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THE PROMISE OF CYCLING

FOR A CAR REDUCTION IN THE NETHERLANDS

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Preface

This thesis has been written as part of the master's degree Environmental and Infrastructure Planning at the Faculty of Spatial Sciences in Groningen. I would like to specially thank my thesis supervisor Farzaneh Bahrami, and my friend Tess ten Have for all the support and advice they provided that kept me going in the easier periods, but also in the difficult periods. I also want to thank my respondents for sharing their knowledge and expertise and helping me to understand how cycling can be used for the reduction of car mobility.

Enjoy reading,

Laura Fransen
Groningen, 10th of July 2022

Abstract

This research aims to understand the relationship between car mobility and cycling in the Netherlands. Despite the high modal split of cycling, car mobility remains prevalent in the Netherlands, even at distances that are suitable for cycling. Hence, this research investigates if and how cycling can contribute to reducing car mobility. Using a transition theory multi-level perspective, these dimensions have been examined. The data is collected via statistical data, policy and document review, and interviews. The results indicate that an increase in cycling's modal split can contribute to a car reduction due to several conditions. First are external pressures from the landscape, such as climate change and the COVID-19 pandemic. Secondly, a strong political view and bottom-up initiatives are needed within the mobility regime. Third, niches like e-bikes and the 15 min. city-concept are effective. Next, promotional instruments are essential to ensure long-term results. First, bicycle incentives, such as improving physical instruments and policies, are needed to encourage cycling. Simultaneously, car restriction policies are required to discourage car use. Due to the combination of regulations and stimulations, governments, planners, private, and institutional organizations can increase cycling's modal share. Moreover, two approaches are discussed to manage the transition based on the spatial context. For urban areas, system improvement is needed, while rural areas need system innovation. Finally, further research should investigate cyclists' perceptions, the role of public transport, and the encouragement of long-distance cycling.

Key words: Sustainable mobility, Active travel, Transition theory, Promotional activities

Table of contents

List of Tables

List of figures

List of abbreviations

BTM= Bus, tram, and metro
CBS= Central Bureau of Statistics
COP21 = 21st Conference of the Parties
COVID-19 = Corona virus disease 2019
CROW = Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek
E-bike = Electric bicycles
ECF = European Cyclists' Federation
LEV = Light electric vehicles
KiM = Het Kennisinstituut voor Mobiliteitsbeleid (National Agency for Transport)
MaaS = Mobility as a Service
MLP = Multi-level Perspective
OECD = The Organization for Economic Co-operation and Development
OViN = Onderzoek Verplaatsingen in Nederland
VELO= Vélocipèdes (racing bicycle)

Introduction

1.1 Background

Mobility is one of the main cornerstones of modern society (Banister, 2008). It is critical for economic growth, employment, and defining people's quality of life (Ferreto et al., 2012). However, the mobility sector not only benefits society; it is also responsible for adverse effects, which are commonly represented as a set of social costs or negative externalities (Ferreto et al., 2012). Especially car mobility is responsible for those negative effects, in which high environmental and health pressures are reached in terms of pollution, congestion, traffic crashes, noise, and other externalities (Attard and Shiftan, 2015). In addition, car mobility takes up a lot of space for circulation and storage of vehicles, which, therefore, cannot be used for other activities that perhaps increases people's livability and wellbeing (Petzer et al., 2021). Hence, mobility remains a major topic in discussions about transitioning to more sustainable consumption and production patterns (Banister, 2008). Sustainable mobility will lead to increased livability, less landscape fragmentation, and improved environmental qualities (Banister, 2008; Berger et al., 2014). One way to achieve sustainable mobility is the promotion of active travel. According to La Rocca (2010), active travel (also referred to as active mobility or soft mobility) includes any non-motorized transport that can be used for short distances that are otherwise done by the car. The most common form of active travel is cycling and walking (La Rocca, 2010).

In the Netherlands, cycling is already one of the main transport modes used daily (CBS, 2022a). Besides the morphological advantages, several historic references contributed to the dominance of cycling in the Netherlands. Due to the accessibility and affordability of a bicycle, cycling became a popular transportation mode in the early 1900s. However, around 1950, more people could afford a car, and the bicycle became seriously competitive with this transportation mode (Riemans, 2016). With the rise of car mobility, the central government made plans to change Dutch cities radically (Riemans, 2016).

Consequently, some people started to act against car mobility, and cycling became a symbol of resistance to car logistics (Verkade and te Brömmelstroet, 2020). This was also seen in Amsterdam, where thousands of people protested against the construction of large-scale highways. Ultimately the protest was successful, and these highways were banned from Amsterdam (Verkade, 2018). Simultaneously, the dangers of car mobility became increasingly apparent. In Dutch traffic alone, thousands of people were killed, and hundreds were children below the age of 14 (Verkade, 2020). Hence, the "Stop the Infanticide' (or in Dutch: Stop de Kindermoord) foundation was established to guarantee the safety of young road users (Verkade, 2020). Thus, cycling received increasing societal and governmental attention from the 1960s forward, with the national government playing a pivotal role at first (Goeverden and Godefrooij, 2010).

Moreover, demonstration bike routes were built, municipalities could receive government grants for cycling initiatives, and the Bicycle Master Plan boosted municipal bicycle policy in the 1990s. Furthermore, based on recent memorandums, municipal bicycle policies have become more ambitious and integrated since the 1990s. Infrastructure (typically the development of missing links in previously realized networks), parking facilities/theft prevention, safety, and communication/promotion were all covered by such policies (Goeverden and Godefrooij, 2010). This has increased cycling in the past 50 years (CBS, 2021d). Worldwide, the Netherlands is, therefore, known as the Cycling Nation, with more bicycles than people living there (CBS, 2022a). Despite this, car mobility remains highly dominant in the Netherlands and continues to grow every year (van der Waard et al., 2013). This grow can also be seen at the number of trips that can be reached with the bicycle as well (Gezonde leefomgeving, 2017).

Even though the car is generally used to drive to activities at a larger distance, the car is also used to a large extent for trips at a shorter distance that can be reached with cycling (Gezonde leefomgeving, 2017). In order to avoid the negative effects caused by car mobility, it is vital to use cycling as an alternative for those shorter distances. Many scholars have argued that the execution and promotion of cycling can promise a reduction in car use, especially in cities (Adriazola-Steil et al., 2021; Berger et al., 2014). This can perhaps be the solution to accommodate the transition toward sustainable mobility.

While cycling is already highly promoted in the Netherlands, there is still very little evidence of whether cycling reduces car mobility significantly (Ton et al., 2019; Pucher et al., 2008). Furthermore, according to Lucas et al. (2011), attempts to encourage people to drive less and use more sustainable modes of transportation have failed due to a variety of subjective and objective factors that limit modal shift, as well as a larger system dynamic that has locked-in patterns of car use over time. If car use is to be successfully controlled, there must be a better understanding of the nature of car dependence, its contributing factors, and the relation between cycling.

1.2 Societal relevance

During the Climate Agreement in Paris (COP21), it became clear that the European Union and its member states must take drastic action to deal with the inevitable consequences of climate change. Hence, the aim is to limit the average temperature increase to 2°C above pre-industrial levels (Europa-nu. 2018). This means that the member states need to scale up their efforts and support actions to reduce emissions. The mobility sector, however**,** as one of the most contributing sectors, did not fully achieve sustainability objectives. It, therefore, shows the importance of urgent actions for change to more sustainable systems (Moradi and Vagnoni, 2018). In addition, the European Commission has estimated the costs for the negative externalities of motorized transport on the environment, health, and mobility at around 800 billion euros per year (ECF, 2018). In the Netherlands, approximately 610 people are killed annually in traffic accidents. About 60% are caused by motorized vehicles (CBS, 2021a). This is significantly higher than the amounts of deaths caused by active travel (CBS, 2021a).

Furthermore, a reduction in car mobility is also needed to reduce the geopolitical dependency on fossil fuels. Gasoline engines drive almost 80% of all passengers' cars, and around 11% are on diesel engines (CBS, 2021a). The share of electric and hybrid vehicles is increasing, yet, it will take many more years before cars on fossil fuels are entirely replaced (KiM, 2010a). In order to be independent of high-risk countries such as Russia and Saudi Arabia concerning fossil fuels, a reduction in car mobility thus is needed.

Regardless of the growing interest, the concept of a "network" for soft mobility has yet to be realized. The provision of fully integrated facilities and services as an alternative to car use appears to be a challenging task (La Rocca, 2010). Furthermore, despite multiple laws and roles that adopt alternative ways of transportation to minimize negative impacts (especially air and noise pollution), European countries have a high disparity in promoting soft mobility (La Rocca, 2010). Primarily due to car dependence on urban short distances.

1.3 Scientific relevance

Most of the present literature discusses the urgency to reduce car mobility and presents solutions to how the promotion of cycling can accommodate this reduction. However, those solutions are mainly based on urban areas, and only limited research has been done into how the promotion of cycling can reduce car mobility in rural areas as well (Adriazola-Steil et al., 2021). Future research should also consider the spatial differences when stimulating more bicycle use. Furthermore, much research is done about the success factors that contributed to the high share of cycling in the Netherlands, yet this does not indicate how those factors did contribute to fewer cars in the country (Ton et al., 2019; Pucher et al., 2008). Moreover, although the literature has produced theoretical and critical insights into embodiment, diversity, and governmentality regarding cycling, it has largely ignored the relationship between cycling and larger political-economic structures (Spinney, 2020). In addition, a knowledge gap in literature can be found that discusses how the promotion of cycling can reduce car mobility from a transition theory-based perspective.

Thus, this research contributes to the existing literature in multiple ways. First, it attempts to understand how the promotion of cycling can contribute to a reduction in car mobility in urban and rural areas. Secondly, it explores whether the success factors regarding cycling contributed to less car use in the Netherlands. Third, it will build upon the present literature regarding cycling while also focusing on the political-economic structures. Lastly, it adds to the limited theoretical evidence that provides new insights into how car mobility can be reduced due to the promotion of cycling from a transition theory perspective.

1.4 Research aim

In order to meet the sustainability goals made by the Climate Agreement in Paris, and to deal with the negative impacts of car mobility, a transition is needed to move towards more sustainable forms of mobility. Therefore, this research aims to understand the relationship between car mobility and cycling, and how cycling can contribute to the reduction of car use in the Netherlands. In addition, this research will investigate how promotion of cycling will enable this transition, and how this can be fostered to ensure long-term results. Hence the following research question is formulated:

Q1: "*How can the increase in cycling's modal split contribute to the transition from car mobility towards sustainable modes of transportation?*"

To structure this research and to be able to answer the main research question, several sub questions have been defined. These are stated below:

Sub questions
Q1.1 If and how has the increase in cycling over the past few decades contributed to the reduction of car mobility in the Netherlands?
Q1.2 What are the characteristics of car mobility in the Netherlands?
Q1.3 How can the promotion of cycling contribute to the reduction of car mobility and how should this be organized in the Netherlands?

1.5 Reading guide

The following chapter provides a theoretical framework for the main concepts of this research, including the conceptual model. Chapter 3 presents the methodology, the research design, data collection, and the process of data analysis. Chapter 4 the results are discussed extensively and n chapter 5 the discussion and conclusion are listed. The recommendations for further research can be found in chapter 6. In the last chapters, the references and appendices are stated.

Theoretical framework

2.1 Car mobility

Car mobility (or automobility) can be conceptualized as a nonlinear, self-organizing system that spreads worldwide (Urry, 2004). Several authors have argued that due to the combination of six components, the automobility system generates and reproduces its domination in the world (Urry, 2004; Sheller and Urry, 2000). These are the following:

Manufactured object

First, it is a *manufactured object*, which means that the car is produced by one of the most powerful and leading economic industries within the 20th century (Urry, 2004). Those powerful economies are Ford, Toyota, Volkswagen, Mercedes, and so on (Bradford DeLong, 2022). Consequently, this led to a revolution in the industry, which introduced mass production, and terms of Fordism and post-Fordism became known (Ankli et al., 1984). Moreover, this affected societies, where modern lives, work and built environments were structurally altered and maintained by car use (Kesselring, 2020).

Individual consumption

Car mobility is also related to the *individual consumption:* Alongside housing, a car provides status for its owner/user through many associated values such as speed, flexibility, safety, career success, freedom, and masculinity (Miller, 2001). In literature, status can be characterized as a symbolic or social aspect related to the expression, social position, comparison to others, and societal norms that explain why people want to own a car (Steg, 2005; van der Waard et al., 2013). Furthermore, individual consumption can also be related to affective aspects. Affective aspects refer to the driver's emotional state and why a particular person chooses their mode of transport. (Steg, 2005). Next, the state of freedom is mentioned, to which people have the idea that they can travel when and wherever they want (van der Waard et al., 2013, Steg, 2005). In addition, the power of control is discussed (Gardner and Abraham, 2007; Steg, 2005). Other literature argues enjoyment as reason, meaning people choose the car because they enjoy driving (Karen et al., 2011; Ramos et al., 2019; Steg, 2005).

Complex system

Moreover, automobility is linked with many social and technical industries, making it a *complex system* (Urry, 2004). It is connected with, among others, the oil and steel sector, garages, hotels, retail and recreation sector, and urban planning to develop, construct, maintain, and distribute cars (Urry, 2004). In addition, Banister (2008) explained why car mobility is also linked with other sectors. Almost every sector (e.g., work, education, and leisure) provides activities where people are traveling. He argues that the value of the activity to its destination will lead to travel and that travel is thus a derived demand (Banister, 2008). The other underlying principle is that people are minimalizing their travel costs and time (Banister, 2008). Hence, people take the most cost-efficient mode of transport. Consequently, this increases car use (Banister, 2008; Urry, 2004).

Subordination of other transport modes

Next, car mobility provides a form of mobility that *subordinates* other transport mobilities such as walking, cycling, and rail transport (Urry, 2004). It will also determine when, how, and where people engage in activities (Kesselring, 2020). Again, this can be related to the principle of Banister (2008) regarding generalized cost minimization. Furthermore, the distance to activities determines whether people take a car or not (Karen et al., 2011; Gardner and Abraham, 2007; van der Waard et al., 2013). Up to 7,5 kilometers, most people are able without much effort to substitute the car for other transport modes, like walking and cycling. For a larger distance, fewer people are able and willing to walk or cycle and will choose motorized vehicles or public transport (CBS, 2017).

Furthermore, due to the decentralization of cities, the use of cars is rising, and cycling and walking have become less attractive (Banister, 2008). In addition, the subordination of other transport modes is also caused by the car dependency of people (Banister, 2008; Wiersma et al., 2017). According to Wiersma et al. (2017), car dependency is the lack of travel choices to daily destinations. To this, a clear distinction is made between objective and subjective (emotional) dependency, whereas objective car dependency refers to the non-availability of alternatives in terms of costs and time. Subjective car dependency depends on habits, motivations, and lack of information about alternative transport modes (Wiersma et al., 2017).

Dominant culture
The car's *dominant culture* in the world refers to the discourse or dialogues of car mobility in people's life (Urry, 2004). This can be related to the image of the American Dream, for example, where people need a car to live their best life (i.e., how to have appropriate citizenship) (Bradford Delong, 2022). In addition, it serves as a dialogue for films, literature, music, and other arts (Urry, 2004; Karen et al., 2011).

Nonrenewable environmental resources
Lastly, car mobility is one of the most important causes of *environmental resource use.* This system uses materials, space, and power to produce cars, roads, and car-only environments (Urry, 2004). Consequently, this contributes to negative environmental pressures and pollution (Kesselring, 2020). These emissions are not only caused by a car's emissions but considered from the whole life circle from its conceptual design to the final re-entry into resource use as scrap (Kesselring, 2020)

Automobility is thus not only about combining humans with machines and infrastructures such as streets, paths, and lanes, but also about the whole systems with their interconnections (Urry, 2004). Despite the different positive effects, such as increased interactions in activities, comfort, and income due to its industry, the negative consequences of the car in daily life are not negligible. Hence, the next section will provide some of the challenges caused by automobility.

2.1.1 Challenges of car mobility

Most of the challenges of car mobility are often interlinked or are an accumulation of effects that will lead to a more severe and significant problem. However, for the sake of this report, the challenges will be divided into several categories: environment and health, energy, livability, and land use. This categorization has been based on the annual report on sustainable mobility of the European Cyclists' Federation (ECF, 2018).

Environment and health
Transport is one of the most significant sectors responsible for climate change (Scarinci et al., 2017). In 2016, the European Union's transport sector was responsible for around 20% of greenhouse gasses, which road transport caused 72% of it (European Environment Agency, n.d.). Greenhouse gasses contribute to global warming. An increase of 3-4 degrees Celsius in temperature will cause a high sea-level rise, significant loss of biodiversity, more extreme weather conditions, and food insecurity, resulting in catastrophic effects and conflicts (Urgenda, n.a.). In addition, the transport sector is emitting harmful air pollutions such as carbon monoxide (CO), nitrous oxides (NOx), particulate matter (PM2.5, PM10), sulfurous oxides (SOx), volatile organic compounds (VOC), and ozone (O3) which lead to among others, acidification, eutrophication, and health issues (Gössling et al., 2019). Furthermore, noise pollution is generated, especially in highly dense urban areas (Gössling et al., 2019). Next, the car industry is also responsible for vast amounts of waste in the environment, mainly due to the production of cars and fuel extractions (National Geographic, 2019; Volkskrant, 2021). Besides air and noise pollution, automobility contributes to other health-related issues. The most problematic ones are obesity and cardiovascular diseases (Douglas et al., 2011). In the European Union alone, around 53% of the population is overweight, of which 17% deal with obesity (CBS, 2018).

Energy
The car mobility industry uses many non-renewable energy sources due to the manufacture of cars, the construction and maintenance of the road network, and the fuels needed to drive the vehicle (Jolly, 2021). In recent years, more cars have been developed that use more sustainable resources (e.g., electric cars, natural gas, or biofuels) (Jolly, 2021). Calculations suggest that electric vehicles will use 58% less energy than petrol cars and emit 65% less carbon dioxide over their lifetime (Jolly, 2021). However, due to the growing interest in sport utility vehicles (SUVs) in the European Union, an increase in emissions can be found. SUVs are typically heavier than other cars and have more powerful engines, resulting in higher fuel consumption (European Environment Agency, 2021).

Livability and land use

Several authors have argued that people's livability is decreasing due to the car mobility system (Berger et al., 2014, Ahmed, 2019). Livability is a critical concept in urban planning and appears in academic and non-academic literature. Despite its widespread use, the term "livability" lacks a precise definition, and one may argue that it is a highly subjective phrase (Ahmed, 2019). Nonetheless, there is still consensus regarding crucial elements of the concept (Ahmed, 2019). According to Mohamad (2016), *"Livability refers to various constructed views regarding the quality of life in any human living environment (p. 240)."* In addition, livability has emerged as a response to some 20th-century planning techniques, whereby it takes a holistic strategy by addressing the physical, social, and cultural dimensions (Chazal, 2010). It thus has progressively broadened to include several guiding principles, namely, *"accessibility, equity, safety, comfort, available services, walkability, transit, and participation" (*Ahmed, 2019, p. 167).

Regarding safety, livability is affected since the car mobility sector causes fatal accidents and facilitates crime due to speeding, street races, car bombs, etc. (Schubert et al., 2019). Livability is also negatively affected due to urban sprawl. Bruegmann (2015) states that urban sprawl is defined as the rapid expansion of low-density settlement patterns in which there is a high reliance on automobility. Many indicators explain the causes of urban sprawl: increased income, population growth, improvements in transportation systems, and diversity in users' choices are the most important ones (Habibi and Asadi, 2011; Bruegmann, 2015). Due to urban sprawl, issues in the transportation sector such as more commuting, increased distance in travel to activities, more congestion, and disconnection with local communities are prevalent (Habibi and Asadi, 2011).

Consequently, this will lead to poorer transit, less walkability, and lower accessibility for people that do not own a car. Additionally, the automobility sector also uses a lot of space for highways, car lanes, tunnels and bridges, and other associated infrastructures, which leads to landscape fragmentation mainly in rural areas (Berger et al., 2014). Simultaneously, spaces have been made available in urban areas for car lanes and parking spaces, leaving less room for pedestrians' walkways and parks, which are more beneficial for people's wellbeing and health (Doheim et al., 2020).

2.2 The mobility transition

To change the car-dominated transport world, a transition is needed. According to Runhaar et al. (2020), sustainability transitions are assumed to require a deep-structural and radical transformation since unsustainable processes, like car transportation, are prevalent in many industries and cannot be improved incrementally but needs to undergo a systematic change in markets, policies, technologies, cultural expectations, networks, and regulations. That systematic change or transition can be defined as "*processes of structural change in major societal subsystems*" (Meadowcroft, 2009, p. 324). Furthermore, this can conceptualize via a Multi-Level Perspective (MLP) and an S-shaped Curve (Meadowcroft, 2009; Van der Brugge et al., 2005). MLP understands transitions due to the interaction between three levels: socio-technical landscape, socio-technical regimes, and technological niches (Runhaar et al., 2020). The socio-technical landscape is the external pressures and macro developments, to which, in this case, climate change is the most important one (Banister 2008). Socio-technical regimes refer to the set of rules (formal and informal) to steer actors and activities in socio-technical systems. Technological niches are the protected spaces where innovations can develop without the pressure of the dominant regime (Runhaar et al., 2020). The MLP is illustrated in figure 1, which is edited to show examples of macro-and micro-developments.

A transition can be seen as a shift from one socio-technical regime to another. According to the MLP, this occurs when new, more sustainable niche alternatives impose bottom-up pressure on the regime. At the same time, landscape forces push top-down pressures and generate windows of opportunity for niche opportunities (Runhaar et al., 2020). Climate change is one of the most critical top-down pressures pushing a sustainable mobility transition (Europees Milieu Agentschap, 2020). Already in European Union, the transport sector contributes to almost 30% of the total greenhouse gas emissions that causes global warming, of which 72% is derived from road transport (Europees Milieu Agentschap, 2020; Europees Parlement, 2019). Therefore, all the European Union member states, including the Netherlands, decided to reduce their transport emissions by 60% in 2050 compared to 1990 (Europees Parlement, 2019). Thus, the Netherlands is pressured by climate change to start the transition toward sustainable mobility to reduce the efforts of greenhouse gasses. In addition, this sustainable mobility transition can be stimulated due to bottom-up initiatives. According to Loorbach (2010), innovations refer to activities, experiments, and actions that operationalize new structures, routines, or actors. Examples of innovations in this sustainable mobility transition are e-bikes, Velo bikes, light-electric vehicles, Mobility as a Service (MaaS), and fast bicycle lanes (De Haas, 2019; Anwb, 2019; Arnold, 2021).

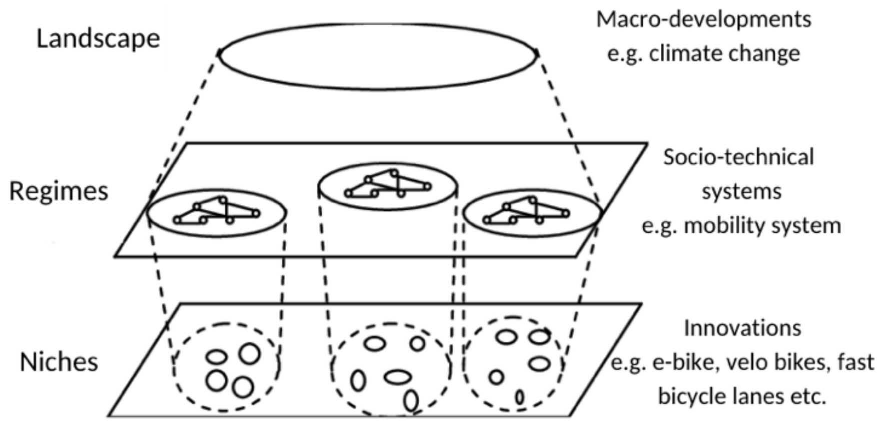


Figure 1: Multi-Level Perspective hierarchy (Source: Geels, 2002, edited by author).

Via the S-shaped curve (figure 2), the pathway of a transition is illustrated. Even though it shows a simplified curve, it indicates how a transition pathway could be considered from a slow equilibrium dynamic through a phase of fast and unstable development towards a new period of stabilization (Van der Brugge et al., 2005). The system undergoes an irreversible change between the two equilibrium states and will thus (re-) organize itself again (Van der Brugge et al., 2005). The transition pathway starts with the pre-development phase, where the status quo is not visibly altered, but changes are taking place under the surface. During the take-off phase, the system starts to transition. In the acceleration phase structurally, changes will take place rapidly due to the accumulation of economic, institutional, socio-cultural, and ecological changes that strengthen each other (Van der Brugge et al., 2005). Lastly, a period of stabilization occurs, where a new dynamic equilibrium is reached (Van der Brugge et al., 2005).

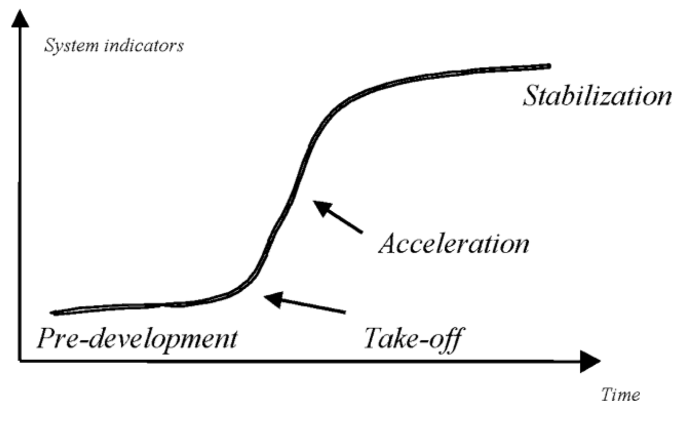


Figure 2: S-shaped curve showing the transition pathway (Source: Van der Brugge et al., 2015).

The center of transition management lies in the challenge of creating long-term change in large socio-technical systems (Meadowcroft, 2009). Nevertheless, managing large systems, such as car mobility, often deals with the complexity and interrelatedness of different subsystems (Geels, 2018; Meadowcroft, 2009). The conventional mobility regime focuses on cost minimization, looking at travel costs and time costs

(Banister, 2008). Consequently, negative environmental and social aspects (e.g. pollution and health effects) are often ignored or are taken for granted (Jordan, 2008). Moreover, this regime deals with a so-called 'lock-in', where society becomes trapped in sub-optimal results or outcomes (Meadowcroft, 2009). Due to the path-dependent pattern of car mobility, in the late 19th century, economies and societies were locked in the so-called steel-and-petroleum car industry (Urry, 2004). This entails significant returns and social benefits for producers and consumers in terms of services, products, and its associated infrastructure, which has led to substantial car-oriented infrastructure and is therefore, often very difficult or expensive to redesign into a more sustainable, car-free (urban) area (Nieuwenhuijsen and Khreis, 2016). This leaves the regime thus trapped in a sub-optimal outcome.

To address the lock-in, transition management theory argues that policymakers must pursue system *improvement* and *system innovation* (Meadowcroft, 2009). System improvement refers to incremental, step-by-step changes to existing practices, whereas system innovation means fundamental adjustments are made to the dominant system (Meadowcroft, 2009). According to Wiersma et al. (2017), such fundamental change is necessary for the mobility sector to address the lock-in. Top-down approaches defined by policymakers currently dominate sustainable development in the mobility sector, yet, all system players, including others, individuals, researchers, and private companies, are responsible for developing sustainable mobility (Wiersma et al., 2017). For system innovation to take place, collaboration is needed between various stakeholders to experiment with niche developments. In addition, Loorbach (2010) explains that the focus must be on the interaction of the multiple actors within the mobility domain to initiate the transition.

2.3 Cycling as part of active travel

Several authors have argued that cycling can be used as an alternative for car mobility in spaces and traveling between places (La Rocca, 2010; Adriazola-Steil et al., 2021; Berger et al., 2014; Jaszczak et al., 2020). Cycling has been increasingly recognized as a clean, sustainable transport mode that contributes to healthy cities, increased physical activity, and positive environmental aspects (Fernández-Heredia et al., 2014). In addition, this mode of transport is expected to contribute to the transition towards sustainable mobility and other transport modes that fall under the category of active travel (La Rocca, 2010). Active travel, active mobility, or soft mobility (hereafter, active travel) all refer to every form of non-motorized transport where it is aimed at increasing urban livability and keeping the individual right to move (La Rocca, 2009). Although more non-motorized transport modes can be distinguished, such as running, rowing, skateboarding, and roller skates, walking and cycling are the most dominant forms, both in practice and in scientific and non-scientific literature. (La Rocca, 2010; Markvica et al., 2020). Hence, only walking and cycling will be discussed when referring to active travel. The potential of active travel has increasingly been recognized and is considered an effective solution to meet sustainability objectives at various political dimensions and being proactively accepted by citizens (Rietveld, 2001; Ferretto, 2021). Unlike other measures and policies, active travel can be perceived as less invasive and implemented in spaces with limited infrastructural capacity (Markvica et al., 2020). Many political institutions have commonly desired and demanded active travel measures and policies due to their positive potential impacts (Markvica et al., 2020). Some possible effects of active travel are increased health benefits, reduced dependency on fossil fuels, less congestion, and less pressure on the environment and eco-systems (Ferretto et al., 2021; La Rocca, 2010). According to Markvica et al. (2020), an effective active travel system can be achieved with a combination of hard (physical) and soft (non-physical) measures. Examples of hard measures include the availability and (to some extent) the quality of bicycle and pedestrian infrastructure and products. At the same time, campaigns, education, and social marketing refer to soft measures. A more sustainable mobility behaviour will occur by frequently combining hard and soft measures (Markvica et al., 2020).

Although walking and cycling share most of the same characteristics, in policy implementation and measures, cycling has often been studied independently. One of the reasons is that cycling is perceived and indicated as a better alternative since people tend to take the bike more instead of walking (Ton et al., 2018). Reasons for this could be the embedded culture, efficiency, and travel distance (Ton et al., 2018).

To investigate how cycling can influence the reduction of auto mobility, a background of cycling in Europe will be given. After that, the decision to cycle will be discussed, together with the benefits and challenges. Finally, a framework of policy instruments to promote cycling will be given.

2.3.1 Cycling characteristics in Europe

After bicycles were introduced in the 19th century, cycling quickly became popular, with more than a billion people using it for transportation, recreation, and sport-related activities (Manners, 2015). This trend changed substantially during the post-war decades in Europe due to mass motorization, and in some countries, the removal of bicycle infrastructure resulted in decreased bicycle share (De Roo, 2003). Nonetheless, during the 1970s, governments became increasingly concerned about the problems caused by mass motorization, to which substantial environmental awareness appeared (Schepers et al., 2021). As a result, policymakers aimed to substitute short-motorized trips with non-motorized transport modes (e.g. cycling). Around the 1990s, the European Commission embraced the goal of promoting cycling by adding it to their agenda, resulting in the establishment of several European projects, namely ADONIS and WALCYING, to develop knowledge and inform policies at the national and even city-level (Goodman and Tolley, 2003). Moreover, explicit and ambitious goals were formulated to enhance and promote bicycle use (Schepers et al., 2021). The Dutch Masterplan Bicycle in the Netherlands in 1990 intended to achieve 30% more bicycle kilometers by people in 2010 than in 1995 (Ministry of Infrastructure and Environment, 1998). Similarly, other European countries and cities, such as Germany (Berlin), Denmark (Copenhagen), and Austria (Vienna), also specified particular aims and goals to improve their bicycle share. (Schepers et al., 2021). This movement of bicycle use in Europe is illustrated in figure 3, which shows the contrast between the pre-war II and post-war II periods concerning cycling.

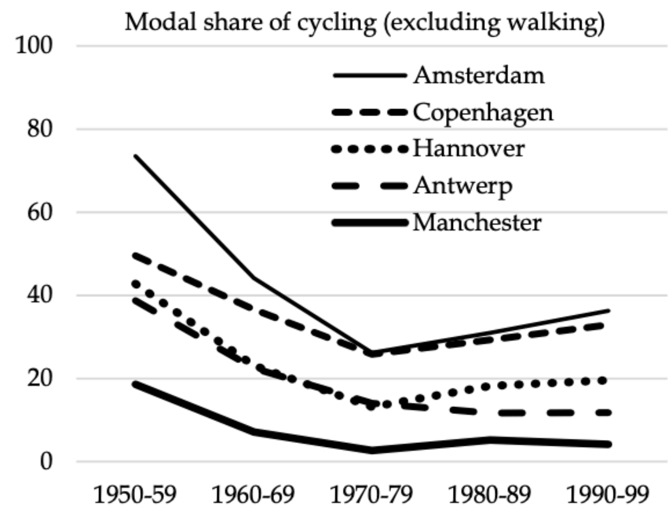


Figure 3: Modal share of cycling (Source: Schepers et al., 2021).

In addition, due to multiple policy implementations and ongoing environmental awareness, bicycles have become more prevalent in Europe, especially in the countries such as the Netherlands and Denmark (figure 4).

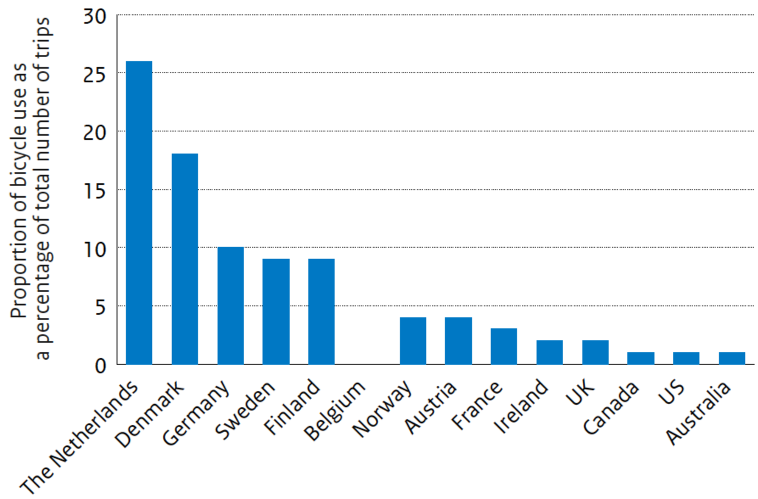


Figure 4: Proportion of bicycle use as a percentage of total number of trips in several countries. (Source: KiM, 2018).

2.3.2 The decision to cycle

Many variables are essential in using the bicycle rather than other transport modes. In their study, Fernández-Heredia et al. (2014) have grouped the most influential variables into three categories to describe which ones affect bicycle use the most. That research was based on extensive data primarily conducted with secondary scientific literature analysis. The groups are general socio-demographic characteristics of users, choice factors, and latent variables. (Fernández-Heredia et al., 2014). Demographic characteristics of users refer to gender, age, economic status, occupation, family size, and the availability of a car or bicycle (Fernández-Heredia et al., 2014; Pinjari et al., 2008). Choice factors are divided based on how these factors affect users individually, collectively (in relation to the environment), structurally, and subjectively (Fernández-Heredia et al., 2014). Individual factors are trip duration, trip purpose, and flexibility of transport mode, whereas collectively (or environmental) refers to weather conditions, topography, and urban design (Fernández-Heredia et al., 2014). Structural factors include a bicycle network, parking spaces, and additional facilities (Hunt and Abraham, 2007). Next, subjective factors indicate the perception of risk, sense of security, and opportunity for physical activity (Fernández-Heredia et al., 2014). Lastly, latent variables were identified, with which the most dominant are sensitivity to time, desire for comfort, and environmental awareness (Steg, 2005; Fernández-Heredia et al., 2014).

In addition, other variables such as cycling context conditions, general transport costs, and cycling mobility costs will also influence the bicycle decision. These variables are also illustrated in the figure below (5).

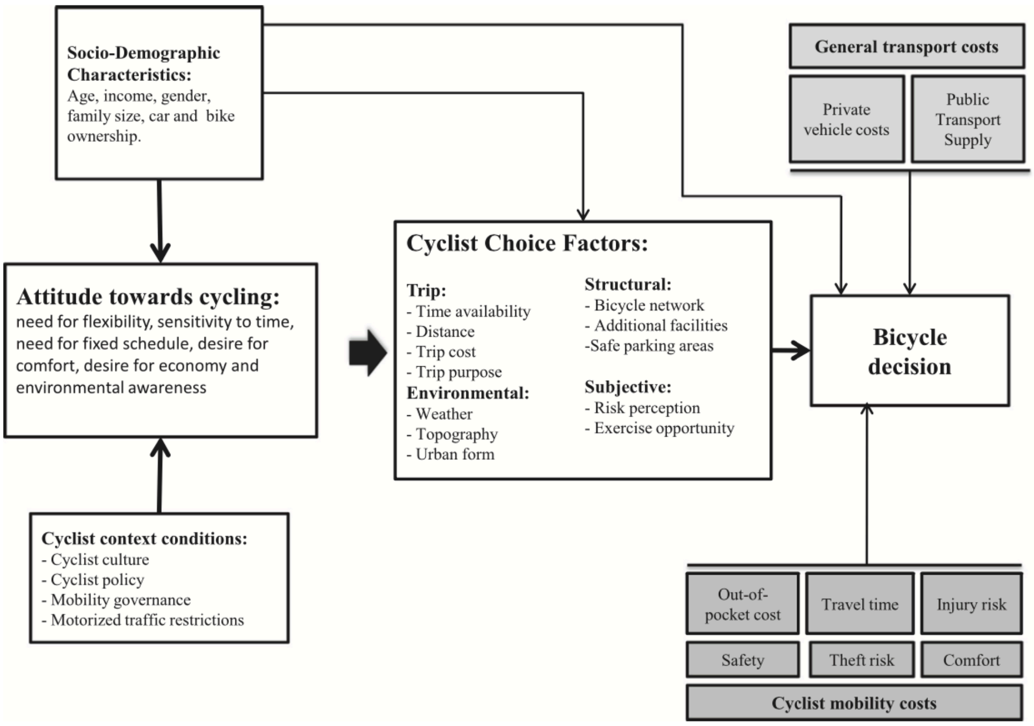


Figure 5: Conceptual model of factors affecting bicycle use (Source: Fernández-Heredia et al., 2014).

In short, these variables thus indicate people's decision to cycle. Next, cycling brings many environmental, economic, spatial, and social aspects along. Hence, the next part will elaborate on this.

2.3.3 Benefits of cycling

Several benefits can be identified concerning cycling. According to the European Commission, cycling produces, already at current levels, globally 150 billion euros each year, to which more than 90 billion euros are linked to positive externalities such as public health, the environment, and the mobility regime (ECF, 2018). These benefits appear not only in the mobility regime or the environmental policy but also in other sectors such as industry, employment, and the social sector. A distinction is made to show the benefits of cycling based on the ECF program (2018). These are environment and health, economy and time/space, and social affairs.

Environment and health

Several environmental and health-related benefits originate from cycling. These benefits are mainly obtained compared to the car. First, cycling contributes to more CO2 emission savings and less air and noise pollution (EEA, 2018; Houthuijs et al., 2014, ECF, 2018). Secondly, no fossil fuels are needed to use the bicycle (excluding the manufacturing costs), reducing the geopolitical dependency on high-risk countries such as Russia, China, and Saudi Arabia (Quaney, 2022). While most materials will remain the same (e.g., steel, aluminum, and polymers), bicycles need less non-renewable resources than cars.

Moreover, materials like platinum or palladium, which cause a lot of environmental damage, are not used anymore in the production of bicycles (ECF, 2018). Cycling also contributes to longer and healthier lives (ECF, 2018; Anderson et al., 2018). It helps to prevent diseases such as type 2 diabetes, cardiovascular diseases, cancer, and osteoporosis that are harmful or even fatal (Anderson et al., 2018). Other positive effects are increased mental health benefits because engaging in moderate physical activity reduces the risk of Alzheimer's disease and lowers the odds of developing depression (Guure et al., 2017; Schuch et al., 2018). From a study in Denmark in 2012, the results show that cycling also increases children's concentration levels when they go by bike to school instead of getting a lift by car (ECF, 2018). Lastly, employees who cycle to work regularly have fewer yearly sickness absences (ECF, 2018). This means that direct and indirect costs of around 5 billion euros in the European Union per year are being saved (Hendriksen et al., 2010).

Economy and Time/Space
Next, economic benefits also occur due to cycling. Due to increased bicycle use, bike manufacturing companies and related industries are growing in value, resulting in positive financial impacts (ECF, 2018). Moreover, the associated cycling tourism provides more than half a million jobs on a national, regional, and local scale in the European Union (European Parliament, 2012). It is also argued that customers coming by bike tend to spend more than customers who come by car (ECF, 2018). In addition, due to the growing interest and increased environmental awareness, the sale of e-bikes is rising (de Haas, 2019). Next, by making use of the bike-sharing system, trips become more efficient, and cities become better connected since it provides easy and fast first-mile (or km) and last-mile (or km) access, thus enhancing productivity in the urban economy (Bullock et al., 2017; ECF, 2018). The positive impacts on the time and space relation are. First, that bicycle use is space-efficient (i.e., seven times more bikes than a car can cross a 3.5-meter-wide space for one hour). Furthermore, 15 bicycles can fit in 1 car parking spot, leaving more room for other purposes (ECF, 2018).

Social affairs
Finally, cycling can also be linked to positive social impacts. In literature, advisory reports, and research documents, the benefits of cycling are often related to environmental, health, or economic matters, whereas the social aspect is under-appreciated (Bielak, 2015). However, it is vital to understand the social benefits since it can incentivize policymakers to actively promote cycling behavior and non-users to engage in cycling activities. One of the social benefits refers to the concept of equality. Owning and using a bike only accounts for 5 % (or 10% for an e-bike) of the total costs rather than using your car (ECF, 2018). This relatively cheap mode of transport provides the opportunity for people with low income to participate in bicycle-related activities, thus creating a higher inclusion rate and improved participation. Cycling also provides a higher perceived security level and increases social control (ECF, 2018). With 'more eyes on the street, ' safety and a sense of community are created, resulting in less crime and better community feeling (Jacobs, 1992). Other social benefits are congestion easing and increased resilience due to the provision of transport options in cases of emergency such as terrorist attacks and natural disasters (CE Delft, 2019; Page, 2014). Lastly, cycling provides a form of social activity whereby it brings people together, connects different neighborhoods, and connects people with places of social and cultural exchange (ECF, 2018).

2.3.4 Challenges of cycling

Despite the positive effects of cycling as a mode of transport, it is essential to note that cycling comes with several risks and potential impairments that separately or combined result in challenges or disadvantages. As stated by Urseche et al. (2019), those challenges of disadvantages will undoubtedly influence their choice of transportation mode. Therefore, such risks and impairments will be discussed to understand why travelers are not able or willing to use their bicycles. One of the risks is related to the (poor) safety of cycling. According to several authors, cyclists are more exposed to dangerous driving behavior (from motorized vehicles) and road hazards resulting in high traffic accidents (Urseche et al., 2019; Int Panis, 2011). Especially since cyclists do not often wear protected clothing or/and are not protected by the vehicles themselves (e.g., airbags). However, people who cycle more frequently are less prone to suffering in cycling crashes (Urseche et al., 2019).

Furthermore, Titze et al. (2007) argue that bicycle theft is a vital disadvantage since bicycles are easier to steal compared to other modes. In addition, due to extreme weather events such as rain, strong wind, or heat, fewer people are willing to use the bike (Urseche et al., 2019; Titze et al., 2007). Also, the distance to a location and the landscape characteristics play an essential role. As stated before, up to 7,5 km, most people are able and willing to go by bike (CBS, 2017). Longer distances are, therefore, less preferred or feasible.

On top of that, some people with physical disabilities are not able to ride a bike in the first place (Inckle, 2020). The landscape characteristics, for instance, a steep slope, poor road surface, and the lack of bicycle infrastructure, also challenge cycling (Stuart, 2018; Sabeli, 2022). Finally, other components such as comfort, the inappropriateness of everyday clothing on a bike, sweating, and stress are more prevalent in bikes than in different transport modes (Titze et al., 2007).

2.4 Promotion of cycling

A rising amount of evidence demonstrates that policies and interventions promoting cycling can positively impact bicycle use (De Nazalle et al., 2011). According to Pucher et al. (2008), these policies of promotional activities are predominantly based on identifying variables that affect bicycle use, as also discussed in chapter 2.3.2. Combinations of several strategies and policy implementations are frequently implemented together. Consequently, this will make it more difficult to isolate specific elements that may change travel behaviors. Still, it also suggests that multi-level policies or interventions are most effective at achieving change (Markvica et al., 2020). Such multi-level interventions include infrastructure improvements (cycling-friendly environments) and public awareness programs (at schools and workplaces). Implementing such interventions will involve many public and private organizations, including planners and developers, commercial and voluntary organizations, and traffic and highway engineers (Karen et al., 2011).

To understand how the promotion of cycling is organized, we need to take a closer look at the policy instruments that allow for the increasing benefits of cycling without causing excessive drawbacks. Before that, several pre-conditions to achieve successful bicycle policy implementations are discussed.

2.4.1 Instruments for the promotion of cycling

Pre-conditions

While most cycling strategies depend on the specific context, Ferretto et al. (2021) argue that some general pre-conditions are most relevant for the success of sufficient promotion of cycling strategies within the complexity of the mobility system. For instance, cycling strategies combined with an efficient public transport system successfully reduce externalities from the transport sector (Ferretto et al., 2021). Other pre-conditions are that the city's design and morphology are well designed, easy to use, and incentivizing (Nocera and Bruzzone, 2019). Furthermore, when demand elasticity is low and when the first- and last-mile (or km) are well organized in urban areas (Ferretto et el., 2021).

Physical instruments

Several hard or physical instruments promote bicycle use (table 1). According to Ferretto et al. (2021), these instruments can be translated into urban and planning policies, in which plans are made to construct or renew bicycle networks and lanes. In addition, hard instruments can improve the accessibility and effectiveness of cycling by adding streetlights (i.e., bicycle-friendly streets), creating public space, and creating bicycle storage (Karen et al., 2011). Next, an improved public transport system can contribute to more cycling. By adding new trams, trains, buses, and metro lines, the accessibility of an area will be improved. This will lead to better use of PT-bicycle modal split since it increases people's flexibility and axis radius (Feretto et al., 2021). Lastly, densification, more mixed-use facilities, and the stimulation of local goods and services will contribute to more cycling in an area Karen et al., 2011).

Table 1: Overview of physical instruments (Source: Ferretto et al., 2021; Karen et al., 2011).

Physical instruments
Construction bicycle network
Bicycle friendly streets
Bicycle storages
Improved public transport: construction of train, tram, and metro
Densification and mix-use policies/ provision of services
Local sourcing of goods and service

Policy instruments for bicycle use

Alongside hard instruments, the promotion of soft instruments (or policy instruments) will enable an increment in cycling mobility. Those instruments can be divided into several categories: incentive-based, technology-based policies, and promotional campaigns (Ferretto et al., 2012; Doheim et al., 2020; Karen et al., 2011). Incentives-based instruments use financial means to encourage polluters to decrease health and environmental risks caused by their facilities, processes, or products, either directly or indirectly (Anderson, 2002). These instruments will reward users or impose various fees for polluting more. Examples of incentive-based policies, in this case, are funding for bicycle infrastructure and technologies and funding for bicycle promotional campaigns (Ferretto et al., 2021, Doheim et al., 2020). Technology-based instruments can improve bicycle use by stimulating technologies and innovations, such as e-bikes, light-electric bikes, Velo-bikes, and cycling apps. According to Karen et al. (2011), promotional campaigns can assist in minimizing the need for travel while encouraging modal shift through better and more targeted information and service marketing. While they are primarily intended to increase participation in local or in-home activities and encourage modal shift among car-reliant journeys, they may also help to create more bicycle trips if they inspire individuals to change their lifestyles. This means supporting local businesses and thereby changing trip destinations to which the bicycle can be used as a transport mode (Karen et al., 2011). Other promotional campaigns include education, increased awareness of the negative impacts of current travel behavior, improved information about the possibilities of cycling, and marketing aimed at a changing image (Ferretto et al., 2021; Karen et al., 2011). Table 2 shows an overview of the policy instruments that promote bicycle use.

Table 2: Overview of policy instruments for bicycle use (Source: Ferretto et al., 2012; Doheim et al., 2020; Karen et al., 2011).

Technology-based policies	**Promotional campaigns**	**Incentive-based policies**
E-bikes	Education	Funding for bicycle infrastructure
Velo-bikes	Communication	Funding for bicycle technologies
Cycling apps	Environmental and health awareness	Funding for promotional campaigns
	Bike-sharing system	

Car-based policies

Specific policies or initiatives that promote cycling do not continually target cycling directly but have an indirect effect by reducing auto-driving and encouraging other modes of transportation (De Nazalle et al., 2011). Hence, it is important to consider those promoting the reduction of car mobility. Pricing policies are the most effective instrument for reducing car use (Doheim et al., 2020). Examples of practical measures are congestion charging, paid parking, tax on C02 production, and increased costs on fossil fuels (Ferretto et al., 2021; de Nazalle et al., 2011). In addition, promotional campaigns can also lead to the reduction of cars in which education and communication about alternatives to car mobility can be promoted, increased awareness of negative environmental and health impacts due to car mobility can be discussed, and social acceptability of non-car-based behavior patterns are presented (Karen et al., 2011). Lastly, physical instruments, such as zero-emission zones, narrow streets, low-traffic zones, and physical barriers will also reduce and discourage car use (Doheim et al., 2020; Ferretto et al., 2021; Karen et al., 2011). All the car-based policies are listed in table 3.

Table 3: Overview of car-based policies (Source: Ferretto et al., 2021; Karen et al., 2011; Doheim et al., 2020; de Nazelle et al., 2011).

Pricing policies	**Promotional campaigns**	**Physical instruments**
Congestion charging	Education	Zero emission zones
Paid parking	Communication	Narrowing the streets
Tax on C02 production	Environmental and health awareness	Low-traffic zones
Increase costs fossil fuels		Physical barriers
Toll driving		

2.5 Conceptual model

The theoretical framework has discussed several relevant concepts and theories related to the research aim. Based on this, a conceptual model has been established, as seen in figure 6.

First, the conceptual model shows the relationship between cycling and car mobility. The promotion of cycling can have a direct positive effect on the use of cycling, as was argued by de Nazalle et al. (2011). In addition, the promotion of cycling also has an indirect negative effect on car mobility, reducing car use. The promotional activities of cycling are divided into physical instruments and policy instruments, to which pre-conditions determine whether those instruments can be successful. Simultaneously, the promotion of car-based policies, or in other words, car-restriction policies, has an indirect effect on the increased use of cycling and a direct negative impact on car mobility (i.e., reduction of car use). By reducing car mobility, while increasing the use of cycling, the transition towards a more sustainable mobility regime can take place, as can be seen as the arrow pointing upwards.

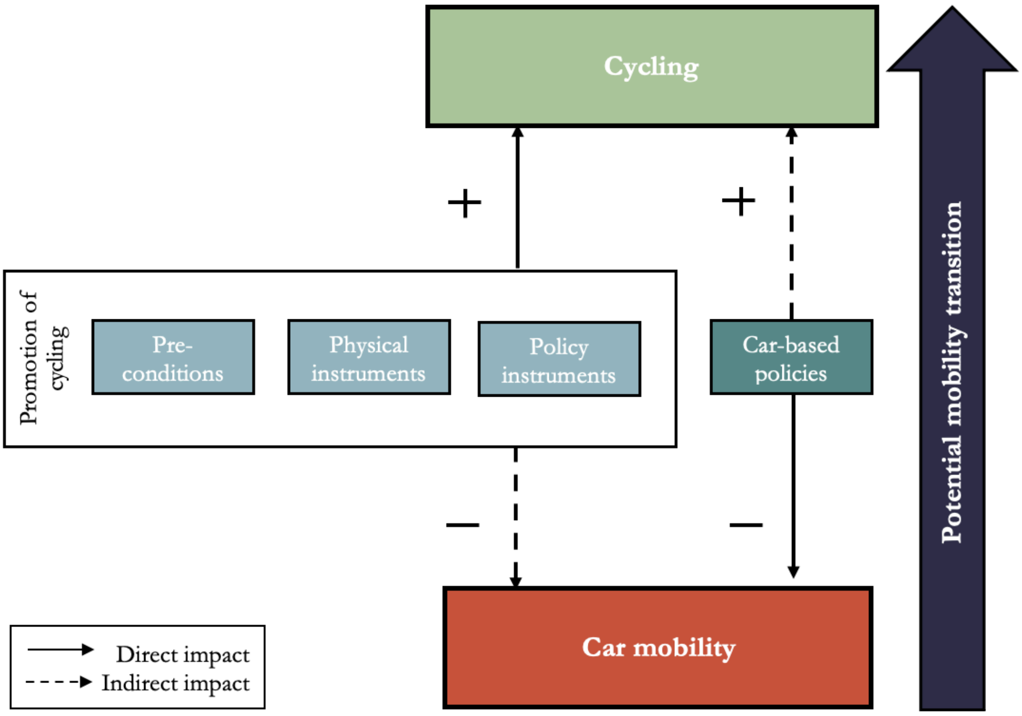


Figure 6: Conceptual model of theoretical framework.

Methodology

This chapter will first discuss the general research design. After this, the case description and selection will be elaborated. Further, an overview of the research design elements will be given, starting with the literature review used to establish the theoretical framework. This is followed by an explanation of the secondary statistical data collection and qualitative data approach, including the interviews. Lastly, the ethical considerations of this explorative study will be discussed.

3.1 Research design

This research uses a single case study, a mixed-methods approach. To answer the main research question: "*How can the increase in cycling's modal split contribute to the transition from car mobility towards sustainable modes of transportation?"* the combination of theoretical, statistical, and empirical research is applied. A theoretical literature review is used to form a basis for the interview guide and code trees. The secondary statistical data, several documents, policies, and the results from the interviews will help answer the first, second, and third sub-question, in which the triangulation method will be used. Yin (2018) explains that a case study "*relies on multiple sources of evidence, with data needing to converge in a triangulating fashion" (p.46).* Furthermore, triangulation strengthens the results by using multiple data sources and/or research methods and increases the validity and credibility of the research findings (Heale and Forbes, 2013). Hence, triangulation will use this method to give a more comprehensive answer to the research objective.

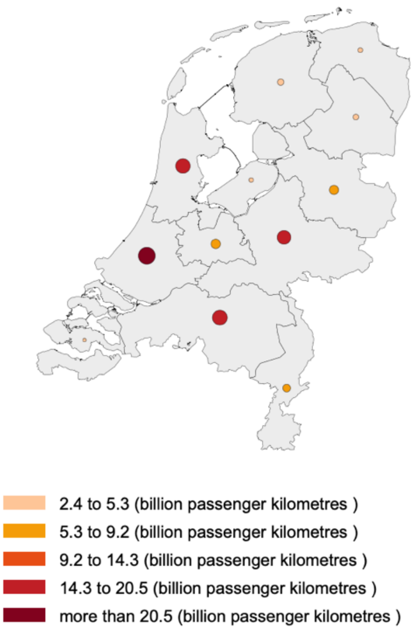
According to Clifford et al. (2016), a single case study can offer the possibility of gaining profound and integral knowledge about a specific object and process in practice. In addition, a single case study is characterized as a qualitative research method, which can uncover links among different phenomena and procedures and answer the *'why'* and *'how'* questions of a particular issue, situation, or process (Yin, 2014). As such, it will give insight into how an increase in cycling's modal split can reduce car mobility in the Netherlands. However, the results of this single case study cannot be generalized. This means that the results of the Netherlands are not automatically applicable in other countries since it provides context-dependent knowledge (Taylor, 2016). Even though a single case study is not generalizable, that does not necessarily mean it has no value. According to Flyvbjerg (2006), a case study can have value *"not in the hope to prove or transfer anything, but rather in the hope of learning something" (p. 224).* In addition, he argues that a single case study within its boundaries will enable to study of a social phenomenon, as capturing these in predictive theory is often unfeasible (Flyvbjerg, 2006). Hence, the Netherlands will be used as a case study to investigate if and how cycling policies can reduce car mobility.

3.2 Case description and selection

The Netherlands has been chosen as the single case study for this research. Taylor (2016) explains that the selection of a case study is determined when the case is unusual or familiar, among other reasons. The Netherlands is a country located in the Western part of Europe and borders Germany, Belgium, and the North Sea (figure 7). The country is divided into 12 provinces and has a population of around 18 million (CBS, 2022a). With a total road network of approximately 140,00 kilometers, the country has one of the densest road networks in the world, which is of sufficient quality compared to other European countries (Nation Master, n.a.; Europedia, 2019). In addition, in 2021, around 9 million passengers' cars have been registered, placing the Netherlands in the top 10 list of most cars in Europe (CBS, 2021c; Statista, 2021a). Of this share, the Netherlands has the highest number in the percentage of cars that use petroleum products and diesel, to which petrol cars is ranged at 83 % (Eurostat, 2021). Moreover, in the Netherlands, more than 50% of all trips are done by car (Eurostat, 2021). This also places the Netherlands in the top 10 European countries where the car is used the most (Fiorello et al., 2016). Simultaneously, the country has the world's biggest share of bicycles (Cycling facts, 2018). There are about 23 million bicycles, and each person owns 1.3 bicycles on average (Fietserbond, 2019). In 2019, of all the travel trips, around 46% were done by car, 28% by bike, and about 15% by public transport (CBS, 2022c).

Figure 7: Map of the Netherlands (Stroe, 2021).

Around one-third of all trips with a distance of less than 7,5 km are done by bicycle, yet one-third is done by car (Gezonde leefomgeving, 2017). The rest is done via walking, train, and BTM (Harms and Kansen, 2018). This division is mainly seen in very high and high-urban areas, while in rural areas, more trips are made per car (CROW, 2019; KiM, 2019). Around 58% of all trips with less than 7,5 km are done by car in rural areas (KiM, 2019). Furthermore, the biggest transport performance by passenger car (driver) is in the province of Zuid-Holland, where 20.5 billion kilometers were covered in 2018 (CBS, 2022d). This is followed by the neighboring province of Noord-Holland and Noord-Brabant, with around 16 billion kilometers (CBS, 2022d). The total number of car passenger-kilometers in the Northern and deep Southern provinces is substantially lower, as seen in figure 8. Furthermore, in the Middle and Northern parts of the Netherlands, the use of cycling is around 45% or more, while in the Southern part of the Netherlands, the share of cycling is often less than 35%. This is illustrated in figure 9.



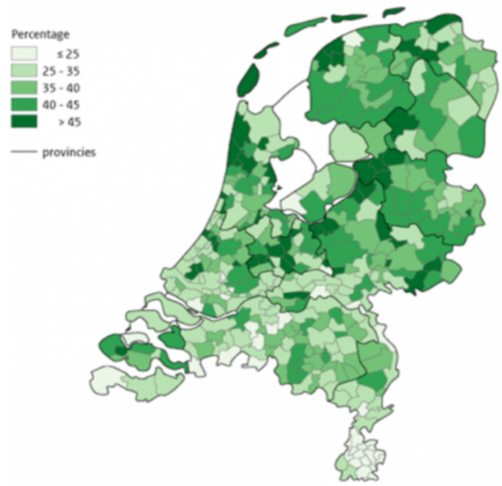


Figure 8 (left): Transport performance by car (driver) in 2018 (Source: CBS, 2022d).

Figure 9: (right) Bicycle use with a distance of < 7,5 km in 2015-2017, in the Netherlands (Source: CBS,2017).

3.3 Data collection

3.3.1 Statistical data

Through statistical data, the first and second sub-question is answered. This data is used to identify the trends and patterns in the mobility sector, especially in car and cycling use, and to set the status quo of the Netherlands. In addition, the dataset contains, when possible, the trends and patterns of the period from the past two decades (approx. 2011-2022). Furthermore, the researcher collected data to compare urban and rural areas in the Netherlands. The statistical data is derived from several sources: CBS, CROW, Stata, Eurostat, Alle cijfers, and the KiM. Furthermore, statistical data was used during the interviews to give the respondents insights into the current trends and patterns, allowing for subsequent discussion of possible causes and processes of the Dutch status quo.

3.3.2 Document and policies review

Alongside the statistical data, several documents and policies are used to answer the research question. These documents and policies are derived from the KiM, CROW, the Dutch Environmental Vision, and the OECD of the European Union. This information will complement the data from the in-depth interviews to gain a broader understanding of the sub-questions. Furthermore, these documents helped to measure and explain similar concepts and/or relations. The last section of the references lists an overview of the documents and policies (7.1).

3.3.3 Literature review

A literature review has identified relevant concepts, theories, debates, and issues about car mobility, transition theory, and cycling. This literature is discussed in the theoretical framework (chapter 2) and formed as a foundation for the conceptual model, the interview guide, and deductive code trees. The review contains a combination of scientific and grey literature that the researcher selected based on relevance. This was collected via several databases, namely SmartCat, Scopus, and Google Scholar. In addition, articles and policy documents were found in the online and physical library of the University of Groningen. The search terms (or key terms) used for these databases and libraries can be found in Table 4. The relevant literature references were also scanned to find other potential literature. This can be referred to as manual snowballing when sampling is executed through referrals (Frey, 2018).

Table 4: Overview of key terms searched in multiple databases and libraries.

Car mobility	Sustainable Mobility transition	Cycling	Other concepts
Auto mobility	Transition Theory	Active travel	Environment
Car use	Transition management	Soft Mobility	Urban planning
Transport sector	Multi-level perspective	Active Mobility	Travel behavior
Mobility	System innovation/ improvement	Promotion of cycling	Livability
Car dependency	Mobility paradigm	Cycling instruments	Congestion
	Transition pathways	Cycling policies	Health

3.3.4 Interviews

In this research, qualitative data was collected through in-depth, semi-structured interviews. This provides detailed and more helpful information about the topic since it will expose underlying reasons that cannot be found in quantitative research (Clifford et al., 2016). In addition, semi-structured interviews allow the interviewer to ask open-ended questions, gaining a deeper understanding of the respondent's opinions. Simultaneously, enough structure (in the form of an interview guide) is preserved to obtain enough targeted data collection and good comparison (Clifford et al., 2016). The respondents were recruited via e-mail, phone, LinkedIn, and in person. In doing so, purposive sampling was used, whereby the respondents were selected based on their relevance to the research objective and other criteria. The first criteria are that the respondents should have either a professional background in public, private or public-private organizations or have an academic background. This is because this study aims to compare both perspectives and to have

a broader understanding of the research aim. Secondly, all respondents should have expertise and knowledge about car or cycling mobility, preferably from the Netherlands, to answer the research questions. All the respondents work in the Dutch policy field and speak (native) Dutch; hence all the interviews were held in Dutch. The interviews were held physically at the University of Groningen or online via Microsoft Teams. An overview has been made, containing the information of the respondents. This is illustrated in table 5.
The interviews were structured in a systematic order. After the short introduction, the perception of cycling and the link between cycling and auto mobility were asked. Next, the collected statistical data, as mentioned in chapter 3.1, was displayed, showing the Dutch trends and patterns of car mobility and cycling. This was helpful to set the status quo of the Netherlands and to enable a deeper conversation about the possible causes and consequences of this status quo. Lastly, possible solutions and future trends were discussed.

Table 5: Overview of respondents.

Code	Background	Profession	Organization	Date (in Dutch)
Respondent 1	Professional	Program manager Smart Mobility	Vervoerregio Amsterdam	05-05-2022
Respondent 2	Professional	Project Manager and Consultant Sustainable Mobility	Royal Haskoning DHV	13-05-2022
Respondent 3	Academic	Assistant Professor in Spatial Planning	University of Groningen	18-05-2022
Respondent 4	Academic	Professor by special appointment in Transport Geography	University of Groningen	20-05-2022
Respondent 5	Academic	Lector Creative Media for Social Change	Hogeschool van Amsterdam	23-05-2022
Respondent 6	Professional	Project Coordinator	Dutch Cycling Embassy	24-05-2022
Respondent 7	Professional	Team leader Smart Mobility	DTV Consultants	24-05-2022
Respondent 8	Professional	Team Leader Traffic Architecture	DTV Consultants	25-05-2022
Respondent 9	Professional	Researcher of the Netherlands Institute for Transport Policy Analysis	Ministry of Infrastructure and Water management	31-05-2022
Respondent 10	Academic	Professor Doctor Transport and Urban Planning	University of Amsterdam	31-05-2022

3.4 Data analysis

Systematic analysis and interpretation of the acquired data are essential to creating persuasive and meaningful conclusions (Cope and Kurtz, 2016). Hence, the conversations from all the interviews were recorded using the Dictaphone app from Apple Inc. These recordings have been transcribed with Trint and O'Transcribe. After that, the transcripts were coded with Atlas.ti. These codes were used to assign concise and specific values to data elements, using a combination of deductive and inductive codes. According to Lewins and Silver (2007), deductive codes (beforehand) can embody a clear set of objectives, which inform and steer thinking from the start while helping look for theoretical relationships. In addition, inductive codes are provided to develop codes that lie as close as possible to the respondents' answers and are based on the interview transcripts (Given, 2008). The deductive code trees and inductive codebook can be found in appendices 5,6,7, and 8.

A systematic overview has been made to illustrate the research design process and how the three sub-questions are answered. This is shown in figure 10 below.

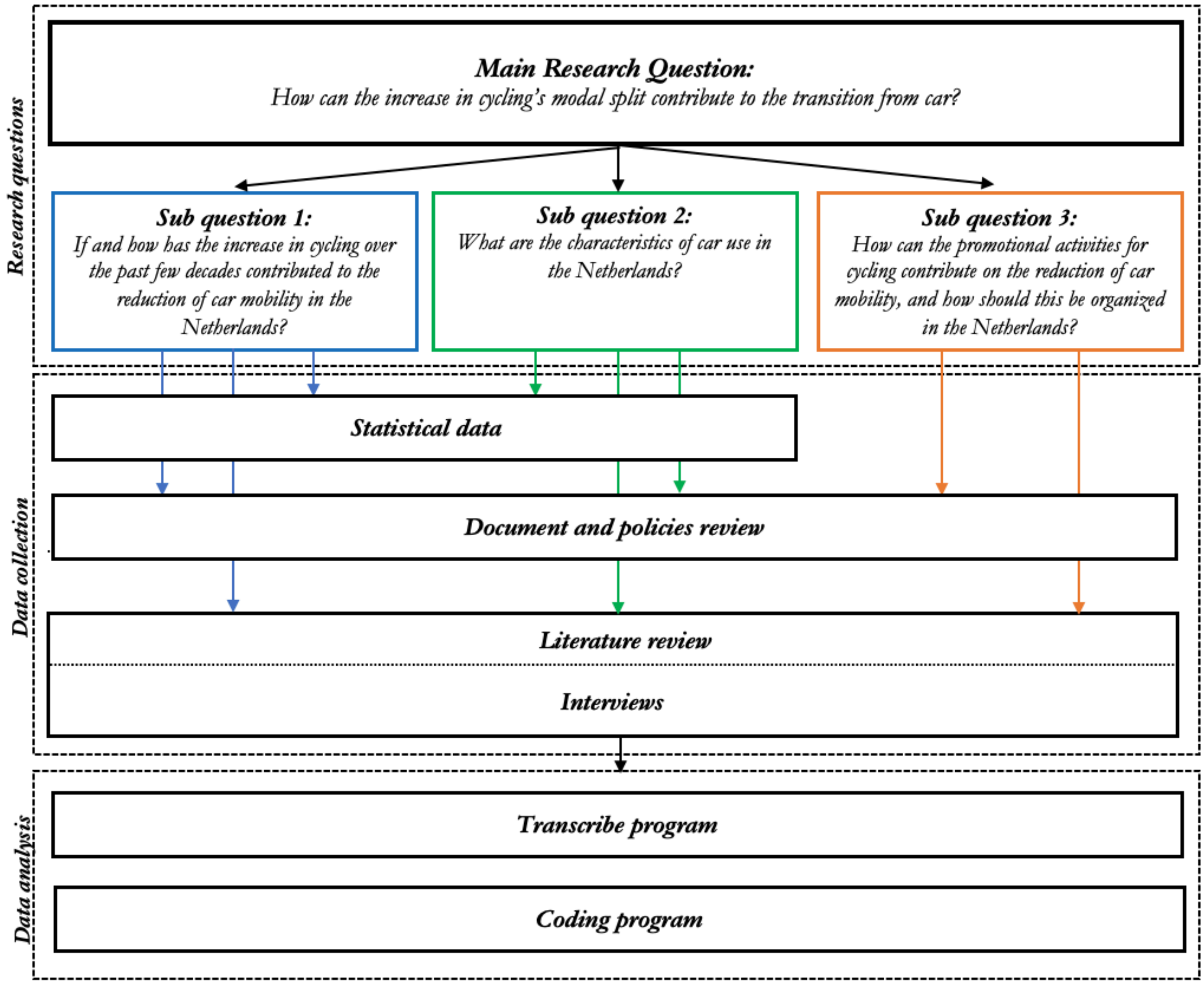


Figure 10: Schematic overview of research design.

3.5 Ethical considerations

There are numerous practical reasons to act ethically. The first is safeguarding individual, communal, and environmental rights (Clifford et al., 2016). Secondly, to retain public confidence, and lastly, to be accountable and sensitive to public opinion (Clifford et al. 2016). A consent form (see appendices 3 and 4) was sent to the participants as part of this study to make the research's precise aim and how the collected data would be utilized. Furthermore, at the start of each interview, the respondents were explicitly asked if they agreed to their name being used and if the session could be audio taped. The researcher thanked the respondents for their time and effort before and after the interviews.

Furthermore, the transcripts were sent to the respondents to check for informational inaccuracies or falsifications. The audio tapes and transcripts were adjusted and deleted afterward. Finally, the researcher's position is worth noting. According to Berger (2015), researchers need to acknowledge and recognize their position that may affect the research objective. Moreover, he explains that results could be interpreted otherwise due to their biases, beliefs, and personal experiences. Hence, due to my limited experience in the planning and mobility field, I allowed other researchers and respondents to assist and help to understand the social phenomena or knowledge, in which the privacy of the data and respondents is not being harmed.

Results

4.1 General overview

In this chapter, the results will be presented. As mentioned in chapter 3, the information is obtained via secondary statistical data, a policy and document review, and interviews. First, a general pattern of mobility in the Netherlands is discussed. After that, the car characteristics and cycling characteristics in the Netherlands are stated. Furthermore, the relationship between car mobility and cycling mobility will be addressed, and the approaches for the future will be presented.

4.1.1 Mobility patterns in the Netherlands

Mobility is used for many possible purposes, such as commuting and business travel, shopping, education, recreation, exercise, visiting family and friends, and vacationing (CBS, 2018). In 2017, on average, 870 trips were made by a person, where 335 hours per year were spent covering more than 10,000 kilometers (table 6). Social and recreation, commuting, and shopping are in the top three times the number of travel trips. The business visit is relatively low; however, those trips are longer and more time-consuming on average, mainly done per car rather than train or BTM. These results exclude the travel trips per plane and trips made outside the country. The average number of foreign kilometers is estimated at around 800 kilometers (OViN, 2017).

Table 6: Travel motives in the Netherlands per person in 2017 (Source: OViN, 2017; edited by author).

	Travel trips per year	**Kilometers per travel trip**	**Kilometers per year**	**Travel duration per travel trip (min.)**	**Hours per year**
From and to work address	160	19	3,000	29	80
Business visit	10	38	400	44	10
Shopping, groceries, care	210	6	1,200	15	50
Education	90	8	700	22	35
Social and recreation	270	14	3,900	25	110
Other travel motives	120	8	900	27	54
Total	**870**	**12**	**10,100**	**23**	**335**

Of the total 870 travel trips per year, the car (i.e., driver and passenger) is the most dominant transportation mode (table 8). After that, cycling and walking are used the most. It is important to note that the trips where multiple modalities were used are attributed to the transportation mode with the longest distance. Public transport is, therefore, low since much of the time spent traveling, for example, the train is not by the train itself, but taken up by the ride to and from the station. Similarly, table 7 only includes domestic travel trips and excludes aviation.

Table 7: Transportation modes in the Netherlands per person in 2017 (Source OViN, 2017; edited by author).

	Travel trips per year	**Kilometers per travel trip**	**Kilometers per year**	**Travel duration per travel trip (min.)**	**Hours per year**
Car driver	290	18	5,200	24	115
Car passenger	120	17	2,100	24	50
Train	20	51	1,200	80	30
BTM	20	13	300	45	15
Cycling	230	3	800	17	65
Walking	150	1	200	20	50
Other	20	14	300	27	20
Total	**870**	**12**	**10,100**	**23**	**335**

Next, the percentages of all travel trips done per car or bicycle also differ per region. On average, in very high urban areas, more than 24% is done per car, while more than 45% of all travel tips are done per car in non-urban regions between 2018-2019 (CROW, 2019). Simultaneously, the bicycle is used in around 34% of all travel trips in very high urban areas to only 26% in non-urban areas (table 8). The data thus illustrate a trend that the percentage of car use for travel trips decreases as the areas become more urbanized. This is the opposite regarding bicycle use since the percentage increases as the areas become more urbanized.

Table 8: Transportation mode on all travel trips between regions (percentage) (Source CROW, 2019, edited by author).*

	Very high urban areas	**High urban areas**	**Moderate urban areas**	**Low urban areas**	**Non-urban areas**	**Total**
Car driver	24.4%	35.6%	38.2%	42.0%	45.3%	100.0%
Car passenger	8.7%	12.0%	12.6%	13.2%	13.2%	100.0%
Train	5.4%	3.2%	2.8%	1.6%	1.3%	100.0%
BTM	6.6%	2.0%	1.6%	1.2%	1.3%	100.0%
Cycling	33.5%	30.4%	30.3%	28.0%	25.6%	100.0%
Walking	21.1%	16.8%	15.0%	14.0%	13.2%	100.0%

*Between 2018 and 2019

These trends are also visible for travel trips at a maximum distance of 7.5 km in the Netherlands (CROW, 2019). Table 10 illustrates that the percentage of cycling in non-urban areas is around 36% to almost 40% in very high urban regions. On trips till 7.5 km, the car is used at about 15% in very high urban areas, while around 30% of all trips in non-urban areas (table 9). In addition, the everyday use of public transport in high and moderate urban areas may indicate why people take the car more, compared to very high urban areas.

Table 9: Transportation mode on travel trips at a maximum distance till 7.5 km between regions (percentage) (Source CROW, 2019, edited by author).*

	Very high urban areas	**High urban areas**	**Moderate urban areas**	**Low urban areas**	**Non-urban areas**	**Total**
Car driver	**15.5%**	**24.9%**	**26.8%**	**29.2%**	**30.7%**	**100.0%**
Car passenger	5.9%	8.8%	9.5%	9.3%	9.3%	100.0%
Train	7.0%	2.2%	1.7%	1.2%	1.4%	100.0%
BTM	5.3%	3.3%	2.8%	1.9%	1.4%	100.0%
Cycling	**39.6%**	**38.1%**	**38.0%**	**37.9%**	**35.9%**	**100.0%**
Walking	26.7%	22.7%	20.7%	21.1%	21.4%	100.0%

*Between 2018 and 2019

4.1.2 Development of mobility

Many different developments and trends influence the magnitude and growth of mobility in society. Such developments and trends can also indicate which transportation mode is more prominent in the mobility regime than others. Using the document, policy reviews, and the respondents, categorization has been made of six development components that **have** influenced mobility. These are the following: socio-demographic, historical and political, behavioral and social, technological, and spatial components (figure 11). In chapters 4.2 and 4.3, those factors will be discussed with regard to car and cycling mobility.

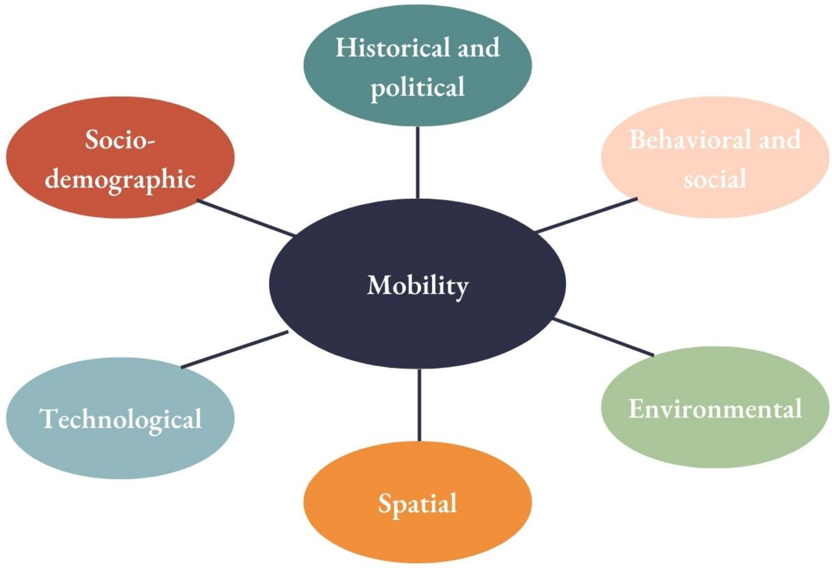


Figure 11: Schematic overview of development components.

4.2 Car characteristics of the Netherlands

In chapter 3, a brief introduction was given about the case description of this research. In short, the Netherlands has a total road network of around 140.000 km, which is categorized into national highways, provincial and municipal roads, and roads controlled by waterboards (CBS, 2021c). Converted to the population, the Netherlands has around 144 km of road per 1 million inhabitants. (CBS, 202c). In addition, in the last couple of decades, the total number of passengers car in the Netherlands has increased significantly (from around 7 million in 2003 to almost 9 million in 2022) (CBS, 2022d). However, in Dutch urban areas, especially in the G4-cities (Amsterdam, Rotterdam, Den Haag, and Utrecht), a decrease in car ownership and use can be seen, whereas, in rural areas, an increase in car ownership is visible (figure 12). Next, from 1990 to 2019, the total number of vehicle kilometers of passenger cars has increased by more than 35 percent to around 110 billion kilometers (CBS, 2021d). Around 72 percent were driven by a gasoline engine (including electric and hybrid cars) and around 27 percent by a diesel engine (CBS, 2021d). It thus can be concluded that car mobility has significantly increased in the past decades in the Netherlands. Hence, the contributing factors, as discussed before, will be presented.

Socio-demographic

According to the respondents, an increase in car mobility in the Netherlands is caused by many socio-demographic developments. The most frequent answer is that population growth has led to a rise in car mobility. The research by OViN (2017) confirms this, which stated that population growth has influenced car mobility growth. Furthermore, respondents 2, 4, and 8 have indicated that the development of car mobility can also be explained due to an increase in economic growth and increased income per household. Simultaneously, respondents 1,3, and 9 have suggested that age is an important factor. On the hand, these respondents and research by the OECD showed that people tend to stay longer mobile in general and that due to the aging population of the Netherlands, car use is longer maintained (Van der Waard et al., 2013). Yet, on the other hand, young adults are postponing their car purchases more often (respondents 1 and 6). The reason for this may be that more young adults are living in urban areas, where car use is less prevalent than in regional areas (R-4). Other socio-demographic factors such as access to driver's licenses and access to cars may also indicate the growth of car mobility in the Netherlands (OViN, 2017). Figure 12 shows the development of car ownership in the Netherland between 2017 and 2018, where you can see that in urban areas, car ownership is decreasing, and in rural areas is increasing. Lastly, increased labor participation among women can explain an increase in car mobility (KiM, 2010b).

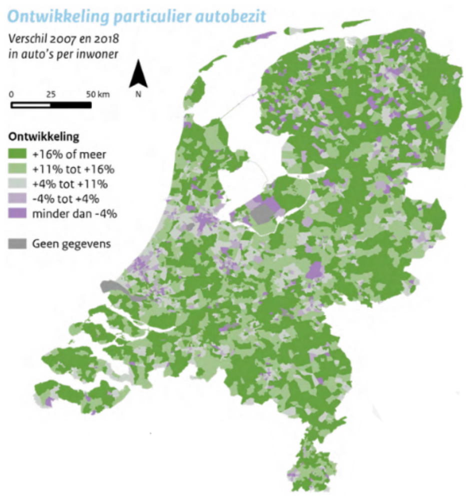


Figure 12: Development car ownership (Source: KiM, 2022)

Historical and political

Due to several historical events and political choices in the past decades, car mobility has significantly grown. At the national level, the government has made considerable investments in road infrastructure to enhance sufficient traffic flow and good accessibility. These decisions were primarily caused by right-wing parties prioritizing car mobility over alternative options (R-2, R-8, R-10). In addition, as respondent 4 has stated: "*I don't think that past governments hindered car users much. So, there has not been enough policy that contributed to the reduction of car mobility*." Therefore, car use became a popular transportation mode because those investments contributed to better accessibility, decreased travel time, and thus overall cost minimization. In addition, the Netherlands Institute for Transport Policy Analysis (2022) has also indicated that car use and ownership received good political and societal support in the Netherlands for the past couple of decades, resulting in overall car mobility. As said: "*Those who own cars are more likely to stand up for their interests, according to election and referendum results*" (KiM, 2022).

Behavioral and social

The continuation of car mobility can be explained due to the formation of a (car use) habit. Even though people are aware of the disadvantages of car use, a gap can be seen between their intentions and behaviors (Gardner, 2009). This entails that individuals would like to change, yet this does not reflect their actual behavior. According to the experts, this gap can be explained due to habits (R-2, R-5, R-5, R-9, R-10). They argue that when people develop a specific behavior, such as commuting to work in a car, this could become a habit when performed in a stable and repetitive environment. As respondent 9 has stated:

> "*But the problem is also that we are all creatures of habit. Every day we do the same thing over and over again. And there are few people who think about how they are going to work every day. So, it makes sense that people end up in a certain pattern*" (R-9).

This is in line with Buhler (2020), who explains that when a person may have the intention to change (e.g., from car to bicycle use), yet might not be able to change their behavior because their current car habit is too strong. This, thus, can result in the continuation of car use. Furthermore, the respondents state that a car-like behavior can be explained due to the high level of comfort and flexibility that a car provides compared to other transportation modes (R-1, R-6, R-8). Besides habitual factors, social trends also influence car use. Many people want to drive a car since it provides them a positive status (R-1, R3). This is consistent with the literature since it states that *individual consumption* (i.e., improved status) contributes to the domination of car mobility. Next, traditionally, it used to be quite common to get your driver's license right after your 18th birthday and purchase a car. Respondent 1 said this: *"So I grew up with, you go to work, and when you buy a car, and with your car, you show who you are and how much money you make."* Due to this perceived status and 'tradition,' car mobility has continued and most likely increased in the past decades.

Environmental

Despite the negative environmental impacts, most people are still using the car due to the many advantages that the car provides (R-6). However, a shift can be seen, whereas more people choose sustainable alternatives, such as public transport or electric vehicles (R-1; KiM, 2022). The use of electric and hybrid cars contributes to less C02 emissions, yet they do not automatically reduce the total number of cars since they often replace diesel or gasoline engine cars (R-2; KiM, 2022). Other respondents argue that environmental concerns were previously less seen on the political agenda because sustainability is often at odds with economic development (R-7, R-8). Hence, the governments took little political action to discourage car use to improve environmental qualities (R-1, R-8).

Spatial

The growth and magnitude of car mobility differ substantially between places, predominantly between urban and rural areas. As mentioned in chapter 3.2, the car travel performance, which is the number of kilometers done by passenger cars, is higher in the Western provinces than in the Southern and Northern provinces in the Netherlands in 2018. A plausible reason for this is that the Western provinces are generally more densely populated, and the economic core (or CBD) is located over there, which can explain more trip activities done per car (Huisman and Rienstra, 2016). In addition, figure 13 shows that in very high urban areas, the duration of an average trip done per car is much longer than the duration in non-urban areas, while the average travel distance is approximately the same. An explanation is that (highly) urban areas often experience traffic congestion that adds extra travel time (R-4).

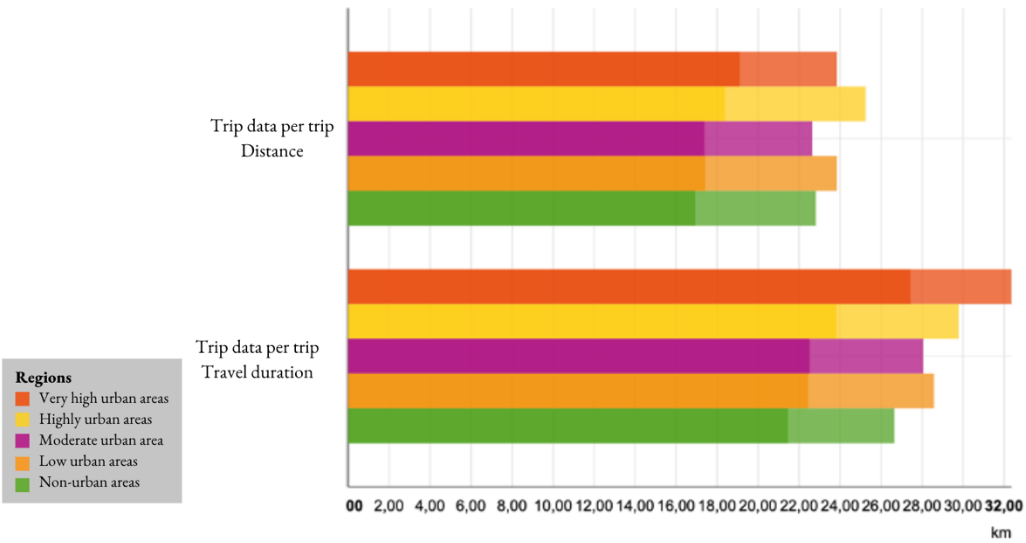


Figure 13: Average travel distance and duration per car from urban to non-urban areas (Source: CBS, 2021a)

From the around 18 million inhabitants, more than 44% of the Dutch population lives in urban areas, about 30% in suburban areas, and about 26% in non-urban (or rural) areas nowadays (Planbureau voor de Leefomgeving, n.d). These areas are illustrated in figure 14. Although a small part of the population lives in rural areas, this group uses cars more frequently than in highly populated areas (table 8). In the suburban areas, which refer to high and moderate urban areas, around 37% of all travel trips are done per car, of which about 26% are done per car with a distance of 7.5 km (table 8 and 9). Possible reasons for the differences between (sub) urban areas are the densification of areas, supply of public transport, and space scarcity which will be discussed more in-depth in chapter 4.5.1.

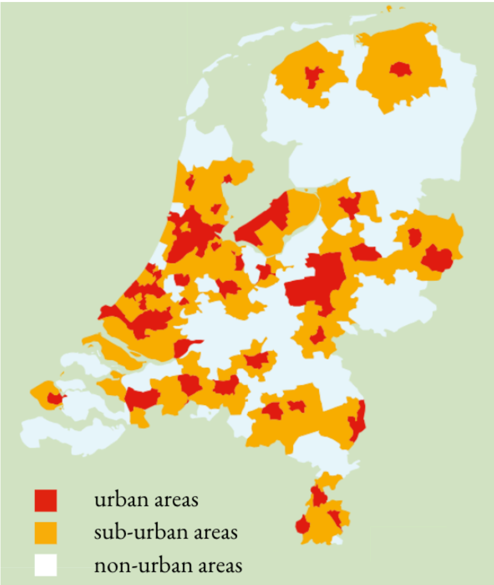


Figure 14: Urbanization of the Netherlands (Planbureau voor de leefomgeving, n.d., edited by author).

Technological

Lastly, technological innovations and structures impact car mobility in the Netherlands. Due to the availability of techniques and automatization, mass production was possible, and people had more access to cars (R-6). Furthermore, respondent 3 has stated that the magnitude of car mobility is still maintained due to the robust road infrastructure network made possible due to technological construction and operations.

4.3 Cycling characteristics of the Netherlands

In this chapter, the cycling characteristics of the Netherlands will be discussed. As stated in the introduction, cycling became popular in the early 1900s due to its accessibility and affordability. This popularity has continued, whereas the Dutch people cycle about 15 billion kilometers each year (Fietserbond, 2018). That is over 880 kilometers per person, divided over approximately 250 to 300 bicycle trips (CBS, 2022e). More than 70% of those bicycle trips covered less than 3.7 kilometers in the total distance (CBS,2021a). In addition, bicycles are mainly used for shopping and groceries (i.e., 21% of the total travel trips). After that, the bike is used for going out, sports, & recreational activities and commuting to and from work (CBS, 2021a). Most of the time is spent on leisure activities such as touring, sports, and hobbies, to which nearly half (45%) of the daily cycling time is devoted to this (CBS, 2021a). In the past decades, kilometers of cycling increased by around 16%, mainly due to an increase in commuting trips and more frequent use for leisure activities (KiM, 2010a). Furthermore, according to the data and interview results, more factors will explain the magnitude and growth of cycling in the Netherlands. These will be discussed below.

Socio-demographic

Most people start learning and riding the bicycle at an early age. Especially before people have their driver's licenses, the bike is used frequently for educational, social, and recreation trips (CBS, 2022). Nowadays, older adults are cycling more often due to the development of e-bikes (R-3, R-4, R-6). After the introduction of e-bikes in the Netherlands, more older adults primarily purchased such bikes, especially for recreation purposes (de Haas, 2019). Nowadays, a shift in usage is visible, whereas the share of older people (+65) is decreasing, and the trip purpose has shifted from recreation to work-related travel (de Haas, 2019). As a result, the popularity of e-bikes has also moved to the population below the age of 65 (de Haas, 2019, R-9). This has contributed to the continuation and some degree of growth in cycling's modal share. However, most e-bikes are nowadays used as an alternative to the traditional bike (de Haas, 2019, 2019; R-3). Next, due to the affordability of a bicycle, compared to alternative transport modes, the growth of cycling can be explained (R-9, OViN, 2017). Other factors that contribute to a slight decrease in cycling use are the rise of immigrants that cannot cycle and the rise in car mobility (e.g., parents drive their children to school instead of cycling) (KiM, 2010a).

Behavioral and social

As mentioned, people already became familiar with this mode of transportation at a young age. This could have led to distinct habit creation, where people still take the bike due to the repetitive use of bicycles over the years (R-3). Moreover, cycling is seen as part of the inherent Dutch culture. In contrast, cycling is considered a transportation mode for multiple activities, rather than only for leisure or recreation, as seen in other countries (KiM, 2010a).

Historical and political

An increase in cycling can also be explained due to the promotion of cycling and infrastructure investments from the past governments (R-2, KiM, 2010). One of the National government's goals was to get more than 200.000 extra commuters on their bike in combination with public transport and to have more than 20% extra bicycle lanes (Rijksoverheid, n.d.; Gezonde leefomgeving, 2017). Hence, more than 100 million euros were made available to construct and renew fast bicycle lanes and bicycle parking in the past years (Rijksoverheid, n.d.). Nowadays, the Dutch government also reserved more than 75 million euros for innovative bicycle solutions (Rijksoverheid, n.d.). In doing so, the Dutch government strives to improve the national cycling policies by bringing parties together, such as local governments, private parties, NGOs, and other stakeholders, and by stimulating innovations and experiments, changing rules and regulations (e.g., no texting while cycling), and provide additional funding to cities (Rijksoverheid, n.d.). An example of a Programme to promote cycling is the Tour de Force. This incentive investigates how cycling and public transport can be synergized, how smart technologies can contribute to cycling, and how older adults can still use their bicycles (Rijksoverheid, n.d.). The Tour de Force aims to have more than 20% of the distance traveled by bike in 2027, compared to 2017 (Tour de Force, 2022). In addition, other cycling policies, are the Better Use program (Beter benutten programma) in 2018 and the National cycling agenda 2.0 (Nationaal Fietsagenda 2.0) (Gezonde leefomgeving, 2017).

In addition, cycling is promoted via environmental visions and the Environment Act of the Netherlands (CROW, 2020). The Environment Act and environmental visions are being drawn up nationally, regionally, and municipally and will provide an opportunity to stimulate cycling and more physical activity (CROW, 2020). Therefore, it has been decided to temporarily add the theme' cycling and environmental vision' as a different project to the implementation program of the Tour de Force with the aim of:

- *Establish an active network of professionals (traffic, space, and health) in and between the cities to stimulate joint knowledge development. Include a recognizable section on promoting cycling and walking in the environmental plans of the cooperating ambitious bicycle cities (F10).*
- *These cities implement specific projects for cyclists and pedestrians in elaborating the environmental vision (Gezonde leefomgeving, 2017).*

Thus, an increase in cycling share can be seen with the promotion and execution of cycling due to political choices.

Environmental
Due to health-related reasons and increased environmental awareness, people started to use their bicycles more frequently (R-2; R-9). This was also stated in I&O Research (2020), from the Fietserbond and Dutch Cycling Embassy, which shows that health (33%) and the environment (15%) are the most important reasons for people to cycle. As a result, the total amount of cycling trips has increased, and for some people, the bicycle will serve as a substitution for the car (CBS, 2021a; I&O Research, 2020).

Spatial
Due to the Dutch country's spatial advantage (i.e., flat land), cycling is considered less effortless than in other countries that deal with altitude differences (R-8). This could explain the greater use of bicycles in the Netherlands. Moreover, a difference in cycling use between urban and rural areas in the Netherlands. As shown in table 9, the very high urban areas have a higher share in cycling's modal split for the total mobility and for trips with a distance till 7.5 km in 2019-2019. While in rural areas, this share is lower. Furthermore, a decrease in cycling trips can be seen between 2013-2019 in rural areas, and an increase in cycling trips in very high urban areas is visible (figure 15). Some plausible reasons are that in rural areas, the distance to facilities is often larger, the influence of weather (more vulnerable than in urban areas), the presence of agricultural vehicles, and the competition with cars (Huisman and Rienstra, 2016; R-10).

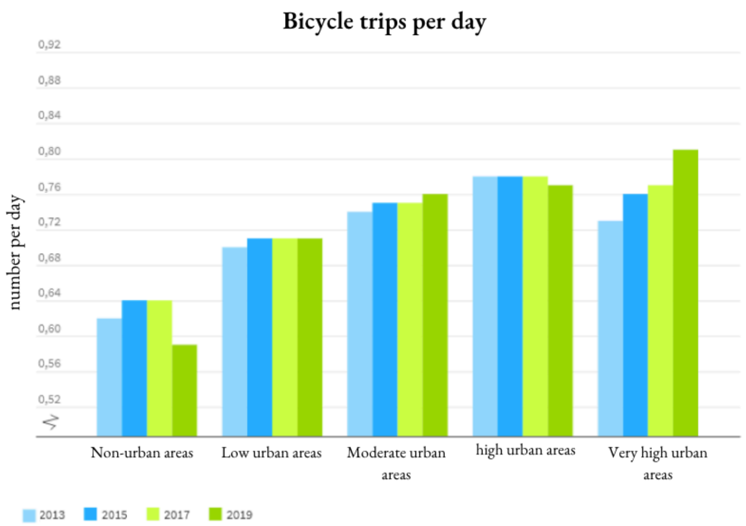


Figure 15: Bicycle trips per day – urbanization (CROW, 2019, edited by author).

Technological

The rise of technological innovations can also explain the growth and magnitude of the cycling share. Innovations such as e-bikes, VELO, LEV bikes, and cycling apps contribute to this since it increases a person's mobility, comfort, and distance (R-1, R-2, KiM, 2017). New technological innovations such as MaaS and the 15 min. city concepts are expected to increase the cycling modal share (R-1, R-2, R-1, R-8, R-10). Later, the e-bikes and 15 min. city concept will be discussed in-depth.

4.4 The relation between car mobility and cycling

The next chapter will discuss the relationship between car mobility and cycling. In order to explain this relation, the data from the interviews have been analyzed, where certain subjects were discussed more in-depth or brought to the respondents' attention (figures 16, 17, and 18). Based on Brown (2010), the frequency of codes has been divided on a Likert scale from very frequently-to-very rarely. In addition, new inductive codes were established, which can be seen in appendix 8. The main deductive and inductive subjects (or codes) will be explained below. Thereafter, these codes will be presented in a new systematic overview (figure 19).

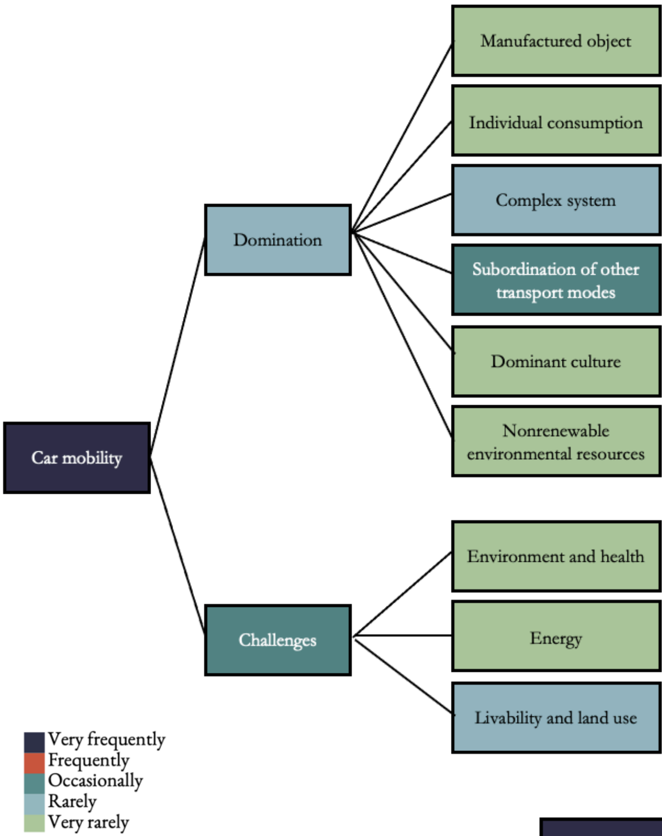


Figure 16: Code analysis of car mobility.

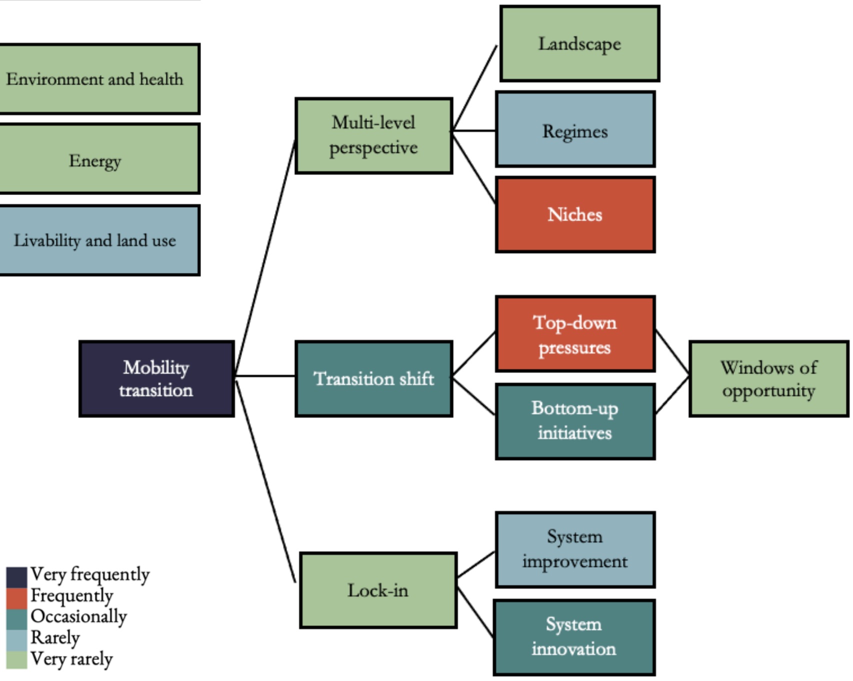


Figure 17: Code analysis of mobility transition.

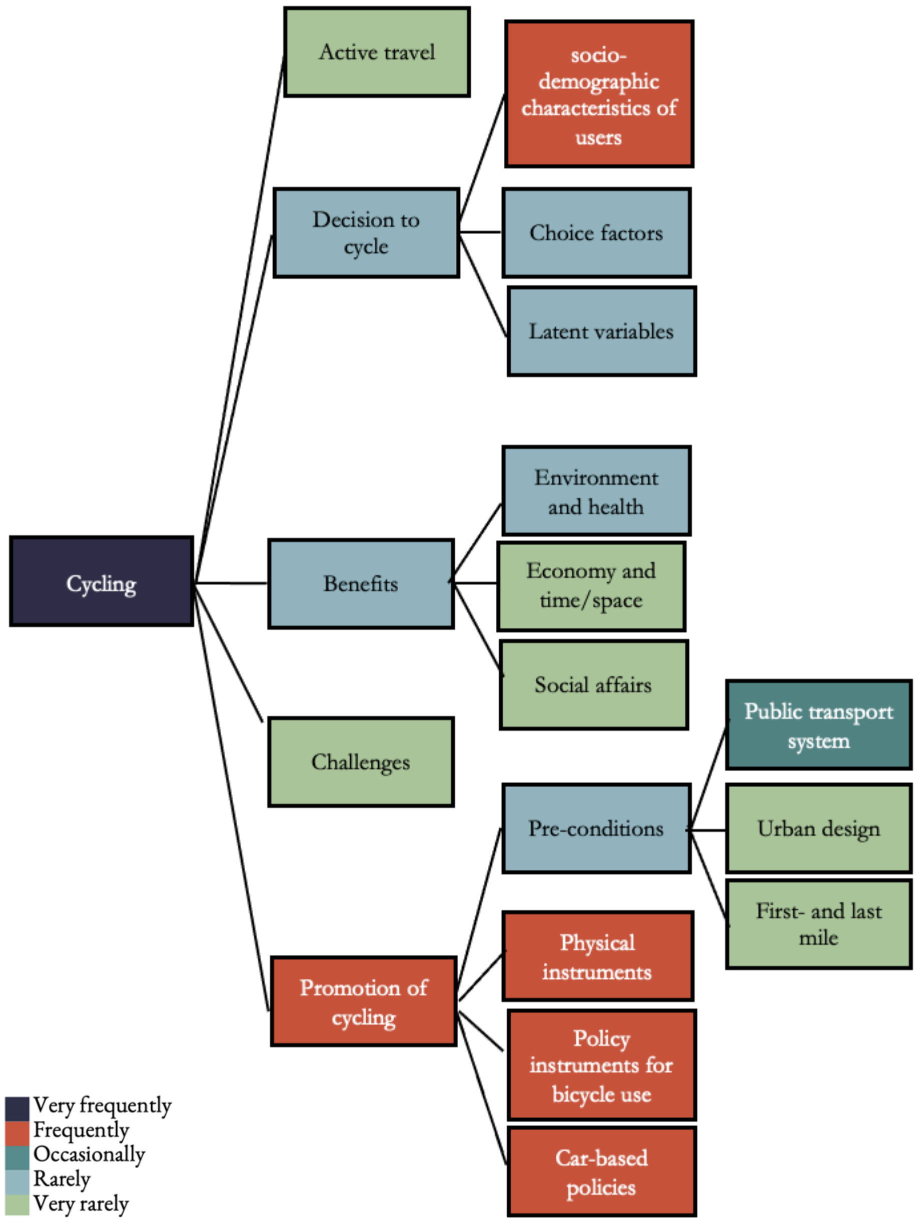


Figure 18: Code analysis of cycling.

4.4.1 Landscape: Climate change and COVID-19

During the interviews, several respondents mentioned that certain external factors would influence the mobility regime, affecting both car and cycling mobility. The most important factors are climate change and the COVID-19 pandemic. Due to climate change, governments are tasked with reducing greenhouse gasses at the national, regional, and local levels. Because of this pressure, it has been stated that the mobility transition has been accelerated in which governments are planning to reduce fossil fuel car mobility and promote cycling more (R-1, R-3, R-4).

> *"There are a number of external facotrs that push this transition. Its [transition] is accelerating, due to the current world situation, regarding climate change [..]"* (R-3).

In addition, the COVID-19 pandemic has first led to a reduction in car use, initially because people had to work from home and the lack of activities and events during the several lockdowns. Simultaneously, this pandemic has led to increased cycling since more people started cycling as a new form of activity, for sports, or as an alternative to public transport (R-4, R-6). Therefore, the respondents' expectation was that after the COVID-19 pandemic, car mobility would decrease because people would continue to work at home or use their bicycles more often as an alternative. This was, however, not the case since car mobility has increased again. Nonetheless, the respondents stated that, in general, bicycle use has grown in terms of more leisure and recreation activities but has not served as a car substitute. Respondent 9 said:

"There is an increase in leisure travel trips since more people started to cycle extra kilometers during this phase [COVID-19 pandemic]. This is not as an alternative, because it just generated more mobility in general."

4.4.2 Explaining the car and cycling regime

The interviewees argue that the mobility regime in the Netherlands is relatively stable in terms of growth (or decline) and magnitude. Moreover, the respondents also mentioned that within the mobility regime, cycling and car use are mostly seen as separate transport systems that undertake developments independent of each other. This means that developments and changes in the cycling mobility regime do not automatically create a reaction in the car mobility regime. As respondent 2 mentioned: *"when you are stimulating cycling, it does not imply that you are driving less."* However, the respondents argued that a reaction could be accomplished due to a strong political view and bottom-up initiatives. Especially since the bicycle can be a suitable alternative for short distances due to its accessibility, affordability, and new technological innovations such as electric bicycles and cargo bikes (R-1, R-7, R-8), hence, this can be seen as a great potential to increase more cycling for the Netherlands.

A clear consensus among the respondents about the responsibilities is visible to shift towards more cycling and less car use. On the hand, there is a strong need for a political view that prioritizes sustainable climate goals, in which they especially strive for less car use and more bicycle use. Furthermore, to also deal with space scarcity, air pollution, and safety risks in urban areas, governments can prioritize low-traffic areas where they keep cars out of the cities. Consequently, more space is made available that can be used for other activities such as houses and for other purposes that can increase urban livability and social cohesion (R-1, R-10). Besides this, a change in traditional transport planning is needed. As respondent 4 explained, nowadays, the central government is still using a conventional transportation model based on reducing travel times. When there is a bottleneck, the easier and most common solution is to expand that car network. As such, the focus is too much on optimizing the car rather than finding sustainable alternative solutions. Thus, instead of using the traditional transportation model, governments must find alternative solutions that will solve bottlenecks without the car's prioritization. Examples are improved proximity of facilities and improved public transport system. With top-down pressure, active political action can be taken where governments can draw up car restriction policies. At the same time, simultaneously, incentives can be created where the bicycle are main transportation mode, is made attractive. Respondent 10 said:

"You need to have a clear objective from the government and that has not been the case in the Netherlands. And certainty not, in which it was made more difficult to use the car. […] I still miss a story at the national level that sets everything in motion." (R-10).

After a sufficient goal formulation, the central government can stimulate and push the lower governments through regulations and funds. However, the regional and local governments need to act upon this since the execution of car reduction and bicycle use is often location-specific (R-2). This means that on a decentralized level, tailor-made plans should be made that encourage bicycle use while simultaneously discouraging car use (R-1). The interviewees also argue that big cities such as Amsterdam, Leiden, Utrecht, and Groningen, already transitioning into low-traffic areas, can serve as examples for other cities in the Netherlands.

On the other hand, there is a need for bottom-up initiatives as well. When private institutions such as your work and education offices promote bicycle use by facilitating and/or funding (e-) bikes, showers at the destination, and safe bicycle storage, people are expected to take the bike more often (R-2, R-6, R-7, R-8). Moreover, when employers or other people have an exemplary function cycle, the greater the chance that the employees or other people will follow this behavior (R-1, R-3, R-8). However, the respondents also said that such incentives or the provision of those facilities need to be continued because when these aspects disappear, people will most likely fall back into their old pattern. Thus, providing long-term incentives increases the share of travel trips done by bike.

During the interviews, it became clear that policies and interventions are necessary to change the mobility regime. Hence, the respondents mentioned which promotional activities are effective and therefore need to be implemented by the governments. They also indicated that the pre-conditions such as the presence of public transport, first-and-last mile, and urban logistics are vital for this transition and that these pre-conditions should be improved. Promotional activities can achieve this via promotional activities as well.
A combination of regulations (sticks) and incentives (carrot) measures is needed. This means that policymakers should promote cycling with physical and soft instruments, while regulations should focus on active restrictions for car use. This will lead to a more integral approach, where policymakers, planners, and other stakeholders can utilize their resources to increase the likelihood of success. For the promotion of cycling, the physical bicycle network is already substantially developed in terms of range. However, several respondents have argued that safety for bicycle road users is still lacking (R-6, R-7). Therefore, safety should be increased in terms of sufficient light, decoupling road and bicycle paths, and safe storage places (R-6, R-7). Respondent 6 has said: "*We need to have a safe cycling environment before we want to promote cycling.*"

The respondents also mentioned that the public transport system, the densification of areas, and the mix-use of facilities should also be improved. A 15 min. city-concept[1] can achieve this (R-2, R-4, R-6, R-8, R-10). This concept will be discussed in the next section. Alongside physical instruments, soft instruments are needed, and the respondents consider funding and technological instruments (i.e., e-bikes, cycling apps) as the most efficient. Regarding the promotional campaigns, there is a difference in opinion on the effectiveness of marketing campaigns, education, and awareness creation. Almost all respondents with a planning background have debated that promotional campaigns are ineffective. However, respondent 5, who is a lector in Creative Media for Social change, does argue that marketing campaigns will have a positive impact on which people will change their behavior.

Nonetheless, most of them agree that when promotional campaigns are implemented, they should be tailor-made for the specific context. This implies that governments should target the promotion of cycling to a particular group of the population. For instance, in a neighborhood with many children, the promotion of the electric cargo bike is more prominent (R-3).

Furthermore, active car restriction policies are needed, to which planners and policymakers must alter the physical and institutional environment (R-10). For the physical environment, physical barriers, one-way car roads, and a reduction in the number of parking places will be effective (R-2, R-10). People are more eager to choose alternative options when it becomes too difficult to circulate and park your car, especially in cities. Next, policy restrictions such as a pricing policy where parking becomes more expensive will also have a positive effect. However, several respondents stated that increasing fossil fuel costs would not be effective since the price elasticities between driving and costs are relatively low (R-1, R-4). Furthermore, only with a strong political view, as mentioned before, can toll driving be implemented, but this is still not the case in the Netherlands due to political choices. This means that such laws and regulations are still not accepted by the government, mainly because governments do not want to create too much resistance from people.

"At the same time, very few measures are taken that discourage car use. I think it's very difficult as a politician to say: we're going to make our inner-city car-free. Because you immediately have many discussions with residents, entrepreneurs etc. […] And if you are bullying the car, you will lose the next election" (R-8).

In addition, it is essential to note that some respondents said that rewarding (carrot) generally works better than punishments (sticks). They argue that according to behavioral theories, rewards or thus incentives will lead to faster behavior change than punishment (R-4, R-6). Therefore, they suggest that enough financial and non-financial means should be available. Lastly, a combination of multiple instruments should be considered to have active policy action.

[1] The 15 min. city refers to a residential urban concept in which the daily necessities and services are within a 15 min. walk or bike radius from home (Pozoukidou and Chatziyiannaki, 2021).

4.4.3 Niches: technological and policy innovations

With regard to niche developments, several technological innovations have contributed to the greater use of bicycles in the Netherlands. They will most likely help to increase the bicycles' modal share in the future. To summarize, these are the improvement of cycling apps, light-electric vehicles, and MaaS, but more importantly, the development of the e-bikes and the 15 min. city concept[1].

E-bikes

Almost all respondents have stated that due to the rise of e-bikes (or speed pedelecs), an increase in cycling and a decrease in car mobility are possible and expected. This means that due to the e-bike, more people are willing and able to cycle longer distances. Respondent 9 has mentioned: "*The e-bike is an excellent means of transport that can be used instead of the car.*" In a report of the Netherlands Institute for Transport Policy, results conclude that the e-bike replaces the regular bike and partly the car and public transport (de Haas, 2019). After purchasing an e-bike, it appears that the car is utilized less frequently for commuting trips (de Haas, 2019).

Furthermore, the data shows that for commuting, leisure, and shopping trips, people use the e-bike more often than the car or traditional bikes (table 10). However, it appears that after purchasing an e-bike, users do not travel more (de Haas, 2019). Although usage of an e-bike is growing every year, the growth rate is slowing down. Whereas in 2014 and 2015, 20% more travel trips were made than in the previous year, the growth in 2016 and 2017 is at only 11% and 8%, respectively (OViN, 2017). The e-bike thus provides the possibility to act as a substitution for the car. However, this is only limited to a certain distance and only for one person. As respondent 10 has stated: *"The e-bike offers many possibilities but has its limits too."*

Table 10: Travel motive before and after purchase of e-bike from 2013-2018 (Source: de Haas, 2019, edited by author).

Traveled distance (km)	**Before purchase**	**After purchase**	**Difference**
Car driver	51,9	50,4	-1,4
Car passenger	18,6	19,2	0,6
Train	6,0	6,4	0,6
Bus/tram/ metro	3,1	2,0	-1,1
Bicycle	6,5	2,9	-3,6
E-bike	2,7	9,1	6,3
Walking	1,5	1,3	-0,2
Total	**96,0**	**96,8**	**0,6**

15-min. city concept

Almost every respondent has argued that the development of a 15. min city-concept serves as a niche that can accelerate this transition. This concept will allow people to go by bike and reduce the dependency on cars due to the densification of the area and the accessibility of daily services (R-1, R-4, R-9, R-10). However, respondent 10 has also argued that this concept involves a lot of investment costs. In such pilot cities, the living expenses are already relatively high, making it difficult for people with a lower income to live there, even when they are willing to cycle more.

"Regarding the city, because it is so crowded, it will become less affordable. Some people want to live in the city but can't afford it and then have to live further away, using the car to do certain activities. You see that internationally as well; where you can cycle easily, like 15 min. city concept, with good proximity and lots of diverse functions, those are also the most expensive cities. And therefore, less affordable "(R-10).

To conclude, due to external pressures on the landscape, a change in the socio-technical regime, and via niches, a discouragement of car use and encouragement of cycling can be achieved. Moreover, during the interviews, the respondents indicated that a change must occur at all three levels to transition to sustainable transportation modes successfully. Finally, figure 19 shows a schematic overview with the most frequent inductive and deductive codes. In addition, the colored blocks are derived during the interview (i.e., inductive codes). The arrows show a relation between the different codes.

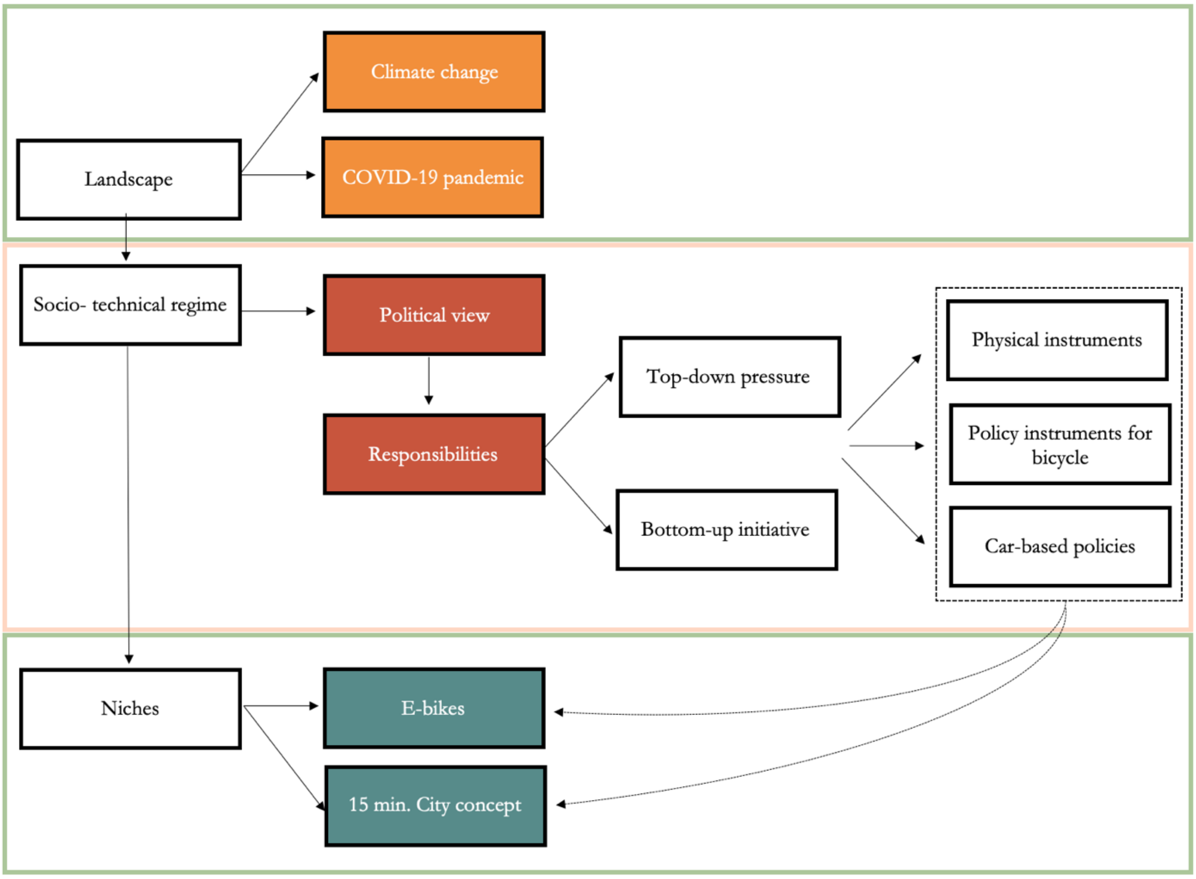


Figure 19: Code analysis scheme with most frequent used deductive and inductive codes.

4.5 Approaches for the future

The respondents discussed two different approaches during the interviews to achieve a transition where car mobility is reduced, and cycling mobility is increased. These are via radical change or incremental steps. In addition, there is a clear distinction between people with academic and professional backgrounds. The respondents with an academic background argue that such transition is only possible when there is a radical change in the socio-technical regime. This means that governments should take not only action and policy measures for car and cycling mobility but that the whole mobility regime should be addressed. This entails that the public transport sector needs to be improved to serve as a proper alternative to cars (R-3, R-4, R-5, R-10). Moreover, by better connecting public transport and cycling, an increment in cycling's modal share is expected since the first-and-last-mile is better organized. As respondent 3 explained:

"*If you want to slow down the growth of car mobility, then you must increase the public transportation volume. […] Then the bicycle can compete with the car" (R-3).*

Also, a radical change is needed to address the mobility regime's lock-in. The Netherlands deals with a so-called 'Law of inhibiting Lead' where fewer new incentives are created to continue new developments due to former infrastructure investments and developments (R-3). For instance, many urban areas are already entirely built and arranged, which makes it challenging to make new adjustments, for example, creating a new metro line or safe bicycle tunnels that will promote the use of bicycles (R-10). Instead of making adjustments that better fit the current mobility regime, a fundamental change is needed to overcome such lock-in. The academics have also argued that besides policymakers, private stakeholders and individuals can steer this transition and that collaboration between all the stakeholders is essential. This implies that on an individual level, people need to change their behavior by purposely choosing the bike instead of the car for small distances. Yet, this change can only be accomplished when the bike is more beneficial than the car. When policymakers and private stakeholders can facilitate a better alternative than the car, the respondents expect that car mobility can be reduced. As said during one of the interviews: *"In my opinion, people will ride a bicycle if it is faster, cheaper, or easier than driving a car" (R-5).*

When looking at the results from the respondents with a professional background, it can be noted that the majority agrees that this transition can be achieved via incremental steps, or in other words, system improvement. They argue that the mobility regime does not have to change entirely but only be improved (R-1, R-7, R-8, R-9). In addition, they state that the existing cycling practice only needs to be extended via step-by-step adjustments since a complete change is not feasible in terms of money and different objectives (i.e., possible shift in political view regarding left- and right-wing parties).

"So I don't think it's bad at all if it's gradual. You have to make sure that you do have the ability to accommodate the people who want to ride the bike, without them facing negative externalities when the policies are still not ready to accommodate this increment" (R-9).

To show the difference between radical change and incremental steps, visualization has been made that show how incremental steps or system improvement could steer this transition and how radical change (steep line) via system innovation can do that (figure 20). In addition, literature is absent on which approach takes longer to guide this sustainable pathway. However, it has been stated by Meadowcroft (2009) that with system improvement, immediate benefits can be found since it is built upon the existing technology that is adequate to solve the challenges. No other technological alternatives are needed invented. Nevertheless, he also explained that system improvement could maintain a lock-in since "*improvement implies refraining from large scale investment in improvement options that only fit into the existing system and which, as a result, stimulate a "lock-in" situation"* (2009 p. 330). Thus, it cannot be concluded that the approach needs more time to achieve this transition, yet system improvement faces the risk of continuing the non-sustainable car mobility regime.

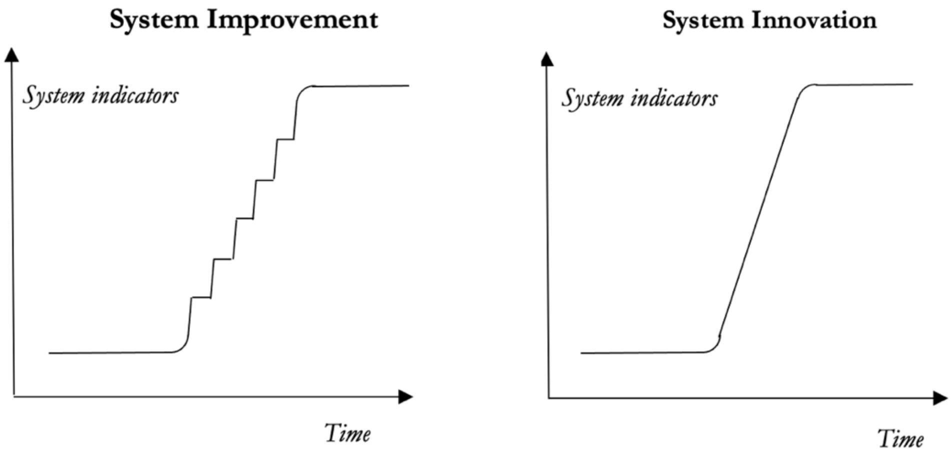


Figure 20: Visualization of approaches for transition.

4.5.1 Urban vs rural areas.

The results also indicate a clear difference regarding transition management in terms of spatial context. The respondents have argued that a transition might be easier achievable in urban areas than in rural areas. They even state that some more prominent cities in the Netherlands, such as Amsterdam, Utrecht, Leiden, and Groningen, are already in the acceleration phase towards more cycling use. In some rural areas, the mobility regime is not yet in the predevelopment phase. As a result, governments in urban areas have already started banning cars and encouraging bicycle use, while in rural areas, less policy action is done.
According to respondents, this has to do with several things. First, urban areas are struggling with a lack of space while the demand for space for housing and other facilities continues to grow. As stated, cars take up a lot of space. Hence cities are planning to reduce car use by creating more low-traffic zones, fewer parking spots, and other car-restricted barriers that ultimately lead to more space for other purposes (R-1, R-3, R-10). Rural areas, however, have fewer problems with space scarcity. Thus, the necessity is not that prominent to already plan car restriction policies (R-10).

"In urban areas you see that we want to do more and more in the same space. And a discussion is beginning to emerge about who the space belongs to. […] thus, governments in urban areas are planning to create more space by reducing the number of cars" (R-2).

Next, due to densification and a wide range of activities in urban areas, more services and facilities are usually within a smaller reach of home, making it easier accessible by bicycle. While in rural areas, such services and facilities are often at a larger distance due to the shrinkage of places and lower density of people (R-9, R-10). Consequently, the people that do live in rural areas take their cars to reach those services. Also, public transport in urban areas is already substantially available in terms of frequency and range, while in rural areas, public transport is often limited (KiM, 2022). One of the reasons for this is that in rural areas, an extensive public transport system where services operate frequently is often not profitable due to low demand (KiM, 2022). This is the opposite in urban areas, and thus more cycling can be achieved due to better utilization of the combination PT and bicycles (i.e., multi-modal) (R-2, R-5).
Consequently, the respondents argue that incremental steps (or system improvement) can achieve a transition, especially in urban areas, since the current system only needs further optimization. While in rural areas, a radical change is necessary because the current system is not functioning sufficiently.

These factors may also indicate why a decrease in-car use and an increase in cycling use in urban areas can be seen, while in rural areas, car use has been growing in the past years (CBS, 2022e).

Conclusion

In this chapter, answers will be given to the three sub questions as stated in the research aim. Thereafter, the main conclusion and future implications on planning practice will be discussed.

To answer the **first sub question**: *"If and how has the increase in cycling over the past few decades contributed to the reduction of car mobility in the Netherlands?"*

Foremost, this study can conclude that the increase in cycling mobility did not lead to a reduction in car mobility since car use continues to grow in terms of distance, travel trips, car ownership, and travel time. Although an increase in cycling mobility can also be seen, this did not strongly influence car reduction because this mainly has led to a rise in the total amount of mobility. The main factors responsible for the growth of cycling mobility were the affordability and accessibility of bicycles, the inherent Dutch culture, spatial advantages of the Netherlands, and other technological innovations. Furthermore, one of the main reasons for this weak relation between car mobility and cycling mobility is that car use and cycling is seen as two separate transport systems that undertake change and developments independently from each other. This implies that an increase in cycling did not significantly lead to a reduction in car mobility. The first reason is that both systems have different users, which means that cycling is mainly used for recreational and leisure activities, while cars are used for commuting. Secondly, both systems have different axis radii, which result in various types of efforts. Although some people take their bicycles for longer distances, most people have a maximum effort (or willingness) to spend on an activity physically. This entails that most people prefer to use the car rather than the bicycle in times of physical mobility and time.

Nevertheless, this research state that for some travel trips, the car is used less due to the development of e-bikes. Consequently, people took the e-bike rather than the car. However, this only accounted for a small part of the total car mobility and did not outweigh the overall car use growth.

The following section provides an answer to the **second sub question** which is stated as the following: *"What are the characteristics of car mobility in the Netherlands?"*

Several factors have contributed to the growth and magnitude of car mobility in the Netherlands. These relate to socio-demographic, historical and political, behavioral and social, environmental, spatial, and technological trends and developments. The most dominant factors are first population growth since more people are driving cars. Secondly, due to increased income and economic welfare, more people are able to purchase a car. Third, due perceived status, and lastly, due to car dependency, mainly in rural areas. The leading causes of car dependency in rural areas originate from the lack of public transport and shrinkage where daily facilities and services are disappearing or not profitable enough at every location, resulting in those services being at a larger distance. This has led to an increment in-car mobility of around 42% in 2019, compared to 1990.

Furthermore, the total number of cars has increased by more than 30% from 2003 to 2022. This also accounted for an incremental increase in car ownership, despite the slight decrease in car ownership in highly urban areas. Another trend is visible regarding car characteristics between different spatial areas. In non-urban areas, on average, the car is used more frequently compared to very high-urban areas. When areas become more urbanized, fewer cars are used as transportation.

To answer the **third sub question**: *"How can the promotional activities for cycling contribute to the reduction of car mobility and how should this be organized in the Netherlands?"*

To conclude, promotional activities can facilitate a reduction in car mobility in the Netherlands. The first is improving and executing physical instruments, where a safe bicycle network is created. To ensure a safe bicycle network, light along the roads, a decoupling between a bicycle path and the main road, and safe bicycle storage should be provided. Additionally, other physical instruments such as improving public transport in terms of increased frequency and availability in predominantly rural areas are insufficient to subordinate an alternative for car use. Thus, providing a dense public transport network will enable a multi-modal transport system. With the combination of bicycles and public transport, the first-and-last-mile for activities will be improved, and fewer people will become car-dependent. Besides physical instruments, other promotional activities will contribute to a car use reduction. These refer to policy instruments for bicycle use, where technological-based policies and incentive-based policies are most effective. Examples are the development of e-bikes, VELO-bikes, and funding. Promotional campaigns, for instance, education, communication, and environmental awareness will not reduce car mobility. Next, there are car-based policies, or in other words, policies that discourage and restrict car use. The most effective car-based policies are implementing low-traffic zones, increased parking costs, and reduced parking spots. Lastly, it is essential to note that more than one measurement is needed and that even for a more successful effect, governments should implement a combination of promotional activities, where incentives are being created that encourage bicycle use. At the same time, simultaneously, car-restricted policies are being formulated. This can be organized via top-down pressure and bottom-up initiatives. The national government should provide a clear goal-setting and funding to that decentralized governments can create tailor-made plans that fit each location's characteristics. Via bottom-up initiatives, other stakeholders such as private parties and individuals can promote bicycle use by facilitating e-bikes, showers, and storage and using the bicycle to encourage others to use this mode of transport.

In answering the **main research question**: *"How can the increase in cycling's modal split contribute to the transition from car mobility to the use of sustainable transportation modes?"*

This research illustrates that an increase in cycling's modal split does not automatically lead to a reduction of car mobility and that only in specific circumstances with specific measurements can a reduction be accomplished. This means that a bigger cycling share does not naturally lead to fewer cars when the bicycle is not used as an alternative transportation mode and is highly promoted. The first specific circumstance is that up to a maximum distance of 7.5 km, cycling can serve as an alternative to cars due to the ability and willingness of most people. This distance is slightly extended with light-electric and electric- bikes. Secondly, there is a need for pressures from the landscape, changes in the socio-technical mobility regime, and niches that will enable this transition. First, climate change can serve as a pressure in which governments are faced with the task of reducing greenhouse gasses, where they strive to minimize fossil fuel car mobility while at the same time promoting sustainable alternatives, including bicycle use. Furthermore, COVID-19 did put pressure on the mobility regime, reducing car mobility, and the cycling share was increased. However, this did not have a causal relation since they occurred mainly independently from each other.

Moreover, it only resulted in a short-term reduction in car mobility since people continued using the car again. Next, changes in the mobility regime are needed. This entails that via a strong political view and bottom-up initiatives, the cycling's modal split can increase, and these conditions can decrease the car's modal split. A strong political view refers to prioritizing climate change goals and improved livability, to which the Dutch national government strives to discourage car use and promote cycling more. With those clear objectives, active policy action can occur where carrot and stick measurements are implemented. This will result in the encouragement of cycling use and discouragement/ restriction of car use. Next, bottom-up initiatives are needed, to which private and institutional organizations promote and facilitate bicycle use, yet this needs to be a long-term incentive in order to succeed. Also, cycling can reduce car mobility when combined with public transport. This modal-split results in better accessibility, cost-effective, and sustainable transportation modes that enable people to become less car-dependent. However, the public transport system needs to be improved first to increase its frequency and axis radius throughout the country before it will have a competitive advantage over cars. In addition, niches are important to increase the cycling's modal split. Via the development of e-bikes and the 15 min. city concept, people have become less car-dependent because people can cycle for a larger distance with the e-bike, or daily services and facilities become within a 15 min. reach for walking and cycling.

Lastly, a differentiation between spatial contexts must be made to transition towards more sustainable transportation modes. This implies that in urban areas, the mobility system only needs to be improved, while in rural areas, the mobility system needs to be radically changed. The reasons for this are that components in the mobility sectors, such as public transport system, densification, and proximity of facilities, are already developed in urban areas. Thus only cycling should be promoted, and car use should be restricted. On the contrary, in rural areas, only the promotion of cycling and car-based policies will not be sufficient due to the lack of those components. Thus, via two different approaches with the help of several measurements, an increase in cycling's modal split can facilitate a reduction in car mobility, consequently leading to more sustainable mobility.

5.1 Implications for planning practice

This research shows that not one central approach is sufficient to achieve more sustainable modes of transportation. Therefore, two frameworks can be made in which policy makers can differentiate for which areas system improvement can take place, and in which areas system innovation should be implemented. Furthermore, policymakers should encourage collaboration between governmental institutions that act on a top-down level and private and institutional organizations that work via bottom-up initiatives. In addition, this research has drawn up several conditions that can ensure the transition. However, this is only focused on the Netherlands and cannot be generalized to other countries. Hence, policymakers from other countries should consider their own context before implementing conditions that perhaps only apply in the Netherlands. Finally, transition management is challenging because it deals with complexity, uncertainty, and different sub-systems. Therefore, policymakers should be aware that operating a transition comes with establishing the societal agreement, negotiating among trade-offs, and distributing scarce resources to help steer the transition in the right direction.

Discussion

The following chapter provides a synthesis of the results and academic literature explored in the theoretical framework. In addition, several recommendations for future research will be discussed. After that, the limitations of this study are presented.

6.1 Explanation of the results

When looking at the results, the empirical findings align largely with the theoretical findings. Similar promotional activities showed a positive impact on increased use of cycling, where with the pre-conditions, physical instruments, and policy instruments, the cycling's modal split can increase in the Netherlands. However, it was expected that promotional campaigns, which are categorized as policy instruments, would have a positive effect on the cycling share and would discourage car use as well. However, this research showed that such promotional campaigns would not be effective. Furthermore, the expectations of car-based policies correspond with the theoretical findings since the results indicate that car-based policies will reduce car use and, therefore, indirectly impact cycling's modal share. Next, new insights show that behavior will strongly influence whether people want to replace the car for cycling. As this has only been investigated lightly for cycling and not for car use, it cannot be stated with certainty how promotional activities could influence this car use behavior. Other insights are that the challenges of cycling, especially regarding safety, limited maximum distance, and purpose of the activity, contribute to greater use of cars and will limit the choice for people to take the bike instead. Next, the dominance of car mobility, as explained in the literature, aligns with the results. This can be explained mainly due to the individual consumption, subordination of other transport modes, and dominant culture. However, additional insights from the data illustrate that population growth and high-income level are also indicators of the dominance of car mobility. This research also showed how this transition should be achieved in rural and urban areas via two different approaches within the same mobility regime. According to the theoretical findings, this can co-occur, and it is argued that policymakers should pursue this (Meadowcroft, 2009). In addition, this research explains the relationship between cycling and political-economic structures. The results state that an increase in cycling's share can be accomplished via a strong political view that provides clear goal objectives, regulations, incentives, and financial funding. The expected results demonstrate that promotional activities will have a positive direct effect on cycling use and an indirect impact on in-car mobility. The empirical results also indicate this, meaning that promotional activities result in more cycling use by making the bicycle more attractive than the car. As a result, car mobility is indirectly affected since it will reduce the number of travel trips done by car, which is now done with the bicycle. However, car-based policies are expected to directly reduce car use, in which people need to find an alternative transportation mode. This aligns with the empirical evidence that states that car restriction (or based) will lead to fewer car use and can increase cycling mobility when it serves as an alternative.

This study also explores how the Netherlands could reduce greenhouse gas emissions by reducing car mobility and encouraging bicycle use. However, it is important to acknowledge that sustainable development generally cannot be solved decisively by organizing transitions in sub-systems, such as the mobility sector. But that, sustainable development is a continuing process, and sustainable mobility is a part of that (Meadowcroft, 2009). However, the results do indicate how increased livability can be accomplished for urban and rural areas, encouraging more bicycle use while also discouraging car use. Lastly, the research provided evidence of how this sustainable mobility transition should be managed by giving guidelines based on the transition theory and the respondents' knowledge and expertise.

6.2 Recommendations for future research

There are several recommendations for future research that will enable a better understanding of the research aim. As mentioned, future research can investigate the perception of car users to understand what incentivizes them to shift towards more sustainable transportation modes. In addition, this research only focused on the perception of people with an academic and professional background. Thus future research can also identify how successful bicycle promotion can be achieved when focusing on the motives and beliefs of cyclists. Moreover, the role of public transport in creating a modal split is expected to reduce car mobility. However, further research is needed to investigate whether this will significantly affect practice. Finally, it has been stated that cycling can provide a suitable alternative, yet only at small distances. Thus, in future research, we need to understand how to encourage long-distance cycling, in which a bigger part of the travel trips per car can be reduced.

6.3 Limitations of the research

According to Theofanidis and Fountouki (2019), it is inevitable that researchers face some limitations which are not always identified prior to the research, even though with careful planning. This research also dealt with several limitations or shortcomings regarding the data collection, selection, and analysis. When focusing on the data collection, due to the limited period of the research (i.e., around eight months), it was impossible to identify all possible factors that could contribute to an increase in cycling's modal split, which would facilitate a reduction in car mobility. Moreover, this also constrained the number of respondents being interviewed, in which a more comprehensive answer could be obtained. Other data collection shortcomings were the limited access or amount of available data that could provide a more detailed explanation of the trends and developments of car and cycling mobility in the Netherlands over the past two decades. The same applies to other European countries, making it difficult to get an appropriate comparison. In addition, this data mainly focused on the total mobility patterns, resulting in that information was lacking in location-specific areas. This thus resulted in a too population-specific result (Theofanidis and Fountouki, 2019).
Furthermore, the data were analyzed using the audio tapes of a mobile device. Consequently, some words could not be identified due to unclear articulation and background noise. Hence some information could not correctly be analyzed and used for this research. In order to avoid these limitations, these could be taken into account in future research.

6.4 Reflection on personal process

Next, I would like to reflect on my process of conducting a master's thesis. Initially, I found it quite challenging to frame the research aim because many factors influence the car mobility regime, cycling regime, and the relationship between them. As a result, I spent a lot of time delineating the research design. This was fortunately solved due to several consultations with my supervisor and insights from other researchers. Lastly, this thesis has given me a better awareness to ride my bicycle more often. I have been driving a car for almost five years, and even for short trips, I take this mode of transportation, while I could have easily used the bicycle. After this research, I have become more aware of the disadvantages of car use and the advantages of bicycle use, which will actively change my travel behavior in the future.

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Appendices

1. Interview guide

Introduction
Hello, my name is Laura Fransen, I am 23 years old, and I am in the finishing phase of my Masters's degree of the study Environmental Planning and Design, (Faculty of Spatial Sciences) in Groningen. First of all, I would like to thank you very much for your time and cooperation in this research project. In addition, I would like to ask you, if you agree that this interview will be recorded for processing purposes. If you have any questions and/or comments, please feel free to ask them in between. Finally, I would like to assure you that you can disconnect the interview at any time if you wish.

Do you have any questions and/or comments currently?

Introduction

1. Could you please tell a bit about yourself? What is your specialty within the mobility sector?
2. Explain the project → link between cycling and car mobility, whether an increase in cycling can decrease car mobility

Perception of (the role of) cycling

3. How do you see the relationship of cycling on the use of cars? / How do you see the link between cycling and car mobility?
    a. Do you think this is different in the Netherlands, than in other European countries?
    b. Do you think this is also different in urban and rural areas?
4. Do you think that there enough policies in the Netherlands that stimulate cycling? Or reduce car mobility? (If the policies are already linked with cycling/ car mobility)

As can be seen in the secondary data, the Netherlands is still one of the most car-used countries in the World, while simultaneously also has the biggest bicycle share. Shows data and figures on these trends.

Status quo: Possible causes and processes

5. How could you explain why the Netherlands has the highest bicycle share, while also is one of the motorized countries in the world?
6. What are the underlying causes/what do you think are the reasons?
    a. Do you think that proximity (or distance) is a determining factor?
    b. Do you think that the increase in ownership of a car contribute to this relation, and could you explain why?
    c. How could you explain the difference between urban and lower density areas, regarding cycling and the use of car mobility?
    d. Current spatial patterns/ urban centers vs rural or lower density
        i. Do you think that commuting patterns (work/travel/home) has a big influence, and why?

Extra questions

e. Do you think that the COVID-19 pandemic has/will influence this relationship between cycling and car mobility?
f. Do you think that the increase income per households will influence this relationship between cycling and car mobility?
g. How do you think that change in behavior would influence cycling and car mobility?
    i. How would the Netherlands differ than other countries in Europe?

Solution and future trends

7. How do you see the future regarding car mobility and cycling in the Netherlands?
    a. What are your expectations on this view?
8. What do you think should be undertaken/done to transition towards more cycling?
    a. Should we focus on a reduction of car use, or at the stimulating of bicycle use?
    b. Who do you think should be main responsible for this?
9. Should we focus on general policies that apply for the whole country, or on tailor-made area specific policies? Also, with the notion of time and costs?
10. What type of policies measures do we need to have this transition?
    a. How should we organize this?

Final questions

Thank you for all your responses and clarifications. Do you perhaps have any further questions and or comments? Do you still agree that this interview may be used for processing purposes for that research?

11. Do you have any idea who else I can approach, who also can explain this relationship between cycling and car mobility, or has possible solutions?
12. Would you be willing to give a second interview if I have any questions during the process of this research?

2. **Interview gids (in Dutch)**

Introductie
Hallo, mijn naam is Laura Fransen, ik ben 23 jaar oud, en ik ben in de afrondende fase van mijn Masterstudie van de studie Environmental Planning and Design, (Faculteit Ruimtelijke Wetenschappen) in Groningen. Allereerst wil ik u hartelijk bedanken voor uw tijd en medewerking aan dit onderzoeksproject. Daarnaast wil ik u vragen, of u ermee akkoord gaat dat dit interview voor verwerkingsdoeleinden wordt opgenomen. Mocht u nog vragen en/of opmerkingen hebben, dan kunt u die gerust tussendoor stellen. Tot slot wil ik u verzekeren dat u het interview te allen tijde kunt afbreken als u dat wenst.

Heeft u van tevoren als vragen en/of opmerkingen?

Introductie

1. Kunt u iets over uzelf vertellen? Wat is uw specialiteit binnen de mobiliteitssector?
2. Licht het project toe: verband tussen fiets- en automobiliteit, of een toename van het fietsen de automobiliteit kan verminderen

Perceptie van de rol van de fiets

3. Hoe ziet u de relatie van fietsen op het gebruik van auto's? / Hoe ziet u het verband tussen fietsen en automobiliteit?
    a. Denkt u dat dit in Nederland anders is, dan in andere Europese landen?
    b. Denkt u dat dit ook anders is in stedelijke en landelijke gebieden?
4. Vindt u dat er in Nederland genoeg beleid is dat fietsen stimuleert? Of de automobiliteit verminderen? (Als het beleid al gekoppeld is aan fiets-automobiliteit)

Zoals uit de secundaire gegevens blijkt, is Nederland nog steeds een van de meest autogebruikte landen ter wereld, terwijl het tegelijkertijd ook het grootste fietsaandeel heeft. Toont gegevens en cijfers over deze trends.

Status quo: Mogelijke oorzaken en processen

5. Hoe zou u kunnen verklaren waarom Nederland het hoogste fietsaandeel heeft, terwijl het toch ook een van de gemotoriseerde landen ter wereld is?
6. Wat zijn de achterliggende oorzaken/wat zijn volgens u de redenen?
    a. Denkt u dat nabijheid (of afstand) een bepalende factor is?
    b. Denkt u dat de toename van het bezit van een auto bijdraagt tot deze relatie, en kunt u uitleggen waarom?
    c. Hoe zou u het verschil kunnen verklaren tussen stedelijke gebieden en gebieden met een lagere dichtheid, met betrekking tot fietsen en het gebruik van automobiliteit?
    d. Huidige ruimtelijke patronen stedelijke centra vs platteland of lagere dichtheid
    e. Denkt u dat het woon-werkverkeer (werk/reis/thuis) een grote invloed heeft, en waarom?

Extra vragen

a. Denkt u dat de COVID-19 pandemie deze relatie tussen fiets- en automobiliteit heeft/zal beïnvloeden?
b. Denkt u dat de stijging van het inkomen per huishouden deze relatie tussen fiets- en automobiliteit zal beïnvloeden?
c. Hoe denkt u dat gedragsverandering van invloed zou zijn op fiets- en automobiliteit?
d. Hoe zou Nederland verschillen van andere landen in Europa?

Oplossing en toekomstverwachtingen

7. Hoe ziet u de toekomst wat betreft automobiliteit en fietsen in Nederland?
    a. Wat zijn uw verwachtingen ten aanzien van deze visie?
8. Wat moet er volgens u ondernomen/gedaan worden om de overgang naar meer fietsen te maken?
    a. Moeten we ons richten op een vermindering van het autogebruik, of op het stimuleren van het fietsgebruik?
    b. Wie moet daar volgens u de hoofdverantwoordelijkheid voor dragen?
9. Moeten we ons richten op algemeen beleid dat voor het hele land geldt, of op gebied specifiek beleid op maat? Ook met de notie van tijd en kosten?
    a. Welk soort beleidsmaatregelen hebben we nodig om deze overgang te bewerkstelligen?
    b. Hoe moeten we dit organiseren?

Afsluitende vragen

Dank u wel voor al uw antwoorden en toelichtingen. Heeft u wellicht nog vragen en of opmerkingen? Gaat u nog steeds akkoord met dat dit interview gebruikt kan worden voor verwerkingsdoeleinden voor die onderzoek?

10. Heeft u nog een idee wie ik nog kan benaderen, die ook hier een perspectief op kan geven?
11. Zou u het goed vinden, om wellicht een tweede interview te geven, wanneer ik tijdens het proces van dit onderzoek nog met vragen kom?

3. Consent form of participation

Research project: Master thesis Environmental and Infrastructure Planning
University: University of Groningen, Faculty of Spatial Sciences
Researcher: Laura Fransen
Title: The promise of cycling to reduce car mobility in the Netherlands

Dear participant,

First of all, I want to thank you for taking the time to participate in this research project. The aim of this research thesis is to gain insight into how the influence of bicycle use can counteract a reduction in car use in the Netherlands. It will focus on the link between cycling and car, thereafter, the status quo in the Netherlands, and solutions and future trends. In this way, I want to inform you about the course of your participation.

The interview will be approximately 30 minutes, depending on length of answers and any new questions that may arise. In addition, this interview will be conducted physically or online. Also, the interview will be recorded and transcribed to analyze it and answer the research question for this research project. In addition, you will have the opportunity to receive the transcript to check for factual inaccuracies.

For further comments and questions, please contact

Laura Fransen
l.fransen.1@student.rug.nl
0627337573

Ms. Farzaneh Bahrami
f.bahrami@rug.nl

I hereby declare that:

I am willing to participate in this research project on a completely voluntary basis. YES/ NO

The results of this interview may be processed in the research project. YES/ NO

Grant permission to have the interview recorded by pre-recording software for processing purposes. YES/ NO

Grant permission to use my name in the research project. YES/ NO

When NO:
A pseudonym can be used YES/NO
(example: respondent 1)

Name of participant…………………………………………………………………………...

E-mail (*to receive transcript*)… ……………………………………...………………………………

Date……………………………………...……………………………………………………...

Signature……………………………………...……………………………………........................

4. Toestemmingsformulier van deelname (in Dutch)

Onderzoeksproject: Master thesis Environmental and Infrastructure Planning
Universiteit: Rijksuniversiteit Groningen, Faculty of Spatial Sciences
Onderzoeker: Laura Fransen
Titel: The promise of cycling to reduce car mobility in the Netherlands

Geachte Deelnemer,

Allereerst wil ik u van hartelijk bedanken dat u de tijd heeft genomen om deel te nemen aan dit onderzoeksproject. Het doel van dit onderzoekscriptie is om inzicht te krijgen hoe de invloed van het fietsgebruik een vermindering kan tegengaan op het autogebruik in Nederland. Daarbij wordt er gekeken naar o.a. de link tussen fiets en auto, de status quo van Nederland en naar de toekomstverwachtingen. Op deze manier wil ik u informeren over het verloop van uw deelname.

Het interview zal circa 30 minuten, afhankelijk van lengte van de antwoorden en de eventuele nieuwe vragen die er kunnen ontstaan. Daarnaast zal dit gesprek fysiek of online gevoerd worden. Ook zal het gesprek opgenomen en getranscribeerd worden om het te analyseren en antwoord te geven op de onderzoeksvraag voor dit onderzoeksproject. Daarnaast heeft u de mogelijkheid om het transcript te ontvangen om te controleren om feitelijke onjuistheden.

Voor verdere opmerkingen en vragen kunt u contact opnemen met

Laura Fransen
l.fransen.1@student.rug.nl
0627337573

Ms. Farzaneh Bahrami
f.bahrami@rug.nl

Hierbij verklaar ik dat:

Ik geheel vrijwillig bereid ben aan dit onderzoeksproject mee te doen JA/NEE

De uitkomsten van dit interview verwerkt mogen worden in het onderzoeksproject. JA/NEE

Toestemming geef om het interview op te laten nemen door middel voor de opnamesoftware voor verwerkingsdoeleinden. JA/NEE

Toestemming geef om mijn naam te gebruiken in het onderzoeksproject. JA/NEE

Wanneer NEE:
Een pseudoniem gebruikt kan worden (voorbeeld: respondent 1) JA/NEE

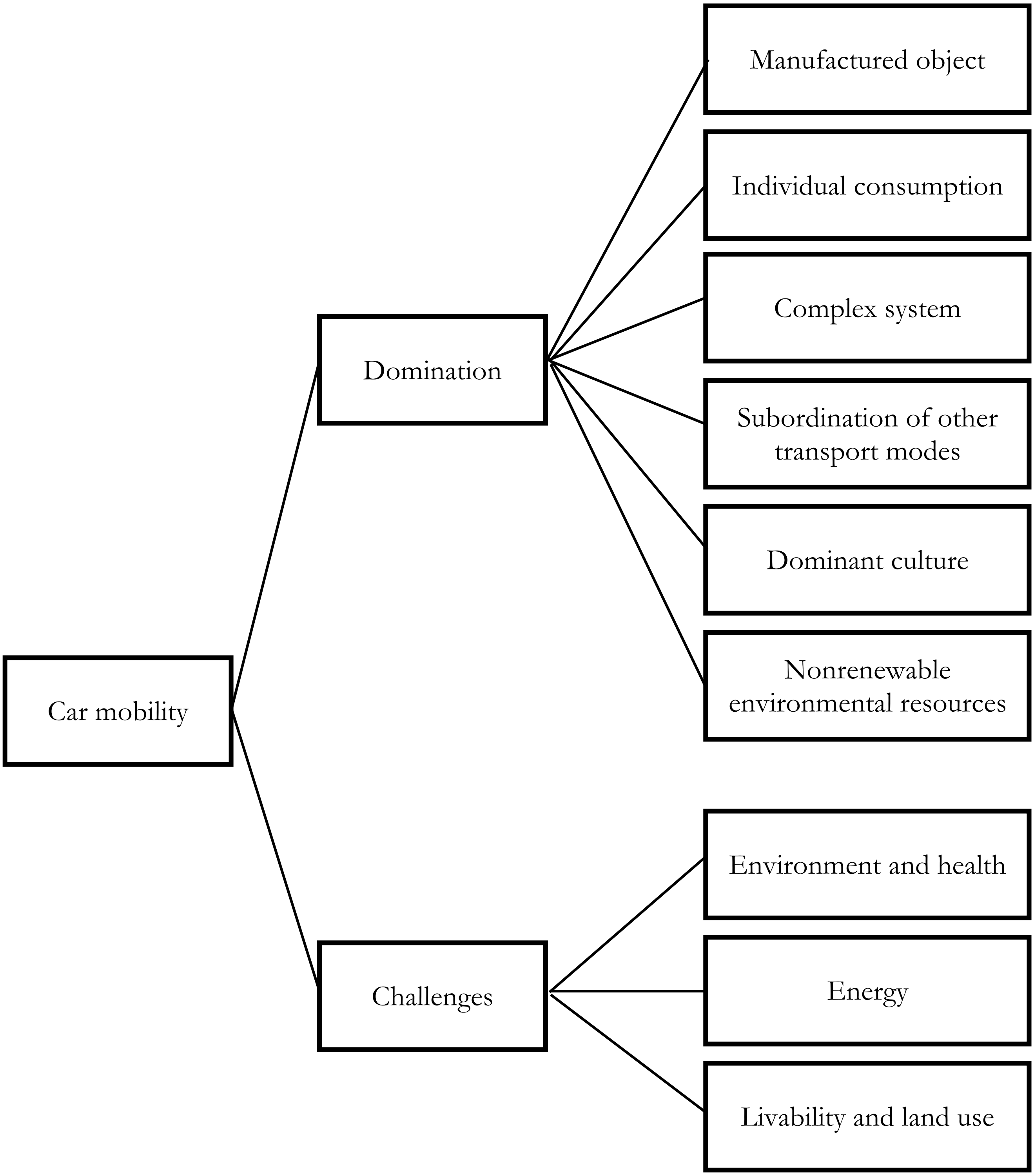
Naam van deelnemer van interview……………………………………………………………….

Email (*voor eventuele ontvangst van transcript*) ....

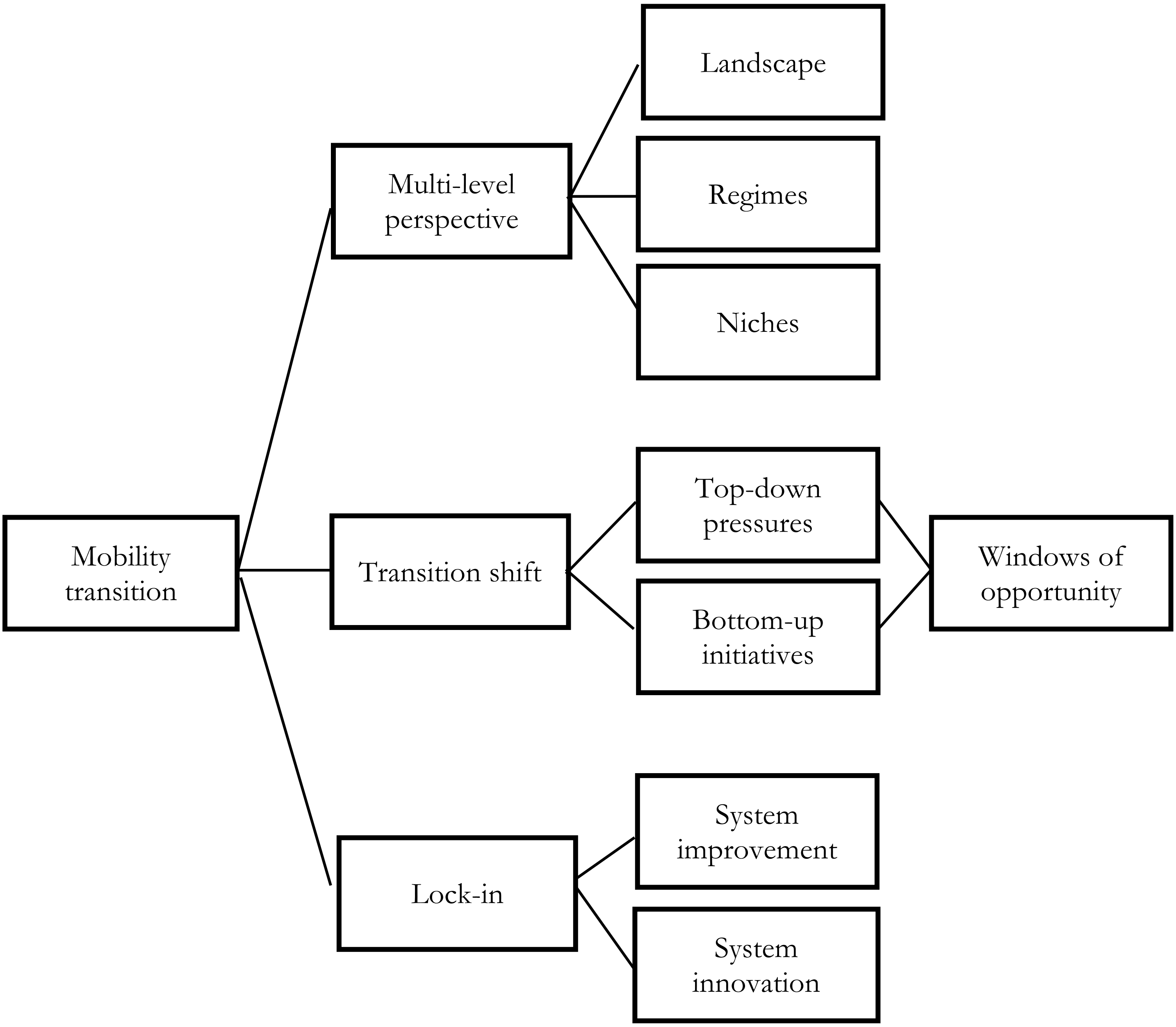
Datum ………………………………………………………………………………………….

Handtekening ……………………………………………………………………………………

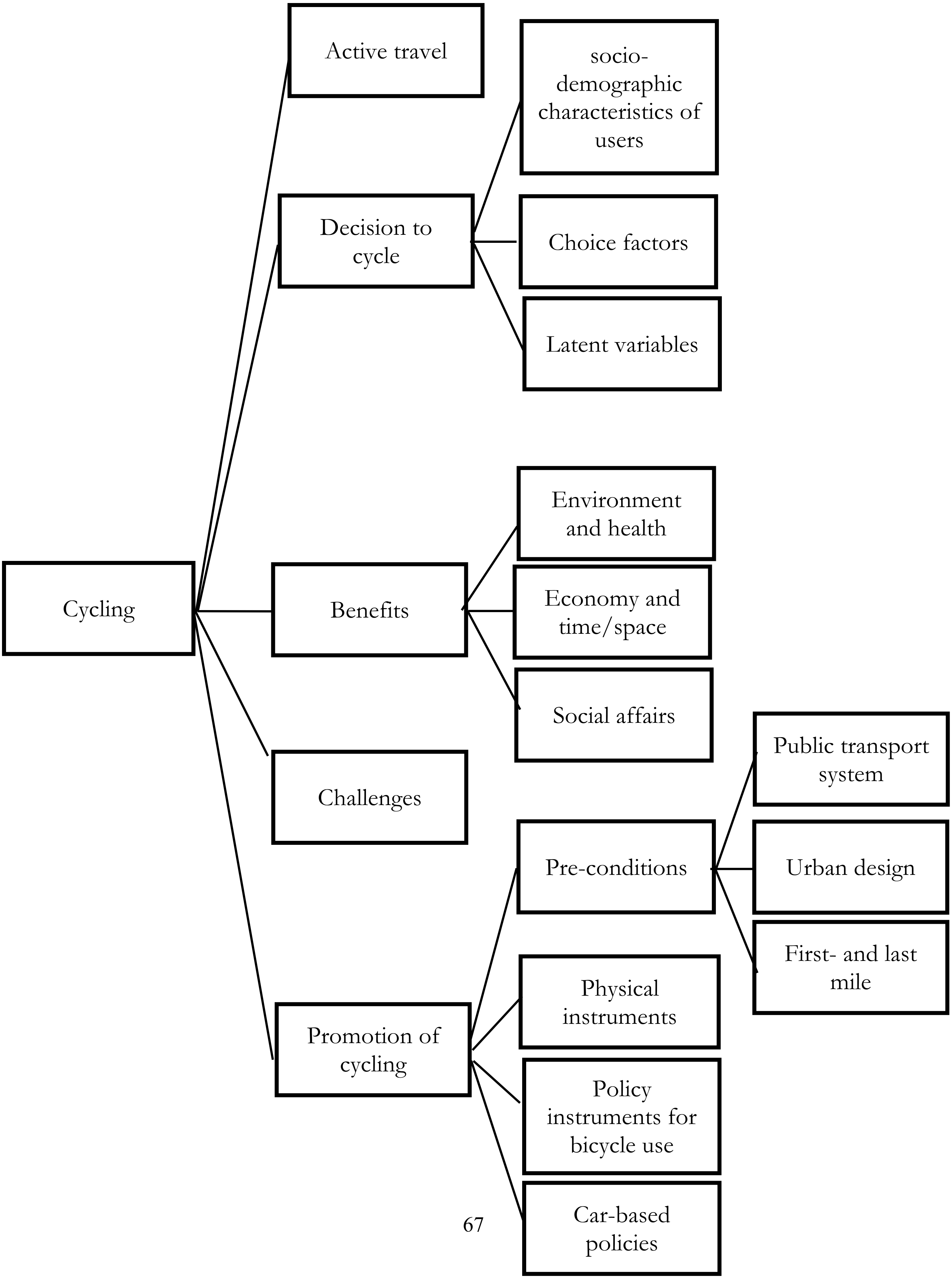
5. Deductive code tree – Car mobility



6. Deductive code tree – Mobility transition



7. Deductive code tree – Cycling



8. Inductive code book

Concepts	Code groups	Codes	Frequency
Differences between areas	Utban and rural areas	Car vs cycling Urban vs rural areas	
Decision for mode of transportation	Transportation choice	Behavioral change Travel motives Routine	
Socio-technical regime	The Netherlands	Political view Responsibilities Characteristics of the Netherlands	
Mobility transition	Windows of opportunity	COVID-19	