackle this problem the focus of planning slowly shifted back to the qualities of traditional urbanism, e.g.: diversity of population and activities, many public spaces and institutions as well as the human scale of buildings, streets, and neighbourhood (Calthrope, 2011). This goes along with the focus on sustainable planning practices like shorter distances and the development of walkable and bikeable areas with far less emphasis on car-travel (Boussauw et al., 2010).

This reemphasis of the traditional urbanism needs to be put under perspective of the actual spatial structure of the place. The concept must be adapted to accommodate the needs of residents in town centres as well as the sometimes car-oriented suburbs. This goes along with the need to secure free space and concentrate building efforts primarily along the main stations of the public transport network (Nuhn & Hesse, 2006; Pretsch & Beckmann, 2004 cited in Nuhn & Hesse, 2006; Priebs, 2019). This concept of urbanism is self-replicating and one of the most cost-effective solutions to climate change with economic, social and environmental benefits (Calthorpe, 2011). These approaches can be seen in the planning concepts of Transit-Oriented Development (TOD) and the compact city (see Chapters 2.3.4 & 2.3.5) (Nuhn & Hesse, 2006).

The "new" of the integrated city- & transport planning practice is, as presented, the (re-) emphasis of the human scale as well as principles of urbanism which should be adapted in accordance with the geographical circumstances. Additionally, the underlining of the interdisciplinary approach and the focus on mobility are mentioned as ways to mitigate and combat the effects of climate change. This opening of perspectives also open opportunities to tackle problems which normally would be better suited for a more formalized city-regional planning approach (Schwedes, 2021b).

2.3.2 Why we should also look at a city-regional scale

As cities outgrew their original core during the main phase of urbanization after the Industrial Revolution, settlements expanded further outwards, crossing municipal boundaries. This led to issues in efficient governing as well as the supply with relevant goods and services (e.g.: firefighters, canalization, etc.). The solution of that era was to incorporate the smaller surrounding municipalities into the core city, e.g.: Altona into Hamburg, 1938 (Stadt Hamburg, n.d.) or Floridsdorf into Vienna, 1905 (Wien Geschichte Wiki, n.d.). Going further, the realization of municipal incorporations came to a hold over the 20th century, although the issues with the starting and growing suburbanization started to transcend the city borders again. Within that time frame, it has shown that municipal incorporations don't solve the problems or make cooperations with the city-region unnecessary (Priebs, 2019).

This opens the view onto the city-regional scale, especially if features of functional city regions are viewed under the lens of the functional division between specific locations or whole municipalities. This functional division, formerly fostered by the Charta of Athens, and brought to the city-regional scale with the suburbanization processes of the late 20th century, has fostered the need to bridge longer distance between the essentials of daily life (Heineberg, 2002 cited in Nuhn & Hesse, 2006; Priebs, 2019). One of these bridging travels is the commute (between home and work location). The need to commute is often linked to the concentration of opportunities (especially in the city centre) and supply of specialized goods in the city which have a catchment area that is larger than the city itself (Nuhn & Hesse, 2006). This concept can be traced back to Christaller's System of central locations where he describes cities as places with an excess of significance in contrast to the surrounding region (Christaller, 1933/2006). This excess of significance is also displayed in a higher transport accessibility of the city in contrast to the region (Nuhn & Hesse, 2006).

Since the 1930s, planning ideas such as the Broadacre City and the Greenbelt New Towns have initiated the trend towards suburbanization (Calthorpe, 2011). While workplaces have typically remained in the core city, not only housing, but later also leisure and shopping have slowly moved from the core city to the city region. These developments have led to more complex activity spaces for individuals, as well as an increase in the volume of traffic within the suburbs (Nuhn & Hesse, 2006). This development was slowly interrupted by concepts that emerged in the 1980s, notably the compact city in Europe and the new urbanism in America. These approaches to more sustainable urban development (in all three dimensions; see also the concept of public mobility; Chapter 2.1) (re-)introduced the idea of mixed-use, dense, walkable neighbourhoods instead of functional separation (Heineberg, 2017; Nuhn & Hesse, 2006).

City-regions are facing a multitude of different problems, but the climate crisis is one of the most prevalent which can be faced also on a city-regional level. Calthorpe (2011) and Priebs (2019) have both emphasized the need for a drastic change in mobility behaviour to achieve the goal of climate neutrality and a more sustainable mobility pattern. Both argue for a change in the used transport modes to challenge the pre-determined car dependency of neighbourhoods. This can be faced by expanding the infrastructure for public transport, cycling and walking, while linking city and mobility planning and development even more closely than before. This also means the abandoning of the dichotomy of city and suburb but to think of polycentric development in a network of smaller and larger cities and neighbourhoods who all have connections to another (Calthrope, 2011; Priebs, 2019; Stöglehner, 2023). The need for intercommunal work is underlined by the often-lacking formalization of the city-region, especially in terms of spatial planning. If spatial planning is focussed, the potential to emphasize larger and necessary investments and foster sustainable planning practices arises, as otherwise a tendency towards singular developments and decisions of municipalities could interfere with overarching goals.

2.3.3 Key planning concepts relating to integrated city- & mobility planning

This subchapter lays the focus on some planning concepts that have to some extent been implemented and foster the main idea of the implemented city- and transport planning. The transit-oriented development (Chapter 2.3.4) and the compact city (Chapter 2.3.5) are the more prevalent planning concepts and thereby are looked at in more detail in the corresponding subchapters. Apart from these two concepts, ideas of the integrated city- and mobility planning can also be found in older planning models.

The ***Garden city concept*** by Ebenezer Howard from 1898 is the first concept to adopt a city-regional perspective. With the introduction of walkable satellite cities, which should be connected through public transport to the main city, he introduced an integrated city- and mobility approach. The implementation however never really met the full potential as the concept was modified and mostly aspects of greenery were implemented in suburbs rather than singular planned satellite cities (Heineberg, 2017; Priebs, 2013,2019; Stöglehner, 2023).

Another classical planning concept for monocentric urban centres is that of ***axes*** (Priebs, 2013, 2019). The planning of axes can be on different scales; on a larger scale (e.g.: federal states) development axes tend to bundle different infrastructures into a smaller corridor (Albrechts & Tasan-Kok, 2009). On a smaller scale, settlement axes show a much more modest scale of orientation. Efficient transport axes (e.g.: light rail) are used as a base for settlement axes. Along these, the settlement development should be fostered and between these axes' settlement should be restricted to also provide open space "wedges", which can be utilized for local recreation and agriculture near the city centre (Priebs, 2013, 2019). The challenge facing urban regions, where the axis model is (or has been) the dominant planning approach, is the increasing necessity for tangential transport between the axes (Priebs, 2019).

The planning model of ***decentralized concentration*** follows a similar principle. The idea is to provide relief to monocentric settlement structures by fostering other cities while also combatting urban sprawl by developing these cities in a compact "concentrated" way. This can lead to a polycentric development of a region while also fostering sustainable growth with a higher level of service provision overall (Benzel et al. 2011; Priebs, 2019). Following the concept through, it is advised that every "core" city for the corresponding development is linked to the public transport network closely according to the principles of TOD (Chapter 2.3.4) (Nuhn & Hesse, 2006; Stöglehner, 2023).

2.3.4 Transit-Oriented-Development (New Urbanism)

The New Urbanism approach originated in the late 20th century in the USA as a response to the ongoing planning system which fostered urban sprawl, car-orientation and suburbanization. The focus lies on infill development as well as the conservation of existing free spaces. It is emphasized that the metropolitan boundary needs to be clearly defined and should not blur with the surrounding landscape (Calthrope, 2011; Congress for the New Urbanism, 2001). New Urbanism can be considered the counterpart to the European compact city model which will be discussed in Chapter 2.3.5 (Boussauw, 2010).

New Urbanism emphasizes the neighbourhood as the basis for mobility decisions, which has consequently become the focus of numerous studies (Cervero & Radisch, 1996; Xiao et al., 2018). Central to the new urbanism approach is the shift from car-oriented neighbourhood design to one that prioritizes transit-oriented and pedestrian-friendly environments. This goal is best achieved by creating high-density, mixed-use neighbourhoods, particularly near transit stops, through the implementation of transit-oriented development (TOD) (Boussauw et al., 2010; Calthorpe, 2011; Congress for the New Urbanism, 2001; Khattak & Rodriguez, 2005 cited by Xiao et al., 2018; Van Acker et al., 2010).

TODs are based on the principle of walkable, dense residential neighbourhoods which are based around a central (high-frequent) transport stop with access to the rest of the city. These dense neighbourhoods should also be more mixed-use around the public transport station and gradually get more residential towards the edges of these developments. The main focal point is that the public transport station should always be reachable through active transport modes (Priebs, 2019; Randelhoff, 2018; Stöglehner, 2023). With that TODs have changed the scales in which a neighbourhood development should be approached. TOD includes the human scale of the streets and mixed-use of the neighbourhood as well as the integration of the neighbourhood in the city-regional transport network. This brings a broad scale range into the development which beforehand could have been overlooked due to the car-dependent development of the new neighbourhoods (Calthorpe, 2011).

The fundamental concept of TOD offers a range of benefits in terms of economic, ecological and social considerations. The construction of denser residential structures necessitates the provision of less infrastructure, thereby reducing the financial burden on municipalities in terms of maintenance. From a social perspective, the greater availability of walkable amenities and the proximity of shared public spaces are beneficial in comparison to typical suburban development. There can also be greater neighbourhood interaction as well as identification with this type of development. From an ecological standpoint, there is a reduced need for heating, as flats and nearby living spaces tend to heat each other, in contrast to detached houses. Additionally, there is a reduced need for private vehicles, which can lead to a reduction in traffic-related emissions (Calthorpe, 2011; Transit Oriented Development Institute w.y. cited in Priebs, 2019).

2.3.5 Compact City

The Compact City approach, which came forth in Europe is comparable to the New Urbanism approach (Chapter 2.3.4) (Boussauw, 2010). The main idea is nearly identical as it also advocates for a less car-dependent mobility form which is accompanied by the advocation for closer spatial distances between homes and the other amenities. There is additionally a focus on the sustainability of the traffic design, as the compact city clearly advocates for a high share of active mobility (walking, cycling) (Boussauw, 2010; Nuhn & Hesse, 2006).

The compact city also encompasses the ideas of medium to high-density, mixed-use development and efficient public transport and thus the advantages of inner city and close to centre locations (Boussauw et al., 2010; Petersen, 2000 cited in Nuhn & Hesse, 2006; Van Acker et al., 2010).

The concept of the compact city allows for the substitution of a large proportion of motorized traffic by integrating various land uses and locating all essential amenities within walking or cycling distance. This approach promotes environmental sustainability and facilitates social interaction through mobility for more people than otherwise would be possible (Nuhn & Hesse, 2006). This goes along with the conversation of rural areas and the focus on inner development and development on the edge of the city (Aditjandra et al., 2011). The compact city approach was later integrated into the term sustainable urban development. This has brought the terms density and diversity as important elements into the discourse (Boussauw et al., 2010).

2.4 Models of Transport Mode Choice

To understand what could influence the transport mode choice it seems necessary to investigate the transport mode choice and underlying models and theories of the behavioural studies. These have examined and outlined many models and approaches to understand decision-making processes and the underlying patterns. This chapter and the theories and models included are a foundation for the literature analysis (Chapters 3.2 & 4.1) as it provides different approaches of explanations for the transport mode choice. In addition, these theories and models provide an explanatory basis for the results of the main research question (Chapter 1.2). The basic idea behind these behavioural models of transport mode choice lies within the traffic development during the 20th century. In this time, the question arose what determines or at least explains the transport mode choice (Pripfl et al., 2010).

The need for travel between different amenities and activities of daily life has already been explored in the chapters above. However, it must be kept in mind that travel is necessary for the daily life due to the structuring of the environment. Therefore, a choice regarding the transport mode must be made before the action takes place (Van Acker et al., 2010). This

choice can be made due to a multitude of different factors and may even not be done consciously as explained by the theories below.

Within this topic different approaches and models have emerged which will be presented in the following subchapters. These include the environmental-psychological approach, aggregated models, behavioural models, action-theory-approaches, cognitive approaches, sociopsychological approaches, objective and subjective behaviour control, integrating approaches and the transport geographic approach of the constant travel-time-budget.

2.4.1 Environmental psychological approach

The primary focus of the environmental psychology is to analyse the human-environment system as a whole, rather than both individually. To a certain extent, the environment and behaviour are mutually dependent. Regarding their relationship, it can be argued that the environment exerts an influence on human behaviour, but it is equally possible to posit that human behaviour can modify the environment (Flade & Wullkopf, 2002; Groß, 1998). This emphasis that changes in the (built) environment result in behavioural changes, which in turn necessitates new environmental changes (Flade & Wullkopf, 2002). The environmental influences can thereby be either physical, societal, or social in nature (Flade & Wullkopf, 2002).
The research focus for the transport sector is primarily concerned with the effects of environmental conditions in the residential environment, the perception of traffic, as well as the evaluation and behaviour of people (Heine, 1995 cited in Groß, 1998; Flade & Wullkopf, 2002).

One example of this, is the change in behaviour, that occurred during the 20th century, which made private transport by car a more attractive option. In this case, the environment was repeatedly adapted to changing societal behaviour, with developments oriented towards cars occurring, especially at greater distances from the city centre. These environmental changes have, in turn, altered the behaviour of residents and their demands in the corresponding locations (Flade & Wullkopf, 2002). Another example is the development of TODs (Chapter 2.3.4) or car-free neighbourhoods, which could, in turn, alter the behaviour of residents and later their needs in these areas.

2.4.2 Aggregated models

The aggregated models are assuming that the behaviour of transport users and, accordingly, their choice of a transport mode, is exclusively the result of external, objective characteristics. Furthermore, the assumption is made that the characteristics of individuals cannot significantly explain this behaviour (Held, 1980 cited in Flade & Wullkopf, 2002).

The analysed unit in this case is not the individual but rather characteristics of certain areas. Based on these, conclusions are drawn about the traffic behaviour within this area. It thus

follows that these models are unable to make any statement about the effects of measures on individuals. In addition, these models also have no informative value regarding the possibility of changing the behaviour of individuals. This would require disaggregated models (Flade & Wullkopf, 2002).

Transport demand models

Transport demand models analyse 'traffic cells' to provide the most accurate and descriptive representation of traffic flows. The smaller the respective traffic cells are, the more accurate the model becomes. The objective environment and the aggregated behaviour of the traffic participants are the decisive parameters of these models. The volume of traffic, the distribution of traffic (i.e. the destinations) and the transport mode choice are determined in each unit under investigation (Flade & Wullkopf, 2002).

Location theories

Alonso (1964 cited in Flade & Wullkopf, 2002) was the first to establish a connection between transport costs and land demand in economic microtheory. In a monocentric city, he assumes that transport costs rise with increasing distance from the centre, but that the price of land falls. He concludes that higher-income earners are drawn to the outskirts of the city, and that settlement density decreases as income increases. The model is implicitly based on the assumption of substitution of public transport by car at greater distances from the city centre (Flade & Wullkopf, 2002).

For the rental housing market, Muth (1969, cited in Flade & Wullkopf, 2002) assumed that the further the distance to the city centre, the lower the rental price must be due to the higher transport costs. A higher income can buy greater proximity to the city centre or more space or a higher quality of housing (Flade & Wullkopf, 2002).

Alonso's original model suggested the substitution of public transport in favour of the car, but due to factors such as congestion, air pollution, parking costs, etc., this can change in the future. The location theory models have become increasingly complex since the 1990s due to the inclusion of more destinations than the city centre and the changing preferences of households, which is also reflected in the change of time and leisure preferences (Flade & Wullkopf, 2002).

2.4.3 Behavioural models

Behavioural models differentiate from the aggregated models by focussing on the individual, their behaviour and the behavioural changes which are a result of certain processes. Included in these models are also the perceptions of different transport modes which can be understood as behavioural values (Flade & Wullkopf, 2002).

Description of individual traffic behaviour based on key values

Following this approach, transport behaviour is analysed based on three parameters: the mobility rate, the mobility performance and the mobility time budget (Limbourg et al. 2000

cited in Flade & Wullkopf, 2002; see also chapter 2.4.9). Within a certain time frame, the mobility rate describes the number of journeys, the mobility performance the sum of the travelled distances and the mobility time budget the required travel time for all location changes. These parameters gain significance in the comparison between certain societal groups or between different periods (Flade & Wullkopf, 2002).

Learning theory approaches

The learning theory suggests that mobility behaviour is learned, which later influences the choice of transport mode. Learning in this context encompasses every form of behavioural change which is based on an experience. This accentuates that behaviour can be changed by behaviour, which can result in feedback loops for certain behaviours. Every behaviour thereby has consequences (in either direction). These consequences are perceived more strongly if they are intermediately linked to the action or happen more frequently (Flade & Wullkopf, 2002).

An example are the financial consequences, i.e. the costs, of the usage of a certain transport mode. The ticket price for public transport is a clear all-inclusive amount that must be paid once (assuming the use of a single ticket), whereas the costs for travelling by car are a combination of various factors, some of them being not immediate. Although fuel costs are paid nearly immediately other costs such as repairs, insurance or tolls are often separated from the individual trip through a longer time-period. This circumstance can be seen in studies regarding the perception of costs (NWL – Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022).

2.4.4 Action theory approaches

In the action theory approaches, it is assumed that people are capable of self-reflection and orientate their actions towards their own goals. The carried-out actions are orientated towards the individual goal as well as the underlying norms (Chapter 2.4.6) of the situation. The goal orientation of the action is essential here (Flade & Wullkopf, 2002).

Rational Choice Theory

A basic theory of economic geography is the consumer choice theory. According to this, consumers behave rational based either on their experiences or the analysis of available information. If applied to the transport sector, the product which a traveller chooses becomes the chosen transport mode. Meaning that the transport modes are compared by the traveller and the choice between them is based on the maximization of the personal utility (Chakrabarti, 2016; Flade & Wullkopf, 2002).

Rational action is goal-oriented, in the case of transport mode choice towards the maximization of the personal utility. This encompasses that the traveller has knowledge about the amount of different costs for every transport mode and accordingly select the option with the most favourable cost-benefit ratio for the journey in question (Flade &

Wullkopf, 2002). Thereby the costs are based on three fundamental determinants, travel time, travel costs and the traffic quality which are assessed and weighted according to the personal preference. The transport mode that is selected against the others must have benefits in at least one of the three determinants (Gorr, 1997 cited in Flade & Wullkopf, 2002).

However, some aspects contradict the rational choice theory. These include the different assessment of past events or altruistic behaviour. For example, there is often an overestimation of positive events and (financial) losses (Flade & Wullkopf, 2002).

Subjective benefit models

Subjective benefit models add the subjective look to the rational choice theory, whereby an action can also be deemed optimal subjectively which would not be the case objectively (Flade & Wullkopf, 2002). This might occur if insufficient knowledge about a particular mode of transport is considered. The knowledge gap can alter the cost-benefit ratio to an extent where it can already become negative through the search for other transport modes. The effort for acquiring the needed knowledge surpasses potential benefits and thereby the choice is limited to the known transport options (Zemlin, 2005 cited in Hobiger, 2021).

2.4.5 Cognitive approaches

The key aspect of cognitive approaches is to focus on understanding the perception and cognitive processing of experienced reality as a foundation for current and future behaviour, rather than relying solely on objective characteristics.

Models of information processing

The ‘objective’ environment is always processed through individuals who subjectively change the information according to their knowledge. These models explain behaviour under three main premises. Firstly, behaviour is not directly influenced by ‘objective’ environmental influences but by the perception of these. Secondly, all perceptions of the environment are individual and therefore differ from person to person. Thirdly, the subjective reality can be reshaped by the behavioural intentions and the realized behaviour. Therefore, knowledge about transport modes is necessary to have a perception about a certain transport mode and be acknowledged within the subjective world view (Flade & Wullkopf, 2002).

Cognitive maps

When we organize our everyday lives, we create an image of our environment, a ‘cognitive map’, in our heads based on our experiences. This map stores key features as well as corresponding subjective impressions of the environment and the relationships between certain places. The ‘cognitive map’ is a representation of the subjective image of reality which contains areas in different grades of detail (based on how often they have been there) as well as gaps (e.g. streets that we have not yet walked along). Essential components of

cognitive maps are individual places such as squares, parks, buildings, extensive areas such as recreational spaces, and the corresponding routes between and through these places, such as roads, railway lines or footpaths (Flade & Wullkopf, 2002).

The used mode of transport is always assigned to the individual routes. This makes the transport mode a part of the cognitive map thus creating a link between certain places and the transport mode used to travel there. This means that every change of a transport mode on a certain route is linked to a restructuring of the inner world view (Flade & Wullkopf, 2002).

Motivation Models

Motivation models consider the main reason for a certain behaviour. Two main directions of the motivation models are the homeostatic motivation concept and the exploration concept (Flade & Wullkopf, 2002).

The homeostatic motivation concept is based on an internal equilibrium. If now a behaviour is performed often that pushes the balance of the equilibrium and is thereby counteracted by other behaviour to maintain the equilibrium (Flade & Wullkopf, 2002). For example, a rise in physical activity can be counteracted be (un-)conscious phases of lower activity (Pontzer et al., 2016).

The exploration concept is based on external stimulus patterns which directly influence the behaviour. Relevant is hereby the complexity of a stimulus which can range from low to overwhelming stimuli. Medium complexity of external stimuli in behaviour is preferred, as this can stimulate, while also being self-rewarding and motivating (Flade & Wullkopf, 2002).

In the area of mobility, internal stimuli can be, for example, the physical experience, the absorption of new impressions, or the feelings of freedom, strength, and competence. Such activities, in which the purpose of the activity recedes into the background and the experience of the activity becomes the focus, are referred to as ‘autotelic activities’ (Flade & Wullkopf, 2002).

2.4.6 Sociopsychological approaches

The focus of the sociopsychological models is placed on the social environment of individuals. Especially the social milieu, which is characterized by values, a sense of responsibility and norms, is a central determinant. In the combination with the learning theory approaches (chapter 2.4.3), the social learning theory focusses on the social environment as a source from whom behaviour is learned through observation and imitation. Following this approach for the analysis of the mobility behaviour would encompass the extension of the analysis not only on the individual but at least their caregivers and other people with major influence on the individual life (Flade & Wullkopf, 2002).

Attitudes and values

In some models, that explain transport mode choice (e.g.: the action theory approaches; chapter 2.4.4), the behaviour of people is assumed to be purely based on their selfish interests. However, everyday experience contradicts this, as, for example, the interests of the social environment also play a role in deciding how to act. Yet, this approach does not stand against the principles of utility maximization as only the well-being of the reference persons is considered additionally (Flade & Wullkopf, 2002).

Behaviour is not only influenced by the wishes and goals of other people, but also by one's own values. Littig (1995, cited in Groß, 1998) fostered the idea that it is unlikely for a person to make a conscious, detailed decision about the transport mode they want to use before every single journey. He instead assumed a habituative, i.e. automated, transport mode choice. Accordingly, there is no new assessment of the relevant subjective and objective criteria before the journey, but a particular mode of transport is chosen out of habit. These habits lead to a shift in the perception and assessment of the means of transport, which is repeatedly confirmed by habitual behaviour (Groß, 1998).

Normative expectations and social norms

Schwartz's norm activation theory (1970; cited in Flade & Wullkopf, 2002) recognizes a close link between norms and values. Social norms are understood as the expression of the individual perceived societal pressure to perform a certain behaviour A three-stage decision-making process is postulated in the norm activation theory. At first, the individual becomes aware of the consequences of their actions, followed by an attribution of responsibility for these consequences, which ultimately leads to the activation of moral and social norms. Linked to this is the idea that people have generally developed values about the well-being of other people, which motivate them to not harm others (Flade & Wullkopf, 2002).

Feelings about certain things or behaviours are dependent on social negotiation processes. Whereby not all problems are direct, understandable, clearly recognizable, and categorizable for everyone. Issues that are not clearly recognizable include climate change or the hole in the ozone layer, which can only be recognized as problems for individuals and ultimately for society through objectively measurable additional factors. Accordingly, a process of social negotiation and mediation takes place in which at the end new values and norms emerge (Flade & Wullkopf, 2002).

In 1999, Hunecke, Matthies, Blöbaum & Höger developed an extended norm-activation model for the transport mode choice (Flade & Wullkopf, 2002; Pripfl et al., 2010; Figure 1). According to this model, decisions are made in a balancing process that is influenced by internal and external, subjectively perceived, norms and values. These norms and values create a sense of obligation in the person, which strongly influences the decision-making process. The sense of obligation is based on a person's self-perception if they can act autonomously within their sphere of influence (Flade & Wullkopf, 2002; Hobiger, 2021).

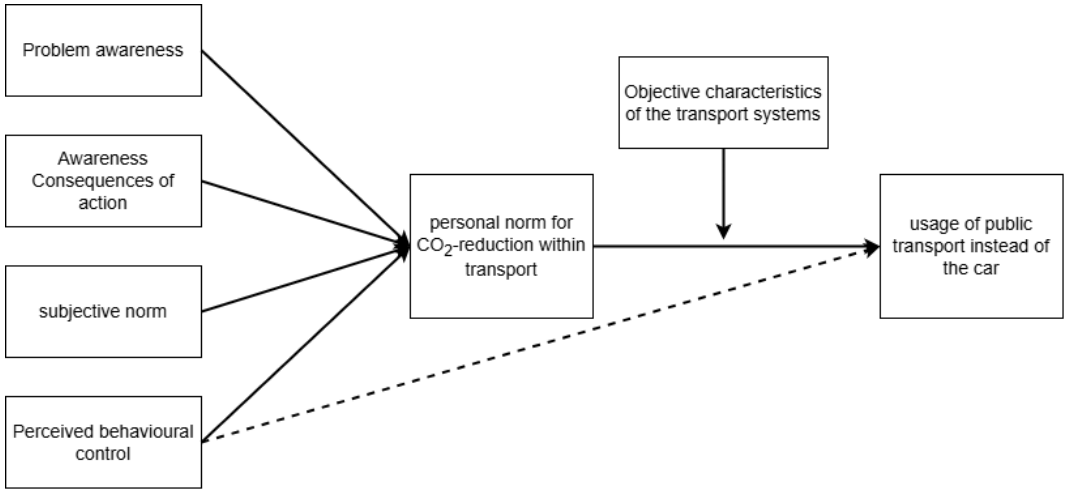


Figure 1: Extended norm-activation model applied to the choice of means of transport (rebuild after Hunecke, 2000 cited in Pripfl, 2010; own translation)

Social representation and lifestyle

'Social representations' can be understood as ideas which are shared between the members of a social group. These gain influence on the individual behaviour if the social system, on which the social representation is grounded, is classified as obligatory by the individual. This influence is gained when a social representation gets adopted by an individual and becomes a part of their cognitive system and is implemented in their everyday thinking (Flade & Wullkopf, 2002).

Closely related to social representations are lifestyles. The term 'lifestyle' refers to recurring patterns of behaviour in which habitualisations and social affinities are expressed. The essential core components of lifestyle include behaviour, attitudes, resources, tastes, and life goals. The identified lifestyle types differ in terms of their mobility behaviour (Flade & Wullkopf, 2002). However, as the distinctions here are often not clearly attributable to mobility behaviour, there are also more explicit adaptations of the lifestyle phenomena to form so-called mobility milieus. One example of this is the pro:NEWmotion-typology published in 2023, which divides people into five mobility milieus (Millonig et al., 2023).

Social-ecological dilemma

The decision-making process can lead to questionable results as the chosen best option by the individual can have (large) negative implications on the community (e.g.: socially or ecologically). This means that their own decision can be the best for oneself due to subjective and objective criteria but can still be socially and environmentally unacceptable. The social ecological dilemma is closely related to the social trap which refers to a situation in which there is a short-term individual gain which has negative consequences for the public in the long term (Flade & Wullkopf, 2002).

If this idea is applied to the transport sector two approaches stem from the social ecological dilemma. On the one hand, the environment can be understood as commons which is damaged by the negative effects of many individual car journeys. These are considered as the best individual option, whereby the costs of climate change and health consequences must be borne by the public. On the other hand, this is similar for the entire transport infrastructure. Roads and railway tracks are used for the individual benefit of certain people or groups while the maintenance, and in the case of public transport the provision of rolling stock, is outsourced to the public or a company. It should be noted that the social-ecological dilemma becomes less of an argument the more people use public transport at the same time, as the costs per person caused are greatly minimized (Flade & Wullkopf, 2002).

2.4.7 Objective and subjective behaviour control

The focus of the following theories are the restrictions people have regarding the transport mode choice due to perceived and/or objective limits

Space-time structures

The space-time structures go back to the founder of time-geography, Hägerstrand. He regarded time and space as essential limitations of the space of possibilities for individuals. Every change of location is associated with a corresponding expenditure of time (Flade & Wullkopf, 2002; Van Acker et al., 2010).

Hägerstrand has, based on this idea, presented the space-time-prism as a possible way to display the space-time changes of an individual. The changes within space-time are represented as a three-dimensional path whereby the two horizontal axes represent the space and the current location, and the vertical axis represents the time. Following this idea, there is only a certain number of places which can be reached through space time as the velocity of the transport mode determines how much location change is possible within a certain time frame (Van Acker et al., 2010).

Hägerstrand has formulated three restrictions for the movement within the space-time-prism: capability constraints, coupling constraints and authority constraints (Flade & Wullkopf, 2002; Van Acker et al., 2010).

Capability constraints arise for two reasons, on the one hand due to physiological needs (sleeping, eating, etc.), which limit time and space. On the other hand, due to the principle that an individual always needs time to move from one place to another. Coupling constraints refers to the barrier of appointments with other individuals, as everyone has different temporal and spatial constraints, there are strong constraints in which all individuals involved have no coupling constraints. Authority constraints are the restrictions imposed ‘externally’ by opening hours (Flade & Wullkopf, 2002; Van Acker et al., 2010).

Even if some of these constraints are minimized by digitalization, they are fundamentally retained, or new ones are created by digitalization. For example, an online meeting requires

a location with a stable internet connection, which can be interpreted as a capability constraint for the online meeting.

Constraint-models

In action theories it is assumed that a human has a space for possibilities which is restricted by barriers of various kinds. These barriers explain that a certain behaviour can be performed not only if it is wanted or should be done but also based on personal abilities. The constraint models focus lies on these barriers and their implications (Flade & Wullkopf, 2002).

The constraint models go back to Frey & Foppa, who expressed their criticism of rational choice theory (Chapter 2.4.4) in 1986. They emphasized that a chosen behaviour may not only be based on individual preferences but may also be limited by personal capabilities (Flade & Wullkopf, 2002).

Frey & Foppa mentioned four categories of limitations on possible courses of action. Firstly, resources, which includes financial, temporal and mental requirements necessary to carry out the action. This not only takes mental maturity but also basic knowledge about alternative options into consideration (see also Chapter 2.4.5). Secondly the state of yard and the availability of the technology for an individual. Thirdly standards values and norms which include both codified and informal norms and values (Chapter 2.4.6). Fourthly self-imposed restrictions (Flade & Wullkopf, 2002).

The restriction to known action alternatives is also called the ipsative possibility space. It is often not enough for individuals to find an objectively best solution, but rather a satisfactory solution within their ipsative possibility space (Flade & Wullkopf, 2002).

2.4.8 Theory of planned behaviour

The theory of planned behaviour (Figure 2), developed by Aizen and Fishbein in 1990 and further developed by Aizen in 1991, is also used to explain mobility behaviour. The theory was developed in the same era as the rational choice theory (Chapter 2.4.4). The theory assumes that an individual is not only interested in the objective maximisation of utility but also makes decisions based on subjectively perceived characteristics of their own utility. The theory also considers attitude towards a behaviour as well as subjective norms and perceived behavioural control. Attitudes, norms and perceived behavioural control are dependent on so-called belief systems, which are acquired in an instrumental and social learning process (Flade & Wullkopf, 2002; Hobiger, 2021; Scheiner & Holzrau, 2007; Tao et al. 2022; Van Acker et al., 2010).

Attitudes towards a certain action are the result of a subjective evaluation of factors associated with the action. Subjective norms are the result of the perception of social pressure to perform a specific behaviour (Chapter 2.4.6). For example, if an individual has a positive attitude towards cycling but doesn't feel physically fit enough a person might choose another transport mode for their trip. Perceived behavioural control describes an

individual's confidence in the skills needed to perform the action, or the knowledge about options for this action. For example, an individual might not know about a public transport option to their destination and therefore travels by car. This indicates that the theory differentiates between perceived behavioural control and actual behavioural control. Within the decision process the chosen option is the option with the highest intention. The intention is based on the attitude the subjective norms and the perceived behavioural control (see Figure 2) (Flade & Wullkopf, 2002; Hobiger, 2021; Van Acker, 2010).

The theory of planned behaviour is also subject to criticism as it only sees behaviour as a consequence of rational decisions (Van Acker et al., 2010). But that isn't necessarily the case as suggested by the motivation models (Chapter 2.4.5) and the socio-psychological approaches (Chapter 2.4.6).

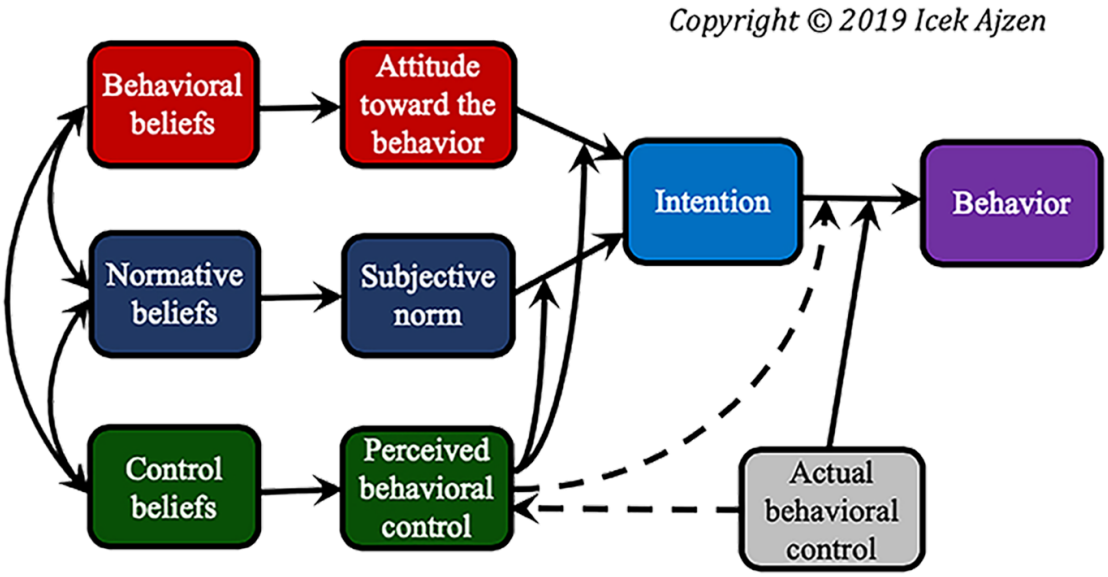


Figure 2: Theory of planned behaviour diagram by Icek Aizen, Source: Aizen, n.d.

2.4.9 Theory of constant travel-time budget

The theory of constant travel time budget stems from transport geography and describes traffic behaviour from a holistic, yet descriptive perspective. Zahavi has hypothesized in 1979 that there is an individual mean travel time budget (TTB) of 60 to 80 minutes per person per day. This travel time budget seems stable across different cities and time-periods. If this hypothesis holds true, that means that any form of travel-time-savings are getting reinvested into other traffic. It is necessary to know that this level of aggregation only holds true on large scales and not within socio-economic groups of a certain city as there are other factors fostering into that (Joly, 2004; Van Wee, 2011; Wittwer & Berger, 2021).

This reinvestment theory would mean that if there is a save in for example commuting time by 20 minutes due to a new high-speed railway that the household tries to move further away from the city centre (this would explain to some extent the urban sprawl). Alternatively, the additional time is used for travel towards other destinations, meaning for example a rising leisure travel time. Meaning that theoretically an increase in travel speed could open more opportunities for an individual. This links to the concept of public mobility (Chapter 2.1) and the space-time-prism (Chapter 2.4.7). This reinvestment theory could hold true on the world level but not on a national, regional, or even urban level (Joly, 2004; Mietzsch, 2021).

The discussion surrounding the TTB is also mentioning the question if there really is a constant travel time budget or if there are constant generalized transport costs or if there should be made more distinctions between population groups. However, despite these discussions, the theory of constant TTB is robust and useful for understanding the impact of land use determinants on travel mode choice and travel behaviour in general (Van Wee, 2011).

3 Methodological framework & study area

The following chapter presents the study area as well as the methodological framework which is used to answer the research questions (Chapter 1.2).

3.1 Study area

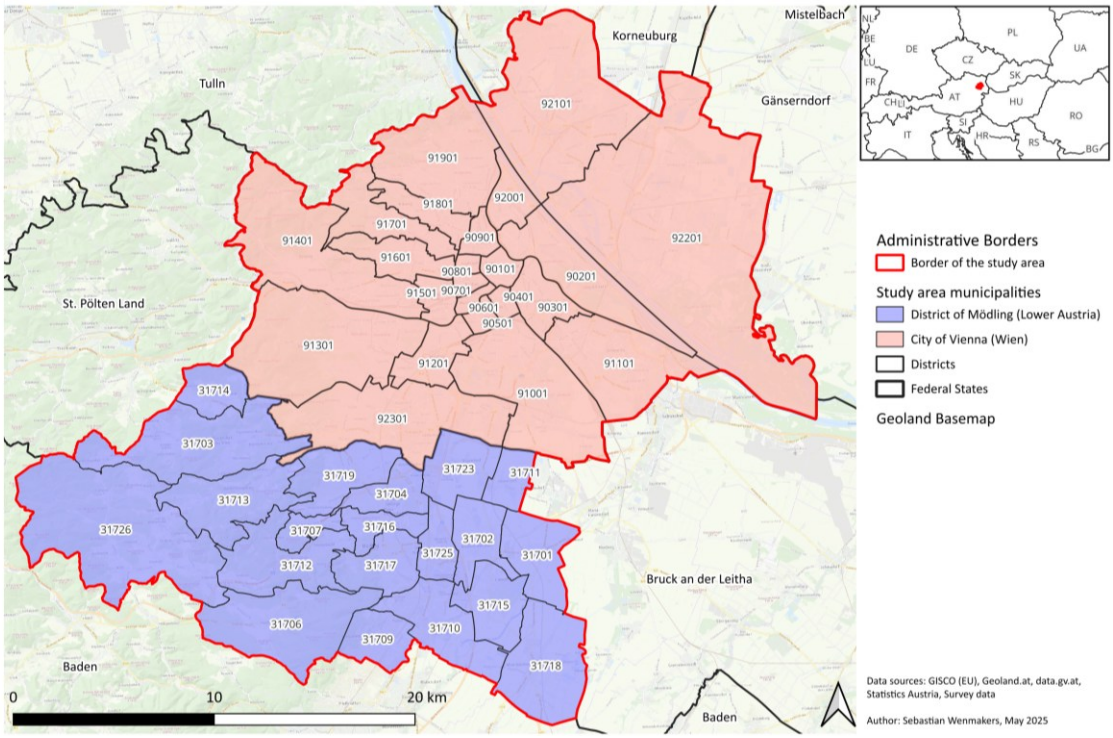


Figure 3: Study area and the corresponding municipalities of the CURB-research project and the master's thesis

The study area for this master's thesis is based on the study area of the PPGIS-survey of the CURB research project (see Chapter 4.2). The study area consists of the Austrian capital, the city of Vienna and the district of Mödling in Lower Austria, which is located adjacent to the southwest of Vienna. The study area is nearly 70,000 ha large and is home to 2.1 million inhabitants (2023) and has had a population growth of 15.8% between 2011 and 2023 (Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a).

The study area was chosen due to a multitude of reasons. The city of Vienna is the major monocentric hub of its city region which spans a large chunk of eastern Austria (KDZ - Zentrum für Verwaltungsforschung, n.d.). Although not a clear border of the city-region has been defined (City-regions are functional regions and therefore often have fuzzy boundaries (Humer, 2019)), it is one of the largest in central Europe with almost 2.7 million inhabitants over 5,000 square kilometres of area within 211 municipalities within three federal states (Wien, Lower Austria, Burgenland) (KDZ - Zentrum für Verwaltungsforschung, n.d.).

Table 1: Municipality number (Gemeindekennziffer) and name of the districts of Vienna and the municipalities of the district of Mödling (Source: Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a)

No.	District of Vienna	No.	Municipality in the District of Mödling
90101	Innere Stadt	**31701**	Achau
90201	Leopoldstadt	**31702**	Biedermannsdorf
90301	Landstraße	**31703**	Breitenfurt bei Wien
90401	Wieden	**31704**	Brunn am Gebirge
90501	Margarethen	**31706**	Gaaden
90601	Mariahilf	**31707**	Gießhübl
90701	Neubau	**31709**	Gumpoldskirchen
90801	Josefstadt	**31710**	Guntramsdorf
90901	Alsergrund	**31711**	Hennersdorf
91001	Favoriten	**31712**	Hinterbrühl
91101	Simmering	**31713**	Kaltenleutgeben
91201	Meidling	**31714**	Laab im Walde
91301	Hietzing	**31715**	Laxenburg
91401	Penzing	**31716**	Maria Enzersdorf
91501	Rudolfsheim-Fünfhaus	**31717**	Mödling
91601	Ottakring	**31718**	Münchendorf
91701	Hernals	**31719**	Perchtoldsdorf
91801	Währing	**31723**	Vösendorf
91901	Döbling	**31725**	Wiener Neudorf
92001	Brigittenau	**31726**	Wienerwald
92101	Floridsdorf		
92201	Donaustadt		
92301	Liesing		

The district of Mödling was chosen as it represents firstly the first suburban ring outside of the municipal borders of Vienna, secondly a diverse range of land-uses ranging from agriculture in the east over a settlement band surrounding the municipalities between Perchtoldsdorf, Mödling and Gumpoldskirchen (along the Sothern Railway "Südbahn" of Vienna) to the Vienna Forrest in the west. Thirdly the district is split according to the Urban-Rural-Typology into a large urban centre structure along the Südbahn and 'rural municipalities near centres' in the west and south-east of the district (Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-b). The district of Mödling consists of 20 municipalities and the city of Vienna consists of 23 districts. (see Table 1 and Figure 3)

The study area shows a wide range of different spatial characteristics which adds onto the research basis as it gives the chance to analyse these spatial criteria and develop a finer toned result from it (see also Boussauw et al., 2010).

3.2 Literature review

For the understanding of what could influence the commuting mode choice and the travel behaviour in general the aforementioned behaviour psychological, and spatial development theories, approaches, and models (Chapters 2.3 & 2.4) are a basis. This is further expanded upon by an extensive literature review of empirical studies, papers and grey literature within the field of transport geography and planning to find possible explanatory determinants for the commuter mode choice.

The literature review was mostly conducted between September 2023 and June 2024 but was supplemented in the following months. The research was mostly conducted via Google Scholar, Scopus and ResearchGate. Furthermore, the Snowball system for literature selection was used for finding more relevant literature. The focus was on finding determinants for the transport mode choice. Therefore, literature was chosen which either hold empirical evidence on the main topic or could enhance the literature analysis by offering a complementary view or the practitioners or state perspective with the grey literature. The literature was also selected based on the authors or organizations publishing the literature. The results of the literature review can be found in chapter 4.1.

3.3 PPGIS

Public participation geographic information science, or short PPGIS, focuses on the participation of the public in processes of mapping and decision-making. PPGIS is to be differentiated from voluntary geographic information (VGI) and participatory GIS (PGIS) (Brown & Kyttä, 2014).

VGI is, as the name suggests, a voluntary form of geographic data production by individuals in mostly a digital form. VGI focuses mostly on generating new spatial data where there isn't any available. An example for VGI could be data generated in Applications and social mediae like Strava or Instagram (Brown & Kyttä, 2014).

Developed as a method in developing countries, **PGIS** brings the ability to collectively map in person, often on in rural areas on non-digital maps. NGOs are a big player in the application of PGIS, as it can be used for countermapping, a form of opposition to dominant power structures in the areas it is applied (Brown & Kyttä, 2014).

PPGIS approaches the understanding of individual location-specific values by combining assets of online questionaries with mapping tasks. It's a predominantly digital form of data collection which is used mostly in developed countries. PPGIS surveys are often conducted via individual probability or random sampling or through household surveys to ensure representativeness (Brown & Kyttä, 2014; Fagerholm et al., 2021). Over the last decades PPGIS has gained more traction as a research method in different research fields in variety of different countries (Fagerholm et al., 2021).

Although the focus of PPGIS is on mapping specific places, routes or areas, surveys typically include questions about non-spatial data. This data could include topics such as socio-economic or demographic characteristics, personal values, personal motivation and behaviour, wellbeing or confidence levels (Fagerholm et al., 2021).

The main process of conducting a PPGIS-Survey begins with the survey-design and goes over the participant recruitment and data collection to the final part, the data analysis. All these steps are explained for the data used in the thesis in chapters 4.2 to 4.4. It is important to mention that PPGIS data and the applied analyses are constrained by the data quality. The data quality is affected by many factors including the mapping efforts, the type of spatial data collected and the fit of the data to the purpose it is used in (Fagerholm et al., 2021).

Participative methods like PPGIS are often applied in research projects with municipalities and citizens for questions about social policy, spatial planning or transport policy and planning (Brown & Kyttä, 2014; Daubitz, 2021; Fagerholm et al., 2021). Although this helps to bring in citizen opinions into the planning phases it does not necessarily need to be considered for the final planning phase (Daubitz, 2021). An extensive list for pros and cons of PPGIS as a tool to promote/demote public participation can be found in Kahila-Tani et al. (2019).

3.4 Descriptive analysis and data preparation

The conducted PPGIS data is then analysed using different statistical methods to get a grasp of the data. This includes the internal and external validation of the data created in the PPGIS-Survey as well as the visualization and description of the data. This is according to the explore phase in Fagerholm et al. (2021). As there are many possible ways the raw data could be visualized and descriptively analysed, only some, but the most relevant analyses are shown in Chapter 4.3.2. This lays the basis for the further analysis in the multinomial logistical regression.

Based on the before explained descriptive analysis the data must be prepared for the multinomial logistical regression as some survey answers have to be grouped due to low response numbers or indexes are to be created.

3.5 Multinomial logistical regression

As it is common to think about the reality in forms of impact analysis in planning practices (Stöglehner, 2023) one form of impact analysis is used in this thesis as well, the multinomial logistical regression. The result should show what predefined variables affect the transport mode choice in the study area (Chapter 3.1), according to the research questions (Chapter 1.2) provided earlier.

Regression analysis is a commonly used statistical technique that provides the ability to test for a (causal) relationship between different variables. Regression analysis is used to describe and explain relationships between variables and to make predictions. In particular, it is used to analyse causal relationships between a dependent variable and one or more independent variables (Backhaus et al., 2023).

The simplest form of a regression analysis is the linear regression, which considers one independent variable (e.g. price) and one dependent variable (e.g. sales volume of a product) (Backhaus et al., 2023). However, as this form of regression does not do justice to the research question and the complexity of the choice of transport mode (see Chapters 2.4 & 4.1), a form of regression analysis is required that tests a dependent categorical variable (choice of transport mode when commuting; three characteristics; Appendix D) with several independent variables. The multinomial logistic regression fulfils these conditions (Backhaus et al., 2023).

Multinomial logistic regression determines the probability that an observation (a respondent) belongs to a category of the dependent variable as a function of one or more independent variables. In contrast to binary logistic regression, multinomial logistic regression allows more than two values of the dependent variable. The PPGIS-survey (Chapter 4.2) was designed to allow for three different answers for the used transport mode which become the three values of the dependent variable that are analysed further (Backhaus et al., 2023).

Logistic regression requires a reference category for the dependent variable, as the result of the regression analysis only indicates the probability with which an alternative characteristic of the dependent variable is selected depending on the independent variables (Backhaus, 2023).

Figure 5 shows the logistic function, which indicates the probability on the vertical axis. This logistic function can be used to convert real values into probabilities.

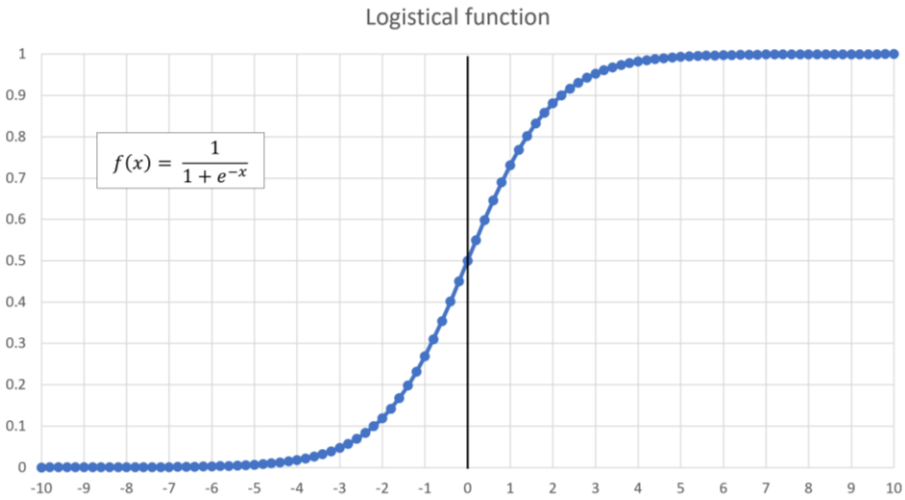


Figure 4: Probability calculation based on the logistical function

Independent variables can be all possible determinants of the dependent variable and must be selected carefully so that no false conclusions arise from the interpretation of the result of the multinomial logistic regression. Independent variables can have any scale level. Whereby categorical and nominal independent variables must be converted into dummy variables with binary coding (Backhaus et al., 2023).

Multinomial logistic regression was used iteratively to determine the best model for mode choice (Chapter 4.4). The model was first calculated with all previously determined variables and then iteratively reduced (backward selection) to minimize the Akaike Information Criterion (AIC) or the Bayesian Information Criterion (BIC). Both AIC and BIC provide information about the model quality, whereby this is not to be seen in absolute terms, but only in relation to other models with different amounts of independent variables. AIC and BIC refer to the deviance in the calculation. The deviance is the basic measure of the goodness of fit of the model. AIC and BIC add a correction variable to the deviance value, which increases according to the number of independent variables used; BIC penalizes a large model more than AIC (Backhaus et al., 2023; Skarke et al., 2016/2024). For this master's thesis the BIC was minimized.

Pseudo R-squared statistics are also used to determine the quality of the model. One of these, which is used in this master's thesis, is the McFadden R^2, which is already an indicator of a good model fit in a value range of 0.2 to 0.4 (Backhaus et al., 2023).

4 Results

The following chapter summarizes the findings which have been gained with the aforementioned methods. Chapter 4.1 focusses on the literature review while chapter 4.2 to 4.4 focus on the process from the PPGIS Survey (Chapter 4.2) over the data preparation (Chapter 4.3) with some descriptive statistics (Chapter 4.3.2) to the multinomial logistical regression (Chapter 4.4).

4.1 Influence factors on the transport mode choice

As shown in chapter 2.4 the behavioural studies as well as the transport and economic geography have different approaches and methods of engaging with the topic of transport mode choice. This makes the transport mode choice a relevant discussable topic where further analysis is needed to combine these approaches into a more fully featured one. To get an intense overview on the discussed factors within the corresponding literature, the following subchapters focus on in total 369 factors. According to different studies, papers, grey literature or state published reports these factors can or could influence traffic mode choice. The factors have been divided based on their context in the mentioned sources (Appendix A) as well as the context of the factor in the transport mode decision-making process, into six categories (Figure 5).

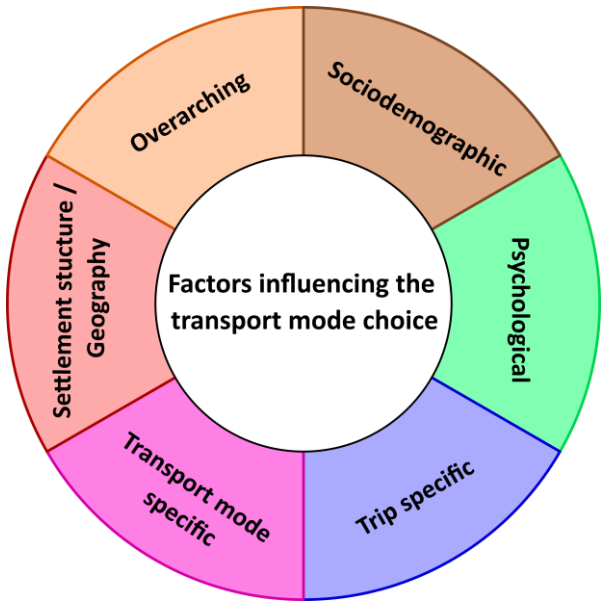


Figure 5: Factors influencing the transport mode choice, own representation

This chapter does not claim to be exhaustive for the factors influencing the transport mode choice. It should also be noted that some factors analysed or mentioned were examined in diverse geographical conditions and therefore do not necessarily assert an influence in other geographical contexts. Since most of the factors (221; 59.2%) were mentioned in multiple

of the thirty core pieces of literature, it can be assumed that the factors are correspondingly more robust. However, the future development of this research field could also oust of these factors as these could be explained based on spurious correlations, false assumptions, geographical circumstances or intermediate factors.

It is also necessary to mention that most of the presented factors, although put into one group most certainly have influences on other factors from the same group or other groups. These interconnections will neither be graphically displayed nor fully discussed and will just be mentioned in the full list of factors in Appendix A.

The following subchapters will follow roughly the order of Figure 5 going counterclockwise, starting with the "Overarching" category and ending with the psychological factors. Each subchapter gives a general overview of the factors with detailed tables with all factors in Appendix A. Each factor has an ID to make it easier to outline connections and refer to the factors. The information regarding the creation and logic of the ID can be found at the beginning of Appendix A.

4.1.1 Overarching factors

The overarching factors can be understood as a kind of landscape defining factors which shape the societal, economic and political landscape and therefore determine the basic tenor for the mindset and discussion surrounding different transport modes. The factors in this category have been organized into three subcategories, the societal factors (6 factors), the political factors (20 factors) and the economic factors (4 factors).

Economic factors (Subcategory 11)

As explained by Kutter (2016, cited in Wolking, 2021) the general economic conditions have implications on the mobility offers which in tandem have influence on the mode choice. The number of mobility options for everyone changes the perception of accessibility (Subcategory 31) with a certain transport mode.

In the literature review four factors related to the economy / economic status of the society have been found (Table 4, Appendix A). The mentioned factors mostly play into two main parts of the provision of SGI as the consumer prices, purchasing power and the unemployment mostly influence the affordability of transport modes. The state of (social) technology can be an indicator for the availability and/or variety of transport modes (Humer et al., 2015). The affordability aspects can thereby be linked to the constraint-models (Chapter 2.4.7) as these factors can be explanatory for financial constraints (322-08).

Societal factors (Subcategory 12)

Kutter (2016, cited in Wolking, 2021) has also mentioned the importance of the societal conditions as these have implications on the mobility offers. The societal conditions have indirect impact on the individual norms (see Chapters 2.4.6 & 2.4.8) as these form different behavioural bases regarding the discourse and general stance of a society towards a certain transport mode. The mentioned individual factors in this subcategory are listed in table 5, in Appendix A. They mostly encompass the demographic structure of the society as well as the distribution of work and living spaces and thereby a close linkage to the geographic factors (Chapter 4.1.2). This underlines the premise that different compositions of the population (especially on a more zoomed-out level) as well as different socio-geographical constructs may influence the transport mode choice. For example, a population with a high share of elderly might choose different transport modes than a younger population.

Political factors (Subcategory 13)

The political factors can on the one hand be extensions of the current societal discourse (through elections and the implementation of laws) or fiscal provider or hurdle for certain transport mode and can thereby foster or diminish the usage of certain means of transport (in)directly. The mentioned factors for the political dimension can be found in table 6, in Appendix A.

The political factors are divided into two main dimensions, the regulatory (group of factors 131) and the financial (group of factors 132). The regulatory factors align with changes in the geographical environment through regulations and guidelines of e.g. parking space (233-17) or travel speed (322-05) and the regulation of the registration of certain vehicles based on goals which should be achieved (e.g.: greenhouse gas emissions per kilometre driven). The financial factors are linked to direct financial involvement in the provision of certain transport modes, measures for the mitigation of social (or locational) inequalities, the levying or decreasing of certain charges such as tolls or taxes (e.g.: VAT).

The mentioned factors range from measures affecting certain transport modes (e.g.: the car with the vehicle registration, 131-03) over measures affecting trip-specific measures of certain transport modes (e.g.: speed limits, 131-01; emission taxation, 132-10) and social measures (e.g.: minimum income support, 132-02; social tickets, 132-01) which would reduce the financial constraints (322-08; Chapter 2.4.7) as well as geographical factors (e.g.: land use and development plans, 131-04; infrastructure investments, 132-07) to the financial burdens of certain transport modes (e.g.: Tax privileges, 132-03). This displays a multitude of possible steering points for politicians ranging from the local to the national or even multinational (EU) level. If these steering points are used to foster sustainable urban planning a multitude of outcomes are the results as they are linked to many areas of the rest of the social and political system.

4.1.2 Settlement structure / geographic factors

The influence of many factors of the residential environment, geography, and settlement structure on the mode choice is only indirect as, according to the models of information processing (Chapter 2.4.5), all 'objective' influences are perceived subjectively and are combined with previous knowledge. Nonetheless, there are some clear tendencies outlined in the influence of the geographical patterns on the mobility behaviour on a generalized level. As Xu (2014, cited in Chen, 2023) has found out, residents of cities are more likely to commute by public transport than those in rural areas. This can be underlined by data from Austria by the federal ministry for traffic, innovation and technology (BMVIT, 2016) as in Vienna public transport accounted for 38% of the modal split while in rural district this value was only at 8%. Furthermore, the data suggests a higher share of active mobility in more urban regions as Vienna and other large cities had a share of more than 20% in 2013 while the rural districts only had a share of 15% (Federal Ministry for Traffic, Innovation and Technology (BMVIT), 2016).

Geographic factors (Subcategory 21)

The geographic factors focus on the general setting in which the start and destination are found and consider factors of the physical environment which can not necessarily be changed in short or middle terms without a change of location. The main points are the topography (210-03) and the geographical area type (210-02). The influence of these factors is easy to grasp for example the topography can be a problem regarding active mobility. The geographical area type (an indicator for the degree of urbanization) can be an indicator for possible public transport routes and accessibility in all transport modes.

Settlement structure (Subcategory 22)

The settlement structure is represented by a multitude of factors (Table 8; Appendix A). The factors range from larger scale points like the population density over the urban planning aspects of the transport services to the street design itself and the elements of it. The settlement structure is thereby a determinator of the features of the trip itself, the length (400-11) and duration of the trip (group of factors 403) as well as for the variety of transport modes (Subcategory 31) (Stöglehner, 2020). The settlement structure also is a huge influence on the space-time prism of the individual (Chapter 2.4.7) as the settlement structure predefines areas of higher or lower permeability in the form of corresponding travel speeds into certain directions (Nuhn & Hesse, 2006).

Many of the factors within this chapter are the 'objective' facete of other, perceived factors mentioned within chapter 4.1.6. This is according to Schwanen & Mokhtarian (2004) who mentioned that the combination of urban form and mode choice might not be a direct one. Additionally, this combination follows the models of information processing (Chapter 2.4.5) as every aspect of the settlement structure is perceived in some way and added to the

knowledge base for decision-making. Nonetheless, the factors should be mentioned as many of these can be addressed through spatial planning or regional development.

The wide variety of the factors stems from the broadness of the term settlement structure itself. Most factors are based on different scales as the street level plays a big role just like the citywide level. The neighbourhood and residential surrounding are excluded in this subgroup as they are the focus of the next section.

Residential factors / housing situation (Subcategory 23)

Following the principles of the compact city (Chapter 2.3.5) and the public mobility approach (Chapter 2.1) the influence of the settlement structure as well as the residential factors and the neighbourhood become clear. This is especially the case for an adjusted planning approach following these principles which should lead to transformations of the chosen transport mode in many areas (Schwanen & Mokhtarian, 2004; Stöglehner, 2020).

The residential environment might also be one of the key factors for the commuter satisfaction and the quality of life (Jang & Ko, 2019; Khosravi et al., 2016). This associates the need for a critical view on housing and neighbourhood characteristics onto the transport mode choice. Especially as in 2013/3014 around 80% of all trips in Austria started and ended at home (Weninger et al., 2021).

4.1.3 Transport mode specific factors

Some factors found in the literature are linked mostly to the transport mode itself. The factors in this category are divided into the accessibility factors and the transport mode specific factors. The accessibility factors are structured along the different transport modes (Table 11, Appendix A) and the transport mode specific factors are structures along four dimensions safety and reliability, comfort, features, and efficiency (Table 11, Appendix A).

Accessibility factors (Subcategory 31)

For the consideration of a transport mode in the decision-making process, there needs to be information about that transport mode available (information-processing models; Chapter 2.4.5), which is part of the psychological factors (group of factors 644) as well as the environmental prerequisites for the usability of the transport mode must be available and accessible. The availability and accessibility of services of general interest have been presented as necessary for the provision by Humer et al. (2015). Accessibility is thereby closely related to usability, as the mere existence of a car, for example, does not constitute sufficient ability to use it (which will be mentioned in Chapter 4.1.6). Although this section only mentions technical, i.e. objectively recognizable, factors that are not related to the user and their personal constraints (group of factors 404), as well as their skills and abilities (612-05) and limitations in terms of health (612-08).

The accessibility factors focus on one of the main constraints for the usage of a certain transport mode as it needs to be feasible to access this transport mode to be able to use it. The accessibility is thereby neither locked to the resource (the transport mode) alone but also to the financial constraints (322-08; Chapter 2.4.7) as well as potential physical or mental restrictions (group of factors 612).

Transport mode specific factors (Subcategory 32)

The transport mode specific factors are divided into three groups of factors. Firstly, safety and reliability which mostly focuses on potential issues leading to injuries as well as possible failures or unforeseen major delays of the transport mode. The second subgroup is the transport mode efficiency, which focusses on the quality, costs and environmental factors. The third subgroup is the comfort which considers crowding, cleanliness and features of the transport mode. Overall, this subcategory encompasses 47 factors. The full list of factors can be found in table 11 (Appendix A).

Many factors of this subcategory are reliant on the perception of the user of the transport mode; related factors of the perception are encompassed in Chapter 4.1.6. The combination of 'objective' and subjective world is following the idea of the models of information processing (Chapter 2.4.5). The build 'objective' environment of the transport options with their according features, efficiency measures and safety and reliability statistics can only foster the usage of certain transport modes to some extent. The individual preferences (Chapter 4.1.6) as well as the experiences (Chapter 4.1.6) play a large role in the subjective evaluation of the transport modes (Chapter 4.1.6). Nonetheless, it is necessary to also look at the 'objective' factors as those can be altered and only then can change the subjective evaluation of a transport mode. Examples for the change of objective factors that changes the perception can be the alteration of the costs (322-06) or the usage of new transport vehicles which alter the comfort aspects (group of factors 323).

4.1.4 Trip specific factors

The trip specific factors revolve around specifics of the trip itself that are not necessarily generalizable. Especially factors of the timeframe (group of factors 401), start and destination of the trip (group of factors 402), the time (404-01) and destination constraints (404-03) the trip has (Chapter 2.4.7), the trip duration (group of factors 403) and the trip situation are brought into the focus. Cervero (2002) has also emphasized the need for the focus on the surroundings of the trip start and destination. The factors are listed in table 11 (Appendix A).

Especially the trip specifics and the constraints can play a huge role if a transport mode is feasible for a trip to use. Limitations of that form can change the perception of options especially regarding the space-time-prism (Chapter 2.4.7) as the travel situation and constraints can make certain transport modes not usable in the available time frame.

Different travel situations can also lead to different decision-making process for example the needs of all travellers (size of travelling group; 400-05) may have to be assessed and evaluated to find a fitting solution, this follows the premise of the adapted rational choice theory (Chapters 2.4.4 & 2.4.6). Similar to the transport mode specific factors the trip specific factors often have a not negligible portion of factors that is subjectively assessed, and the perception of these factors might influence the transport-mode choice more than the factor itself. This follows the ideas of the models of information processing (Chapter 2.4.5). For some trips, especially if they are done regularly (400-10) habitual (620-01) elements of decision-making come into play (Chapter 2.4.6).

4.1.5 Sociodemographic factors

Sociodemographic factors of a person and the corresponding household can assert an influence on the transport mode choice. Factors such as Age (510-01), Gender (510-02), Income (520-01), the level of education (510-07) or the workplace (group of factors 511) can influence the transport mode choice or can be explanatory towards life circumstances and correlating behaviour (Wittwer & Berger, 2021). It has been found by van Acker (2010, cited in Ko et al., 2018) that the influence of the socioeconomic factors exceeds that of the subjective lifestyle (group of factors 621). It has become a standard to assess at least part of them for mobility questionnaires (Widmer et al., 2020).

Personal factors (Subcategory 51)

The personal factors are focussed on the person who performs the trip and their demographic factors as well as their education and work-related factors. The income (520-01) is mentioned as a factor of the household (Subcategory 52) although some literature has not clarified if the personal or household income is the relevant factor.

Household factors (Subcategory 52)

The household factors mostly focus on the household structure, with some information about the people living in the same household as the person.

4.1.6 Psychological factors

In the presented models of information processing (Chapter 2.4.5) the relevance of the subjective evaluation of the ‘objective’ world is emphasized. The subjective view and the psychological dimension in general are the focus of this, last, category. The evaluation of these factors for planning purposes is a part of the differentiation between mobility planning and traffic planning (Rammert, 2021; Chapter 2.1) The category is divided into five subcategories, the physical and mental requirements (15 factors), the behavioural factors (18 factors), the social environment factors (14 factors), the perception (69 factors) and the values, attitudes and preference (28 factors). The detailed lists of factors can be found in the Appendix A, in the tables 16 to 20.

Physical and mental requirements (Subcategory 61)

The basis of the psychological factors are the physical and mental requirements. The focus of the factors (Table 15, Appendix A) of this category is on the one hand the physical well-being (group of factors 611) as this decides to some extent about the ability to travel. On the other hand, physical and mental restrictions (group of factors 612) that might hinder the usage of certain transport mode. Those restrictions include among other things the perceived fitness (612-02), the skills and abilities of the person (612-05), psychomotor disabilities (612-07) as well as the mental and physical health (612-08) and potential illnesses (612-09).

Behaviour / Characteristics (Subcategory 62)

The behaviour and the characteristics of the person can also influence the transport mode choice. Especially habits (620-01) which establish themselves over time can be an issue for not changing the transport mode. A habit can be compared to the equilibrium state of the motivation models (Chapter 2.4.5) as a habit is a behaviour that has been built from experiences and is not evaluated further due to lesser effort needed to perform the habitual behaviour. A bigger (external) shock is needed to change the behaviour (Wittwer & Berger, 2021).

In addition to habits this subcategory encompasses the experiences (620-05) a person has made, which is relevant for the decision-making process according to the rational choice theory (Chapter 2.4.4), the usage of the internet (620-09), the personality (620-10) and the lifestyle (group of factors 621) and mobility style (621-05).

Especially lifestyle and mobility style can provide information about the sociocultural dimension of a person. An example for the measurement of the lifestyle (group of factors 621) could be the for Germany developed ‘Münsteraner Typologie der Lebensführung’, which evaluates two main dimensions, the social situation and the biographic route. These dimensions divide the population into twelve lifestyle-categories (Selzer & Heyse, 2016). For the mobility styles (621-05) a possible division of the population are those of the pro:NEWmotion project by Millonig et al. (2023), which divides the population into five groups with different mobility styles.

Social environment (Subcategory 63)

The third subcategory with the social environment as the focus encompasses factors such as the status (630-02), prestige (630-03), the internal household organization (630-05) as well as sociocultural norms (631-01) and society’s expectations (631-06). The norms and expectations are also part of the sociopsychological approaches (Chapter 2.4.6) especially the subjective norms are part of the norm-activation model of Schwartz (Chapter 2.4.6) and the theory of planned behaviour (Chapter 2.4.8). Norms can also become to some extent mental restrictions (group of factors 612), especially if norms lower the perceived behaviour control (641-01) dramatically.

Perception (Subcategory 64)

As shown in the models of information processing (Chapter 2.4.5) the perceptions of the world can play a role in the decision-making process. The factors are like the Categories "Geography/Settlement structure" (Chapter 4.1.2), "Transport mode specifics" (Chapter 4.1.3) and "Trip specifics" (Chapter 4.1.4) very broad. Among other things this subcategory includes the perceived behaviour control (641-01; see also Theory of planned behaviour, Chapter 2.4.8), fears (641-02), the psychological travel expense (group of factors 642) which relates to the subjective benefit models (Chapter 2.4.4) and the effort (649-03) to build up knowledge, the cognitive capacity to judge different attributes (642-03), the perception of a transport mode (group of factors 643) which relates to the models of information processing (Chapter 2.4.5), the information situation (group of factors 644) as well as the attractiveness of the neighbourhood (group of factors 647), the workplace (group of factors 648) and the travel route (group of factors 649). Not all the factors mentioned in table 18 might influence every mode choice as the trip purpose (400-04) could for example make the workplace related factors obsolete.

Values / Attitudes / Preferences (Subcategory 65)

The interest into the values, attitudes, and preferences of the people has got a boost recently as with the measures of travel-demand-management and the conjoined concerns about the climate crisis and air quality. (Fujii and Kitamura, 2003, cited in Schwanen & Mokhtarian, 2004).

The subcategory focuses on the individual values, e.g.: curiosity (651-04), willingness to take risks (651-06), life/personal satisfaction (651-08), the values connected to the society, e.g.: open/conservative (652-02), privacy (652-05), freedom (652-06), independence (652-07), the values connected to travel, e.g.: wanderlust (653-01), flexibility (653-03), fun while using a transport mode (653-05), and the environmental values, e.g.: environmental awareness (654-01).

4.1.7 Overview

As shown in this chapter, there is a large variety of different factors ranging from the overarching situation, over the settlement structure, trip, and transport mode specific factors to personal characteristics and the psychological level. It seems clear that not every factor can have the same impact or is evaluated (even if it would be subconsciously) continuously to find the "best" transport mode and route for each trip, which would follow the ideas of the rational choice theory (Chapter 2.4.4). This leads to the development of the before discussed habits (620-01; Chapter 4.1.6), which are presented in the sociopsychological approaches (Chapter 2.4.6), especially for the transport mode choice. The habituative behaviour is very prevalent and reaches to very different sections of the trip.

In a study commissioned by the Swiss federal railway (SBB) it was found that 75% of commuters have a strongly habituative behaviour. Commuters use the same transport mode

at the same time, wait at the same spot at the platform and often sit on the same seat in the bus or train (Weninger et al., 2021). Additionally, the linkage between the trip, the transport mode and the experiences gathered along the way are interlinked with the activity performed at the destination (DB AG 1997a, cited in Groß, 1998) which follows the concept of the cognitive maps (Chapter 2.4.5). Which might in turn lead to habits if the trip and the associated activity are performed regularly.

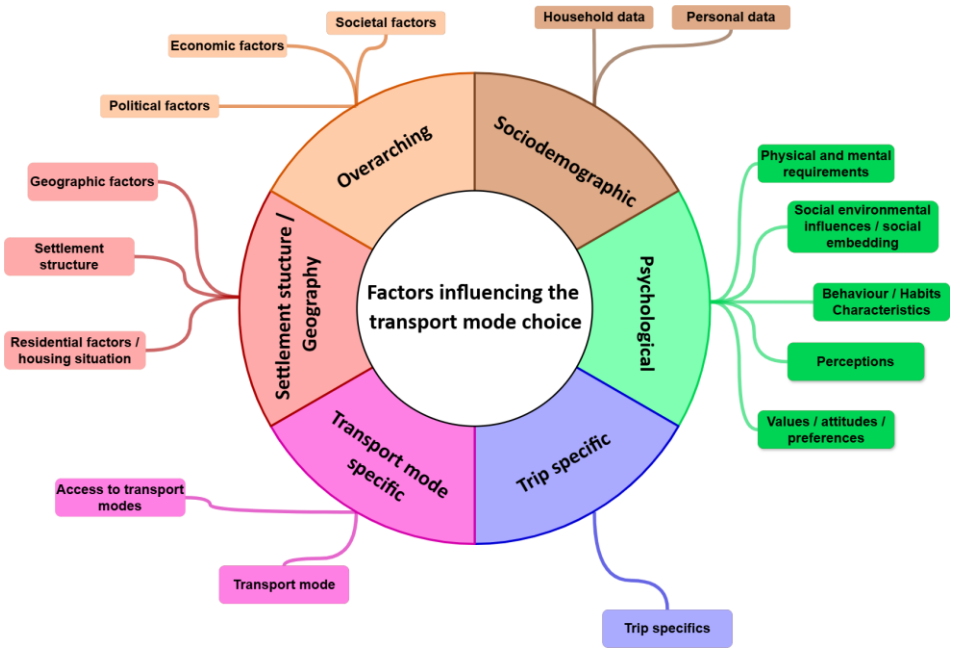


Figure 6: Overview over the categories and subcategories of the literature review

This habituative behaviour will occur most often for trips that are done routinely (400-10) (Schneider 2013, cited in Chakrabati, 2016). These trips can be changed due to internal (different constraints (group of factors 404), position in household changes (630-04), changes in lifestyle (group of factors 621)) or external shocks (changes in the speed limit (131-01), repairs on streets/tracks (321-08) that lead to diversions (643-10), change of the home (subgroup 23) or workplace (511-06)) which alter the habituative behaviour, and it may be necessary to change the behaviour to adapt to these changes (De Vos et al., 2018, cited in Ramezani et al., 2021). Every change in the behaviour needs to some extent a new evaluation of the trip situation based on those factors where the needed knowledge (models of information processing; Chapter 2.4.5) is available, the cognitive capacity for the decision is available (642-03) and the effort (323-01) to research the needed information is lower than the expected benefit of choosing a different transport mode (subjective benefit model; Chapter 2.4.4).

In this context, the evaluation is based on the personal restrictions (group of factors 612) and constraints (constraint models; Chapter 2.4.7), which can be e.g.: financial (322-08), time based (404-01) or authority constraints (404-02). Although some of these constraints and restrictions can't be altered from a planning perspective, obstacles that raise the effort

or lead to higher costs or more time needed can be altered to lower these obstacles. This is for the usage of certain transport mode. Examples for such a procedure can be the change of the interval of a public transport line (221-03), the barrier-free accessibility (649-04) or the provision of infrastructure for cyclists and pedestrians (402-01). This can change not only the 'objective' accessibility of places but also the perception of that transport mode if these changes are communicated clearly (information is needed for an evaluation of changes; models of information processing; Chapter 2.4.5). In addition, it is necessary to assess the psychological factors of the decision-making process to change the traffic planning approach towards a mobility planning approach (Rammert, 2021 ;Chapter 2.1).

As seen in the factors listed in Appendix A, as well as in the chapters beforehand the settlement structure could influence the travel behaviour, especially the availability of facilities. The perception of the neighbourhood could be very influential in the transport mode choice (Meurs and Haaijers, cited in Tyrinopoulos & Antoniou, 2012). This gets underlined when political concepts like the mobility master plan 2030 for Austria of the ministry for climate action, environment, energy, mobility, innovation and technology are brought into the discussion. One goal is to transform traffic according to the avoid – shift – improve idea. The main idea is that through efficient planning methods and the link between settlement and mobility planning the need to travel can be reduced (avoid). Any remaining traffic should shift to be more environmentally friendly (shift) and to improve the used technology for the necessary trips that can't be shifted (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), 2021).

Some planning theories, such as the transit-oriented development (Chapter 2.4.4) and compact city (Chapter 2.4.5) try to incorporate this main idea already in the settlement structure. It has already been shown that planning in mixed-use neighbourhoods, which both planning concept advocate for, can enhance the usage of active transport modes and lower the usage of the car (Meurs and Haaijer, 2001 cited in Van Wee, 2011). According to van Wee (2011) the travel time benefits, based on the theory of the constant travel time budget (Chapter 2.4.9), outweigh environmental benefits in the evaluation of transport modes.

This chapter and the mentioned factors in addition to the theories, mentioned in Chapter 2.4, have shown the many angles and dimensions of the transport mode choice. These different points of view, show not only the to some extent not predictability of some decisions but also the variety of factors an (un-)conscious decision for the transport mode is based on. The factors are often intertwined and refer to each other as not a clear lever / entry point for changes can be found. Each change in the system might change other factors to an extent that can change the outcome of the decision process. It is also shown that there is not one theory that explains the decision process, instead through different factors and their interplay, different approaches of planning (Chapter 2.3) and behavioural theories (Chapter 2.4) can be underlined (Appendix A, Chapter 4.1).

4.2 PPGIS-survey

For the analysis of the factors which might influence the traffic mode choice in the Vienna city region, the PPGIS-survey, conducted in the CURB research project was a major data source. The survey has collected different data about the respondents, their behaviour and has included four digital mapping tasks (Figure 7). The survey includes information on a person-based level about the individual commuting behaviour, the mapped residence and workplace as well as some perceptions about their residence and neighbourhood.

The CURB research project

The research project CURB (The COVID-19 pandemic as a disruptive force for urbanization) is based within the sustainable urban regions (SUUREG) working group of the Institute for Urban and Regional Research (ISR) at the Austrian Academy of Sciences (ÖAW). The project is funded by the Austrian Science Fund (FWF) (Grant-Nummer P 35066 G) (Institute for Urban and Regional Research (ISR) at the Austrian Academy of Sciences (ÖAW), n.d.).

The research project uses a mixed-methods approach towards its main research question: 'if the COVID-19 pandemic has disrupted the general urbanization trend in the Vienna city-region'. The methods used include a qualitative media analysis, statistical data collection and analysis, focus groups with planning experts and stakeholders as well as the mentioned PPGIS-survey. (Institute for Urban and Regional Research (ISR) at the Austrian Academy of Sciences (ÖAW), n.d.) The data used in this master's thesis only relates to the PPGIS-survey of the project.

4.2.1 Structure of the survey

The structure of the survey was following eight thematic blocks (Figure 7). It posed questions regarding the respondents' personal characteristics (sociodemographic data) in block one and seven. Additionally, the focus of the survey expanded to encompass the neighbourhood of the respondents' primary place of residence, possible multilocality, access to green and blue spaces, and their workplace.

The survey was conducted in German and English using the online tool Maptionnaire (https://www.maptionnaire.com) and had a total of 20 pages with four mapping tasks. The mapping tasks showed a background map on which the respondents could map one or multiple point features. In some mapping tasks, the respondent received additional questions in a pop-up window regarding the point they have mapped before.

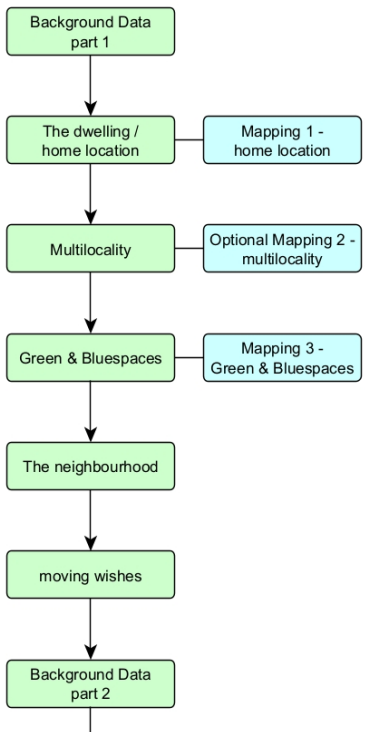


Figure 7: Structure of the survey blocks within the CURB PPGIS-Survey, own representation

4.2.2 Sampling of the survey

As found by Khaila Tani et al. (2019, cited in Fagerholm et al., 2021) the sampling strategy impacts the representativeness of the sample with random sampling promoting a good representativeness.

The sampling strategy of the CURB PPGIS-survey was a random sampling of 16,000 people from the "Zentrales Melderegister" (ZMR) (Central residents register). The sampling was limited to people aged between 20 and 69, 8,000 of them having their main residence within the city of Vienna, 8,000 in the district of Mödling. A more detailed description of the study area can be found in Chapter 3.1. The survey was conducted from May until June 2023.

The 16,000 sampled people all received a two-sided cover letter via post. The letter included information about the research project and why they were chosen in German and English. Additionally, a short link and a QR-Code to access the survey were included on the cover letter. The project webpage (https://www.oeaw.ac.at/en/isr/curb) included a FAQ in German and English as well as a German GDPR-Document for the survey.

4.2.3 Response rate

1,713 people have finished the survey, the response rate is thereby 10.70%, which is a bit lower than to be expected from international examples. As Brown and Kyttä (2014) have stated the mean response-rate across multiple online PPGIS studies with a random household sampling is around 13%. But since PPGIS-Studies, especially in that scope have, to the knowledge of the author, not been carried out in Austria before, the response rate can be interpreted as good.

The data set was later adapted to be useable for the further analyses; the used data of the survey can be found in table 22 in appendix C.

4.3 Preparation for further analysis

Following the analytical phases mentioned by Fagerholm et al. (2021) is the first part of the analysis the "Explore" phase which involves descriptive and univariate analysis with the PPGIS data and some additional geospatial data. In this context, some other analyses on the data have already been conducted. In the "Explain" phase additional data is added for a closer observation of the PPGIS data (Fagerholm et al.,2021). Both phases are to some extent part of this chapter.

The 1,713 respondents have mapped 1,217 workplaces. These points and the corresponding respondents have been cleaned following the list in Appendix B. After the data clean-up the number of OD-pairs (trips) has dropped to 808 which have been mapped by 730 respondents. The descriptive analyses in Appendix D only encompasses these 808 OD-pairs. Therefore,

the trips are not entirely independent of another but will be analysed further if they were independent.

Based on the literature review (chapter 4.1) as well as the availability of the data a preliminary list of dependent variables is shown in chapter 4.3.1. The literature review was used to determine whether geospatial or statistical data available from different sources were already being discussed. This should lead to a more appropriate set of data points, supported to the extent that each factor is part of the discussion to potentially influence mode choice. The chosen data set is then descriptively analysed in chapter 4.3.2 and checked for correlation and collinearity in chapter 4.3.3. The multinomial logistical regression and the results are presented in chapter 4.4.

4.3.1 Data used

In total 72 dependent and one independent variable have been assessed through different sources. In a first step, some data has been combined into indexes, and some have been eliminated since they have been used to determine other values. This has led to the list of variables in table 22 (Appendix C). The table shows the name of the variable, the data type, the source, and the linkage to the factors found in the literature review (Chapter 4.1 & Appendix A).

The mentioned independent variables try to capture a huge variety of factors of the literature review (Chapter 4.1) to foster them into the analysis. Additionally, different spatial levels are viewed ranging from the personal data like the age, gender, or income over the data of the neighbourhood, defined by a 300m buffer around the home location, to the municipal level.

The usage of circular buffers at certain distances around the home location and determine landscape characteristics and urban structure is a common analysis method, especially if used on different spatial scales (Fagerholm et al., 2021). The 300m buffer for the neighbourhood definition was chosen based on a recommendation of the WHO for the access of green spaces (WHO, 2016 cited in Fagerholm et al.,2022) and the possibility for most people to reach this area by foot in a small time duration. With an estimated average speed of 4.26 km/h of elderly (Willberg et al.,2022) the distance of 300m could be covered in less than 5 minutes by foot.

Although in the survey the answer option for the transport mode was given as “by foot or by bike” only the bike attribute was used as this provides data for the transport mode with the higher speed. This makes the active mobility option probably more attractive.

It is relevant to note that any further analysis of the data is constrained by the data quality, especially the survey data (Fagerholm et al., 2021). The data quality is not further assessed, and the data is not changed further based on the data quality as some measures have already been taken in the preparation of the data (Appendix B).

4.3.2 Descriptive analysis of the data

To give an overview over the data, some features are described here, the complete list of descriptive features of the in table 22 mentioned factors can be found in appendix D (Table 23 & 24).

Of the respondents nearly 40% chose the car on their commuting trip, while 47.4% chose the public transport and 12.62% chose to use an active form of mobility (Table 23).

86.5% of respondents were employed at the time of the survey. 52.6% of respondents identified themselves as female or other, while 47.40% identified themselves as male. Over 60% of respondents have a completed tertiary education. Nearly a third of respondents lives with their partner and another third lives with their partner and a child or multiple children. Nearly a third of the respondents is 50 years or older (Table 23).

Close to 88% of respondents agree or strongly agree that they are overall satisfied with their neighbourhood. Approximately 73% of respondents agree or strongly agree that there are enough green areas in their neighbourhood (Table 23).

Over 60% of respondents live in Apartments, and around 22% in detached houses. Over half of the respondents own their living space and 26% live in privately rent properties. More than half of the respondents live in the two best "ÖV-Güteklassen" and therefore have an objectively high accessibility of the public transport. Of the workplaces nearly three quarters are placed in areas with the two best "ÖV-Güteklassen" (Table 23).

The median distance of a trip from home to work is 9.1 km with a standard deviation of 15.9 km. The median trip duration with the public transport is 41 minutes with a standard deviation of 21.06 minutes. For the bike the numbers change to a median of 45 minutes with a standard deviation of 84.1 minutes. For car trips the median duration is 27 minutes with a standard deviation of 13.17 minutes (Table 24).

4.3.3 Correlation and collinearity in the used data

Following Backhaus et al. (2023), the categorical variables were recoded into binary "dummy" variables to be usable in the multinomial logistical regression. From each categorical variable one value was chosen to be the reference category as otherwise multicollinearity would occur between the new binary variables. The reference categories can be found in Appendix E, including a short description of the reasoning.

A correlation analysis was then carried out on the dataset. The dataset was checked for correlation exceeding the absolute of 0.8. This has led to the exclusion of thirteen independent variables (variable IDs 38; 39; 40; 43; 45; 50; 55; 57; 58; 59; 60; 61; 62) which are marked in cursive in table 22 (Appendix C).

The factors 38, 39, 40 and 43 have a correlation above the absolute of 0.8 with the total network distance. The factor 45 has correlations among others with the factor 50 and the

population density around the home location. The factor 50 correlates with the average household income as well as some election results. The factor 55 correlates above the absolute of 0.8 with the percentage of one or two unit residential buildings. The election results mostly correlate with geographical features of the corresponding municipality e.g. share of migrant people, share of elderly, unemployment rate or annual household income.

After the correlation analysis only 49 independent variables remain for the multinomial logistical regression. The collinearity was then checked, and none was found to be present.

4.4 Multinomial regression analysis

To answer the second research question "What could influence the transport mode choice on commuting ways in the Vienna city-region?" (Chapter 1.2) a multinomial logistical regression was carried out. This follows the general premise of Fagerholm et al. (2021) who emphasized the Predict/Model phase as the third phase of PPGIS data analysis.

The multinomial logistical regression is used to model the transport mode choice based on the data mentioned in table 22 (Appendix C), which includes the survey data but also additional geospatial and statistical data. Using the data a model was created that can, based on an assortment of the variables, predict the usage of a certain transport mode. Those predicted transport modes are then compared to the actual transport mode, which shows the fit of the model to the real-world data. Additionally, other criteria are used to assess the quality of the model e.g.: the BIC (Chapter 3.5).

The multinomial logistical regression was calculated with the statistical software IBM SPSS version 30. The multinomial logistical regression was performed backwards iteratively, following the BIC which is based on the log likelihood ratio (Universität Zürich, n.d.; Backhaus et al., 2023). SPSS provides next to the BIC of the current calculated model an estimation for the BIC of the model reduced by every individual factor. The model was reduced by the factor which would lead to the lowest BIC if excluded.

The list of excluded variables, the corresponding AIC, BIC and Mc Fadden R^2 can be found in table 26, in appendix F. Iteration number 85 has the lowest BIC in the iterative model creation.

4.4.1 Results

The remaining factors that have the highest explanatory value for the model of the transport mode choice are shown in table 2.

Table 2: Factors with the highest explanatory value for the transport mode choice

Var. ID	Name
02	Main occupation: Employed
07	Since when in current main residence: three years or less
08	Household type: Several generations / families
28	Average population density around home location
31	Average population density around workplace
32	Duration of the trip with the public transport
37	Cost for a public transport trip in relation to a car trip
42	Duration of the trip with the car
48	Share of people with tertiary education

The model has a BIC from 1148.437 which cannot be lowered by removing more factors. The value of the McFadden pseudo R^2 for the final transport mode choice model is 0.360 which can be interpreted as a good model fit (Louviere et al., 2000 cited in Backhaus et al., 2023). The model correctly predicts 72.2% of respondents transport mode choice, with 74.6% correct predictions for car users, 80.4% correct predictions for public transport and only 33.3% of correct predictions for active commuters. The concrete numbers of correct predictions are shown in figure 8.

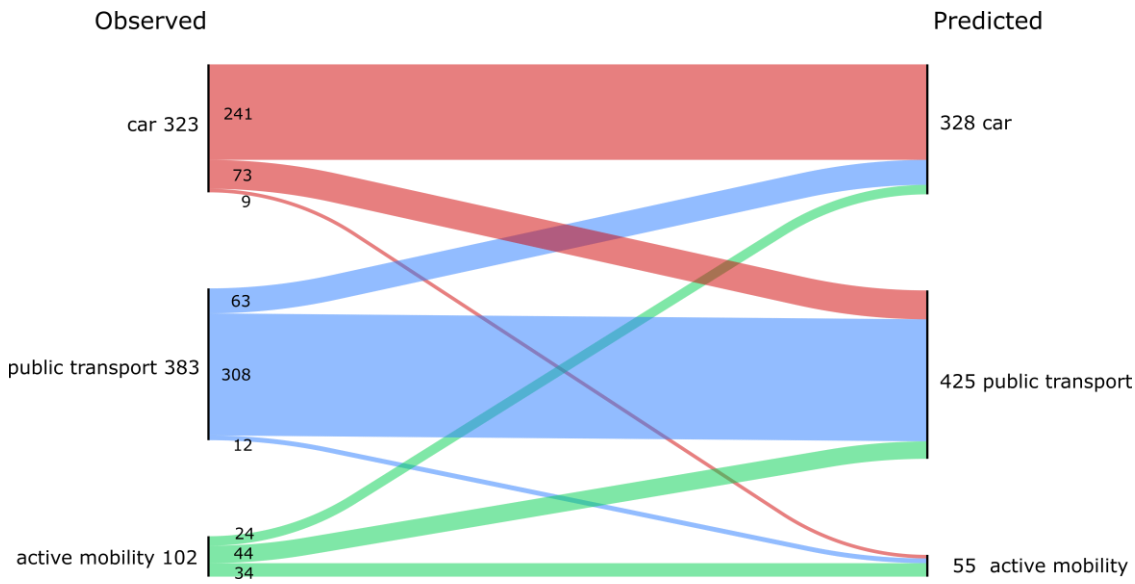


Figure 8: Observed and by the model predicted transport mode choice on the 808 OD-pairs

These differences might occur based on additional (personal) factors which have not been put into the model e.g.: environmental awareness (654-01) or the possession of a driving licence (311-01) Additionally the model may not be able to handle every respondent ideally as, on a personal level, the influences factors have, might even out. This could lead to lower probabilities for the predicted transport mode (Figure 9)

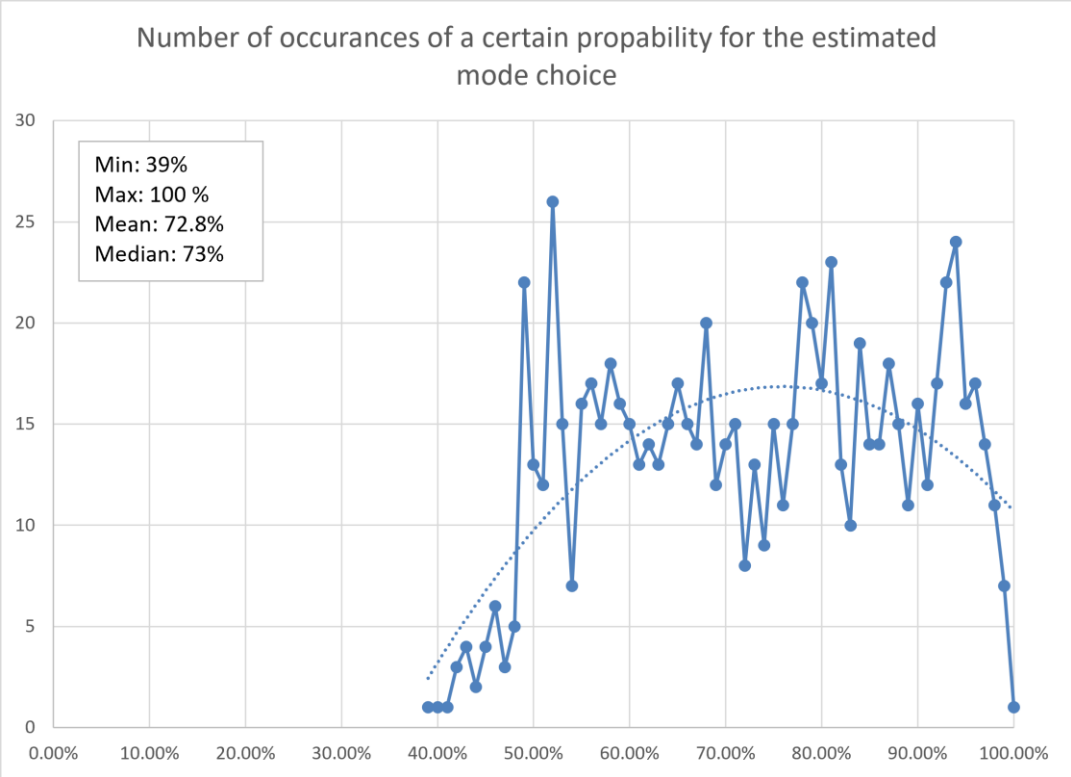


Figure 9: Number of occurrences of certain probabilities for the predicted transport mode choice

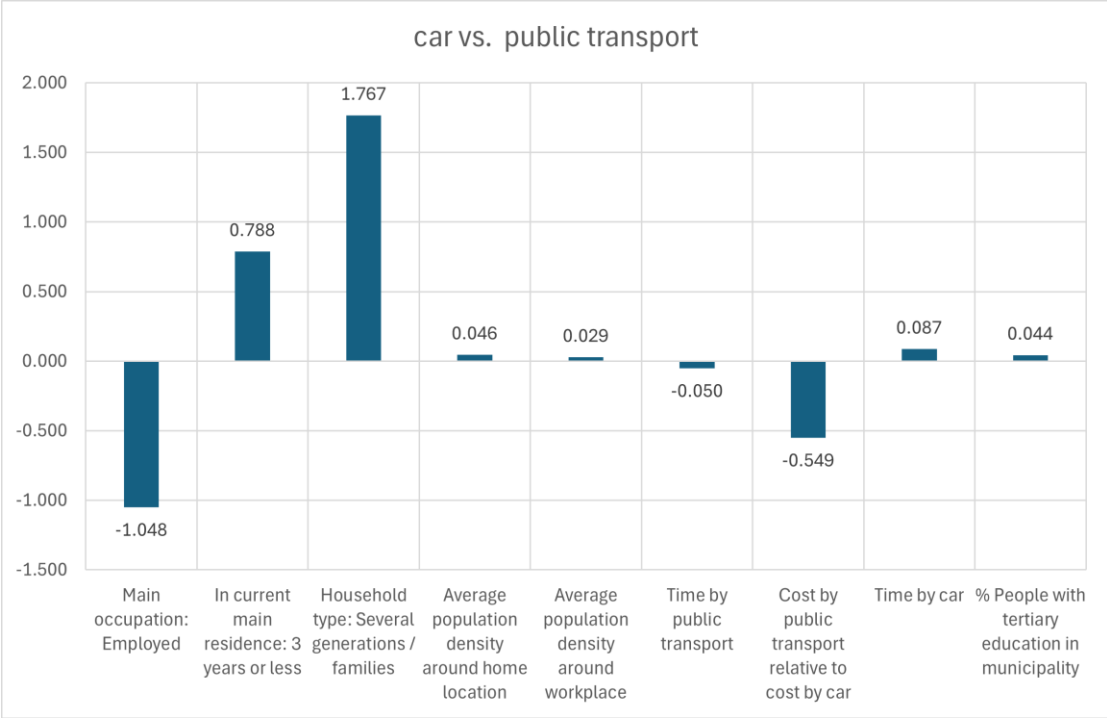


Figure 10: Value of the coefficients of the factors in the model between car and public transport

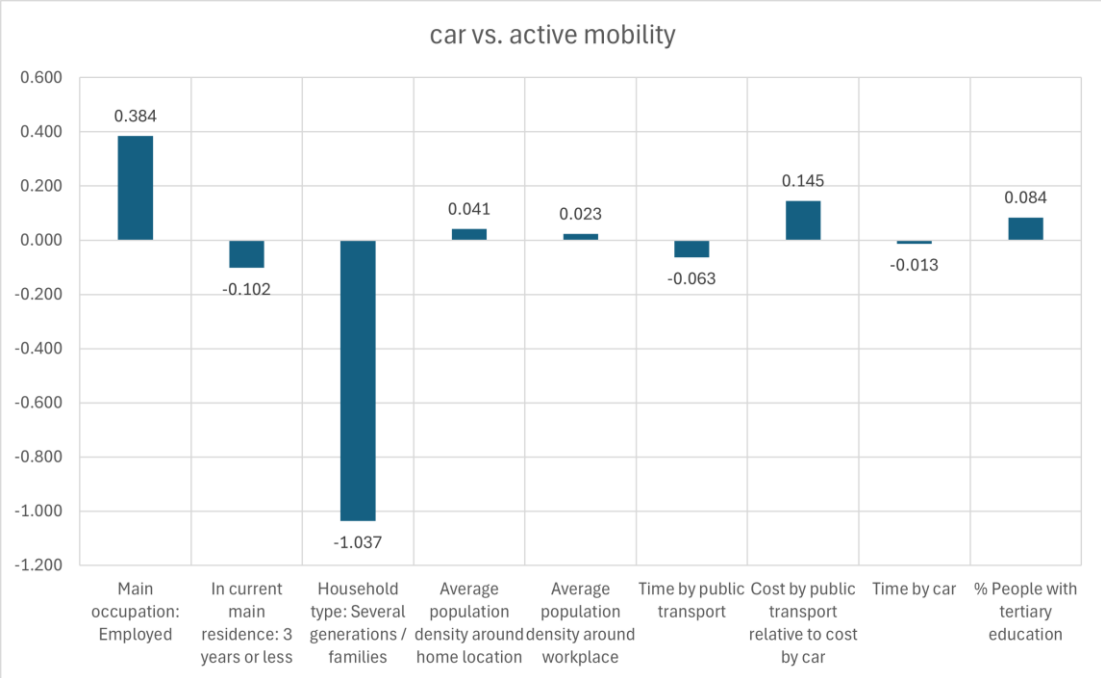


Figure 11: Value of the coefficients of the factors in the model between car and active mobility

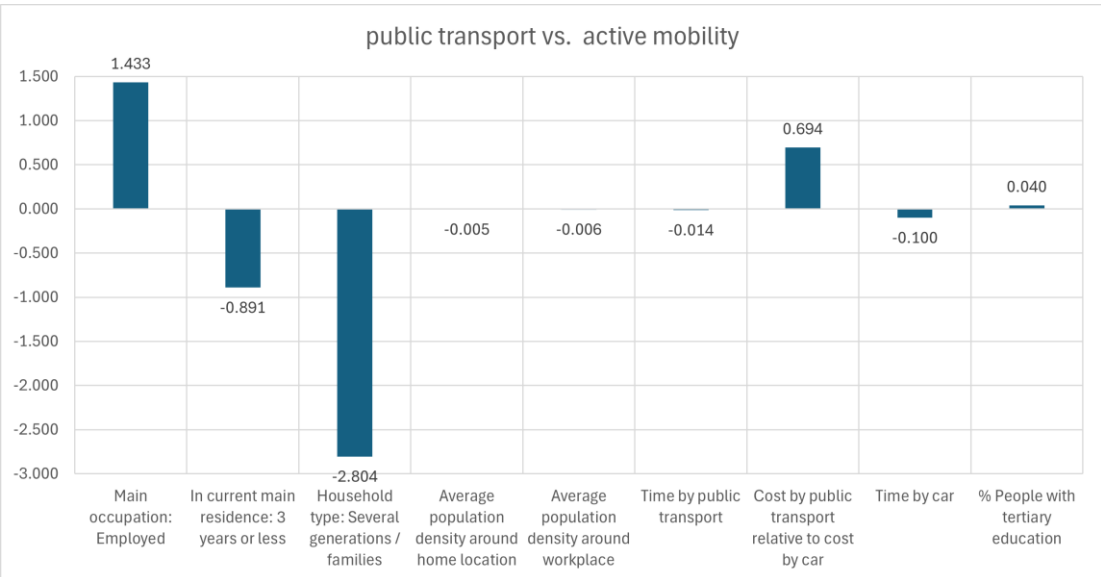


Figure 12: Value of the coefficients of the factors in the model between the public transport and active mobility

As the multinomial logistical regression has a reference category it shows the differences between the other categories and the reference category. Leaving each predicting factor to be positive or negative towards a certain transport mode. For the difference between the car usage and the public transport the factors all are significant. The values of the factors are shown in figure 10, values below zero showing that a rising of the factor would result in a higher probability to use the car. Values above zero showing a higher probability for the public transport if the factor would rise. Following this, if a person is employed, the probability to use the public transport lowers, as well as when the time using the public

transport is rising for the trip or the cost for the public transport trip are higher relative to the assumed costs of the car trip. The other factors show that a public transport trip probability rises in comparison to the usage of the car (figure 10).

If the other two comparisons between the car and the active mobility (figure 11) and between the public transport and active mobility (figure 12) are considered, some factors are promoting. Some are demoting the probability of the usage of a certain transport mode.

As seen in table 3, every variable is demoting one transport mode if the value of the variable rises. This is for example the case with the travel time by car. If the travel time rises, the probability to use means of active mobility lowers in every comparison (table 3).

Table 3: Parameter estimators of the factors for the final model; significance & classification

	Car vs. public transport	Car vs. active mobility	Public transport vs. active mobility
Main occupation: Employed *Reference category: Other (appendices D & E)*	**-1.048****	0.384	**1.433****
In current main residence: 3 years or less *Reference category: 10 to 4 years (appendices D & E)*	**0.788****	-0.102	**0.891****
Household type: Several generations / families *Reference category: Living alone with a child or children (appendices D & E)*	**1.767****	-1.037	-2.804*
Average population density around home location [POP/300m Buffer]	**0.046****	**0.041****	-0.005
Average population density around workplace [POP/300m Buffer]	**0.029****	0.023*	-0.006
Time by public transport [min]	**-0.050****	**-0.063****	-0.014
Cost by public transport relative to cost by car	**-0.549****	0.145	**0.694****
Time by car [min]	**0.087****	-0.013	**-0.100****
% People with tertiary education in municipality	**0.044****	**0.084****	0.040*

*: significant (α=0.05) (Groß, 1997)
**: highly significant (α=0.01) (Groß, 1997)
Orange: If the variable rise in the corresponding model raises the probability for the car use
Green: If the variable rise in the corresponding model raises the probability for the active mobility use
Blue: If the variable rise in the corresponding model raises the probability for the public transport use

Further Information on the data can be found in the appendices D & E

4.4.2 Interpretation of the results

Some results, shown in table 3, are to an extent self-explanatory. If the time by public transport rises the car gets more attractive for the user. In addition, the active mobility gets less attractive if the tip duration in the public transport rises as a higher trip duration correlates with a longer trip distance. Longer trip distances are usually not covered with means of active mobility due to the rising effort (649-03) and trip duration (group of factors 403) which correlates with the concept of the space time prism (Chapter 2.4.7). The variable of the travel time by car can be interpreted similar as the probability for the usage of the public transport rises if the travel time by car rises. The probability to use an active transport mode is also lowered with a rise of the trip duration by car due to similar reasons as mentioned before. This emphasizes the relevance of the trip duration (group of factors 403) as a significant factor in travel mode decisions.

The population density at the start and destination of the trip are also mentioned as significant factors in comparisons with the car. A rise in the population density at either start or destination or both results in a lower probability of car usage for the trip. This follows the results of the literature as a higher population density (220-03), and a higher accessibility of transport modes (subcategory 31) as well as a higher part of mixed-use development (220-04). Normally has a lower share of trips with the car and simultaneously a higher share of trips with the public transport and means of active mobility (Widmer et al. 2020). The perception of population density as the aforementioned variable 14, the perceived urbanity index, could also play a role, although it was excluded from the model, as it was significantly positively correlated (value: 0.405; significant for α=0.01) with the population density around the place of residence.

The price of the transport mode was also included in the final variable set (Table 3) in the form of the relation between the cost for the public transport and the cost for the car trip. A rise in this variable means higher costs for the public transport in comparison to the car. A rise in the cost factor would lower the probability to use the public transport significantly and raise the probability to use the car or an active transport mode. This emphasizes that the price is a relevant factor for the evaluation of the transport mode. Financial constraints (322-08; chapter 2.4.7) play a role in the high relevance of the price as well as the perceived price difference between the transport modes (643-03) which is limited by the information situation (group of factors 644; → models of information processing: chapter 2.4.5).

One of the remaining factors is also the household type, especially if several families or generations live in the same household. Respondents of these households are predicted to use the public transport more often. This could be related to the internal household organization (630-05) as well as the location of the residence as the residence would need more living space (231-03) to house different generations or families. This factor also has a very low number of cases (37; Appendix D) to which this value applies. In combination with the much larger confidence interval of the factor (Appendix G) leads to a lower reliability

of the factor, as this could also be an error of the sampling or of the combination of values done before the regression analysis.

Additionally, the age (510-01) might play a huge role for this aspect as 37.8% of respondents that live in this household type are 24 or younger. So, there might be differences in the perception and interpretation of the household type as the high percentage of young adults in this category suggests that adult children living with their parents could see themselves in a different type of household structure than their parents, but this can't be verified based on the data. It is only a possible solution for the dissonance in this particular group compared to the overall share of young adults under the respondents. As this subgroup often has financial constraints (322-08) regarding their mobility options, might not possess a driving licence (311-01) or still be influenced by the usage of the public transport for school / university (as most of them have answered to still be in education). Trips there could have a bias to use the public transport more.

If a person has lived 3 years or less in their current main residence the person is predicted to use the public transport significantly more than the car or means of active mobility. This might be linked to the age (510-01) of the person as there is a low, but positive correlation between the age groups from the lowest up until the age group '35 -39' with living 3 years or less in their current main residence. This may also link the duration of living in the current main residence to the location and the geographical (subcategory 21) and accessibility (subcategory 31) factors of transport modes at these locations. In addition, habits (620-01) might have not been built for the commuting relation leading to opportunities for behaviour change (Wittwer & Berger, 2021). Within the time frame of this opportunities for behaviour change the information situation (group of factors 644) for the transport modes might not be ideal and therefore certain transport modes might not be as prevalent as others. This follows the ideas of the subjective-benefit model (chapter 2.4.4).

If the self-assessed main occupation is employed than the probability to use the public transport for their trips to their workplace lowers, while the other mode probability rises. This may link to the before described age factors (510-01) and their implications on the mode choice. There could also be a change in the length of the trip chain of the employed respondents (400-09), convenience could play a role (651-05) or the home location. There is a significant correlation between homes with a lower population density and respondents who said that their main occupation is employed (value: -0.096; significant for α=0.01).

The last relevant factor is the share of people with tertiary education in the home municipality of the respondent. A higher share of people with tertiary education could change part of the social norms (631-01) for example in terms of the environmental awareness (654-01). The share of tertiary educated people in the municipality is correlated significantly with a number of other municipal factors for example in municipalities with a higher share of people with tertiary education have fewer people under the age of 15 (value: -0.537; significant for α=0.01), a lower unemployment rate (value: -0.315; significant for

α=0.01), a higher average annual household income (value: 0.571; significant for α=0.01) and the population density of the municipality is higher (value: 0.316; significant for α=0.01). All of these factors, employment (group of factors 511), unemployment rate (110-04), age structure (121-04), income (520-01), population density (220-03) and geographic area type (210-02) might have (in-)direct effects on the transport mode choice leading to the possible conclusion that the share of people with tertiary education might not have a direct implication on the transport mode choice but might be a kind of proxy in the model that represents municipal factors that can't be explained on a personal level.

In total, it shows that most transport mode choices for commuting trips of the respondents can be explained with only a few factors which all derive from 'objective' measurable factors. As these nine factors (table 3) can predict over 70% of trips by the respondents. A look at the remaining nearly 30% of trips will be taken in the next sections.

Wrong predictions

As some respondents and their trips have not been predicted correctly, these were looked at specifically, if the corresponding geographical locations have some things in common, especially if they are clustered. The not correctly predicted OD-pairs have been divided by their misprediction and the observed transport mode. For each of the six subgroups a map overview with the corresponding home and work locations can be found in Appendix H.

For the group of OD-pairs that was wrongfully assumed to use the car instead of the public transport that was used according to the survey, almost all home locations were mapped in either the district of Mödling or the outskirts of city of Vienna, while the workplaces are often in the city of Vienna close to public transport lines. Maybe some assumptions e.g. the price for the single ticket in the public transport or the lower imperviousness of these places may have led to false conclusions regarding the transport mode (Figure 16 in Appendix H).

The cases where the prediction was the usage of the public transport and the mentioned transport mode was the car, show a similar but not as clear picture. Most of the home locations are also found in the suburban areas of the study area, but the workplaces are more scattered over Vienna. Both groups of OD-pairs may show results of the limited answer options in the survey as only four answer options for the transport mode (car, public transport, by bike or by foot, other). Options like the usage of park and ride facilities may be included in either those OD-pairs who have chosen the car or the public transport as the main transport mode for the trip.

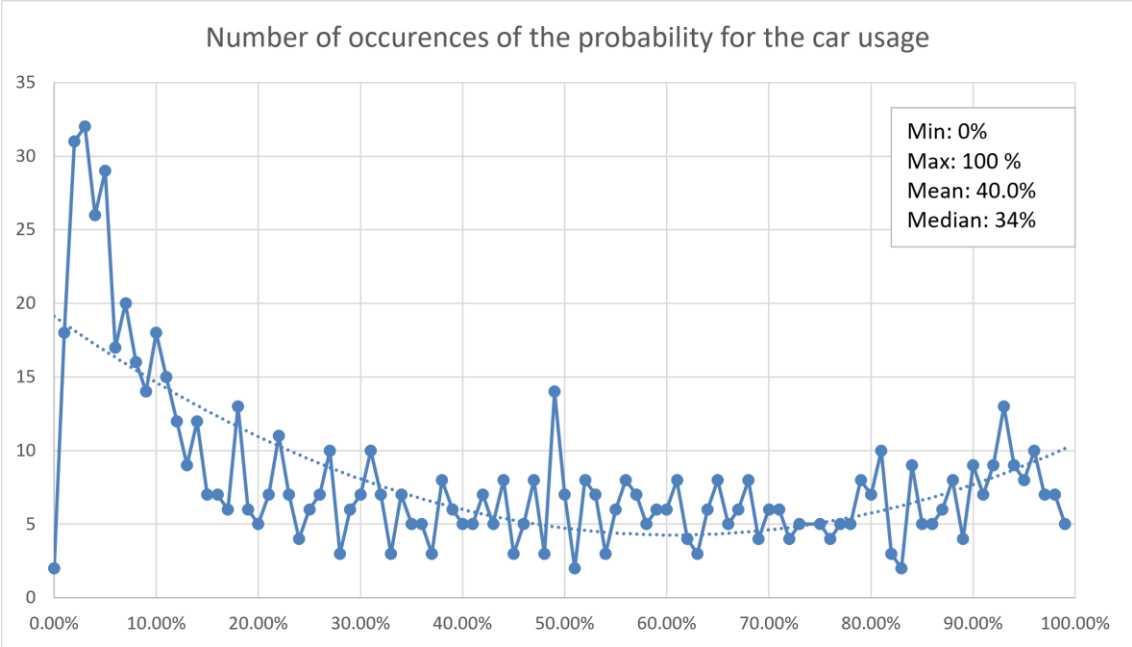


Figure 13: Number of occurrences of certain probabilities for car usage

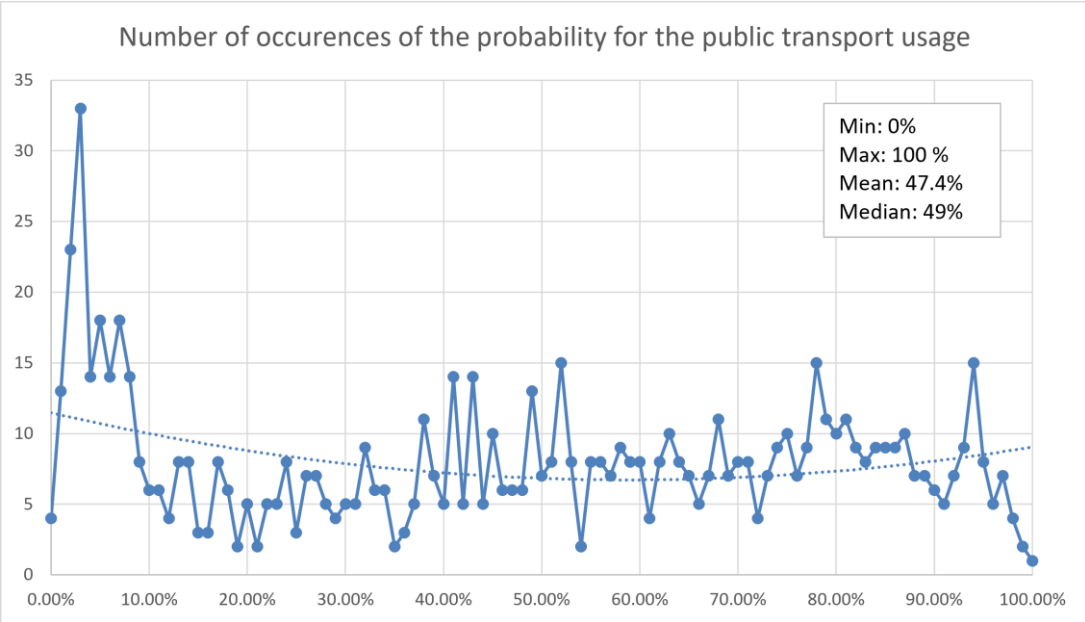


Figure 14: Number of occurrences of certain probabilities for public transport usage

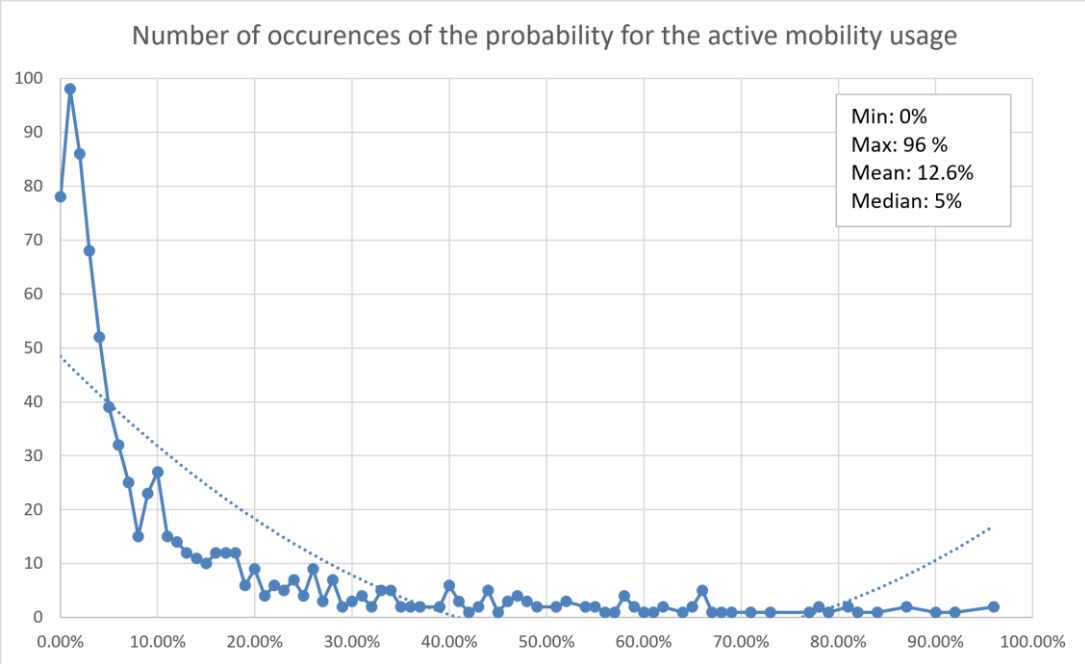


Figure 15: Number of occurrences of certain probabilities for active mobility usage

For the active mobility there is the problem with the data that there are not many cases, which may have led to difficulties in the evaluation of those cases with the model. Especially in the comparison with the public transport in the more urban areas, the differences in trip duration (group of factors 403) and trip distance (400-11) are not that large and can thereby lead to mispredictions of the chosen transport mode. The issue in the prediction of the probability for the active transport can to some extent be seen in figure 15, as many trips (63.9%) have a predicted probability of under 10% to be performed through means of active mobility.

4.4.3 Transferability to the general population

The transferability of the results to the general population is given to some extent. The variables in the used model are all significant for α=0.01. Some variables might not be significant for the comparison of two transport modes (see table 3). The low BIC and the high statistical significance of the variables makes the model itself highly reliable for the behaviour of the respondents. The problem lies in the representativeness of the data in comparison to the general population. The distribution of home locations for example varies to some extent greatly as e.g. 5.4% of respondents should have mapped their home location in Wien-Favoriten but only 3.4% did. This could, due to the local scale of some variables, interfere with the transferability of the results.

For the sociodemographic data, the gender is closely represented in the sample to the general population of that area (52.3% female respondents compared to 51.1% female residents). The age groups are also relatively good represented, the age groups between 30 and 59 are slightly overrepresented, the age group under 30 is slightly underrepresented. The age group

above 60 is highly underrepresented in comparison to the population, but that might be the case because most of these people are in (early) retirement and therefore had no commuting way to work to insert into the survey. Overall, the age distribution can thereby interpret as fitting. The main issue stems from the educational level as in the overall population of the corresponding age groups around 25% of residents have completed a tertiary education. In the analysed sample, over 60% have mentioned that they have completed a tertiary education. This leads to a large underrepresentation of lower educational levels. As a result, the model may not be applicable to the general population or may only be applicable with a higher expected margin of error compared to the sample, which the model is based on.

To resolve this issue weights could be given to observations (OD-pairs) so the balance between the attributes would be given again, but this was not done in this master's thesis as the model gives a good fit for the available data. The variables show general trends which mostly have been found in the literature or could be attributed to other factors. Thereby some implications of the model and some remarks regarding influential factors for the transport mode choice can be made (Chapter 5.3). However, it should be kept in mind that these effects might differ in other geographical areas as well as over the whole population.

5 Discussion and conclusion

The final chapter concludes on the before presented chapters and aims to concisely compile the results of the master's thesis as well as the linkages between the results and the theory chapters. In addition, limitations of the research are discussed and areas for future research, as well as possible policy implications, are outlined.

5.1 Summary of findings

To answer the research question(s), especially the main one "***Which individual, neighbourhood and city level variables could explain the transport mode choice on commuting trips in the Vienna city region?"*** a literature review and a multinomial logistical regression model based on a PPGIS-Survey have been conducted. As a basis for the literature review, theories and concepts of the integrated city- and transport planning as well as the psychological decision-making process have been portrayed. These models and concepts ranging from SGI, over the compact city and transit-oriented development to the different decision-making models each have some explanatory value and show different approaches towards the transport mode choice as a (un-)conscious decision.

Some main ideas of these models are that an individual decides based on their own personal benefits (rational choice theory, chapter 2.4.4) although other behaviour types like altruistic behaviour or the social environment (chapter 2.4.6) can contradict the choice. This would be made purely based on personal benefits. Autotelic behaviours (motivation models, chapter 2.4.5) in which a person uses a certain transport mode because of the experience which is linked to the usage can alter the transport mode choice as well as the information situation. The information situation is based on the prior knowledge and the accessibility and understandability of information regarding transport modes as not only the 'objective' (geographic) information is processed subjectively (models of information processing, Chapter 2.4.5). Furthermore, that the effort to obtain new knowledge can exceed the assumed benefits of the knowledge (subjective benefit models, Chapter 2.4.4) and lead to less information as a decision basis. Especially if trips have already been done with one transport mode, this transport mode is linked to the trip and the destination in cognitive maps (Chapter 2.4.5). This in tandem with norms and values (Chapter 2.4.6) of the social environment and the society, can lead to habitual behaviour (Chapter 2.4.6) in the transport mode choice. Nearly every trip and the person itself may be influenced by certain constraints. These could be financial, time constraints or authority constraints (Chapter 2.4.7). These constraints can to some extent dictate the transport mode choice, especially time and authority constraints which can incentivize the need to use a certain transport mode based on the model of the space-time-prism (Chapter 2.4.7).

The integrated city- and transport planning approaches mostly focus on the 'objective' features of the geographic environment and try to give solutions to the problem of car-dependency for many short trips due to design. This should follow the avoid – shift – improve principle (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), 2021). The provision of SGI as displayed by Humer et al. (2015) also mentions some factors for the evaluation of the mobility as the concept of public mobility (Schwedes, 2021) can be interpreted as a form of SGI.

These findings about the integrated city- and transport planning, as well as the psychological models have laid the foundation for the literature review which was based on the supplemental research question "***What could influence travel mode choices?***". The literature review of papers, as well as grey literature has shown a huge variety of different factors. A total amount of 369 factors which could, according to the analysed literature, potentially influence the transport mode choice have been found. These factors have been grouped into six categories (Figure 5 & Appendix A). The list of factors (Appendix A) includes factors like the consumer prices (110-02), demographic structure (group of factors 121) or commuter allowance (132-06) for the overarching factors, the topography (210-03), mixed-use in neighbourhoods (220-04), street design (group of factors 222) or the land-use (232-10), in the geographical factors. The transport mode specific factors encompass for example the accessibility (subcategory 31), the price (322-06), emission (322-13), comfort (group of factors 323) or features of the transport stop (group of factors 324) and vehicles (group of factors 325). The trip specific factors include for example the trip purpose (400-04), distance of the trip (400-11), regularity of the trip (400-10), weather (401-05), trip duration (group of factors 403) and constraints (group of factors 404). The sociodemographic category consists of factors like the age (510-01), gender (510-02), employment (group of factors 511), income (520-01) or household structure (group of factors 521). The category with the most factors being the psychological, which include e.g. skills and abilities (612-05), the lifestyle (group of factors 421), subjective norms (631-05), the psychological travel expense (group of factors 642), the self-perception (group of factors 641), the attractiveness of the neighbourhood (group of factors 647), travel route (group of factors 649) and workplace (group of factors 648) as well as the persons values (subcategory 65). The list of these factors underlines the complexity of the transport mode choice as not only most of these factors are not easy measurable, but also highly subjective and can change in a matter of days or less (e.g.: sleep duration (612-03)). As most of the factors have been identified as being interconnected it could be sufficient to look at a considerable smaller amount than the in Appendix A listed. The list in Appendix A nonetheless can help to build an understanding for the complexity of the decision process regarding the transport mode and show that changes on any of the mentioned factors might influence the transport mode choice or other factors for that matter. It can be influential in the necessary transformation of the mobility sector.

The second part of the master's thesis is the multinomial logistical regression model. The model is a result of the question "***What could influence the transport mode choice for commuting trips in the Vienna city-region?***". It allows for an evaluation of variables regarding their influence on the transport mode choice and produces a model which predicts the probabilities of a person to use a certain transport mode.

The model is based on personal level data collected in a PPGIS -Survey conducted within the CURB-Research project in May and June of 2023, neighbourhood level data from different sources, mostly from the Copernicus Land Monitoring Service of the European Union and municipal level (in Vienna: district level) data was obtained from Statistics Austria. This data was cleaned, combined and then used for a backwards iterative multinomial logistical regression.

The results of the multinomial logistical regression have shown that nine variables have produced a model that could predict nearly three quarters of respondents' transport mode choice. The model itself has an Mc Fadden Pseudo-R^2 of 0.36 which means it has a good fit on the study population (Backhaus et al., 2023). The factors that were mentioned included the population density (220-03) around the start and destination of the trip as well as the trip duration (group of factors 403) with the car and public transport , the costs (322-06) of the public transport relative to the costs with the car for the trip. The household type (group of factors 521), the duration of residence (230-02), the main occupation (group of factors 511) and the share of people with tertiary education in the home municipality of the respondent. A higher population density was linked in the model with a lower probability to use the car. Similarly, the share of people with tertiary education in the home municipality of the respondent was linked to a lower probability to use the car for the commuting trips. The household type (several generations / families; not as reliable; Chapter 4.4 & Appendix G) and a duration of residence of 3 years or less are linked to a higher probability of public transport usage. The probability to use the public transport is lowered if the respondent is employed compared to other main occupations. Time and costs are to some extent self-explanatory as a rise in the needed time for one transport mode leads to a lower probability to use that transport mode or an active transport mode. A rise in the cost ratio between public transport and car leads to a rise in the probability to use the car (Table 3). The factors have shown that the geographical features as well as the transport mode, trip specific and sociodemographic factors are relevant for the model. Three of the nine relevant factors of the model are on the individual/ household level, two are on the neighbourhood level (although different neighbourhoods), three variables are trip specific, and one is a municipality level variable. The iteratively excluded perception values were focussed on the living space and neighbourhood and have mostly correlated with the geographic or sociodemographic factors, which might have led to the underrepresentation of psychological factors in the results.

As discussed in chapter 4.4.3, the results are only conditionally transferable to the general population, as the study population is only to some extent representative for the total population. Nonetheless, this indicates that the general premises of the model, as they mostly align with existing literature and are to some extent self-explanatory, can be a basis for actions in the neighbourhood design and the basis for future research (Chapter 5.3).

5.2 Limitations of the research

The research in this master's thesis has its limitations which will be mentioned in this section. Firstly, the focus is on the habituative behaviour of people which might exceed the transport mode choice and influence the analysis through residential self-selection. Secondly the focus is on the quality of the data.

5.2.1 Habituative behaviours and residential self-selection

As explained in the chapters 5.1, 4.1 and 2.4.6, the transport mode choice is often a habituative decision. In a study of the Swiss Federal Railway (SBB) it has been found that 75% of commuters have a very habituative travel behaviour (Wenninger, 2021). The building of habits also follows the learning theory approaches (chapter 2.4.3) as positive reinforcements can consolidate the behaviour (Tao et al., 2022). This leads to difficulties in the assessment of the reasons behind the transport mode choice. As these habits need a change in the internal or external shocks to be reevaluated . These time frames are mentioned in the literature under the term windows of opportunity (De Vos, 2019; Van Acker, 2010; Wittwer & Berger, 2021). Thereby, analyses of the travel mode choice and travel behaviour in general would also profit from longitudinal analyses which would follow the travel behaviour of a group of respondents over a longer period. As this would give the opportunity to not only assess differences in the travel mode choice based on the stage of life, but also to assess differences in the overarching trends, such as the 'climate' for certain modes of transport (130-02), changes in terms of home-office usage (511-07), changes in the built environment (subcategory 23), ownership of transport options (520-02), values towards transport modes (group of factors 653) or the general trends of e.g.: a pluralisation of lifestyles (group of factors 621) (Ramezani et al., 2021; Wolking, 2021).

The analysis in this master's thesis can't provide information in this regard as it is linked to a specific time frame. In addition, the analysis can't show any causality more certainly it shows possible predictors, but there might be effects such as the attitudes towards travel and residential self-selection which could not be controlled for based on the available data (Handy et al., 2005; Schwanen & Mokhtarian, 2004, Van Acker et al., 2010).

Residential self -selection is a concept in which a person would choose their home location (partly) based on their travel attitudes. If individuals wish not to drive as much, they are more likely will select a residence or neighbourhood which accommodates their travel behaviour (Cao et al., 2009 cited in De Vos, 2019; Handy et al., 2005; Pinjari et al., 2007; Ramezani et al., 2021; Schwanen & Mokhtarian, 2004; Van Acker et al., 2010).

This would follow the positive reinforcing decision behaviour, already discussed for the transport mode choice, as the learned mobility behaviour (621-06; → learning theory approaches; Chapter 2.4.3) or mobility style (621-05) which a person has learned from their social environment (Chapter 2.4.6) is reinforced by decisions, leading to a behaviour in the residential selection which could be considered habituative. Regarding the resulting mobility behaviour, residential self-selection would not allow for a window of opportunity to be opened, as differences from the habitual transport mode choice would be minimized through the selection of a neighbourhood that reinforces that habitual behaviour. The change of the behaviour would not be considered, as the effort to gain information about non-habituative behaviours would take more effort than the perceived change of behaviour would bring (→ subjective benefit model, Chapter 2.4.4) which would lead to a transport mode lock-in.

If the concept of residential self-selection holds true, then the effect of it is a key factor in the understanding of causality in the relationship of the built environment and the transport mode choice (Handy et al., 2005; Ramezani et al., 2021; Widmer et al., 2020). Which leads to a need on studies focussing on the existence and effect of residential self-selection in terms of the travel behaviour. Residential self-selection would also emphasize the need to conduct longitudinal studies to find out if the mentioned lock-in effects can happen. Nonetheless, studies have shown that even corrected for residential self-selection a significantly smaller effect of the built environment on the transport mode choice persists (Cervero and Duncan, 2003 cited in Pinjari et al., 2007).

In addition, Widmer et al. (2021) has emphasized the need for studies on the factors which emphasize the acquisition of mobility options such as a season ticket, bike, or car. The availability of transport options is a main factor not only in the provision of SGI (Humer et al., 2015) but also in the understanding if constraints regarding the transport mode choice exist and how they could be mitigated.

Even though the causality is not clear, the idea that the built environment influences the transport mode choice or traffic behaviour in general is prevalent in the integrated city- and transport planning approaches (Chapter 2.3) (Chakrabati, 2016).

5.2.2 Issues with the available data

Many of the used data points for the multinomial logistical regression (Table 22; Appendix C) stem from the PPGIS-Survey, which was conducted in the FWF financed, ÖAW based CURB-research project (Chapter 4.2). The analysis conducted on the data in this master's

thesis was not the main purpose of the survey. Hence, the available data and the data quality from the survey are not that fitting for the conducted research in this master's thesis. Relevant indicators which have been found in the literature review (Chapter 4.1 and Appendix A), like information about the driving licence possession (311-01) were not collected within the survey and could thereby not be recognized in the analysis. The data collected in the survey also has not allowed for the differentiation between bicycle usage and walking to the workplace which might have changed the outcome of the regression model.

Moreover, many factors of the psychological category found in the literature review (Chapter 4.1) could not be assessed, leaving the question open to what extent the objective built environment influences the traffic mode choice and if it is a direct or indirect influence. For this, according to the models of information processing (Chapter 2.4.5), there would have been the need for more information about the respondents' preferences and attitudes (Schwanen & Mokhtarian, 2004).

Nonetheless, the biggest limiting factor of the data is the problem with the reliability. As people were asked to map their home- and work location. Some quality measures were applied in the preparation of the data (Appendix B) but still an insecurity in the spatial accuracy of the mapped data persists (Brown, 2012 cited in Brown & Kyttä, 2014). But it can be assumed that the mappings are still reasonable, as some studies have proven that mapping via online PPGIS-surveys provide reasonable accuracy (Brown & Kyttä, 2014).

Perhaps the 808 OD-pairs might not be independent of one another, although they were interpreted as such which could have led to different associations displayed in the multinomial logistical regression model.

5.3 Policy implications and further research

As presented in chapter 5.2, there is still a need for research in this area as some factors have not been analysed in this master's thesis. One area for research is that of the transport mode choice as a ***habituative behaviour*** where assessments on the possibilities to change the mobility behaviour of people could be made. This could help with the preparation and implementation of fitting policy and image campaigns to foster the necessary change to climate neutral travel options.

Another area for research is the ***residential self-selection*** (chapter 5.2.1) which could be a huge impact factor for the transport mode choice as the impact of the built environment would diminish. The mobility style, and habitual behaviour types would determine the transport mode choice to a higher extent. This would have to go along with (semi-) ***longitudinal studies*** of the transport mode choice which could emphasize changes in the

lifestyle, transport options or the general 'climate' for transport modes as well as account for residential self-selection.

An analysis on ***activity spaces*** of individuals could also provide necessary insights into the daily mobility behaviour not linked to certain trip purposes and could be used to analyse trip chains in daily life. Different special scales of the analysis could also enhance the view on the individual mobility behaviour as well as the soft space of city-regions.

For policymakers some implications could follow from the research done in this master's thesis. The results of this master's thesis have shown that ***population density*** is a key factor for the usage of the public transport as well as the ***travel time*** and ***travel costs***. All three factors can be (to some extent) addressed by policymakers. Changes in these factors could lead to changes in the perception of the corresponding transport mode and in turn could change the transport mode choice. Although the effect could not be determined based on the research in this master's thesis by itself, the results align with existing literature in this area and underline these factors for the Viennese case.

In addition, this master's thesis has emphasized the broader look onto mobility under the framing concept of ***public mobility*** (Chapter 2.1) in combination with an ***integrated city- and mobility planning*** approach (Chapter 2.3). This could bring in new directions for transport planning, emphasizing the equality of all people participating in traffic and their mobility needs, which leads to a more just and sustainable mobility planning, along with more accessible opportunities within reach. This would imply the usage of ***push- and pull factors*** to drive the transition of the personal mobility behaviour into the direction of environmentally friendly transit.

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Appendix A: Factors that could have an influence on the traffic mode choice

The ID is a three or five-digit number created after the following scheme:

XXX

XXX-XX

1st digit: The category defined in chapter 4.1; figure 5

1- Overarching
2- Settlement structure / Geography
3- Transport mode specific
4- Trip specific
5- Socio-demographic
6- Psychological

2nd digit: Subcategory

11- Economic factors
12- Societal factors
…

3rd digit: **Groups of factors**; groups of factors are always bold. Individual factors that are not part of a group of factors receive "0" as the third and fourth digit.

121 - Demographic structure
…
131 – Regulations

4th & 5th digit: Factors within groups

121-01 - Growing and shrinking of the population

The mentioned linkages to other concepts or factors are mostly based on the author's combination of the literature of literature review and shall not be seen as complete or fully backed by the literature mentioned.

Table 4: Mentioned economic factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
110-01	State of (social) technology		▪ Flade & Wullkopf, 2002 ▪ Nuhn & Hesse, 2006
110-02	Consumer prices	▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Income (520-01)	▪ Wittwer & Berger, 2021
110-03	Purchasing power	▪ Financial constraints (322-08; Chapter 2.4.7)	▪ Wittwer & Berger, 2021
110-04	Unemployment	▪ Income (520-01) ▪ Job-related factors (521) ▪ Personal satisfaction (651-08)	▪ McCreery-Phillips & Heydari, 2023 ▪ Tao et al., 2022 ▪ Wittwer & Berger, 2021

Table 5: Mentioned societal factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
120-01	Ratio between working and resident population	▪ Geographical area type (210-02) ▪ Land use and development plans (131-04)	▪ Nuhn & Hesse, 2006
121	**Demographic structure**		▪ Groß, 1998 ▪ Nuhn & Hesse, 2006
121-01	Growing and shrinking of the population		▪ Nuhn & Hesse, 2006
121-02	Migration	▪ Mobility style (621-05) ▪ Social / Cultural norms (631-01)	▪ Nuhn & Hesse, 2006
121-03	Household structure	▪ Household size (521)	▪ Nuhn & Hesse, 2006
121-04	Age structure		▪ Nuhn & Hesse, 2006

Table 6: Mentioned political factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
130-01	setting the course for urban and transport planning	e.g.: Austrian Mobility Master Plan 2030 (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), 2021)	▪ Groß, 1998
130-02	'Climate' for certain modes of transport		▪ Groß, 1998
131	**Regulations**		▪ Khosravi et al., 2016 ▪ Wittwer & Berger, 2021
131-01	Speed limits	▪ Travel speed (322-05) ▪ Trip duration (403)	▪ Nuhn & Hesse, 2006
131-02	Parking space regulations	▪ Land use and development plans (131-04) ▪ Parking space availability (221-05)	▪ Wittwer & Berger, 2021
131-03	Vehicle registration	▪ Emissions (322-13) ▪ Safety (321-01)	▪ Wittwer & Berger, 2021
131-04	Land use and development plans	▪ Characteristics of the neighbourhood (232) ▪ Street design (222)	▪ Handy et al., 2005 ▪ Khosravi et al., 2016 ▪ Wittwer & Berger, 2021

132	**Fiscal factors**	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7)	▪ Chakrabarti, 2016 ▪ Khosravi et al., 2016 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021
132-01	Social tickets for public transport	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Daubitz, 2017 cited in Rammert, 2021 ▪ Khosravi et al., 2016
132-02	Minimum income support	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7)	▪ Daubitz, 2017 cited in Rammert, 2021
132-03	Tax privileges for certain transport modes	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Schwedes, 2021a ▪ Wittwer & Berger, 2021
132-04	VAT reductions	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Schwedes, 2021a
132-05	Lower diesel taxes / Subsidies for fuel	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Schwedes, 2021a
132-06	Commuter allowance	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Schwedes, 2021a
132-07	Infrastructure investments	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Comfort (323) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06) ▪ Trip duration (403)	▪ Groß, 1998 ▪ McCreery-Phillips & Heydari, 2023
132-08	Parking space management	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Hoor, 2021
132-09	Tolls	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Chakrabarti, 2016 ▪ Nuhn & Hesse, 2006
132-10	Emission taxation	▪ Affordability; SGI (Chapter 2.1; Humer et al., 2015) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Price (322-06)	▪ Chakrabarti, 2016 ▪ Wittwer & Berger, 2021

Table 7: Mentioned geographical factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
210-01	Size of the urban structure		▪ Nuhn & Hesse, 2006 ▪ Stöglehner, 2020
210-02	Geographical area type	▪ DEGURBA (Eurostat, n.d.) ▪ Urban-rural-typology of Austria (Saul, 2021)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Wolking, 2021
210-03	Topography	▪ Effort (649-03) ▪ Fitness (612-02)	▪ Cao et al., 2022 ▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ McCreery-Phillips & Heydari, 2023 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
210-04	Climate	▪ Season (401-04)	▪ Heinen et al., 2019

Table 8: Mentioned factors of the settlement structure for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
220-01	Street type	▪ Speed (322-05) ▪ Trip duration (403)	▪ McCreery-Phillips & Heydari, 2023
220-02	Traffic density	▪ Safety (649-09) ▪ Trip duration (403)	▪ Khosravi et al., 2016 ▪ Handy et al., 2005 ▪ McCreery-Phillips & Heydari, 2023
220-03	population/ settlement/ building density	▪ Compact City (Chapter 2.3.5) ▪ Transit-Oriented-Development (Chapter 2.3.4) ▪ Minimal population density necessary for public transport (Forschungsgesellschaft für Straßen und Verkehrswesen e.V. (FGSV), 2010; Cooke & Behrens, 2017)	▪ Cao et al., 2022 ▪ Chakrabati, 2016 ▪ Chen et al., 2023 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Schwanen & Mokhtarian, 2004 ▪ Silva et al., 2006 ▪ Stöglehner, 2020 ▪ Sun et al., 2022 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021

220-04	Mixed use in neighbourhoods	▪ Compact City (Chapter 2.3.5) ▪ Public mobility (Chapter 2.1) ▪ Transit-Oriented-Development (Chapter 2.3.4) ▪ Accessibility of amenities (220-06)	▪ Cao et al., 2022 ▪ Heinen et al., 2019 ▪ Schwanen & Mokhtarian, 2004 ▪ Silva et al., 2006 ▪ Stöglehner, 2020 ▪ Sun et al., 2022 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
220-05	Public spaces	▪ Attractiveness of the travel route (649) ▪ Street design (222)	▪ Sun et al., 2022
220-06	Accessibility of amenities	▪ Land-use and development plans (131-04)	▪ Khosravi et al., 2016 ▪ Nuhn & Hesse, 2006 ▪ Widmer et al., 2020
220-07	Equipped with opportunities	▪ Public mobility (Chapter 2.1) ▪ Accessibility of amenities (220-06) ▪ Mixed-use in neighbourhoods (220-04)	▪ Nuhn & Hesse, 2006
220-08	Clearness of city design	▪ Attractiveness of the travel route (649) ▪ Comfort of the travel route (649-01) ▪ Land-use and development plans (131-04) ▪ Street design (222)	▪ Wittwer & Berger, 2021
220-09	Green spaces	▪ Attractiveness of the travel route (649) ▪ Public spaces (220-05) ▪ Street design (222)	▪ Cao et al., 2022 ▪ Chen et al., 2023
220-10	Parking space costs	▪ Constraint models (Chapter 2.4.7) ▪ Financial constraints (322-08) ▪ Land-use and development plans (131-04) ▪ Parking space management (132-08) ▪ Parking space regulations (131-02) ▪ Price (322-06) ▪ "Time costs"; Trip duration (403)	▪ Cevero & Radisch, 1996 ▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
221	**Transport services**	▪ Characteristics of the neighbourhood (232) ▪ Transport mode specific factors (subcategory 32)	▪ Chakrabati, 2016 ▪ Nuhn & Hesse, 2006 ▪ Schwedes, 2021b ▪ Widmer et al., 2020
221-01	Degree and quality of transport accessibility	▪ Cognitive approaches (Chapter 2.4.5) ▪ Transport accessibility indices (232-07); (e.g.: Mietzsch, 2021; Österreichische Raumordnungskonferenz, 2022)	▪ Groß, 1998
221-02	Environmental design for certain modes of transport	▪ Transit-Oriented-Development (Chapter 2.3.4) ▪ Street design (222)	▪ Jang & Ko, 2019
221-03	Frequency of public transport	▪ Constraint models (Chapter 2.4.7) ▪ Flexibility (323-05) ▪ Time-Constraints (404-01)	▪ Wolking, 2021
221-04	Existence and quality of pedestrian and cycling infrastructure	▪ Comfort (323) ▪ Comfort of the travel route (649-01) ▪ Safety (611-01)	▪ De Vos, 2019
221-05	Parking space availability	▪ Land-use and development plans (131-04) ▪ Parking space management (132-08) ▪ Parking space regulations (131-02) ▪ "Time costs"; Trip duration (403)	▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021

222	**Street design**	▪ Attractiveness of the travel route (649)	▪ Chatterjee et al., 2019 ▪ Wittwer & Berger, 2021
222-01	Safety of road crossings	▪ Attractiveness of the travel route (649) ▪ Safety (649-09)	▪ Cao et al., 2022 ▪ De Vos, 2019 ▪ Wittwer & Berger, 2021
222-02	Lighting	▪ Constraint models (Chapter 2.4.7) ▪ Daytime (401-01) ▪ Fears (641-02) ▪ Safety (611-01) ▪ Season (401-04) ▪ Time Constraints (404-01)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ Handy et al., 2005 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
222-03	Quality of the pavement	▪ Comfort (323) ▪ Problems due to bad condition → Costs (322-06) ▪ Infrastructure investments (132-07) ▪ Safety (611-01) ▪ Travel satisfaction (642-01)	▪ Cao et al., 2022 ▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Heinen et al., 2019 ▪ McCreery-Phillips & Heydari, 2023 ▪ Wittwer & Berger, 2021
222-04	Walkway width	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Luggage (400-08) ▪ Safety (611-01) ▪ Minimum standards; e.g.: Österreichisches Normungsinstitut (2005)	▪ Cao et al., 2022 ▪ Wittwer & Berger, 2021
222-05	Pedestrian friendliness	▪ Attractiveness of the travel route (649) ▪ Comfort (323) ▪ Safety (611-01)	▪ Calthorpe, 2011 ▪ Schwanen & Mokhtarian, 2004 ▪ Sun et al., 2022
222-06	Ground floor zones	▪ Attractiveness of the travel route (649)	▪ Wittwer & Berger, 2021
222-07	Recreation facilities	▪ Attractiveness of the travel route (649) ▪ Comfort (323)	▪ Wittwer & Berger, 2021
222-08	Seating	▪ Attractiveness of the travel route (649) ▪ Comfort (323) ▪ Fitness (612-02) ▪ Luggage (400-08)	▪ Wittwer & Berger, 2021
222-09	Attractive buildings	▪ Attractiveness of the travel route (649)	▪ Wittwer & Berger, 2021
222-10	Trees / Greenery	▪ Attractiveness of the travel route (649) ▪ Green spaces (220-09) ▪ Season (401-04) ▪ Travel satisfaction (642-01) ▪ Weather (401-05)	▪ De Vos, 2019 ▪ Handy et al., 2005 ▪ Wittwer & Berger, 2021

Table 9: Mentioned residential factors and factors of the housing situation for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
230-01	type of parking space at the place of residence	▪ Accessibility of transport options (Subcategory 31) ▪ Ownership of transport options (520-02)	▪ Widmer et al., 2020
230-02	duration of residence	▪ Socio-psychological approaches (Chapter 2.4.6) ▪ Habits (620-01) *for a habit change a 'window of opportunity', often externally induced, is needed (Wittwer & Berger, 2021)*	▪ Handy et al., 2005 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018
231	**Characteristics of the residence**	▪ Settlement structure (Subcategory 22) ▪ Sociodemographic factors (Category 5)	▪ Widmer et al., 2020
231-01	Ownership type	▪ Geographical area type (210-02) ▪ Income (520-01)	▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023
231-02	Building type	▪ Geographical area type (210-02) ▪ Income (520-01) ▪ Land-use and development plans (131-04) ▪ Sociodemographic factors (Category 5)	▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023
231-03	Living space	▪ Geographical area type (210-02) ▪ Income (520-01) ▪ Land-use and development plans (131-04) ▪ Sociodemographic factors (Category 5) ▪ Well-being (620-08)	▪ Khosravi et al., 2016 ▪ Widmer et al., 2020
232	**Characteristics of the neighbourhood**	▪ Compact City (Chapter 2.3.5) ▪ Transit-Oriented Development (Chapter 2.3.4) ▪ Accessibility of facilities (233) ▪ Settlement structure (Subcategory 22) ▪ Davies (1938; cited in Khosravi et al., 2016): quality of housing relates to home surroundings	▪ Chakrabati, 2016 ▪ Chen et al., 2023 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ Schwanen & Mokhtarian, 2004 ▪ Stöglehner, 2020
232-01	Diversity of residents	▪ Mobility style (621-05) ▪ Quality of relations with neighbours (647-01)	▪ Handy et al., 2005
232-02	Crime rate	▪ Quality of relations with neighbours (647-01) ▪ Safety (611-01)	▪ Handy et al., 2005
232-03	Cleanliness	▪ Attractiveness of the neighbourhood (647) ▪ Health (612-08)	▪ Chen et al., 2023
232-04	Noise	▪ Attractiveness of the neighbourhood (647) ▪ Health (612-08)	▪ Handy et al., 2005 ▪ Rammert, 2021
232-05	Accessibility of high-level roads	▪ Space-time prism (Chapter 2.4.7) ▪ Spatial resistance of the trip (642-04) ▪ Time resistance of the trip (642-05) ▪ Travel speed (322-05) ▪ Trip duration (403)	▪ Handy et al., 2005 ▪ Widmer et al., 2020
232-06	Street connectivity	▪ Space-time prism (Chapter 2.4.7) ▪ Accessibility of transport modes (Subcategory 31) ▪ Spatial resistance of the trip (642-04) ▪ Time resistance of the trip (642-05) ▪ Travel distance (400-11) ▪ Trip duration (403)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ Sun et al., 2022
232-07	Public transport accessibility (index)	▪ Space-time prism (Chapter 2.4.7) ▪ Spatial resistance of the trip (642-04)	▪ Handy et al., 2005

		▪ Time resistance of the trip (642-05) ▪ Travel distance (400-11) ▪ Trip duration (403) ▪ E.g.: Mietzsch, 2021; Österreichische Raumordnungskonferenz, 2022	▪ McCreery-Phillips & Heydari, 2023
232-08	Bicycle paths out of the neighbourhood	▪ Space-time prism (Chapter 2.4.7) ▪ Accessibility of transport modes (Subcategory 31) ▪ Spatial resistance of the trip (642-04) ▪ Time resistance of the trip (642-05) ▪ Travel distance (400-11) ▪ Trip duration (403)	▪ Handy et al., 2005 ▪ Widmer et al., 2020
232-09	Pedestrian friendliness	▪ Attractiveness of the neighbourhood (647) ▪ Street design (222)	▪ Handy et al., 2005
232-10	Land-use	▪ Compact City (Chapter 2.3.5) ▪ Transit-Oriented Development (Chapter 2.3.4) ▪ Land-use and development plans (131-04) ▪ Land-use diversity of the neighbourhood (647-08) ▪ Mixed use in neighbourhoods (220-04) ▪ Public spaces (220-05)	▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Schwanen & Mokhtarian, 2004
232-11	Suitable for children to play	▪ Attractiveness of the neighbourhood (647) ▪ Safety (611-01)	▪ Handy et al., 2005
233	**Accessibility of facilities**	▪ Compact City (Chapter 2.3.5) ▪ Public mobility (Chapter 2.1) ▪ Space-time prism (Chapter 2.4.7) ▪ Transit-Oriented Development (Chapter 2.3.4) ▪ Accessibility of amenities (220-06) ▪ Land-use and development plans (131-04) ▪ Mixed use in neighbourhoods (220-04) ▪ Trip duration (403) ▪ 15-minute city (Pozoukidou & Chatziyiannaki, 2021) ▪ Christaller (1933/2006): Different levels of goods need different accessibilities ▪ Standard for the provision of SGI (Chapter 2.2; Humer et al., 2015)	▪ Daubitz, 2021 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Nuhn & Hesse, 2006
233-01	Accessible within X minutes	▪ Public mobility (Chapter 2.1) ▪ Space-time prism (Chapter 2.4.7) ▪ X-minute city (Logan et al., 2022)	▪ Widmer et al., 2020
233-02	Work	▪ Purpose of the trip (400-04) ▪ Trip length (400-11) ▪ Work related factors (511) ▪ *Research indicates that individuals consistently accept commute times of up to 30 minutes, irrespective of the chosen transport mode (Wu et al., 2021 & Marchetti, 1994 both cited in Logan et al., 2022).*	▪ Khosravi et al., 2016
233-03	Green spaces /parks	▪ Attractiveness of the neighbourhood (647) ▪ Health (612-08; Kajosaari & Pasanen, 2020 for exercising) ▪ Fitness (612-02) ▪ Climate (210-04)	▪ Cao et al., 2022 ▪ Handy et al., 2005 ▪ McCreery-Phillips & Heydari, 2023 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021

233-04	Maintenance of green spaces	▪ Attractiveness of the neighbourhood (647) ▪ Health (612-08) ▪ Quality standard for SGI (Humer et al., 2015)	▪ Khosravi et al., 2016
233-05	Blue spaces	▪ Attractiveness of the neighbourhood (647) ▪ Climate (210-04) ▪ Fitness (612-02)	▪ McCreery-Phillips & Heydari, 2023
233-06	Leisure facilities	▪ Amount of leisure time (612-04) ▪ Attractiveness of the neighbourhood (647)	▪ Khosravi et al., 2016 ▪ Widmer et al., 2020
233-07	Sport facilities	▪ Fitness (612-02) ▪ Health (612-08)	▪ Chen et al., 2023 ▪ Khosravi et al., 2016
233-08	Health facilities	▪ Fitness (612-02) ▪ Health (612-08)	▪ Khosravi et al., 2016
233-09	Educational facilities	▪ Learning theory approaches (Chapter 2.4.3) ▪ Learned mobility behaviour (621-06) ▪ Length of trip chain (400-09)	▪ Daubitz, 2021 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020
233-10	Community centre	▪ Quality of relations with neighbours (647-01)	▪ Handy et al., 2005
233-11	Church / religious places	▪ Quality of relations with neighbours (647-01)	▪ Khosravi et al., 2016
233-12	Shopping centre	▪ Length of trip chain (400-09) ▪ Christaller (1933/2006): Different levels of goods need different accessibilities	▪ Cao et al., 2022 ▪ Handy et al., 2005 ▪ Khosravi et al., 2016
233-13	Shops	▪ 15-minute city (Logan et al., 2022) ▪ Christaller (1933/2006): Different levels of goods need different accessibilities	▪ Daubitz, 2021 ▪ Handy et al., 2005 ▪ Khosravi et al., 2016 ▪ Stöglehner, 2020 ▪ Widmer et al., 2020
233-14	Entertainment Centres	▪ Amount of leisure time (612-04) ▪ Attractiveness of the neighbourhood (647)	▪ Chen et al., 2023 ▪ Khosravi et al., 2016
233-15	City-centre	▪ Public mobility (Chapter 2.1) ▪ Length of trip chain (400-09) ▪ Trip purpose (400-04)	▪ Khosravi et al., 2016 ▪ Handy et al., 2005 ▪ Silva et al., 2006
233-16	Walking areas	▪ Attractiveness of the neighbourhood (647) ▪ Surroundings of start and destination (402)	▪ Khosravi et al., 2016
233-17	Car parks	▪ Convenience (651-05) ▪ Surroundings of start and destination (402) ▪ Trip duration (403)	▪ Khosravi et al., 2016
233-18	Public transport stops	▪ Public transport accessibility (312)	▪ Cao et al., 2022 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ Widmer et al., 2020
233-19	Proximity to family and relatives	▪ Length of the trip (400-11)	▪ Khosravi et al., 2016

Table 10: Mentioned accessibility factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
311	**Car accessibility**	▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Accessibility as a factor of the provision of SGI (Humer et al., 2015; Chapter 2.2)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
311-01	Driving licence possession	▪ Learning theory approaches (Chapter 2.4.3) ▪ Internal household organisation if no driving licence is owned (630-05) ▪ Habits (620-01; Chapter 2.4.6)	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021
311-02	Car available in household	▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Ownership of transport modes (520-02)	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Ko et al., 2018 ▪ Nuhn & Hesse, 2006 ▪ Vrtic and Fröhlich, 2006 ▪ Wittwer & Berger, 2021
311-03	Number of cars in household	▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Ownership of transport modes (520-02) *The higher the number of cars in a household the higher the share of car trips (Hobiger, 2021)*	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ McCreery-Phillips & Heydari, 2023
312	**Public transport accessibility**	▪ Accessibility as a factor of the provision of SGI (Humer et al., 2015; Chapter 2.2) ▪ Quality of the connection as part of the SGI provision (Humer et al., 2015; Chapter 2.2) ▪ Information situation (644) → Is public transport a viable option for the trip?	▪ Mietzsch, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
312-01	Type of public transport	▪ Learning theory (Chapter 2.4.3) ▪ Perception of the transport mode (643) ▪ *An extensive distinction and definition of different transport mode types can be found in Schiefelbusch (2018; in German).*	▪ Chakrabati, 2016
312-02	Location	▪ Access to a public transport mode at start and destination (402-05) ▪ Comfort (323) ▪ Trip duration (403)	▪ Groß, 1998 ▪ Mietzsch, 2021 ▪ Wittwer & Berger, 2021
312-03	Distance / accessibility of public transport stops	▪ Access time to public transport (403-01) ▪ Accessibility of public transport stops at start and destination (402-05) ▪ Effort (649-03) ▪ Fitness (612-02) ▪ Trip duration (403) ▪ *An extensive distinction and definition of different transport mode types can be found in Schiefelbusch (2018; in German).*	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ Ko et al., 2018 ▪ Mietzsch, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021

312-04	Availability of public transport season ticket	▪ Perceived knowledge gap; subjective benefit models (Chapter 2.4.4) ▪ Costs (322-06) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Information situation (644) ▪ Tariff information (644-03)	▪ Groß, 1998 ▪ Hobiger, 2021 ▪ Vrtic and Fröhlich, 2006 ▪ Wittwer & Berger, 2021
312-05	Intermodal connection	▪ Access time to public transport (403-01) → *can be mitigated to some extent through better intermodal connections*	▪ Hobiger, 2021 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021
312-06	Quality of public transport connections	▪ Accessibility index (e.g.: ÖV-Güteklassen in Austria; 232-07) ▪ Duration of waiting times (403-03) ▪ Need to transfer (400-01) ▪ Quality as a factor of the provision of SGI (Humer et al., 2015)	▪ Cevero & Radisch, 1996 ▪ Mietzsch, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
312-07	Ticket purchase options	▪ *Personalized information* → Information situation (644) ▪ *Personal interaction* → Staff (323-07) ▪ *Payment methods* ▪ *Time of ticket purchase*	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
313	**Accessibility of sharing offers**	▪ Perceived knowledge gap → subjective benefit models (Chapter 2.4.4) ▪ Information situation (644) ▪ Tariff information (644-03)	▪ Wittwer & Berger, 2021
313-01	Carsharing	▪ Information situation (644) ▪ Tariff information (644-03) ▪ *often designed as a free-floating system* (Bogenberger et al., 2016)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
313-02	e-scooter sharing	▪ Information situation (644) ▪ Tariff information (644-03)	▪ Wittwer & Berger, 2021
313-03	Bike sharing (incl. cargo bike)	▪ Information situation (644) ▪ Intermodal connections (312-05/ 314-01) ▪ Tariff information (644-03)	▪ McCreery-Phillips & Heydari, 2023 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021
314	**Bike accessibility**	▪ Ownership of transport options (520-02) ▪ Skills and abilities (612-05)	▪ Daubitz, 2021 ▪ Groß, 1998 ▪ Wittwer & Berger, 2021
314-01	Intermodal connection	▪ Access time to public transport (403-01) → *can be mitigated to some extent through better intermodal connections*	▪ Nuhn & Hesse, 2006
314-02	Ownership of a bicycle	▪ Internal household organisation (630-05) ▪ Ownership of transport options (520-02)	▪ Daubitz, 2021 ▪ Groß, 1998 ▪ Heinen et al., 2019
315	**Accessibility of other transport modes**		
315-01	Motorbike ownership	▪ *Can be an* autotelic activity (Chapter 2.4.5) ▪ Costs (322-06) ▪ Driving licence possession (311-01) ▪ Freedom (652-06) ▪ Perception of safety (611-01) ▪ Season (401-04) ▪ Skills and abilities (612-05) ▪ Weather (401-05)	▪ Groß, 1998

315-02	Moped ownership	▪ *Can be an* autotelic activity (Chapter 2.4.5) ▪ Costs (322-06) ▪ Driving licence possession (311-01) ▪ Freedom (652-06) ▪ Perception of safety (611-01) ▪ Season (401-04) ▪ Skills and abilities (612-05) ▪ Weather (401-05)	▪ Groß, 1998

Table 11: Mentioned transport mode specific factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
321	**Safety and reliability**		
321-01	Safety	▪ Daytime (401-01) ▪ Perception of the transport mode (643) ▪ Perception of safety (611-01) ▪ Street design (222)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
321-02	Risk of accidents and traffic jams	▪ Trip duration (403) ▪ Perception of safety (611-01) ▪ Planning reliability (321-04) *The general trends in Austria show a lowering of road accidents by nearly 20% between 2002 and 2022 (European Commission - Directorate-General for Mobility and Transport (MOVE) & Community database on road accidents (CARE), 2024).*	▪ Chakrabati, 2016 ▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Groß, 1998 ▪ Jang & Ko, 2019 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021
321-03	Reliability	▪ Failure of the transport mode (321-06) ▪ Perception of the transport mode (643) ▪ Planning reliability (321-04) ▪ Timeliness (321-05) ▪ Travel satisfaction (642-01) *Within a study conducted in North Rhine-Westphalia in 2022 the punctuality and reliability had not only the lowest satisfaction but also the highest share of disappointed public transport users. (INFO Markt- & Meinungsforschung GmbH, 2023)*	▪ Chakrabati, 2016 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Vrtic and Fröhlich, 2006 ▪ Widmer et al., 2020
321-04	Planning reliability	▪ Availability of car parks (233-17) ▪ Frequency / timetable interval (322-04) ▪ Information situation (644) ▪ *Predictability of the* trip duration (403) ▪ Real-time information (644-02) ▪ Risk of traffic jams (321-02)	▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Widmer et al., 2020
321-05	Timeliness	▪ Information situation (644) ▪ Reliability (321-03) ▪ Trip duration (403) *Within a study conducted in North Rhine-Westphalia in 2022 the punctuality and reliability had not only the lowest satisfaction but also the highest share of disappointed public transport users. (INFO Markt- & Meinungsforschung GmbH, 2023)*	▪ De Vos, 2019 ▪ Groß, 1998

321-06	Failure of the transport mode	▪ Control over the travel situation (642-06) ▪ Flexibility (323-05) ▪ Labour strikes (321-07) ▪ Reliability (321-03) ▪ Repairs (321-08)	▪ Groß, 1998
321-07	Labour strikes	▪ Flexibility (323-05) ▪ Information situation (644) ▪ Reliability (321-03)	▪ Groß, 1998
321-08	Repairs	▪ Changes in routes; Information situation (644) ▪ Comfort (323) ▪ Control over the travel situation (642-06) ▪ Duration of waiting times (403-03) ▪ Flexibility (323-05) ▪ Planning reliability (321-04) ▪ Trip duration (403)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
322	**Transport mode efficiency**		
322-01	Infrastructure availability	▪ Effort (649-03) ▪ Trip duration (403) ▪ Trip length (400-11) ▪ Availability as a factor of the provision of SGI (Humer et al., 2015)	▪ Groß, 1998 ▪ Khosravi et al., 2016 ▪ Nuhn & Hesse, 2006
322-02	Quality of infrastructure	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Reliability (321-03) ▪ Risk of accidents and traffic jams (321-02)	▪ Khosravi et al., 2016
322-03	Network density	▪ Population density (220-03); *Close link according to Nuhn & Hesse (2006)* ▪ Accessibility is enhanced; factor of the provision of SGI (Humer et al., 2015)	▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Heinen et al., 2019 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006
322-04	Frequency / timetable interval	▪ Information situation (644) ▪ Perception of the transport mode (643) ▪ Planning reliability (321-04)	▪ Chakrabati, 2016 ▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Vrtic and Fröhlich, 2006 ▪ Wittwer & Berger, 2021
322-05	Speed	▪ Space-time prism (Chapter 2.4.7) ▪ Speed limits (131-01) ▪ Trip duration (403)	▪ Chakrabati, 2016 ▪ Chatterjee et al., 2019 ▪ Groß, 1998 ▪ Hoor, 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021

322-06	Price/costs	▪ Financial costs vs. opportunity costs (due to lost time → Public mobility (Chapter 2.1) & Space-time prism (Chapter 2.4.7) ▪ Financial constraints (322-08; Chapter 2.4.7) ▪ Fiscal factors (132) ▪ Information situation (644) ▪ Perception of prices (643-03) ▪ Timing of costs (322-10) *For the active transport modes, the financial burden is lowered as for walking the financial costs can be expected to be zero or nearing zero, for cycling the costs for maintenance of the bicycle remain but these costs or not that high if the bicycle is often used. For the car a financial burden is often mixed from prices for fuel, maintenance, insurance, etc. It is important to mention that the perception and the assessment of the costs for a car trip are often underestimated (NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022).* → Learning theory approaches (Chapter 2.4.3)	▪ Chakrabati, 2016 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Handy & Thigpen, 2018 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Hoor, 2021 ▪ Ko et al., 2018 ▪ Nuhn & Hesse, 2006 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Rammert, 2021 ▪ Schwanen & Mokhtarian, 2004 ▪ Stöglehner, 2020 ▪ Vrtic and Fröhlich, 2006 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
322-07	Price-performance ratio	▪ Rational choice theory (Chapter 2.4.4) ▪ Subjective benefit model (Chapter 2.4.4)	▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
322-08	Financial constraints	▪ Constraint models (Chapter 2.4.7) ▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Status (630-02)	▪ Chakrabati, 2016 ▪ Daubitz, 2021 ▪ Rammert, 2021
322-09	Price relationship to other destinations	▪ Perception of the price (643-03) ▪ Perception of the transport mode (643) ▪ Trip distance (400-11) ▪ Trip duration (403)	▪ Groß, 1998
322-10	Timing of costs	▪ Perception of the transport mode (643) ▪ Perception of the price (643-03) *Costs that are not directly linked to the trip itself are often underestimated, e.g.: repairs, insurance (Wenninger et al., 2021 & NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022)* → Learning theory approaches (Chapter 2.4.3)	▪ Flade & Wullkopf, 2002 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021
322-11	Environmental friendliness	▪ Emissions (322-13) ▪ Environmental awareness (654-01)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
322-12	Energy balance	▪ Emissions (322-13) ▪ Environmental awareness (654-01) ▪ Environmental friendliness (322-11) ▪ Subsidies for fuel (132-05)	▪ Groß, 1998

322-13	Emissions	▪ Air pollution (647-03) ▪ Environmental friendliness (322-11) ▪ Noise level (323-03) ▪ Perception of the transport mode (643)	▪ Groß, 1998 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021
322-14	Required space	▪ Emissions *per user* (322-13) ▪ Environmental friendliness (322-11)	▪ Groß, 1998
323	**Comfort**	▪ Attractiveness of the travel route (649) ▪ Information situation (644) ▪ Perception of the transport mode (643)	▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ Vrtic and Fröhlich, 2006 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
323-01	Planning effort	▪ Learning theory approaches (Chapter 2.4.3) ▪ Subjective benefit model (Chapter 2.4.4) ▪ Information situation (644)	▪ Wittwer & Berger, 2021
323-02	Weather dependency	▪ Planning reliability (321-04) ▪ Weather (401-05)	▪ Groß, 1998
323-03	Noise level	▪ Emissions (322-13) ▪ Occupation level (323-11) ▪ Perception of the transport mode (643)	▪ Groß, 1998 ▪ Rammert, 2021 ▪ Widmer et al., 2020
323-04	Convenience	▪ Socio-psychological approaches (Chapter 2.4.6) ▪ Subjective benefit model (Chapter 2.4.4) ▪ Accessibility of a transport mode (Subcategory 31) ▪ Availability of public transport season ticket (312-04) ▪ Driving licence possession (311-01) ▪ Features of the transport mode (324 & 325) ▪ Habits (620-01) ▪ Information situation (644) ▪ Learned mobility behaviour (621-06) ▪ Ownership of transport options (520-02) ▪ Planning effort (323-01)	▪ Groß, 1998 ▪ Hobiger, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020
323-05	Flexibility	▪ Constraint models (Chapter 2.4.7) ▪ Space-Time-Prism (Chapter 2.4.7) ▪ Authority constraints (404-02) ▪ Failure of the transport mode (321-06) ▪ Financial constraints (322-08) ▪ Flexibility of destination (404-03) ▪ Frequency / timetable interval (322-04) ▪ Reliability (321-03) ▪ Time constraints (404-01) ▪ Trip purpose (400-04)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020
323-06	Individual atmosphere	▪ Individualism (651-02) ▪ Noise level (323-03) ▪ Occupation level (323-11) ▪ Perception of other traffic participants (646-01)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021

323-07	Staff	▪ Learning theory approaches (Chapter 2.4.3) ▪ Perception of the transport mode (643) ▪ Ticket purchase options (312-07)	▪ De Vos, 2019 ▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
323-08	Time utilisation during the journey	▪ Learning theory approaches (Chapter 2.4.3) ▪ Space-Time-Prism (Chapter 2.4.7) ▪ Fun while using certain transport modes (653-05) ▪ Perception of the transport mode (643) ▪ Perception of the travel time (643-04)	▪ De Vos, 2019 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Handy & Thigpen, 2018 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
323-09	Design	▪ Aesthetics of the travel route (649-02) ▪ Features of the transport stop (324) ▪ Features of the Vehicles (325) ▪ Perception of the transport mode (643) ▪ Street design (222)	▪ Chatterjee et al., 2019 ▪ Groß, 1998
323-10	Seat Design	▪ Aesthetics of the travel route (649-02) ▪ Comfort (323)	▪ Hobiger, 2021
323-11	Occupation level	▪ Learning theory approaches (Chapter 2.4.3) ▪ Daytime (401-01) ▪ Environmental friendliness (322-11) ▪ Individual atmosphere (323-06) ▪ Noise level (323-03) ▪ Perception of the transport mode (643) ▪ Travel satisfaction (642-01)	▪ Chatterjee et al., 2019 ▪ Hobiger, 2021 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
323-12	Cleanliness	▪ Attractiveness of the travel route (649) ▪ Cleanliness of the neighbourhood (232-03) ▪ Features of the transport stop (324) ▪ Perception of the transport mode (643) ▪ Vehicles (325)	▪ De Vos, 2019 ▪ Groß, 1998 ▪ Wittwer & Berger, 2021
324	**Features of the transport stop**	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Perception of the transport mode (643)	▪ Chatterjee et al., 2019 ▪ Groß, 1998
324-01	Seating Area	▪ Age (510-01) ▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Luggage (400-08) *Recommended by the Forschungsgesellschaft Mobilität – FGM (2009)*	▪ Groß, 1998
324-02	Bus shelter	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Weather (401-05) ▪ Weather dependency (323-02) *Recommended by the Forschungsgesellschaft Mobilität – FGM (2009)*	▪ Groß, 1998
324-03	Passenger information	▪ Barrier-free accessibility (649-04) ▪ Information situation (644)	▪ Groß, 1998
325	**Features of the vehicles**	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Perception of the transport mode (643)	▪ Chatterjee et al., 2019 ▪ Groß, 1998
325-01	Power outlets	▪ Comfort (323) ▪ Perception of the transport mode (643) ▪ Time utilisation during the journey (323-08)	▪ Weninger et al., 2021

325-02	Wi-Fi	▪ Comfort (323) ▪ Perception of the transport mode (643) ▪ Time utilisation during the journey (323-08)	▪ Chatterjee et al., 2019 ▪ Weninger et al., 2021
325-03	Legroom	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Perception of the transport mode (643) ▪ Seat Design (323-10)	▪ Hobiger, 2021
325-04	Air conditioning	▪ Comfort (323) ▪ Perception of the transport mode (643) ▪ Season (401-04) ▪ Stress (641-03) ▪ Weather (401-05)	▪ Hobiger, 2021
325-05	Option to take bike with you	▪ Comfort (323) ▪ Intermodal connection (312-05/ 314-01) ▪ Luggage (400-08) ▪ Perception of the transport mode (643)	▪ Wittwer & Berger, 2021

Table 12: Mentioned trip specific factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
400-01	Need to transfer	▪ Information situation (644) ▪ Reliability (321-03) ▪ Stress (641-03) ▪ Timeliness (321-05)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Weninger et al., 2021
400-02	Number of transfers	▪ Effort (649-03) ▪ Information situation (644) ▪ Reliability (321-03) ▪ Stress (641-03) ▪ Timeliness (321-05) ▪ Travel satisfaction (642-01)	▪ Chakrabati, 2016 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Vrtic and Fröhlich, 2006 ▪ Weninger et al., 2021 ▪ Wolking, 2021
400-03	Transfer convenience	▪ Comfort of the transport mode (323) ▪ Convenience of the travel route (649-10) ▪ Effort (649-03) ▪ Perception of the transport mode (643) ▪ Trip duration (403)	▪ Groß, 1998 ▪ Weninger et al., 2021
400-04	Trip purpose	▪ Authority constraints (404-02; Chapter 2.4.7) ▪ Luggage (400-08) ▪ Length of trip chain (400-09) ▪ Regularity of the trip (400-10) ▪ Size of travelling group (400-05) ▪ Transport function (400-07)	▪ Cao et al., 2022 ▪ Cevero & Radisch, 1996 ▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Nuhn & Hesse, 2006 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Vrtic and Fröhlich, 2006 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021

400-05	Size of travelling group	▪ Rational choice theory based on all in the travel group (Chapter 2.4.4 & 2.4.6)	▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
400-06	Social contact	▪ Size of travelling group (400-05) ▪ Perception of other traffic participants (646-01) ▪ Perception of the transport mode (643)	▪ Groß, 1998
400-07	Transport function	▪ Effort (649-03) ▪ Luggage (400-08) ▪ Trip purpose (400-04)	▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
400-08	Luggage	▪ Transport function (400-07) ▪ Trip purpose (400-04)	▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Widmer et al., 2020
400-09	Length of trip chain	▪ Information situation (644) ▪ Trip purpose (400-04) *The more complex the trip chain gets, the less probable it is that the public transport is chosen over the car (Hensher & Reyes, 2000 cited in NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022).*	▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Tao et al., 2022 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020
400-10	Regularity of the trip	▪ Habits (620-01; Chapter 2.4.6) ▪ Trip purpose (400-04)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
400-11	Distance / Length of the trip	▪ Space-time prism (Chapter 2.4.7) ▪ Effort (649-03) ▪ Fitness (612-02) ▪ Length of trip chain (400-09) ▪ Speed of the transport mode (322-05) ▪ Time constraints (404-01; Chapter 2.4.7) ▪ Travel satisfaction (642-01) ▪ Trip duration (403)	▪ Cao et al., 2022 ▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Handy & Thigpen, 2018 ▪ Heinen et al., 2019 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Stöglehner, 2020 ▪ Wittwer & Berger, 2021
401	**Time factors**	▪ Availability of public transport options (402-05) ▪ Occupation level (323-11) ▪ Risk of traffic jams (321-02)	▪ Wolking, 2021
401-01	Daytime	▪ Authority constraints (Chapter 2.4.7) ▪ Availability of public transport options (402-05) ▪ Lighting (222-02) ▪ Occupation level (323-11) ▪ Perceived safety (611-01) ▪ Risk of traffic jams (321-02) ▪ Traffic situation (401-02)	▪ Cevero & Radisch, 1996 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022

401-02	Traffic situation	▪ Daytime (401-01) ▪ Effort (649-03) ▪ Occupation level (323-11) ▪ Perceived safety (611-01) ▪ Season (401-04) ▪ Stress (641-03) ▪ Risk of traffic jams (321-02) ▪ Weekday (401-03)	▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Nuhn & Hesse, 2006 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
401-03	Weekday	▪ Authority constraints (Chapter 2.4.7) ▪ Availability of public transport options (402-05) ▪ Occupation level (323-11) ▪ Risk of traffic jams (321-02) ▪ Traffic situation (401-02)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
401-04	Season	▪ Authority constraints (Chapter 2.4.7) ▪ Availability of public transport options (402-05) ▪ Comfort (323) ▪ Effort (649-03) ▪ *Need for* air conditioning (325-04) ▪ Occupation level (323-11) ▪ Perceived safety (611-01) ▪ Risk of traffic jams (321-02) ▪ Traffic situation (401-02) ▪ Weather (401-05)	▪ De Vos, 2019 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
401-05	Weather	▪ Climate (210-04) ▪ Comfort (323) ▪ Effort (649-03) ▪ Perceived safety (611-01) *Colder and wetter weather correlates with less bicycle usage (Dill and Carr,* 2003 cited in *McCreery-Phillips & Heydari, 2023)*	▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ McCreery-Phillips & Heydari, 2023 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
402	**Surroundings of start and destination**	▪ Subjective benefit models (Chapter 2.4.4) ▪ Accessibility of transport modes (Subcategory 31) ▪ Diversity of land use along the route (649-07) ▪ Information situation (644) ▪ Perception of transport modes (643) ▪ Settlement structure (Subcategory 22)	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
402-01	Bicycle infrastructure	▪ Bike accessibility (314) ▪ Effort (649-03) ▪ Infrastructure availability (322-01) ▪ Perceived safety (611-01) ▪ Availability as a factor of the provision of SGI (Humer et al., 2015)	▪ Cao et al., 2022 ▪ Daubitz, 2021 ▪ Heinen et al., 2019
402-02	Bike parking facilities	▪ Fears (641-02) ▪ Perceived safety (611-01) ▪ *If designed as a shelter:* Weather dependency (323-02)	▪ Daubitz, 2021 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021

402-03	Bike service stations	▪ Failure of the transport mode (321-06) ▪ Perceived safety (611-01) ▪ Reliability (321-03) ▪ Staff (323-07)	▪ Weninger et al., 2021
402-04	Cycle paths	▪ Bike accessibility (314) ▪ Effort (649-03) ▪ Infrastructure availability (322-01) ▪ Perceived safety (611-01)	▪ Daubitz, 2021 ▪ Heinen et al., 2019
402-05	Public transport infrastructure	▪ Infrastructure availability (322-01) ▪ Public transport accessibility (312) ▪ Public transport accessibility (index) (232-07)	▪ Mietzsch, 2021
402-06	Availability of parking space	▪ Land-use and development plans (131-04) ▪ Parking space management (132-08) ▪ Parking space regulations (131-02)	▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
402-07	Availability of showers and changing facilities	▪ Comfort (323) ▪ Effort (649-03) ▪ Perception of health/hygiene (612-08) ▪ Perception of the transport mode (643) ▪ Travel satisfaction (642-01)	▪ Heinen et al., 2019 ▪ Weninger et al., 2021
403	**Trip duration**	▪ Accessibility of transport modes (Subcategory 31) ▪ Distance / Length of the trip (400-11) ▪ Information situation (644) ▪ Need to transfer (400-01) ▪ Time factors (401) ▪ Risk of traffic jams (321-02) ▪ Speed (322-05)	▪ Cevero & Radisch, 1996 ▪ Chakrabati, 2016 ▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2019 ▪ Flade & Wullkopf, 2002 ▪ Ko et al., 2018 ▪ Handy & Thigpen, 2018 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Schwanen & Mokhtarian, 2004 ▪ Stöglehner, 2020 ▪ Tao et al., 2022 ▪ Vrtic & Fröhlich, 2006 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021 ▪ Wolking et al., 2021
403-01	Access time to public transport	▪ Accessibility of transport modes (Subcategory 31) ▪ Information situation (644) ▪ Time factors (401) ▪ Fitness (612-02) ▪ Intermodal connections (312-05/ 314-01)	▪ Chakrabati, 2016 ▪ Vrtic & Fröhlich, 2006

403-02	Subjective assessment (waiting time vs. driving time)	▪ Models of information processing (Chapter 2.4.5) ▪ Access time to public transport (403-01) ▪ Comfort (323) ▪ Information situation (644) ▪ Need to transfer (400-01) ▪ Occupation level (323-11) ▪ Perception of the transport mode (643) ▪ Time factors (401)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
403-03	Duration of waiting times	▪ Access time to public transport (403-01) ▪ Comfort (323) ▪ Connections in public transport (403-04) ▪ Need to transfer (400-01) ▪ Occupation level (323-11) ▪ Perception of the transport mode (643) ▪ Subjective assessment (waiting time vs. driving time) (403-02) ▪ Time factors (401)	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
403-04	Connections in public transport	▪ Information situation (644) ▪ Need to transfer (400-01) ▪ Number of transfers (400-02) ▪ Subjective assessment (waiting time vs. driving time) (403-02)	▪ Chakrabati, 2016 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
403-05	Time to find a parking space	▪ Land-use and development plans (131-04) ▪ Parking space management (132-08) ▪ Parking space regulations (131-02) ▪ Stress (641-03) ▪ Time factors (401)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
403-06	Variance in trip duration	▪ Flexibility (323-05) ▪ Planning reliability (321-04) ▪ Risk of accidents and traffic jams (321-02) ▪ Time constraints (404-01)	▪ Handy & Thigpen, 2018
404	**Constraints**	▪ Constraint models (Chapter 2.4.7)	▪ Handy et al., 2005
404-01	Time constraints	▪ Constraint models (Chapter 2.4.7) ▪ Space-Time prism (Chapter 2.4.7) ▪ Accessibility of transport modes (Subcategory 31) ▪ Speed (322-05) ▪ Time factors (401) ▪ Trip duration (403)	▪ Chatterjee et al., 2019 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Nuhn & Hesse, 2006 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Weninger et al., 2021 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
404-02	Authority constraints	▪ Constraint models (Chapter 2.4.7) ▪ Time factors (401) ▪ Trip duration (403) ▪ Trip purpose (400-04) ▪ Flexibility of destination (404-03)	▪ Flade & Wullkopf, 2002 ▪ Nuhn & Hesse, 2006
404-03	Flexibility of destination	▪ Trip purpose (400-04) *Fixed destinations (e.g. work, home) vs. flexible destinations (e.g.: supermarkets, parks)*	▪ Wittwer & Berger, 2021

Table 13: Mentioned personal sociodemographic factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
510-01	Age	▪ Employment (511) ▪ Fitness (612-02) ▪ Health (612-08) ▪ Household structure (521) ▪ Lifestyle (621) ▪ Ownership of transport modes (520-02) ▪ Society's expectations (631-06)	▪ Cevero & Radisch, 1996 ▪ Chen et al., 2023 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Rammert, 2021 ▪ Vrtic & Fröhlich, 2006 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
510-02	Gender	▪ Household structure (521) ▪ Lifestyle (621) ▪ Perceived safety (611-01) ▪ *Personal* Income (520-01) ▪ Form of Employment (511-01) ▪ Society's expectations (631-06) ▪ Well-being (620-08)	▪ Chen et al., 2023 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Schwanen & Mokhtarian, 2004 ▪ Tao et al., 2022 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
510-03	Socio-economic class	▪ Age (510-01) ▪ Ethnic background (510-06) ▪ Gender (510-02) ▪ Level of education (510-07) ▪ Lifestyle (621) ▪ Income (520-01) ▪ Mobility style (621-05)	▪ McCreery-Phillips & Heydari, 2023
510-04	Body mass index	▪ Age (510-01) ▪ Effort (649-03) ▪ Fitness (612-02) ▪ Gender (510-02)	▪ Chen et al., 2023
510-05	Nationality	▪ Ethnic background (510-06) ▪ Lifestyle (621) ▪ Mobility style (621-05)	▪ Groß, 1998
510-06	Ethnic background	▪ Learned mobility behaviour (621-06) ▪ Lifestyle (621) ▪ Mobility style (621-05) ▪ Nationality (510-05)	▪ McCreery-Phillips & Heydari, 2023

510-07	Level of education	▪ Employment (511) ▪ Lifestyle (621) ▪ Mobility style (621-05) ▪ Socio-economic class (510-03) ▪ Status (630-02)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Widmer et al., 2020 ▪ Weninger et al., 2021
511	**Employment**	▪ Age (510-01) ▪ Attractiveness of the workplace (648) ▪ Flexibility (323-05) ▪ Gender (510-02) ▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Social environment / network (630-01) ▪ Time constraints (404-01)	▪ Handy et al., 2005 ▪ Groß, 1998 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Rammert, 2021 ▪ Tao et al., 2022
511-01	Form of employment	▪ Attractiveness of the workplace (648) ▪ Income (520-01) ▪ Internal household organisation (630-05) ▪ Time constraints (404-01) ▪ *Self-employed* ▪ *Full-time vs. part-time vs. marginal employment*	▪ Jang & Ko, 2019 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006
511-02	Duration of employment	▪ Socio-psychological approaches (Chapter 2.4.6) ▪ Habits (620-01) ▪ Income (520-01)	▪ Jang & Ko, 2019
511-03	Labour hours	▪ Amount of leisure time (612-04) ▪ Attractiveness of the workplace (648) ▪ Internal household organisation (630-05) ▪ Time constraints (404-01) ▪ *Full-time vs. part-time vs. marginal employment*	▪ Hobiger, 2021 ▪ Nuhn & Hesse, 2006 ▪ Tao et al., 2022 ▪ Wittwer & Berger, 2021
511-04	Number of working days	▪ Accessibility of transport mode options (Subcategory 31) ▪ Amount of leisure time (612-04) ▪ Attractiveness of the workplace (648) ▪ Internal household organisation (630-05) ▪ Time constraints (404-01) ▪ Time factors (401)	▪ Jang & Ko, 2019
511-05	Flexibility in work time	▪ Accessibility of transport mode options (Subcategory 31) ▪ Amount of leisure time (612-04) ▪ Attractiveness of the workplace (648) ▪ Flexibility (323-05) ▪ Internal household organisation (630-05) ▪ Stress (641-03) ▪ Time constraints (404-01) ▪ Time factors (401)	▪ Chatterjee et al., 2019 ▪ Tao et al., 2022 ▪ Weninger et al., 2021
511-06	Work-location	▪ Attractiveness of the workplace (648) ▪ Distance/Length of commuting trip (400-11) ▪ Flexibility (323-05) ▪ Surroundings of start and destination of the trip (402)	▪ Chen et al., 2023 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021

511-07	Home office share	▪ Flexibility (323-05) ▪ Level of education (510-07) ▪ Lifestyle (621) ▪ Stress (641-03)	▪ Weninger et al., 2021
511-08	Profession	▪ Level of education (510-07) ▪ Skills and abilities (612-05)	▪ Khosravi et al., 2016 ▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021

Table 14: Mentioned household sociodemographic factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
520-01	Income	▪ Employment (511) ▪ Financial constraints (322-08) ▪ Flexibility (323-05) ▪ Number of working people in the household (521-02) ▪ Stress (641-03)	▪ Cao et al., 2022 ▪ Cevero & Radisch, 1996 ▪ Chen et al., 2023 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2019 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Nuhn & Hesse, 2006 ▪ Rammert, 2021 ▪ Weninger et al., 2021
520-02	Ownership of transport options	▪ Subjective benefit model (Chapter 2.4.4) ▪ Accessibility of transport modes (Subcategory 31) ▪ Costs (322-06) ▪ Financial constraints (322-08) ▪ Planning effort (323-01)	▪ Cao et al., 2022 ▪ Cevero & Radisch, 1996 ▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020
521	**Household structure**	▪ Rational choice theory based on all in the travel group (Chapter 2.4.4 & 2.4.6) ▪ Employment (511) ▪ Internal household organisation (630-05) ▪ Lifestyle (621) ▪ Size of the household ▪ Size of travelling group (400-05)	▪ Cevero & Radisch, 1996 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Ko et al., 2018 ▪ Nuhn & Hesse, 2006 ▪ Rammert, 2021 ▪ Schwanen & Mokhtarian, 2004 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021

521-01	Married	▪ Constraint models (Chapter 2.4.7) ▪ Internal household organisation (630-05) ▪ Number of working people in the household (521-02) ▪ Social/cultural norms (631-01) ▪ Time constraints (404-01)	▪ Chen et al., 2023 ▪ Jang & Ko, 2019
521-02	Number of working people in the household	▪ Constraint models (Chapter 2.4.7) ▪ Internal household organisation (630-05) ▪ Ownership of transport modes (520-02) ▪ Social/cultural norms (631-01) ▪ Time constraints (404-01)	▪ Khosravi et al., 2016
521-03	Children in the household	▪ Constraint models (Chapter 2.4.7) ▪ Rational choice theory based on all in the travel group (Chapter 2.4.4 & 2.4.6) ▪ Financial constraints (322-08) ▪ Internal household organisation (630-05) ▪ Learned mobility behaviour (621-06) ▪ Size of travelling group (400-05) ▪ Social/cultural norms (631-01) ▪ Time constraints (404-01)	▪ Handy et al., 2005 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
521-04	Children at school age	▪ Constraint models (Chapter 2.4.7) ▪ Rational choice theory based on all in the travel group (Chapter 2.4.4 & 2.4.6) ▪ Financial constraints (322-08) ▪ Internal household organisation (630-05) ▪ Size of travelling group (400-05) ▪ Time constraints (404-01)	▪ Jang & Ko, 2019 ▪ Tao et al., 2022

Table 15: Mentioned physical and mental requirement factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
611	**Physical well-being**	▪ Life / personal satisfaction (651-08) ▪ Satisfaction with neighbourhood (647-10) ▪ Satisfaction with workplace (648-08)	▪ Chakrabati, 2016 ▪ Daubitz, 2021 ▪ Groß, 1998
611-01	Safety	▪ Crime rate (232-02) ▪ Employment (511) ▪ Job-stability (611-02) ▪ Physical and mental health (612-08) ▪ Shelter (611-03)	▪ Groß, 1998 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020
611-02	Job-stability	▪ Age (510-01) ▪ Employment (511) ▪ Gender (510-02)	▪ Jang & Ko, 2019
611-03	Shelter	▪ Building type (231-02) ▪ Financial constraints (322-08) ▪ Living space (231-03) ▪ Ownership type (231-01)	▪ Widmer et al., 2020
612	**Restrictions**	▪ Constraint models (Chapter 2.4.7) ▪ Constraints (404) ▪ Physical well-being (611)	▪ Wittwer & Berger, 2021
612-01	(Self-) imposed restrictions	▪ Constraint models (Chapter 2.4.7) ▪ Constraints (404) ▪ Illness (612-09) ▪ Permanent restrictions (612-06) ▪ Physical and mental health (612-08)	▪ Daubitz, 2021 ▪ Flade & Wullkopf, 2002 ▪ Wittwer & Berger, 2021

612-02	Fitness	▪ Effort (649-03) ▪ Freedom (652-06) ▪ Independence (652-07) ▪ Lifestyle (621) ▪ Mental and physical health (612-08) ▪ Permanent restrictions (612-06) ▪ Psychomotor disabilities (612-07) ▪ Sleep duration (612-03)	▪ De Vos, 2019
612-03	Sleep duration	▪ Cognitive capacity to judge different attributes (642-03) ▪ Fitness (612-02) ▪ Mental and physical health (612-08)	▪ Jang & Ko, 2019 ▪ Tao et al., 2022
612-04	Amount of leisure time	▪ Constraint models (Chapter 2.4.7) ▪ Mental and physical health (612-08) ▪ Leisure time activities (621-03) ▪ Time constraints (404-01)	▪ Nuhn & Hesse, 2006 ▪ Jang & Ko, 2019 ▪ Tao et al., 2022
612-05	Skills and abilities	▪ Age (510-01) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Driving licence possession (311-01) ▪ Information situation (644) ▪ Level of education (510-07) ▪ Mental and physical health (612-08) ▪ Permanent restrictions (612-06) ▪ Psychomotor disabilities (612-07)	▪ Daubitz, 2021 ▪ Groß, 1998
612-06	Permanent restrictions	▪ Psychomotor disabilities (612-07) ▪ Mental and physical health (612-08) ▪ Level of education (510-07) ▪ Learned mobility behaviour (621-06) ▪ Learning theory approach (Chapter 2.4.3) ▪ Cultural anchoring / cultural group (631-04)	▪ Daubitz, 2021 ▪ Groß, 1998
612-07	Psychomotor disabilities	▪ Constraint models (Chapter 2.4.7) ▪ Barrier-free accessibility(649-04) ▪ Mental and physical health (612-08) ▪ Permanent restrictions (612-06) ▪ Staff (323-07)	▪ Groß, 1998
612-08	Mental and physical health	▪ Cognitive capacity to judge different attributes (642-03) ▪ Fitness (612-02) ▪ Illness (612-09) ▪ Permanent restrictions (612-06) ▪ Physical well-being (611) ▪ Skills and abilities (612-05)	▪ Daubitz, 2021 ▪ Heinen et al., 2019 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
612-09	Illness	▪ Constraint models (Chapter 2.4.7) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Fitness (612-02) ▪ Physical well-being (611) ▪ Skills and abilities (612-05)	▪ Groß, 1998
612-10	Nausea when using a mode of transport	▪ Perception of a transport mode (643) ▪ Physical well-being (611) ▪ Skills and abilities (612-05)	▪ Groß, 1998

Table 16: Mentioned behaviour / characteristic factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
620-01	**Habits**	▪ Cognitive maps (Chapter 2.4.5) ▪ Learning theory approach (Chapter 2.4.3) ▪ Socio-psychological approaches (Chapter 2.4.6) ▪ Behaviour control (641-01) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Convenience of the route (649-10) ▪ Experiences (620-05) ▪ Perception of the transport mode (643) ▪ Regularity of use (643-08) ▪ Subjective norms (631-05) ▪ Society's expectations (631-06) *A study of the Swiss Federal Railway (SBB) has found that 75% of commuters have a heavy habituative travel behaviour ranging from the same train, over waiting at the same spot at the platform to choosing the same seat in the train. (Weninger et al., 2021)*	▪ Chakrabati, 2016 ▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Ko et al., 2018 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Tao et al., 2022 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
620-02	Self-determination	▪ Individualism (651-02) ▪ Independence (652-07)	▪ Widmer et al., 2020
620-03	Self-esteem	▪ Independence (652-07) ▪ Prestige (630-03) ▪ Status (630-02) ▪ Subjective norms (631-05)	▪ Groß, 1998
620-04	Self-presentation	▪ Individualism (651-02) ▪ Independence (652-07) ▪ Lifestyle (621) ▪ Material / post-material attitude (652-01) ▪ Personality (620-10) ▪ Prestige (630-03) ▪ Status (630-02) ▪ Wanting to be a role model (651-03)	▪ Hoor, 2021
620-05	Experiences	▪ Learning theory approach (Chapter 2.4.3) ▪ Learned mobility behaviour (621-06) ▪ Mobility behaviour of reference persons (621-07) ▪ Perception of a transport mode (643) ▪ Personality (620-10)	▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Ko et al., 2018 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Tao et al., 2022
620-06	Desire for variety	▪ Curiosity (651-04) ▪ Independence (652-07) ▪ Personality (620-10) ▪ Preferences towards certain transport modes (653-04)	▪ Widmer et al., 2020
620-07	Authority	▪ Open / Conservative (652-02) ▪ Position in the household (630-04) ▪ Self-esteem (620-03) ▪ Self-presentation (620-04) ▪ Subordination vs. organisation (630-06)	▪ Widmer et al., 2020

620-08	Well-being	▪ Theory of planned behaviour (Chapter 2.4.8) ▪ Behaviour control (641-01) ▪ Health (612-08) ▪ Perceived options for action (642-02) ▪ Physical well-being (611) ▪ Restrictions (612)	▪ Daubitz, 2021 ▪ Handy & Thigpen, 2018 ▪ Khosravi et al., 2016 ▪ Tao et al., 2022
620-09	Use of internet	▪ Trip purpose (400-04) *The use of the internet can have a substituting, or stimulating effect on the need to travel (Nuhn & Hesse, 2006)*	▪ Nuhn & Hesse, 2006 ▪ Wittwer & Berger, 2021
620-10	Personality	▪ Learning theory approach (Chapter 2.4.3) ▪ Experiences (620-05) ▪ Habits (620-01) ▪ Lifestyle (621) ▪ Religious principles (621-01)	▪ Widmer et al., 2020
621	Lifestyle	▪ Mobility style (621-05) ▪ Personality (620-10) ▪ Society's expectations (631-06) ▪ Values connected to society (652)	▪ Chakrabati, 2016 ▪ Hoor, 2021 ▪ Ko et al., 2018 ▪ Nuhn & Hesse, 2006
621-01	Religious principles	▪ Lifestyle (621) ▪ Personality (620-10) ▪ Values (650)	▪ Widmer et al., 2020
621-02	Exclusivity in lifestyle	▪ Lifestyle (621) ▪ Individualism (651-02) ▪ Prestige (630-03) ▪ Status (630-02) ▪ Values connected to society (652)	▪ Widmer et al., 2020
621-03	Leisure time activities	▪ Amount of leisure time (612-04) ▪ Personality (620-10) ▪ Trip purpose (400-04)	▪ Widmer et al., 2020
621-04	Being active	▪ Effort (649-03) ▪ Fitness (612-02) ▪ Impact on health (643-07) ▪ Physical and mental health (612-08)	▪ Heinen et al., 2019
621-05	Mobility style	▪ Learned mobility behaviour (621-06) ▪ Lifestyle (621) ▪ Mobility behaviour of reference persons (621-07) ▪ e.g.: pro:NEWmotion-typology (Millonig et al., 2023)	▪ Rammert, 2021 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020
621-06	Learned mobility behaviour	▪ Learning theory approach (Chapter 2.4.3) ▪ Subjective benefit model (Chapter 2.4.4) ▪ Fun while using certain transport modes (653-05) ▪ Information situation (644) ▪ Mobility behaviour of reference persons (621-07) ▪ Preferences towards transport modes (653-04) ▪ Social environment / network (630-01)	▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Hoor, 2021 ▪ Tao et al., 2022 ▪ Wittwer & Berger, 2021
621-07	Mobility behaviour of reference persons	▪ Fun while using certain transport modes (653-05) ▪ Mobility style (621-05) ▪ Preferences towards transport modes (653-04) ▪ Social environment / network (630-01)	▪ Groß, 1998

Table 17: Mentioned social environment factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
630-01	Social environment / network	▪ Lifestyle (621) ▪ Mobility behaviour of reference persons (621-07) ▪ Perception of (relationships to) other persons (646) ▪ Values connected to society (652)	▪ Khosravi et al., 2016 ▪ Rammert, 2021 ▪ Widmer et al., 2020
630-02	Status	▪ Individualism (651-02) ▪ Prestige (630-03) ▪ Self-perception (641) ▪ Self-presentation (620-04)	▪ Groß, 1998 ▪ Hoor, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
630-03	Prestige	▪ Individualism (651-02) ▪ Self-perception (641) ▪ Self-presentation (620-04) ▪ Status (630-02)	▪ Flade & Wullkopf, 2002 ▪ Groß, 1998 ▪ Hoor, 2021 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
630-04	Position in the household	▪ Age (510-01) ▪ Children in the household (521-03) ▪ Gender (510-02) ▪ Household structure (521) ▪ Income (520-01) ▪ Number of working people in the household (521-02) ▪ subordination vs. organisation (630-06)	▪ Groß, 1998
630-05	Internal household organisation	▪ Children in the household (521-03) ▪ Household structure (521) ▪ Number of working people in the household (521-02) ▪ Ownership of transport options (520-02)	▪ Groß, 1998
630-06	subordination vs. organisation	▪ Position in the household (630-04) ▪ Personality (620-10) ▪ Lifestyle (621)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
631	**norms & expectations**	▪ Norm activation theory (Chapter 2.4.6)	
631-01	social / cultural norms	▪ Norm activation theory (Chapter 2.4.6) ▪ Social-psychological approaches (Chapter 2.4.6) ▪ Cultural anchoring / cultural group (631-04) ▪ Society's expectations (631-06)	▪ Daubitz, 2021 ▪ Flade & Wullkopf, 2002 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Ko et al., 2018 ▪ Tao et al., 2022 ▪ Weninger et al., 2021 ▪ Wolking, 2021
631-02	Informal norms and values	▪ Norm activation theory (Chapter 2.4.6) ▪ Constraints (404) ▪ Society's expectations (631-06)	▪ Flade & Wullkopf, 2002
631-03	Codified standards	▪ Norm activation theory (Chapter 2.4.6) ▪ Constraints (404) ▪ Society's expectations (631-06)	▪ Flade & Wullkopf, 2002

631-04	Cultural anchoring / cultural group	▪ Ethnic background (510-06) ▪ Experiences (620-05) ▪ Learned mobility behaviour (621-06) ▪ Lifestyle (621) ▪ Mobility style (621-05) ▪ Social environment / network (630-01)	▪ Chakrabati, 2016 ▪ Daubitz, 2021 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023
631-05	Subjective norms	▪ Norm activation theory (Chapter 2.4.6) ▪ Theory of planned behaviour (Chapter 2.4.8) ▪ Perception of a transport mode (641-01) ▪ Society's expectations (631-06)	▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Ko et al., 2018 ▪ Tao et al., 2022 ▪ Widmer et al., 2020
631-06	Society's expectations	▪ Behaviour control (641-01) ▪ Expectations regarding the use of transportation modes (631-07) ▪ Fears (641-02) ▪ Prestige (630-03) ▪ Social / cultural norms (631-01) ▪ Status (630-02) ▪ Stress (641-03) ▪ Subjective norms (631-05)	▪ Widmer et al., 2020
631-07	Expectations regarding the use of transportation modes	▪ Behaviour control (641-01) ▪ Society's expectations (631-06) ▪ Subjective norms (631-05)	▪ Chakrabati, 2016 ▪ Groß, 1998 ▪ McCreery-Phillips & Heydari, 2023 ▪ Wittwer & Berger, 2021

Table 18: Mentioned perception factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
641	**Self-perception**	▪ Lifestyle (621) ▪ Personality (620-10) ▪ Physical and mental health (612-08) ▪ Prestige (630-03) ▪ Self-esteem (620-03) ▪ Self-presentation (620-04) ▪ Status (630-02)	▪ Rammert, 2021
641-01	Behaviour control	▪ Norm activation theory (Chapter 2.4.6) ▪ Theory of planned behaviour (Chapter 2.4.8)	▪ Flade & Wullkopf, 2002 ▪ Heinen et al., 2019 ▪ Hobiger, 2021 ▪ Tao et al., 2022
641-02	Fears	▪ Constraint models (Chapter 2.4.7) ▪ Authority constraints (404-02) ▪ Crime rate (232-02) ▪ Lighting (222-02) ▪ Nausea when using a mode of transport (612-10) ▪ Restrictions (612) ▪ Street design (222) ▪ Time constraints (404-01)	▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Groß, 1998 ▪ Hoor, 2021

641-03	Stress-level	▪ Behaviour control (641-01) ▪ Control over travel situation (642-06) ▪ Perceived options for action (642-02) ▪ Risk of accidents and traffic jams (321-02) ▪ Stress at work (641-04)	▪ Chatterjee et al., 2019 ▪ Handy & Thigpen, 2018 ▪ Hoor, 2021 ▪ Jang & Ko, 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Tao et al., 2022 ▪ Weninger et al., 2021
641-04	Stress at work	▪ Attractiveness of the workplace (648) ▪ Employment (511) ▪ Stress-level (641-03)	▪ Chen et al., 2023
642	**Psychological travel expense**	▪ Subjective benefit model (Chapter 2.4.4) ▪ Effort (649-03) ▪ Expectations regarding the use of transportation modes (631-07) ▪ Habits (620-01) ▪ social / cultural norms (631-01) ▪ Society's expectations (631-06)	▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Weninger et al., 2021
642-01	Travel satisfaction	▪ Constraint models (Chapter 2.4.7) ▪ Authority constraints (404-02) ▪ Control over travel situation (642-06) ▪ Habits (620-01) ▪ Time constraints (404-01)	▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Tao et al., 2022
642-02	Perceived options for action	▪ Models of information processing (Chapter 2.4.5) ▪ Norm activation theory (Chapter 2.4.6) ▪ Control over travel situation (642-06) ▪ Information situation (644)	▪ Flade & Wullkopf, 2002
642-03	Cognitive capacity to judge different attributes	▪ Subjective benefit model (Chapter 2.4.4) ▪ Effort (649-03) ▪ Habits (620-01) ▪ Society's expectations (631-06)	▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Widmer et al., 2020 ▪ Wolking, 2021
642-04	Spatial resistance of the trip	▪ Space-Time prism (Chapter 2.4.7) ▪ Distance / Length of the trip (400-11) ▪ Diversion factor (643-10) ▪ Information situation (644) ▪ Public transport accessibility (index) (232-07) ▪ Street connectivity (232-06)	▪ Nuhn & Hesse, 2006
642-05	Time resistance of the trip	▪ Space-Time prism (Chapter 2.4.7) ▪ Diversion factor (643-10) ▪ Information situation (644) ▪ Public transport accessibility (index) (232-07) ▪ Street connectivity (232-06) ▪ Trip duration (403)	▪ Nuhn & Hesse, 2006
642-06	Control over travel situation	▪ Flexibility (323-05) ▪ Flexibility in working time (511-05) ▪ Freedom (652-06) ▪ Information situation (644) ▪ Stress-level (641-03) ▪ Travel satisfaction (642-01)	▪ Chatterjee et al., 2019

642-07	Impairment due to travel situation	▪ Control over travel situation (642-06) ▪ Flexibility in working time (511-05) ▪ Risk of accidents and traffic jams (321-02) ▪ Stress-level (641-03) ▪ Travel speed (322-05) ▪ Trip duration (403)	▪ Chatterjee et al., 2019 ▪ Groß, 1998
643	**Perception of a transport mode**	▪ Learning theory approach (Chapter 2.4.3) ▪ Experiences (620-05) ▪ Learned mobility behaviour (621-06) ▪ Mobility behaviour of reference persons (621-07)	▪ Chakrabati, 2016 ▪ Widmer et al., 2020
643-01	Image	▪ Constraint models (Chapter 2.4.7) ▪ Accessibility of the transport mode (Subcategory 31) ▪ Advertisement (643-02) ▪ 'Climate' for certain modes of transport (130-02) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Costs (322-06) ▪ Information situation (644) ▪ Restrictions (612) ▪ Trip duration (403)	▪ Groß, 1998
643-02	Advertisement	▪ Image (643-01) ▪ Information situation (644)	▪ Groß, 1998
643-03	Costs	▪ Constraint models (Chapter 2.4.7) ▪ Financial constraints (322-08) ▪ Price-performance ratio (322-07) ▪ Price relationship to other destinations (322-09) ▪ Timing of costs (322-10)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Weninger et al., 2021
643-04	Travel time	▪ Constraint models (Chapter 2.4.7) ▪ Authority constraints (404-02) ▪ Effort (649-03) ▪ Fears (641-02) ▪ Fitness (612-02) ▪ Information situation (644) ▪ Need to transfer (400-01) ▪ Stress (641-03) ▪ Time constraints (404-01) ▪ Topography (210-03) ▪ Trip duration (403)	▪ Handy et al., 2005 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
643-05	Difficulty	▪ Behaviour control (641-01) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Comfort (323) ▪ Effort (649-03) ▪ Fitness (612-02) ▪ Need to transfer (400-01) ▪ Perceived options for action (642-02) ▪ Trip duration (403) ▪ Topography (210-03)	▪ Groß, 1998

643-06	Safety of a transport mode	▪ Barrier-free accessibility (649-04) ▪ Comfort (323) ▪ Risk of accidents and traffic jams (321-02) ▪ Safety (611-01) ▪ Street design (222)	▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ Wittwer & Berger, 2021
643-07	Impact on health	▪ Physical and mental health (612-08) ▪ Restrictions (612)	▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
643-08	Regularity of use	▪ Cognitive maps (Chapter 2.4.5) ▪ Habits (620-01)	▪ Groß, 1998
643-09	Accessibility	▪ Accessibility of transport modes (Subcategory 31) ▪ Barrier-free accessibility (649-04) ▪ Effort (649-03) ▪ Fitness (612-02) ▪ Information situation (644)	▪ Cao et al., 2022 ▪ Daubitz, 2021 ▪ Groß, 1998
643-10	Diversion factor	▪ Impairment due to travel situation (642-07) ▪ Trip distance (400-11) ▪ Trip duration (403) ▪ Speed (322-05)	▪ Groß, 1998
644	**Information situation**	▪ Cognitive capacity to judge different attributes (642-03) ▪ Subjective benefit model (Chapter 2.4.4) ▪ Perception of the transport mode (643) ▪ Habits (620-01) ▪ Effort (649-03) ▪ Comfort (323) ▪ Curiosity (651-04) ▪ Convenience (651-05)	▪ Federal Ministry for Digital and Transport - Germany (BMDV), 2022 ▪ Wolking, 2021
644-01	Information options	▪ Counselling services (644-05) ▪ Real time information (644-02) ▪ Timetable (-design) (644-08) ▪ Use of the internet (620-09)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
644-02	Real time information	▪ Subjective benefit model (Chapter 2.4.4) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Information quality (644-06) ▪ Use of the internet (620-09)	▪ Chakrabati, 2016
644-03	Tariff information	▪ Cognitive capacity to judge different attributes (642-03) ▪ Costs (322-06) ▪ Price-performance ratio (322-07) ▪ Price relationship to other destinations (322-09)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021
644-04	Transport offers	▪ Accessibility of transport modes (Subcategory 31) ▪ Barrier-free accessibility (649-04) ▪ Daytime (401-01) ▪ existence and quality of pedestrian and cycling infrastructure (221-04) ▪ Type of public transport (312-01) ▪ Weekday (401-03)	▪ Groß, 1998

644-05	Counselling services	▪ Information options (644-01) ▪ Information quality (644-06) ▪ Tariff information (644-03) ▪ Transport offers (644-04)	▪ Groß, 1998
644-06	Information quality	▪ Cognitive capacity to judge different attributes (642-03) ▪ Real-time information (644-02)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
644-07	Comprehensibility of the timetables	▪ Cognitive capacity to judge different attributes (642-03) ▪ Timetable (-design) (644-08) ▪ Transport offers (644-04) ▪ Type of public transport (312-01)	▪ Groß, 1998
644-08	Timetable (-design)	▪ Barrier-free accessibility (649-04) ▪ Comprehensibility of the timetables (644-07) ▪ Information quality (644-06) ▪ Real time information (644-02)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
645	**Environmental perceptions**	▪ Environmental-psychological approaches (Chapter 2.4.1) ▪ Environmental awareness (654-01) ▪ Values connected to the environment (654)	▪ Flade & Wullkopf, 2002
646	**Perception of (relationships to) other persons**		
646-01	Other traffic participants	▪ Flexibility (323-05) ▪ Independence (652-07) ▪ Prestige (630-03) ▪ Status (630-02) ▪ Traffic safety (649-09)	▪ De Vos, 2019 ▪ Groß, 1998 ▪ Wittwer & Berger, 2021
646-02	Social security	▪ Environmental awareness (654-01) ▪ Income (520-01) ▪ Prestige (630-03) ▪ Society's expectations (631-06) ▪ Status (630-02)	▪ Groß, 1998 ▪ Wittwer & Berger, 2021
646-03	Social environment	▪ Lifestyle (621) ▪ Mobility behaviour of reference persons (621-07) ▪ Mobility style (621-05) ▪ Quality of relations with neighbours (647-01) ▪ Society's expectations (631-06)	▪ Rammert, 2021
647	**Attractiveness of the neighbourhood**	▪ Accessibility of facilities (233) ▪ Attractiveness of the street space (649-06) ▪ Characteristics of the neighbourhood (232) ▪ Street design (222) ▪ Subjective perceived environmental attributes (654-02)	▪ Cao et al., 2022 ▪ Chatterjee et al., 2019 ▪ Jang & Ko, 2019 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
647-01	Quality of relations with neighbours	▪ Perception of (relationships to) other persons (646) ▪ Satisfaction with the neighbourhood (647-10)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ Jang & Ko, 2019 ▪ Khosravi et al., 2016 ▪ Sun et al., 2022

647-02	Cleanliness	▪ Aesthetics (647-06) ▪ Environmental awareness (654-01) ▪ Physical and mental health (612-08)	▪ Chen et al., 2023
647-03	Air pollution	▪ Emissions (322-13) ▪ Environmental awareness (654-01) ▪ Environmental perceptions (645)	▪ Chen et al., 2023 ▪ Khosravi et al., 2016 ▪ McCreery-Phillips & Heydari, 2023 ▪ Rammert, 2021 ▪ Sun et al., 2022
647-04	Share of green space	▪ Aesthetics (647-06) ▪ Green spaces /parks (233-03) ▪ Land-use (232-10) ▪ Maintenance of green spaces (233-04) ▪ Physical and Mental health (612-08) ▪ Season (401-04) ▪ Trees (647-05) ▪ Weather (401-05)	▪ Chen et al., 2023 ▪ Widmer et al., 2020
647-05	Trees	▪ Aesthetics (647-06) ▪ Green spaces /parks (233-03) ▪ Maintenance of green spaces (233-04) ▪ Physical and Mental health (612-08)	▪ Widmer et al., 2020
647-06	Aesthetics	▪ Physical and Mental health (612-08) ▪ Share of green space (647-04) ▪ Trees (647-05)	▪ Khosravi et al., 2016
647-07	Representation of social status	▪ Accessibility with transport modes (Subcategory 31) ▪ Aesthetics (647-06) ▪ Cleanliness (232-03) ▪ Land-use (232-10) ▪ Noise (232-04) ▪ Status (630-02) ▪ Prestige (630-03) ▪ Population/settlement/building density (220-03)	▪ Khosravi et al., 2016
647-08	Land-use diversity	▪ Accessibility of facilities (233) ▪ Characteristics of the neighbourhood (232) ▪ Land-use (232-10) ▪ Share of green space (647-04) ▪ Population/settlement/building density (220-03)	▪ Cao et al., 2022
647-09	Safety of the neighbourhood	▪ Crime rate (232-02) ▪ Quality of relations with neighbours (647-01) ▪ Safety (611-01) ▪ Traffic safety (649-09)	▪ Cao et al., 2022 ▪ Chen et al., 2023 ▪ Khosravi et al., 2016 ▪ Sun et al., 2022
647-10	Satisfaction with the neighbourhood	▪ Accessibility of facilities (233) ▪ Accessibility of transport modes (Subcategory 31) ▪ Attractiveness of the neighbourhood (647) ▪ Attractiveness of the street space (649-06) ▪ Characteristics of the neighbourhood (232) ▪ Street design (222) ▪ Subjective perceived environmental attributes (654-02)	▪ Jang & Ko, 2019 ▪ Rammert, 2021

648	**Attractiveness of workplace**	▪ Employment (511) ▪ Income (520-01) ▪ Surroundings of start and destination (402)	▪ Chatterjee et al., 2019
648-01	Freedom in terms of work intensity	▪ Amount of leisure time (612-04) ▪ Flexibility in working time (511-05) ▪ Labour hours (511-03) ▪ Number of working days (511-04) ▪ Physical and mental health (612-08) ▪ Regularity of heavy physical work (648-04) ▪ Regularity of heavy mental work (648-05) ▪ Satisfaction with the workplace (648-08) ▪ Well-being (620-08)	▪ Chen et al., 2023
648-02	Working hours (per month)	▪ Flexibility in working time (511-05) ▪ Form of employment (511-01) ▪ Income (520-01) ▪ Labour hours (511-03) ▪ Number of working days (511-04)	▪ Chen et al., 2023
648-03	Regular overtime	▪ Constraint models (Chapter 2.4.7) ▪ Authority constraints (404-02) ▪ Flexibility in working time (511-05) ▪ Labour hours (511-03) ▪ Number of working days (511-04) ▪ Stress-level (641-03) ▪ Time constraints (404-01)	▪ Chen et al., 2023
648-04	Regularity of heavy physical work	▪ Fitness (612-02) ▪ Labour hours (511-03) ▪ Number of working days (511-04) ▪ Physical and mental health (612-08) ▪ Stress-level (641-03) ▪ Well-being (620-08)	▪ Chen et al., 2023
648-05	Regularity of heavy mental work	▪ Flexibility in working time (511-05) ▪ Labour hours (511-03) ▪ Number of working days (511-04) ▪ Physical and mental health (612-08) ▪ Stress-level (641-03) ▪ Well-being (620-08)	▪ Chen et al., 2023
648-06	Offers for employees	▪ Income (520-01) ▪ Self-esteem (620-03) ▪ Surroundings of start and destination (402)	▪ Heinen et al., 2019
648-07	Respect from employers	▪ Physical and mental health (612-08) ▪ Satisfaction with workplace (648-08) ▪ Self-esteem (620-03) ▪ Well-being (620-08)	▪ Chen et al., 2023
648-08	General satisfaction with workplace	▪ Constraint models (Chapter 2.4.7) ▪ Attractiveness of the workplace (648) ▪ Employment (511) ▪ Financial constraints (322-08) ▪ Income (520-01) ▪ Travel distance (400-11) ▪ Travel satisfaction (642-01) ▪ Trip duration (403)	▪ Chen et al., 2023

649	**Attractiveness of the travel route**	▪ Information situation (644) ▪ Accessibility of the transport mode (Subcategory 31) ▪ Mixed-use in neighbourhoods (22-04) ▪ Experiences (620-05)	▪ Heinen et al., 2019
649-01	Comfort of the travel route	▪ Accessibility of the transport mode (Subcategory 31) ▪ Barrier-free accessibility (649-04) ▪ Comfort of the transport mode (323) ▪ Effort (649-03) ▪ Information situation (644) ▪ Street design (222)	▪ Chatterjee et al., 2019 ▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022
649-02	Aesthetics	▪ Attractiveness of the street space (649-06) ▪ Diversity of land-use along the route (649-07) ▪ Street design (222)	▪ Cao et al., 2022
649-03	Effort	▪ Fitness (612-02) ▪ Comfort (323) ▪ Cognitive capacity to judge different attributes (642-03) ▪ Information situation (644) ▪ Models of information processing (Chapter 2.4.5) ▪ Barrier-free accessibility (649-04)	▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Wittwer & Berger, 2021
649-04	Barrier-free accessibility	▪ Accessibility of the transport mode (Subcategory 31) ▪ Comfort of the travel route (649-01) ▪ Effort (649-03) ▪ Street design (222)	▪ De Vos, 2019
649-05	Experience value	▪ Autotelic activities (Chapter 2.4.5) ▪ Aesthetics (647-06) ▪ Attractiveness of the street space (649-06) ▪ Environmental perception (645) ▪ Street design (222)	▪ Groß, 1998
649-06	Attractiveness of the street space	▪ Aesthetics (647-06) ▪ Barrier-free accessibility (649-04) ▪ Experience value (649-05) ▪ Safety (611-01) ▪ Street design (222)	▪ Wittwer & Berger, 2021
649-07	Diversity of land-use along the route	▪ Aesthetics (647-06) ▪ Attractiveness of the street space (649-06) ▪ Experience value (649-05) ▪ Land-use diversity in the neighbourhood (647-08) ▪ Mixed-use in neighbourhoods (220-04) ▪ Street design (222)	▪ Cao et al., 2022
649-08	Traffic volume	▪ Risk of accidents and traffic jams (321-02) ▪ Speed (322-05) ▪ Stress-level (641-03) ▪ Traffic safety (649-09)	▪ Chatterjee et al., 2019 ▪ McCreery-Phillips & Heydari, 2023

649-09	Traffic safety	▪ Clearness of city design (220-08) ▪ Pedestrian friendliness (232-09) ▪ Perception of a transport mode (643) ▪ Safety (611-01) ▪ Safety of the transport mode (321-01) ▪ Speed (322-05) ▪ Speed limits (131-01) ▪ Street design (222) ▪ Traffic volume (649-08)	▪ Cao et al., 2022 ▪ Chatterjee et al., 2019 ▪ De Vos, 2019 ▪ Groß, 1998 ▪ Handy et al., 2005 ▪ Heinen et al., 2019 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Rammert, 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
649-10	Convenience of the route	▪ Cognitive maps (Chapter 2.4.5) ▪ Experiences (620-05) ▪ Habits (620-01) ▪ Theory of planned behaviour (Chapter 2.4.8) ▪ Planning effort (323-01) ▪ Socio-psychological approaches (Chapter 2.4.6)	▪ McCreery-Phillips & Heydari, 2023 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022

Table 19: Mentioned value / attitude / preference factors for the transport mode choice

ID	Factor	Selected linkages to other concepts / factors	Source(s)
650	**Values / attitudes / preferences**	▪ Constraint models (Chapter 2.4.7) ▪ Norm activation theory (Chapter 2.4.6) ▪ Subjective benefit models (Chapter 2.4.4) ▪ Theory of planned behaviour (Chapter 2.4.8)	▪ Chakrabati, 2016 ▪ Hobiger, 2021 ▪ Jang & Ko, 2019 ▪ Nuhn & Hesse, 2006 ▪ Tao et al., 2022 ▪ Weninger et al., 2021
651	**Individual values**	▪ Lifestyle (621) ▪ Personality (620-10) ▪ Physical and mental restrictions (612) ▪ Self-perception (641)	▪ Wittwer & Berger, 2021
651-01	Interest in exercise	▪ Environmental awareness (654-01) ▪ Fitness (612-02) ▪ Health (612-08) ▪ Lifestyle (621) ▪ Personality (620-10)	▪ Heinen et al., 2019 ▪ Jang & Ko, 2019 ▪ Wittwer & Berger, 2021
651-02	Individualism	▪ Freedom (652-06) ▪ Independence (652-07) ▪ Internal household organisation (630-05) ▪ Lifestyle (621) ▪ Personality (620-10) ▪ Privacy (652-05)	▪ Nuhn & Hesse, 2006 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wolking, 2021
651-03	Wanting to be a role-model	▪ Environmental psychological approach (Chapter 2.4.1) ▪ Environmental awareness (654-01) ▪ Open / conservative (652-02) ▪ Personality (620-10) ▪ Preferences towards transport modes (653-04)	▪ Wittwer & Berger, 2021
651-04	Curiosity	▪ Attractiveness of the travel route (649) ▪ Personality (620-10) ▪ Preferences towards transport modes (653-04)	▪ Groß, 1998

651-05	Convenience	▪ Subjective benefit model (Chapter 2.4.4) ▪ Comfort (323) ▪ Features (324 & 325) ▪ Habits (620-01)	▪ Groß, 1998 ▪ Heinen et al., 2019 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
651-06	Willingness to take risks	▪ Curiosity (651-04) ▪ Perception of a transport mode (643) ▪ Personality (620-10) ▪ Traffic safety (649-09) ▪ Safety (611-01)	▪ Groß, 1998 ▪ Widmer et al., 2020
651-07	Security	▪ Mental health (612-08) ▪ Safety (611-01)	▪ Groß, 1998 ▪ Widmer et al., 2020
651-08	Life / personal satisfaction	▪ Lifestyle (621) ▪ Perception of a transport mode (643) ▪ Personality (620-10) ▪ Travel satisfaction (642-01) ▪ Work satisfaction (648-08)	▪ Chatterjee et al., 2019 ▪ Chen et al., 2023 ▪ Rammert, 2021
652	**Values connected to society**		
652-01	Material / post-material attitude	▪ Personality (620-10) ▪ Preferences towards transport modes (653-04)	▪ Nuhn & Hesse, 2006
652-02	Open / conservative	▪ Lifestyle (621) ▪ Personality (620-10) ▪ Preferences towards transport modes (653-04)	▪ Widmer et al., 2020
652-03	Gender equality	▪ Open / Conservative (652-02) ▪ Personality (620-10)	▪ Widmer et al., 2020
652-04	Awareness of tradition	▪ Open / Conservative (652-02) ▪ Personality (620-10) ▪ Preferences towards transport modes (653-04)	▪ Widmer et al., 2020
652-05	Privacy	▪ Individualism (651-02)	▪ Groß, 1998 ▪ Khosravi et al., 2016 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
652-06	Freedom	▪ Constraint models (Chapter 2.4.7) ▪ Independence (652-07) ▪ Internal household organisation (630-05)	▪ Groß, 1998
652-07	Independence	▪ Internal household organisation (630-05) ▪ Individualism (651-02) ▪ Freedom (652-06) ▪ Convenience (651-05) ▪ Household structure (521) ▪ Age (510-01) ▪ Employment (511)	▪ Groß, 1998 ▪ NWL - Stabsstelle Strategie, Innovation und Digitale Entwicklung, 2022 ▪ Wittwer & Berger, 2021 ▪ Wolking, 2021
652-08	Mobility independence	▪ Accessibility of transport options (Subcategory 31) ▪ Availability of public transport season ticket (312-04) ▪ Driving licence possession (311-01) ▪ Freedom (652-06) ▪ Internal household organisation (630-05) ▪ Ownership of transport options (520-02)	▪ Weninger et al., 2021

653	**Values connected to travel**	▪ Attractiveness of the travel route (649) ▪ Learned mobility behaviour (621-06) ▪ Mobility style (621-05) ▪ Perception of transport modes (643)	▪ Schwanen & Mokhtarian, 2004
653-01	Wanderlust / enjoyment of driving / travelling	▪ Subjective benefit models (Chapter 2.4.4) ▪ Fun while using transport modes (653-05) ▪ Perception of transport modes (643) ▪ Psychological travel expense (642) ▪ Travel satisfaction (642-01)	▪ De Vos, 2019 ▪ Handy & Thigpen, 2018
653-02	Speed rush	▪ Lifestyle (621) ▪ Personality (620-10) ▪ Preferences towards transport modes (653-04) ▪ Psychological travel expense (642)	▪ Groß, 1998
653-03	Flexibility	▪ Curiosity (651-04) ▪ Flexibility in work time (511-05) ▪ Perception of the travel route (649) ▪ Time constraints (404-01)	▪ Heinen et al., 2019 ▪ Wittwer & Berger, 2021
653-04	Preferences towards transport modes	▪ Subjective benefit models (Chapter 2.4.4) ▪ Enjoyment of travelling (653-01) ▪ Fun while using transport modes (653-05) ▪ Perception of transport modes (643) ▪ Travel satisfaction (642-01)	▪ Cao et al., 2022 ▪ Chakrabati, 2016 ▪ De Vos, 2019 ▪ Handy et al., 2005 ▪ Hoor, 2021 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Tao et al., 2022
653-05	Fun while using a transport mode	▪ Subjective benefit models (Chapter 2.4.4) ▪ Enjoyment of travelling (653-01) ▪ Perception of transport modes (643) ▪ Preferences towards transport modes (653-04) ▪ Speed rush (653-02)	▪ Heinen et al., 2019 ▪ Hoor, 2021 ▪ McCreery-Phillips & Heydari, 2023 ▪ Wittwer & Berger, 2021
654	Values connected to the environment	▪ Environmental psychological approach (Chapter 2.4.1)	▪ Widmer et al., 2020
654-01	Environmental awareness	▪ Environmental psychological approach (Chapter 2.4.1) ▪ Wanting to be a role model (651-03)	▪ Chen et al., 2023 ▪ Hoor, 2021 ▪ Ko et al., 2018 ▪ McCreery-Phillips & Heydari, 2023 ▪ Weninger et al., 2021 ▪ Widmer et al., 2020 ▪ Wittwer & Berger, 2021
654-02	Subjective perceived environmental attributes	▪ Environmental psychological approach (Chapter 2.4.1) ▪ Attractiveness of the travel route (649) ▪ Experiences (620-05)	▪ Widmer et al., 2020

Appendix B: Data preparation of the PPGIS data

The raw data provided by Maptionnaire was edited and condensed following specified criteria to allow for the multinomial logistical regression. In a first step, the mapped home locations were cleaned of potential multiple mappings, leaving only one home-location for each respondent. Following this reduction, the data was enriched with information from the urban atlas class 2018 (European Environment Agency, 2020c) at the home location, the "ÖV-Güteklasse" 2023 (austriatech, 2024) at home location and workplace. The street network distance between the home location and workplace based on the modified GIP (Graphenintegrationsplattform Österreich) Network (ÖVDAT - Österreichisches Institut für Verkehrsdateninfrastruktur, 2023).

For the calculation of the distance the GIP-Network (ÖVDAT - Österreichisches Institut für Verkehrsdateninfrastruktur, 2023) has been modified. The in table 20 mentioned functional road classes (FRCs) have been deleted from the data set. Additionally, with the QGIS plugin "disconnected Islands" (Smythe, 2020) all disconnected Islands were removed from the remaining GIP.

Table 20: Deleted FRCs from the GIP for the calculation of the road network distance between home location and workplace

FRC	German name (Long)	English translation
020	Bahntrasse Hauptnetz	Railway line – Main network
021	Bahntrasse Ergänzungsnetz	Railway line – Supplementary network
022	Bahntrasse Anschlussbahn, Verbindungsgleis, sonstiges Gleis	Railway line – Railway siding, connecting track, other tracks
024	Straßenbahntrasse	Tram route
025	U-Bahn-Trasse	Underground line
031	Fähre	Ferry
103	Seilbahn und Sonstige	Cable car and other

The edited GIP was the basis for the distance determination which was done using the QGIS Plugin QNEAT3 (Raffler, 2023) with the function "OD Matrix from Layers as Table (M:N)". The calculated total distance, including a value for the entry and exit of the network was used further.

The dataset was then iteratively condensed to be suitable for the multinomial logistical regression (Chapter 4.4; Appendix E). The steps of data clean up and the number of OD-Pairs available at a certain step can be found in table 21.

Table 21: Data clean-up steps for the multinomial logistical regression

Step no.	Description	No. of remaining OD-Pairs	Share of remaining OD-Pairs
Base	-	2,190	100.0%
01	No. of mapped **workplaces** > 8	2,123	96.9%
02	**Home location** has been mapped	2,009	91.7%
03	**Workplace** has been mapped	1,142	52.1%
04	**Main occupation** is given	1,142	52,1%
05	**Age** is given	1,142	52,1%
06	**Gender** is given	1,142	52,1%
07	**Monthly household income** is given	1,118	51.1%
08	**Household structure** is given	1,115	50,9%
09	Answers for the **children's age** have been answered	1,115	50,9%
10	**Level of education** is given	1,114	50,9%
11	**Years in current main residence** is given	1,110	50.7%
12	**Ownership type** of residence is given	1,038	47.4%
13	**Housing type** of the residence is given	983	44.9%
14	Has answered "**The air is clean in my neighborhood**"	951	43,4%
15	Has answered "**There are enough green areas in my neighborhood**"	919	42,0%
16	Has answered "**Overall I am satisfied with my neighborhood**"	899	41,1%
17	Has answered "**There are many places to go within easy walking distance of my home**"	898	41,0%
18	Has answered "**There are all kinds of stores in my neighborhood**"	898	41,0%
19	Has answered "**I can find most services I need in my neighborhood**"	897	41,0%
20	Has given a main **transport mode** for the trip to work	874	39,9%
21	The mapped **workplace** is within Austria	864	39,5%
22	The **transport mode** is either car, public transport or active mobility	853	38,9%
23	The **distance** between home location and workplace is larger than 50 meters.	841	38,4%
24	Home Location is within study area; Distance between work locations of same respondent is below 50 meters; mapped work location has a distance over 500m to the next building	835	38,1%
25	Check for availability of trip data (see Chapter 4.3.1) for all analysed transport modes using VOR AnachB (anachb.vor.at) for each trip	818	37,4%
26	Has answered "**The dwelling has enough space for everyone living in it**"	809	36,9%

Appendix C: List of variables for the multinomial logistical regression

Table 22: List of variables for the multinomial logistical regression

Var. ID.	Name	Data type	Data Source	Factors of Chapter 4.1
01	Independent Variable: Transport Mode for commuting	Categorical	Survey	
	Dependent Variables			
02	Main occupation	Categorical	Survey	▪ Employment (511)
03	Age category	Categorical	Survey	▪ Age (510-01)
04	Gender	Binary*	Survey	▪ Gender (510-02)
05	Monthly household income	Categorical	Survey	▪ Income (520-01)
06	Highest level of education	Categorical	Survey	▪ Level of education (510-07)
07	Since when in main residence	Categorical	Survey	▪ duration of residence (230-02)
08	Household type	Categorical	Survey	▪ Household structure (521)
09	Children aged 0-5	Binary	Survey	▪ Children in the household (521-03) ▪ Children at school age (521-04)
10	Children aged 6-14	Binary	Survey	▪ Children in the household (521-03) ▪ Children at school age (521-04)
11	Children aged 15 or older	Binary	Survey	▪ Children in the household (521-03)
12	Home office usage	Categorical	Survey	▪ Home office share (511-07)
13	Enough space in dwelling	Likert	Survey	▪ Lifestyle (621) ▪ Personality (620-10)
14	Perceived urbanity index ▪ *places in walking distance* ▪ *all kinds of stores* ▪ *most services I need*	Interval	Survey	▪ Pedestrian friendliness (232-09) ▪ Mixed-use in neighbourhoods (220-04)
15	Enough green areas in neighbourhood	Likert	Survey	▪ Green spaces /parks (233-03) ▪ Share of green space (647-04)
16	Air is clean in neighbourhood	Likert	Survey	▪ Air pollution (647-03)
17	Neighbourhood satisfaction	Likert	Survey	▪ Satisfaction with the neighbourhood (647-10)
18	Housing type	Categorical	Survey	▪ Building type (231-02)
19	Ownership type	Categorical	Survey	▪ Ownership type (231-01)

20	Urban Atlas Class of home location (Aggregated)	Categorical	European Environment Agency, 2020c	▪ Geographical area type (210-02)
21	ÖV-Güteklasse of home location	Categorical	Austriatech, 2024	▪ Public transport accessibility (index) (232-07)
22	Average Tree Cover Density in a 300m buffer around home location	Interval	European Environment Agency, 2020b	▪ Green spaces /parks (233-03) ▪ Trees / Greenery (222-10)
23	Average Imperviousness in a 300m buffer around home location	Interval	European Environment Agency, 2020a	▪ Green spaces /parks (233-03) ▪ population/ settlement/ building density (220-03) ▪ Geographical area type (210-02)
24	Number of Urban Atlas Classes in a 300m buffer around the home location	Interval	European Environment Agency, 2020c	▪ Geographical area type (210-02) ▪ Mixed-use in neighbourhoods (220-04)
25	Number of **aggregated** Urban Atlas Classes **(Level 3)** in a 300m buffer around the home location	Interval	European Environment Agency, 2020c	▪ Geographical area type (210-02) ▪ Mixed-use in neighbourhoods (220-04)
26	Percentage of Blue spaces in a 300m buffer around the home location	Interval	European Environment Agency, 2020c	▪ Blue spaces (233-05)
27	Percentage of Green spaces in a 300m buffer around the home location	Interval	European Environment Agency, 2020c	▪ Green spaces /parks (233-03)
28	Average Population density within the 300m buffer around the home location	Interval	Bondarenko et al., 2020	▪ population/ settlement/ building density (220-03)
29	Total network distance between home location and workplace	Interval	Calculated; explanation plus data sources in Appendix B	▪ Distance / Length of the trip (400-11)
30	ÖV-Güteklasse of the workplace	Categorical	Austriatech, 2024	▪ Public transport accessibility (index) (232-07)
31	Average Population density within the 300m buffer around the workplace	Interval	Bondarenko et al., 2020	▪ population/ settlement/ building density (220-03)
32	Duration of the trip between home and work location with public transport ±	Interval	ITS Vienna Region et al., n.d.	▪ Trip duration (403)
33	Walking time from the home location to the first public transport stop ±	Interval	ITS Vienna Region et al., n.d.	▪ Trip duration (403) ▪ Effort (649-03) ▪ Public transport accessibility (312)
34	Walking time from the last public transport stop to the work location ±	Interval	ITS Vienna Region et al., n.d.	▪ Trip duration (403) ▪ Effort (649-03) ▪ Public transport accessibility (312)
35	Waiting / Walking time at public transport transfers ±	Interval	ITS Vienna Region et al., n.d.	▪ Trip duration (403) ▪ Effort (649-03)

				▪ Public transport accessibility (312)
36	Number of public transport transfers ±	Interval	ITS Vienna Region et al., n.d.	▪ Need to transfer (400-01) ▪ Number of transfers (400-02)
37	Cost for a one-way, one-time public transport ticket in relation to the millage allowance for the car (0,42€/km) multiplied with the distance by car ± #	Interval	ITS Vienna Region et al., n.d.	▪ Price / Costs (322-06) ▪ Commuter allowance (132-06)
38	*Duration of the trip between home and work location with the bike ± []*	*Interval*	*ITS Vienna Region et al., n.d.*	▪ *Trip duration (403)*
39	*Total slope on the bicycle route ± []*	*Interval*	*ITS Vienna Region et al., n.d.*	▪ *Effort (649-03)*
40	*Distance of the bicycle route ± []*	*Interval*	*ITS Vienna Region et al., n.d.*	▪ *Distance / Length of the trip (400-11)*
41	Distance of the bicycle route multiplied with the mileage allowance (0,38€/km) in relation to the millage allowance for the car (0,42€/km) multiplied with the distance by car ± #	Interval	ITS Vienna Region et al., n.d.	▪ Price / Costs (322-06) ▪ Commuter allowance (132-06)
42	Duration of the trip between home and work location by car ±	Interval	ITS Vienna Region et al., n.d.	▪ Trip duration (403)
43	*Distance of the car route± []*	*Interval*	*ITS Vienna Region et al., n.d.*	▪ *Distance / Length of the trip (400-11)*
44	Average Population change per year of the home municipality between 2011 and 2024	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Growing and shrinking of the population (121-01)
45	*Share of migrant population in the home municipality on the 1st of January 2024 []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Migration (121-02)*
46	Share of people under 15 in the home municipality on the 1st of January 2024	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Age structure (121-04)
47	Share of people over 60 in the home municipality on the 1st of January 2024	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Age structure (121-04)
48	Share of people with tertiary education in the home municipality on the 31st of October 2022	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Level of education (510-07)
49	Number of workplaces within the home municipality on the 31st of October 2022	Interval	Statistik Austria - Bundesanstalt	▪ Ratio between working and resident population (120-01)

			Statistik Österreich, n.d.-a	
50	*Share of unemployed people within the home municipality on the 31st of October 2022 []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Unemployment (110-04)*
51	Average household size in the home municipality on the 31st of October 2022	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Household structure (121-03)
52	Percentage of residential buildings of total number of buildings in the home municipality on the 31st of October 2022	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Ratio between working and resident population (120-01) ▪ Building type (231-02)
53	Percentage of residential buildings with 1 or 2 units of residential buildings within the home municipality on the 31st of October 2022	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Building type (231-02)
54	Average annual gross salary within the home municipality in 2022	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Income (520-01)
55	*Population density of the home municipality []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *population/ settlement/ building density (220-03)*
56	Proportional commuter balance of the home municipality on the 31st of October 2022 (>1 more incoming commuters than outgoing)	Interval	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a	▪ Ratio between working and resident population (120-01)
57	*Percentage of Votes for the ÖVP in the home municipality at the 2019 parliamentary election []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Lifestyle (621)* ▪ *Personality (620-10)*
58	*Percentage of Votes for the SPÖ in the home municipality at the 2019 parliamentary election []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Lifestyle (621)* ▪ *Personality (620-10)*
59	*Percentage of Votes for the Greens in the home municipality at the 2019 parliamentary election []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Lifestyle (621)* ▪ *Personality (620-10)*
60	*Percentage of Votes for the Neos in the home municipality at the 2019 parliamentary election []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Lifestyle (621)* ▪ *Personality (620-10)*

61	*Percentage of Votes for the FPÖ in the home municipality at the 2019 parliamentary election []*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Lifestyle (621)* ▪ *Personality (620-10)*
62	*Number of traffic accidents in the home municipality in 2023[]*	*Interval*	*Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-a*	▪ *Traffic safety (649-09)*
63	Is the municipality classified as a large urban centre according to the urban rural typology	Binary	Statistik Austria - Bundesanstalt Statistik Österreich, n.d.-b	▪ Geographical area type (210-02)
64	Is the home municipality part of the Wienerwald biosphere reserve	Binary	(Biosphärenpark Wienerwald Management GmbH, n.d.)	▪ Geographical area type (210-02) ▪ Values connected to the environment (654)

** Change in data type due to aggregation*
[] not used in the multinomial logistical regression model – filtered through correlation or collinearity
± Calculated for the 21st of October 2024 with the arrival time at 7:50 (based on timetable data)
 # based on data for 2024 (Federal Ministry of Finances (BMF), 2025)

Appendix D: Key measures of the analysed data

Table 23: Key measures of categorical, Likert scaled and binary variables

No.	Variable	Category	n	%
01	Transport mode	Car	323	39.98%
		Public Transport	383	47.40%
		By foot or by bike	102	12.62%
02	Main occupation	Employed	699	86.51%
		In education / student	64	7.92%
		Other	45	5.57%
03	Age category	≤ 24	62	7.67%
		25 – 29	82	10.15%
		30 – 34	97	12.00%
		35 – 39	97	12.00%
		40 – 44	99	12.25%
		45 – 49	97	12.00%
		50 – 54	107	13.24%
		55 – 59	117	14.48%
		≥ 60	50	6.19%
04	Gender	Male	383	47.40%
		Female & other	425	52.60%
05	Monthly household income	I don't want to answer	90	11.14%
		Up to 900€	25	3.09%
		Up to 1,800€	105	13.00%
		Up to 2,600€	128	15.84%
		Up to 3,500€	143	17.70%
		Up to 5,000€	157	19.43%
		More than 5,000€	160	19.80%
06	Highest level of education	No degree / compulsory school	19	2.35%
		Apprenticeship	77	9.53%
		Secondary school	224	27.72%
		Tertiary education	488	60.40%
07	Since when in main residence	Three years or less	212	26.24%
		Ten to four years	213	26.36%
		More than ten years	383	47.40%

08	Household type	Living alone	153	18.94%
		Living alone + child	25	3.09%
		Living w. partner	268	33.17%
		Living w. partner + child	272	33.66%
		Several generations / families	37	4.58%
		Several non-related adults (WGs)	35	4.33%
		Other	18	2.23%
09	Children aged 0-5	Yes	112	13.86%
		No	696	86.14%
10	Children aged 6-14	Yes	173	78.59%
		No	635	21.41%
11	Children aged 15 or older	Yes	130	16.09%
		No	678	83.91%
12	Home office usage	Doesn't apply to me	23	2.85%
		No, I don't work from home	319	39.48%
		Yes, less than half of the workdays	280	34.65%
		Yes, more than half of the workdays	143	17.70%
		Yes, usually	43	5.32%
13	Enough space in dwelling	Strongly disagree	15	1.86%
		Disagree	48	5.94%
		Neither disagree nor agree	53	6.56%
		Agree	153	31.31%
		Strongly agree	439	54.33%
15	Enough green areas in neighbourhood	Strongly disagree	50	6.19%
		Disagree	71	8,79%
		Neither disagree nor agree	96	11.88%
		Agree	286	35.40%
		Strongly agree	305	37,75%

16	Air is clean in neighbourhood	Strongly disagree	39	4.83%
		Disagree	102	12.62%
		Neither disagree nor agree	160	19.80%
		Agree	343	42.45%
		Strongly agree	164	20.30%
17	Neighbourhood satisfaction	Strongly disagree	7	0.87%
		Disagree	26	3.22%
		Neither disagree nor agree	64	7.92%
		Agree	389	48.14%
		Strongly agree	322	39.85%
18	Housing type	Apartment	496	61.39%
		Row House /Semi-detached house	178	10.64%
		Detached House	86	22.03%
		Other	53	5.94%
19	Ownership type	Owned	415	51.36%
		Private rental	217	26.86%
		Genossenschaftswohnung	99	12.25%
		Gemeindewohnung	53	6.56%
		Other	24	2.97%
20	Urban Atlas Class at home	Continuous urban fabric	182	22.52%
		Discontinuous dense urban fabric	180	22.28%
		Discontinuous medium density urban fabric	120	14.85%
		Discontinuous low density urban fabric	42	5.20%
		Industrial, commercial, public, military and private units	92	11.39%
		Other roads and associated lands	91	11.26%
		Green urban areas	27	3.34%
		Other strongly by humans influenced areas	35	4.33%
		Other close to nature areas	39	4.83%

21	ÖV-Güteklasse at home	A	234	28.96%
		B	201	24.88%
		C	180	22.28%
		D	99	12.25%
		E	50	6.19%
		F	23	2.85%
		G or none	21	2.60%
30	ÖV-Güteklasse at work	A	433	53.59%
		B	185	22.90%
		C	82	10.15%
		D	56	6.93%
		E	22	2.72%
		F, G or no	30	3.71%
63	Municipality is classified as large urban centre	Yes	759	93.94%
		No	49	6.06%
64	Municipality is part of the Wienerwald biosphere reserve	Yes	440	54.46%
		No	368	45.54%

Table 24: Key measures of interval scaled variables

No.	Variable	Mean	Median	Min	Max	Standard deviation
14	Perceived Urbanity Index	3.54	3.67	1.00	5.00	1.11
22	Average Tree Cover Density around home	8.39	4.76	0.00	79.73	11.32
23	Average Imperviousness around home	48.59	46.45	0.00	92.75	22.76
24	Number of Urban Atlas classes around home	6.90	7.00	2.00	14.00	1.81
25	Number of aggregated Urban Atlas classes around home	3.79	4.00	2.00	8.00	1.13
26	Percentage of blue spaces around home	0.89	0.00	0.00	58.90	4.07
27	Percentage of Green spaces around home	18.83	12.19	0.00	100.00	19.74

28	Average Population density around home [POP/Buffer]	32.12	24.66	0.00	67.56	21.68
	Equals in POP/km²	113.60	87.22	0.00	238.94	76.67
29	Total network distance between home and work [m]	12,240.69	9,162.85	209.34	183,670.73	15,888.56
31	Average Population density around work [POP/Buffer]	44.83	56.60	0.00	67.74	20.29
	Equals in POP/km²	158.55	200.18	0.00	239.58	71.74
32	Duration of public transport trip	43.15 min	41.00 min	6.00 min	159.00 min	21.06 min
33	Walking time to first stop on public transport trip	6.80 min	6.00 min	1.00 min	23.00 min	4.07 min
34	Walking time from the last public transport stop	6.52 min	6.00 min	1.00 min	25.00 min	3.54 min
35	Walking / Waiting time for public transport transfers	6.32 min	6.00 min	0.00 min	34.00 min	5.66 min
36	Number of public transport transfers	1.36	1.00	0.00	6.00	0.95
37	Cost for public transport in relation to car costs	1.03	0.70	0.15	11.43	1.06
38	*Duration of bike trip*	*62.62 min*	*45.00 min*	*1.00 min*	*963.00 min*	*84.10 min*
39	*Total slope of bike trip*	*242.18 m*	*195.50 m*	*6.00 m*	*3645.00 m*	*268.95 m*
40	*Distance of the bicycle route*	*14.71 km*	*10.45 km*	*0.20 km*	*230.20 km*	*20.20 km*
41	Costs for bike in relation to car costs	0.85	0.85	0.32	4.25	0.19
42	Duration of the car trip	26.96 min	27.00 min	2.00 min	126.00 min	13.17 min
43	*Distance of the car route*	*15.45 km*	*11.00 km*	*0.50 km*	*198.10 km*	*18.51 km*
44	Average population change per year	0.81%	0.61%	-0.28%	2.98%	0.78%
45	*Share of migrant population*	*24.56%*	*19.74%*	*6.61%*	*45.74%*	*11.14%*
46	Share of people under the age of 15	13.86%	13.77%	9.71%	17.03%	1.71%
47	Share of people over the age of 60	26.31%	25.74%	19.82%	37.89%	4.52%
48	Share of people with tertiary education	26.54%	26.13%	12.28%	46.50%	8.18%
49	Number of workplaces	4370.73	2468.00	100.00	13381.00	3650.41
50	*Share of unemployed people*	*6.85%*	*4.76%*	*1.92%*	*14.94%*	*3.73%*
51	Average household size	2.08	2.09	1.80	2.49	0.12
52	Percentage of residential buildings	88.44%	88.38%	43.33%	94.45%	5.28%
53	Percentage of residential buildings with 1 or 2 units	65,78%	75.17%	2.09%	97.76%	20.64%

54	Average annual gross salary	55480.21€	55743.00€	40614.00€	84549.00€	9227.93€
55	*Population density of municipality [POP/km²]*	*4958.36*	*2049.80*	*60.47*	*27064.68*	*6327.10*
56	Proportional commuter balance	0.96	0.72	0.02	6.91	0.98
57	*Proportion of ÖVP-Votes at the federal election 2019*	*30.54%*	*32.43%*	*17.31%*	*45.85%*	*7.50%*
58	*Proportion of SPÖ-Votes at the federal election 2019*	*22.73%*	*22.25%*	*11.75%*	*38.70%*	*7.16%*
59	*Proportion of Green-Votes at the federal election 2019*	*18.44%*	*17.83%*	*9.73%*	*36.39%*	*5.80%*
60	*Proportion of NEOS-Votes at the federal election 2019*	*11.03%*	*10.53%*	*5.15%*	*18.27%*	*3.12%*
61	*Proportion of FPÖ-Votes at the federal election 2019*	*12.96%*	*12.51%*	*6.39%*	*22.12%*	*3.64%*
62	Number of traffic accidents	156.16	94.00	3.00	525.00	152.79

Appendix E: Reference categories for categorical variables

Table 25: Reference categories for the categorical variables

No.	Variable	Reference Category	Reason
01	Transport mode	Car Public Transport	Both were used as reference categories for models as each model only shows the difference between the other two modes to the reference category. To display the effects on all transport mode comparisons, the final model was calculated with both reference categories each.
02	Main occupation	Other	To show the differences of being employed or in education
03	Age category	40 – 44	Most similar to the total respondents in terms of mode choice
04	Gender	Male	Already binary variable
05	Monthly household income	Up to 2,600€	Most similar to the total respondents in terms of mode choice
06	Highest level of education	No degree / compulsory school	"Lowest" value
07	Since when in main residence	Ten to four years	To examine the difference to living long or rather short in a certain location
08	Household type	Living alone + child	Most similar to the total respondents in terms of mode choice
09	Children aged 0-5	No	Already binary variable
10	Children aged 6-14	No	Already binary variable
11	Children aged 15 or older	No	Already binary variable
12	Home office usage	No, I don't work from home	To check for the influence of home-office usage
18	Housing type	Other	To assess differences for each housing type
19	Ownership type	Genossenschaftswohnung	Most similar to the total respondents in terms of mode choice
20	Urban Atlas Class at home	Other roads and associated lands	Most similar to the total respondents in terms of mode choice
21	ÖV-Güteklasse at home	E	Most similar to the total respondents in terms of mode choice
30	ÖV-Güteklasse at work	B	Most similar to the total respondents in terms of mode choice
63	Municipality is classified as large urban centre	No	Already binary variable
64	Municipality is part of the Wienerwald biosphere reserve	No	Already binary variable

Appendix F: Excluded variables in the iterative model selection

Table 26: List of excluded variables in the iterative model selection

Iteration	AIC	BIC	Mc Fadden Pseudo-R^2	Excluded variable	Var. ID (Table 2)
0	1157.282	2058.650	0.513	*Base model with all variables*	
1	1153.288	2045.255	0.513	Age : 45 – 49	03
2	1149.311	2031.889	0.513	Number of Workplaces	49
3	1145.382	2018.570	0.512	Ownership: Owned	19
4	1141.468	2005.268	0.512	Number of UAC around home	24
5	1137.583	1991.994	0.512	Housing type: Apartment	18
6	1133.691	1978.712	0.512	Walking time to the first public transport stop	33
7	1129.871	1965.503	0.512	Age: 25 – 29	03
8	1126.261	1952.504	0.512	Share of residential buildings with 1 or 2 units	53
9	1122.710	1939.563	0.512	Neighbourhood satisfaction	17
10	1119.264	1926.728	0.511	ÖV-Güteklasse at home: F	21
11	1115.795	1913.870	0.511	Share of population under 15	46
12	1112.356	1901.042	0.511	Age: 35 – 39	03
13	1108.977	1888.274	0.510	Urban Atlas Class at home: Other strongly by humans influenced areas	20
14	1105.597	1875.505	0.510	Age: 55 – 59	03
15	1102.396	1862.915	0.509	Children aged 0-5	09
16	1099.142	1850.272	0.509	Household type: Several non-related adults (WGs)	08
17	1095.834	1837.574	0.508	Main occupation: In education / student	02
18	1092.712	1825.064	0.508	Ownership: Private rental	19
19	1089.670	1812.633	0.507	Urban atlas class at home: Discontinuous dense urban fabric	20
20	1086.618	1800.191	0.507	Urban atlas class at home: Industrial, commercial, public, military and private units	30
21	1083.625	1787.809	0.506	Since when in current residence: more than 10 years	07
22	1080.706	1775.501	0.505	Air is clean	16
23	1077.700	1763.106	0.505	Children aged 6 – 14	10

24	1074.729	1750.746	0.504	Highest level of education: Apprenticeship	06
25	1071.636	1738.264	0.503	Household type: Other	08
26	1068.694	1725.933	0.503	Urban atlas class at home: Continuous urban fabric	20
27	1065.940	1713.790	0.502	Home-office usage: Yes, more than half of the workdays	12
28	1063.336	1701.797	0.501	Walking time from the last public transport stop	34
29	1060.649	1689.720	0.500	ÖV-Güteklasse at work: A	30
30	1057.956	1677.638	0.500	ÖV-Güteklasse at home: B	21
31	1055.340	1665.633	0.499	Household type: living alone + child	08
32	1052.658	1653.562	0.498	Waiting / Walking time at public transport transfers	35
33	1050.212	1641.727	0.497	ÖV-Güteklasse at work: E	30
34	1047.745	1629.870	0.496	ÖV-Güteklasse at home: A	21
35	1045.346	1618.083	0.495	Urban Atlas Class at home: Green urban areas	20
36	1043.049	1606.396	0.494	Percieved Urbanity Index	14
37	1040.516	1594.475	0.493	Housing type: Row house / semi-detached house	18
38	1038.536	1583.105	0.492	Monthly household income: Up to 5.000€	05
39	1036.265	1571.445	0.490	Monthly household income: Up to 900€	05
40	1033.994	1559.785	0.489	Enough green areas	15
41	1031.939	1548.340	0.488	ÖV-Güteklasse at work: F, G or none	30
42	1029.744	1536.757	0.487	Wienerwald biosphere reserve	64
43	1027.775	1525.399	0.486	Household type: living with partner + child	08
44	1025.850	1514.085	0.484	Enough space in dwelling	13
45	1024.161	1503.007	0.483	Monthly household income: no answer	05
46	1022.439	1491.896	0.482	Number of transfers in the public transport	36
47	1021.002	1481.069	0.480	ÖV-Güteklasse at home: C	21
48	1019.893	1470.571	0.478	ÖV-Güteklasse at work: C	30
49	1018.837	1460.126	0.476	Monthly household income: Up to 1,800€	05
50	1017.554	1449.454	0.475	Home-office usage: Yes, usually	12

51	1016.417	1438.927	0.473	Urban Atlas Class at home location: Other close to nature areas	20
52	1015.018	1428.140	0.471	Monthly household income: Up to 3.500€	05
53	1014.109	1417.842	0.469	Urban Atlas Class at home: Discontinuous medium density urban fabric	20
54	1013.115	1407.458	0.467	ÖV-Güteklasse at home: G or none	21
55	1012.147	1397.101	0.465	Total distance between home and work on the GIP-Network	29
56	1011.494	1387.059	0.463	Home-office usage: Yes, less than half of the workdays	12
57	1011.116	1377.292	0.461	Age: 50 – 54	03
58	1010.656	1367.443	0.459	Number of aggregated Urban Atlas Classes around home	25
59	1010.364	1357.762	0.456	Annual population change 2011-2024	44
60	1009.151	1347.159	0.455	Urban-Rural-Typology: large urban centre	63
* *61*	1006.184	1334.803	0.454	Proportional commuter balance	56
62	1006.412	1325.642	0.451	Highest level of education: Secondary school	06
63	1006.490	1316.331	0.449	Home office usage: Doesn't apply to me	12
64	1006.628	1307.080	0.446	Housing type: Detached house	18
65	1006.733	1297.795	0.444	Age: 30 – 34	03
66	1006.900	1288.573	0.441	Average tree-cover-density around home	22
67	1007.190	1279.474	0.438	ÖV-Güteklasse at workplace: D	30
68	1008.083	1270.979	0.435	Ownership type: Gemeindewohnung	19
69	1008.685	1262.191	0.432	Gender	02
70	1010.083	1254.200	0.429	Age: ≥ 60	03
71	1011.441	1246.169	0.425	Share of blue spaces around home	26
72	1012.475	1237.814	0.422	Share of residential buildings	52
73	1013.487	1229.437	0.419	Share of people over 60	47
74	1012.253	1218.814	0.417	Average annual gross salary	54
75	1009.566	1206.736	0.417	Average household size	51
** *76*	1011.052	1198.835	0.413	Highest level of education: Tertiary	06
77	1013.455	1191.849	0.409	Age: ≤ 24	03
78	1015.793	1184.797	0.405	ÖV-Güteklasse at home: D	21
79	1020.454	1180.070	0.400	Household type: Living alone	08

80	1025.218	1175.444	0.394	Monthly household income: More than 5,000€	05
*** *81*	1030.555	1171.392	0.388	Urban Atlas Class at home: Discontinuous low density urban fabric	20
82	1036.425	1167.872	0.382	Cost by bike in relation to the cost by car	41
83	1042.775	1164.834	0.375	Children aged 15 or older	11
84	1048.711	1161.381	0.369	Share of green spaces around home	27
85	1048.341	1151.621	0.367	Average imperviousness around home	23
**** *86*	1054.546	1148.437	0.360	Ownership: Other	19

* Lowest value for the AIC

** all variables significant for α=0.05

*** all variables significant for α=0.01

**** Lowest value for the BIC

Appendix G: SPSS Output of the final regression model

Reference category: car

Nominal Regression

Table 27: Information of the SPSS-Output of the final regression model for the reference category: car

Information

Output created		16-APR-2025 21:48:15
Comments		
Input	Data	*Not given due to privacy reasons*
	Active dataset	DataSet1
	Filter	<none>
	Weighting	<none>
	Split file	<none>
	Number of rows in the work file	808
Treatment of missing values	Definition of Missing	User-defined missing values are considered missing.
	Used cases	The statistics are based on all cases with valid data for all variables in the model.
Syntax		NOMREG Trans_M (BASE=0 ORDER=ASCENDING) WITH m_occ_emp swih_3 hht_sev_fam POP_dens_h POP_dens_w Dur_trip_pt pt_cost_rel_car Dur_trip_car Pop_tert_edu /CRITERIA CIN(95) DELTA(0) MXITER(100) MXSTEP(5) CHKSEP(20) LCONVERGE(0) PCONVERGE(0.000001) SINGULAR(0.00000001) /MODEL /STEPWISE=PIN(.05) POUT(0.1) MINEFFECT(0) RULE(SINGLE) ENTRYMETHOD(LR) REMOVALMETHOD(LR) /INTERCEPT=INCLUDE /PRINT=CLASSTABLE FIT PARAMETER SUMMARY LRT CPS STEP MFI IC.
Resources	Processor time	00:00:00,09
	Elapsed time	00:00:00,07

Table 28: Warnings of the SPSS-Output of the final regression model for the reference category: car

Warnings

There are 1616 (66.7%) cells (i.e. levels of the dependent variable for subpopulations) with a frequency of zero.

Table 29: Processed cases of the SPSS-Output of the final regression model for the reference category: car

Processed cases

		Number	Marginal percentage
Transport Mode	car	323	40.0%
	public transport	383	47.4%
	active mobility	102	12.6%
Valid		808	100.0%
Missing		0	
Total		808	
Subpopulation		808[a]	

a. The dependent variable only has a value observed in 808 (100.0%) subpopulations.

Table 30: Information on model customisation of the SPSS-Output of the final regression model for the reference category: car

Information on model customisation

	Criteria for model customisation			Likelihood quotient tests		
Model	AIC	BIC	-2 Log-Likelihood	Chi-Quadrat	Degrees of freedom	Significance
Constant term only	1590.360	1599.749	1586.360			
Final	1054.546	1148.437	1014.546	571.814	18	<.001

Table 31: Quality of the customisation of the SPSS-Output of the final regression model for the reference category: car

Quality of the customisation

	Chi-Quadrat	Degrees of freedom	Significance
Pearson	1567.785	1596	.688
Deviation	101.546	1596	1.000

Table 32: Pseudo R square of the SPSS-Output of the final regression model for the reference category: car

Pseudo R-square

Cox und Snell	.507
Nagelkerke	.590
McFadden	.360

Table 33: Likelihood quotient tests of the SPSS-Output of the final regression model for the reference category: car

Likelihood quotient tests

Effect	Criteria for model customisation	Likelihood quotient tests

	AIC of the reduced model	BIC of the reduced model	-2 Log-Likelihood of the reduced model	Chi-Quadrat	Degrees of freedom	Significance
Constant term	1068.647	1153.149	1032.647	18.101	2	<.001
Employed	1067.520	1152.022	1031.520	16.975	2	<.001
Less than 3 years in the current residence	1066.163	1150.665	1030.163	15.617	2	<.001
living several families	1066.579	1151.082	1030.579	16.034	2	<.001
Average population density around home location	1117.113	1201.615	1081.113	66.567	2	<.001
Average population density around workplace	1069.728	1154.230	1033.728	19.183	2	<.001
Time by public transport	1075.030	1159.532	1039.030	24.485	2	<.001
Cost by public transport relative to cost by car	1065.656	1150.158	1029.656	15.110	2	<.001
Time by car	1087.983	1172.485	1051.983	37.438	2	<.001
% People with tertiary education	1073.246	1157.748	1037.246	22.701	2	<.001

The chi-squared statistic represents the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is calculated by omitting an effect from the final model. This is based on the null hypothesis that all parameters of this effect are 0.

Table 34: Parameter estimator of the SPSS-Output of the final regression model for the reference category: car

Parameter estimator

Transport Mode[a]		B	Standard error	Wald	Degrees of freedom	Significance	95% confidence interval for Exp(B)	
							Lower limit	Upper limit
public transport	Constant term	-2.710	.788	11.833	1	<.001		
	Employed	-1.048	.344	9.300	1	.002	.179	.688
	Less than 3 years in the current residence	.788	.242	10.600	1	.001	1.369	3.536
	living several families	1.767	.530	11.093	1	<.001	2.069	16.553
	Average population density around home location	.046	.006	56.267	1	<.001	1.035	1.060
	Average population density around workplace	.029	.007	18.020	1	<.001	1.016	1.043
	Time by public transport	-.050	.012	18.023	1	<.001	.930	.974
	Cost by public transport relative to cost by car	-.549	.195	7.918	1	.005	.394	.847
	Time by car	.087	.017	27.894	1	<.001	1.056	1.127
	% People with tertiary education	.044	.014	9.738	1	.002	1.017	1.075
active mobility	Constant term	-3.592	1.068	11.308	1	<.001		
	Employed	.384	.545	.497	1	.481	.504	4.277
	Less than 3 years in the current residence	-.102	.349	.086	1	.769	.455	1.790
	living several families	-1.037	1.252	.686	1	.407	.030	4.124
	Average population density around home location	.041	.009	20.346	1	<.001	1.024	1.061
	Average population density around workplace	.023	.011	4.194	1	.041	1.001	1.046
	Time by public transport	-.063	.020	10.105	1	.001	.903	.976
	Cost by public transport relative to cost by car	.145	.131	1.227	1	.268	.894	1.495
	Time by car	-.013	.032	.156	1	.693	.927	1.052
	% People with tertiary education	.084	.018	20.889	1	<.001	1.049	1.127

a. The reference category is: car.

Table 35: Classification of the SPSS-Output of the final regression model for the reference category: car

Classification

		Predicted		
Observed	car	public transport	active mobility	Percent correct
car	241	73	9	74.6%
public transport	63	308	12	80.4%
active mobility	24	44	34	33.3%
Percent correct	40.6%	52.6%	6.8%	72.2%

Reference category: public transport

Nominal Regression

Table 36: Information of the SPSS-Output of the final regression model for the reference category: public transport

Information

Output created		16-APR-2025 21:58:00
Comments		
Input	Data	*Not given due to privacy reasons*
	Active dataset	DataSet1
	Filter	<none>
	Weighting	<none>
	Split file	<none>
	Number of rows in the work file	808
Treatment of missing values	Definition of Missing	User-defined missing values are considered missing.
	Used cases	The statistics are based on all cases with valid data for all variables in the model.
Syntax		NOMREG Trans_M (BASE=0 ORDER=ASCENDING) WITH m_occ_emp swih_3 hht_sev_fam POP_dens_h POP_dens_w Dur_trip_pt pt_cost_rel_car Dur_trip_car Pop_tert_edu /CRITERIA CIN(95) DELTA(0) MXITER(100) MXSTEP(5) CHKSEP(20) LCONVERGE(0) PCONVERGE(0.000001) SINGULAR(0.00000001) /MODEL /STEPWISE=PIN(.05) POUT(0.1) MINEFFECT(0) RULE(SINGLE) ENTRYMETHOD(LR) REMOVALMETHOD(LR) /INTERCEPT=INCLUDE /PRINT=CLASSTABLE FIT PARAMETER SUMMARY LRT CPS STEP MFI IC.
Resources	Processor time	00:00:00.08
	Elapsed time	00:00:00.07

Table 37: Warnings of the SPSS-Output of the final regression model for the reference category: public transport

Warnings

There are 1616 (66.7%) cells (i.e. levels of the dependent variable for subpopulations) with a frequency of zero.

Table 38: Processed cases of the SPSS-Output of the final regression model for the reference category: public transport

Processed cases

		Number	Marginal percentage
Transport Mode	car	323	40.0%
	public transport	383	47.4%
	active mobility	102	12.6%
Valid		808	100.0%
Missing		0	
Total		808	
Subpopulation		808[a]	

a. The dependent variable only has a value observed in 808 (100.0%) subpopulations.

Table 39: Information on model customisation of the SPSS-Output of the final regression model for the reference category: public transport

Information on model customisation

	Criteria for model customisation			Likelihood quotient tests		
Model	AIC	BIC	-2 Log-Likelihood	Chi-Quadrat	Degrees of freedom	Significance
Constant term only	1590.360	1599.749	1586.360			
Final	1054.546	1148.437	1014.546	571.814	18	<.001

Table 40: Quality of the customisation of the SPSS-Output of the final regression model for the reference category: public transport

Quality of the customisation

	Chi-Quadrat	Degrees of freedom	Significance
Pearson	1567.785	1596	.688
Deviation	1014.546	1596	1.000

Table 41: Pseudo R square of the SPSS-Output of the final regression model for the reference category: public transport

Pseudo R-square

Cox und Snell	.507
Nagelkerke	.590
McFadden	.360

Table 42: Likelihood quotient tests of the SPSS-Output of the final regression model for the reference category: public transport

Likelihood quotient tests

	Criteria for model customisation			Likelihood quotient tests		
Effect	AIC of the reduced model	BIC of the reduced model	-2 Log-Likelihood of the reduced model	Chi-Quadrat	Degrees of freedom	Significance
Constant term	1068.647	1153.149	1032.647	18.101	2	<.001
Employed	1067.520	1152.022	1031.520	16.975	2	<.001
Less than 3 years in the current residence	1066.163	1150.665	1030.163	15.617	2	<.001
living several families	1066.579	1151.082	1030.579	16.034	2	<.001
Average population density around home location	1117.113	1201.615	1081.113	66.567	2	<.001
Average population density around workplace	1069.728	1154.230	1033.728	19.183	2	<.001
Time by public transport	1075.030	1159.532	1039.030	24.485	2	<.001
Cost by public transport relative to cost by car	1065.656	1150.158	1029.656	15.110	2	<.001
Time by car	1087.983	1172.485	1051.983	37.438	2	<.001
% People with tertiary education	1073.246	1157.748	1037.246	22.701	2	<.001

The chi-squared statistic represents the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is calculated by omitting an effect from the final model. This is based on the null hypothesis that all parameters of this effect are 0.

Table 43: Parameter estimator of the SPSS-Output of the final regression model for the reference category: public transport

Parameter estimator

Transport Mode[a]		B	Standard error	Wald	Degrees of freedom	Significance	95% confidence interval for Exp(B)	
							Lower limit	Upper limit
car	Constant term	2.710	.788	11.833	1	<.001		
	Employed	1.048	.344	9.300	1	.002	1.454	5.596
	Less than 3 years in the current residence	-.788	.242	10.600	1	.001	.283	.731
	living several families	-1.767	.530	11.093	1	<.001	.060	.483
	Average population density around home location	-.046	.006	56.267	1	<.001	.943	.966
	Average population density around workplace	-.029	.007	18.020	1	<.001	.959	.985
	Time by public transport	.050	.012	18.023	1	<.001	1.027	1.075
	Cost by public transport relative to cost by car	.549	.195	7.918	1	.005	1.181	2.537
	Time by car	-.087	.017	27.894	1	<.001	.887	.947
	% People with tertiary education	-.044	.014	9.738	1	.002	.931	.984
active mobility	Constant term	-.882	1.099	.643	1	.423		
	Employed	1.433	.485	8.715	1	.003	1.619	10.849
	Less than 3 years in the current residence	-.891	.315	7.993	1	.005	.221	.761
	living several families	-2.804	1.214	5.335	1	.021	.006	.654
	Average population density around home location	-.005	.009	.327	1	.567	0.978	1.012
	Average population density around workplace	-.006	.011	.231	1	.630	.972	1.017
	Time by public transport	-.014	.020	.470	1	.493	.949	1.026
	Cost by public transport relative to cost by car	.694	.207	11.263	1	<.001	1.335	3.003
	Time by car	-.100	.031	10.253	1	.001	.851	.962
	% People with tertiary education	.040	.016	6.418	1	.011	1.009	1.073

a. The reference category is: public transport

Table 44: Classification of the SPSS-Output of the final regression model for the reference category: public transport

Classification

		Predicted		
Observed	car	public transport	active mobility	Percent correct
car	241	73	9	74.6%
public transport	63	308	12	80.4%
active mobility	24	44	34	33.3%
Percent correct	40.6%	52.6%	6.8%	72.2%

Appendix H: Maps of the wrongly predicted OD-Pairs

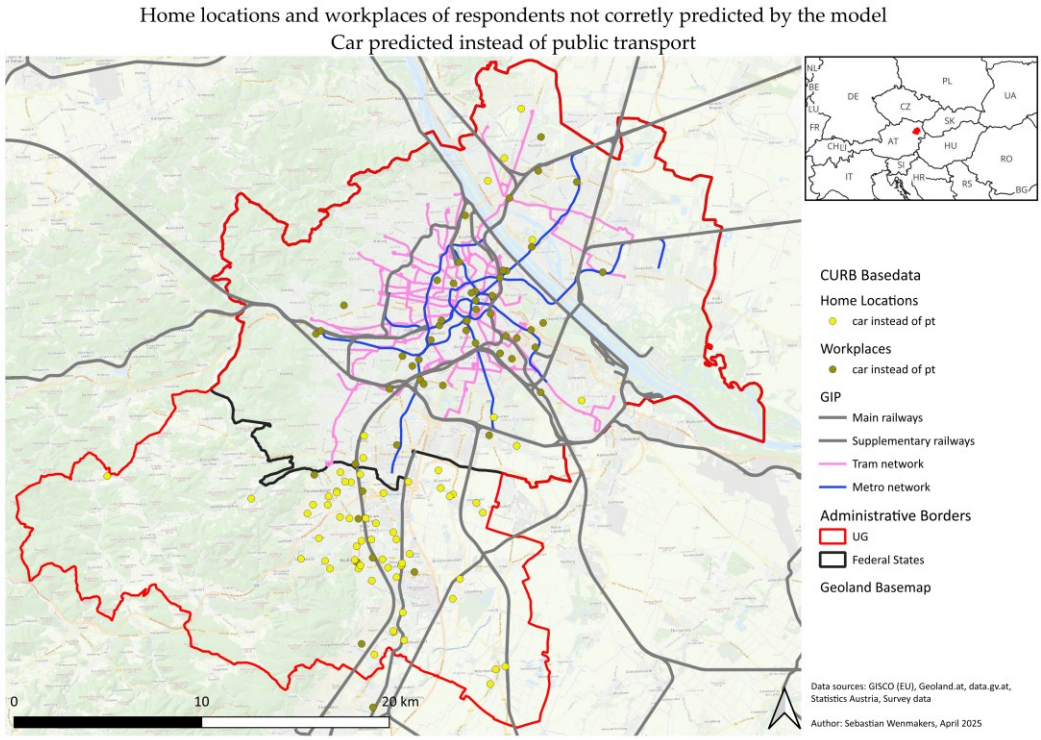


Figure 16: Home- and work locations of OD-pairs that were wrongly predicted by the model - Car predicted instead of public transport

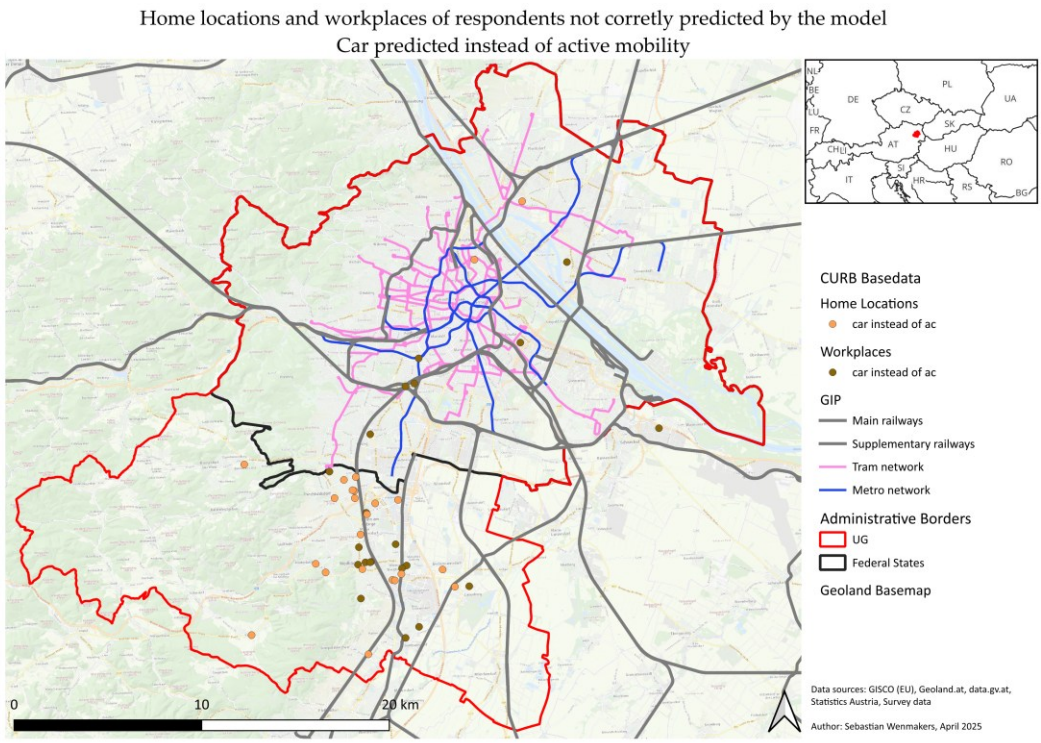


Figure 17: Home- and work locations of OD-pairs that were wrongly predicted by the model - Car predicted instead of active mobility

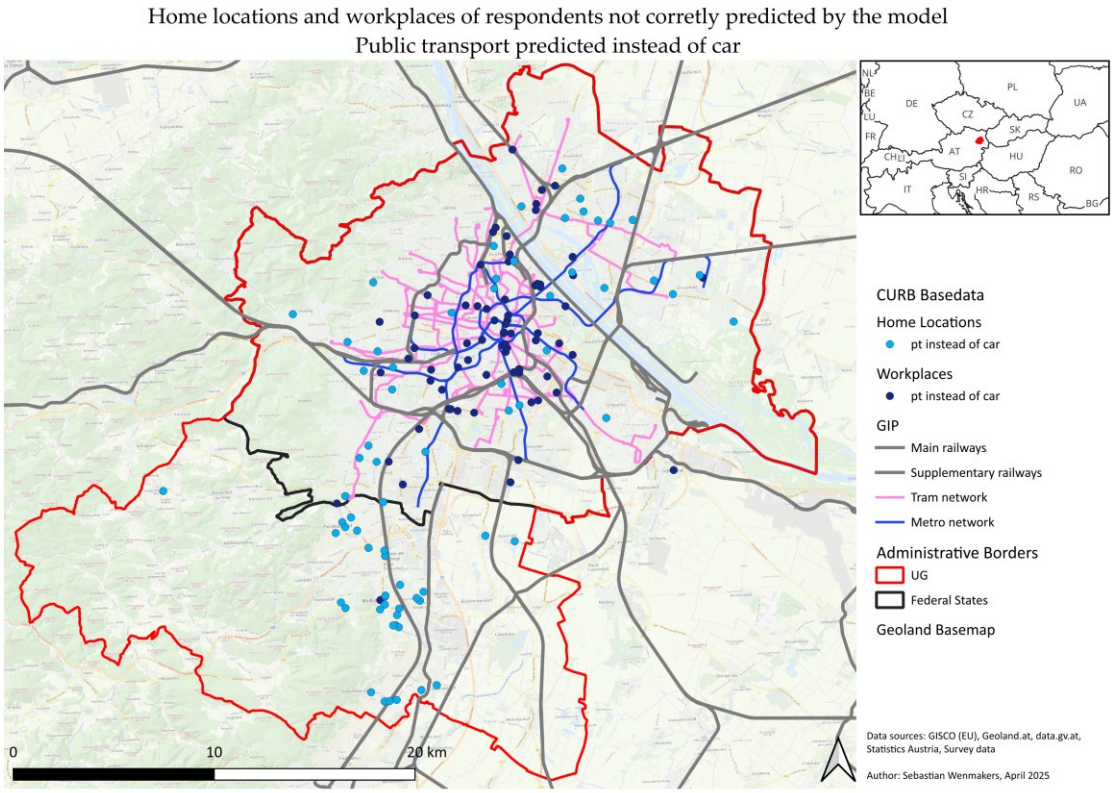


Figure 18: Home- and work locations of OD-pairs that were wrongly predicted by the model – Public transport predicted instead of the car

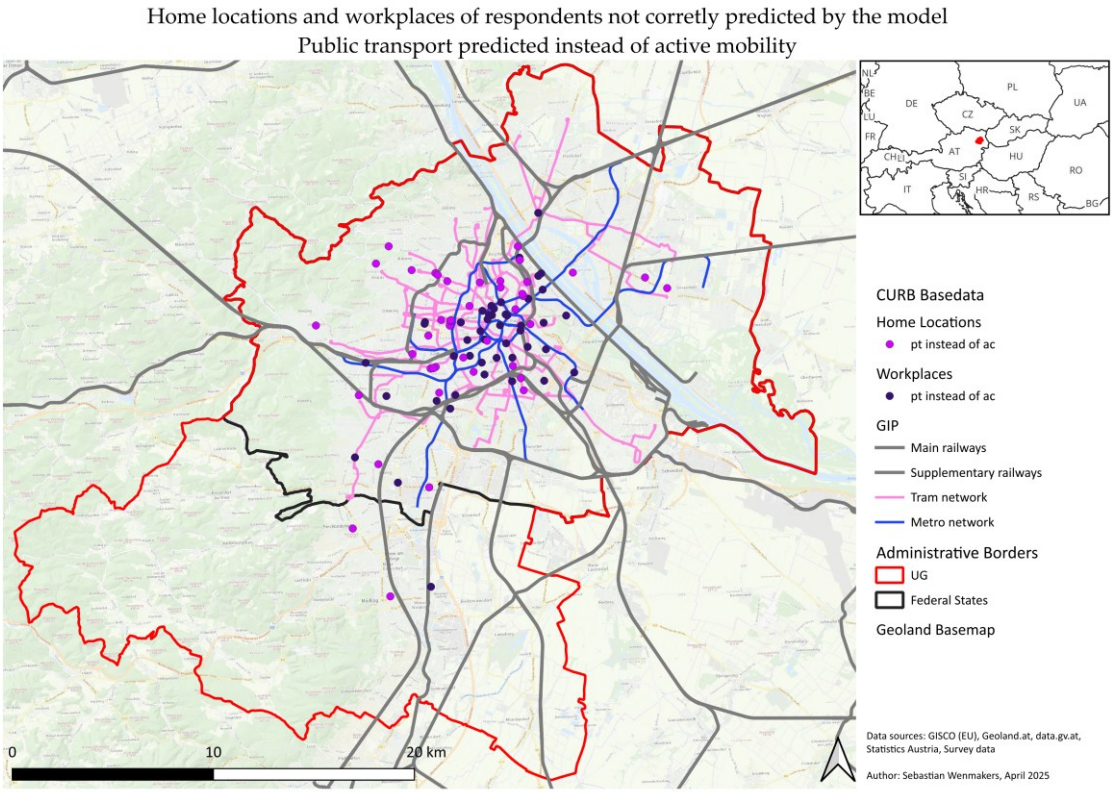


Figure 19: Home- and work locations of OD-pairs that were wrongly predicted by the model – Public transport predicted instead of active mobility

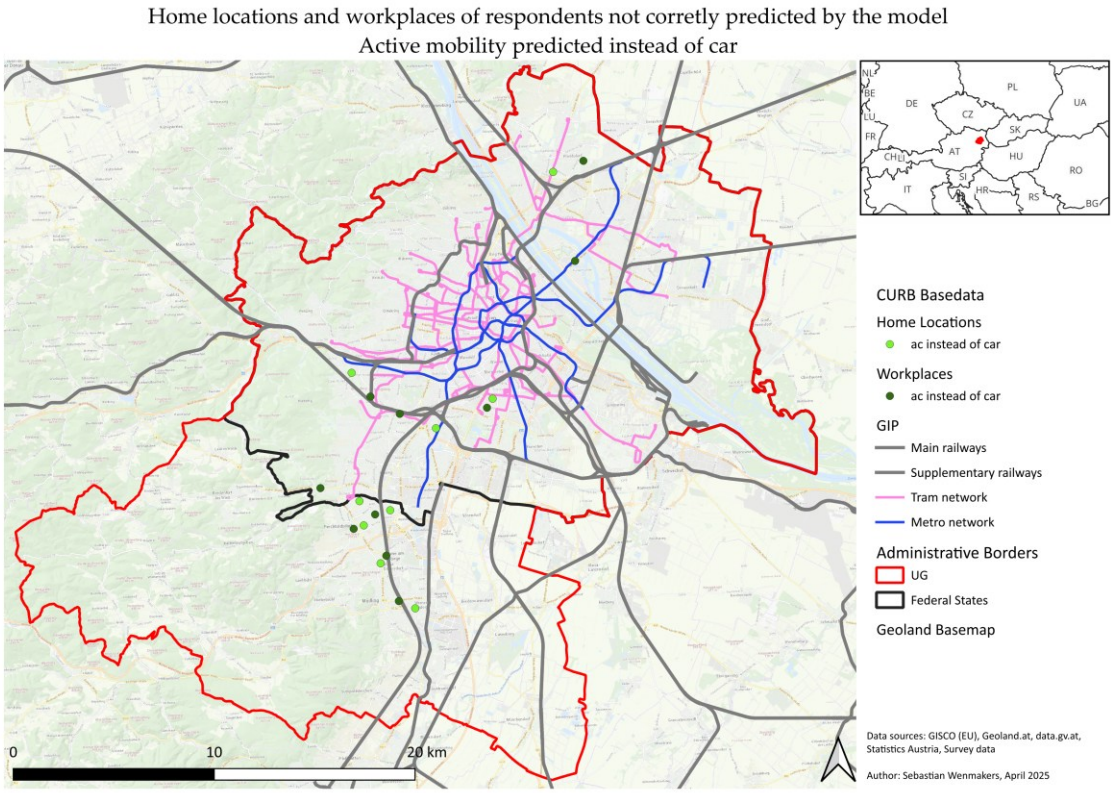


Figure 20: Home- and work locations of OD-pairs that were wrongly predicted by the model – Active mobility predicted instead of the car

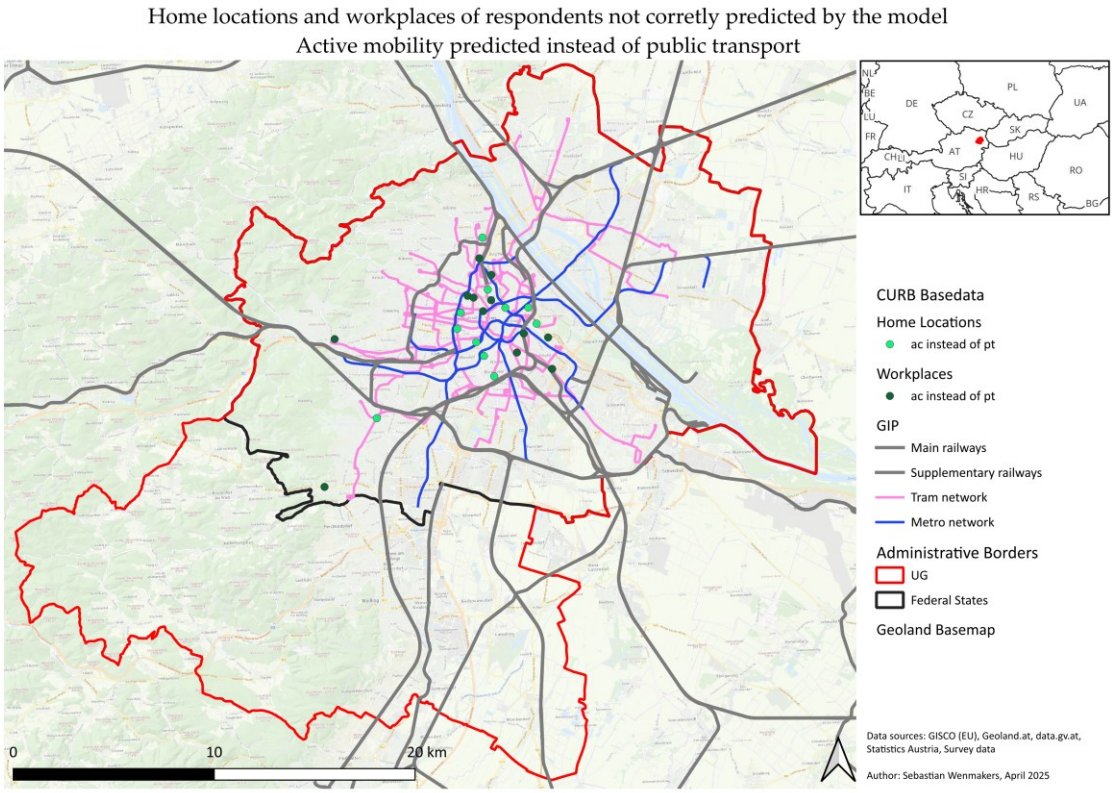


Figure 21: Home- and work locations of OD-pairs that were wrongly predicted by the model – Active mobility predicted instead of the public transport