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Pathway to Progress?

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Preface

This thesis has been written as part of the Master Society Sustainability and Planning at the Faculty of Spatial Sciences in Groningen. I especially want to thank my supervisor, Farzaneh Bahrami, for the constructive feedback and for steering me in the right direction. I also want to thank Ferry Van Kann for the time he dedicated to reviewing my proposal. Lastly, I want to thank Fietscommunity Groningen for sharing my questionnaire and all the respondents for sharing their knowledge and experiences, which was essential for writing this thesis.

Mathijs Meijer

Abstract

Embracing cycling as a sustainable alternative to motorized vehicle use offers manifold benefits. Nonetheless, cycling's primary disadvantage lies in its limited range compared to other modes of transport. The concept of bicycle highways might offer a solution in encouraging cyclists to cycle further distances due to its infrastructural design and ability to ride faster. In particular, bicycle highways are gaining popularity in urban areas due to their ability to reduce traffic congestion, noise, and air pollution. However, extending this infrastructure beyond urban boundaries involves unique challenges. The primary goal of this study is to discover the benefits of the nearly 30-kilometer-long bicycle highway between Assen and Groningen. It employed a mixed-method approach, including spatial analysis through ArcGIS, literature reviews, and interviews with users of the bicycle highway.

Initial findings suggest that the bicycle highway may not drastically reduce travel times and distances in most regions of the study area but enhance the overall cycle experience through improved safety and comfort. Moreover, respondents indicated that the bicycle highway provides multiple benefits compared to other cycle infrastructure; however, the infrastructure didn't influence their decision to cycle. Furthermore, based on ODiN data, it became apparent that commuters cycled more frequently in the study area. However, the ArcGIS analysis indicated this differed significantly among regions within the study area. In particular, for villages around the city of Groningen close to the bicycle highway, an increase in commuting trips by bicycle was evident. However, based on ODiN data, an increase in cycle trips between the city of Assen and the city of Groningen was not noticeable. Additionally, there is no evidence that the distance of cycle trips increased through the implementation of the bicycle highway.

This research contributes to a better understanding of bicycle highways predominantly located beyond urban boundaries. In addition, the study highlights how the benefits and use of a bicycle highway might vary among different regions. Therefore, this study may serve as a model for other areas considering similar projects, illustrating the challenges and benefits of implementing bicycle highways in less densely populated areas.
Future research should be conducted when the bicycle highway is fully operational. Additionally, this research could benefit from the application of new methods, to have a better understanding about the users of the infrastructure, and related travel times.
Furthermore, focusing on the region's commuters instead of cycling commuters could provide more comprehensive insights and significantly more responses.

Keywords: Bicycle Highways, Modal Split, Modal Shifts, Active Mobility, Rural Areas

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Introduction: Background and problem definition

Active transportation (such as cycling) is increasingly seen as a solution for many (urban) problems, such as congestion, noise, air pollution, and health issues (de Nazelle *et al.*, 2011). Daily cycling increases fitness and reduces the risk of all-cause mortality (cardiovascular diseases, overweight, and colon cancer morbidity) (Oja *et al.*, 2011). According to Davis et al. (2007), the built environment should be reorganized 'to discriminate in favor of cycling" as car use led to a decline in human energy expenditure and obesity. Sommar *et al.* (2021) agreed on that and argued that local measures to increase cycling are essential for public health. In addition, exposure to air pollution is associated with several non-communicable diseases (Sommar *et al.*, 2021). Forms of active mobility cause less air pollution and more cycling significantly leads to a reduction of "mobility-related CO2 emissions' (Brand et al., 2019) and (Jang *et al.,* 2021)

Urban planners are adopting the idea of "bicycle highways" more frequently, which is implemented in many northern European regions (Rayaprolu *et al.*, 2020). Bicycle highways are a relatively new concept in spatial planning, adopted to provide better cycling conditions and to promote cycling as a competitive alternative to cars. Bicycle highways are frequently planned, targeting commuters who generally cycle for longer distances Lierop *et al.*, (2020). This is also confirmed by Banerjee *et al.* (2021), who argue that bicycle highways are frequently conceived as the foundational infrastructure, with a specific focus on meeting the needs of commuters.

In 2018, the "Green Axis" construction started, a bicycle highway between Assen and Groningen. This bicycle highway aims to foster cycling in the Assen-Groningen region and improve regional accessibility (Drenthe, 2019). According to the province of Drenthe, the bicycle highway is fast and comfortable, serving commuters and recreational cyclists by offering a seamless and rapid connection between Assen and Groningen. The considerable width of the cycle path, spanning 4 meters, couples with minimal intersections along its expansive 30-kilometer length, renders it an efficient and direct connection.

Problem statement

Literature provides plenty of evidence of bicycle highways that encourage sustainable modes of transportation, particularly in urban and metropolitan settings. According to (Pucher and Buehler, 2017), bicycle highways are becoming increasingly popular and necessary to serve longer distances in metropolitan areas. Banerjee *et al.* (2021) argue that the very essence of bicycle highways is to provide a fast and safe connection between suburbs and city centers. According to Grigoropoulos *et al.* (2021), bicycle highways have multiple advantages in urban areas. Bicycle highways are often seen as a sustainable transportation solution that, especially in urban and metropolitan areas, could reduce traffic congestion, lower noise pollution, and improve air quality. Applying a bicycle highway in a predominantly rural area, such as between Assen and Groningen, presents unique challenges that need to be more understood and often addressed in existing literature.

Furthermore, strategically placing bicycle highways as fast and direct connections between points of interest is crucial for their success. Bicycle highways are often seen as a premium network from the core of an entire bicycle network. Therefore, bicycle highways should ideally directly connect urban cores and densely populated areas to maximize utility and encourage higher cycle rates. However, the location of the "Green Axis" bicycle highway raises critical questions. The bicycle highway is located along a running canal along the edge of Assen. Not all neighborhoods are near the cycle path. The same applies to Groningen, where the bicycle track ends at the city's edge (in 2026 at the central station).

The presence of the bicycle highway in a natural environment, along a running canal, may not sufficiently improve accessibility and make it more appealing for recreational users. Additionally, the location beyond urban boundaries raises critical concerns about its potential users. According to a study in the Netherlands (Scheepers *et al.*, 2013), the probability of using active forms of transportation is less in rural areas. Therefore, the user rates of improved cycle infrastructure may be minimized in these regions. Lastly, it's uncertain if the Green Axis meets the design standards of bicycle highways, highlighted by (CROW, 2016) and (CROW, 2014), to provide a direct, safe, and comfortable route between residential areas and points of interest.

The stakeholders of this project aimed to attract commuters willing to make a modal shift towards cycling (Benak, 2020). However, given alternative modes of transportation, such as a direct train connection, a highway, and different bus networks, the almost 30-kilometer-long cycling track may pose challenges for commuters. Additionally, it is still being determined if potential modal shifts due to the bicycle highway vary between commuters living around the bicycle highway in various regions. It's therefore uncertain to what extent the bicycle highway's benefits vary in different areas. Cycling might not be the most appealing option for commuters in every region due to the accessibility of other modes and the travel distance to the working location, despite the availability of a dedicated path.

Research aim

This research explores the advantages of bicycle highways for commuters in the Assen-Groningen region. It aims to evaluate whether the bicycle highway can become a viable and preferred commuting option despite potential limitations due to its rural character and infrastructural design. This is done by analyzing the bicycle highway's impact on travel times and distances among different areas. Furthermore, this study aims to investigate the advantages commuters experience while using the bicycle highway. Moreover, this study will examine if modal splits have changed in recent years and how this varies among different areas near the bicycle highway. This information will be used to evaluate the potential of the bicycle highway to encourage cycling for commuters in the region of Assen-Groningen.

Main research question

What are the benefits of establishing a bicycle highway between Assen and Groningen for commuters, and how might these advantages encourage a modal shift?

Sub-questions

- What are the benefits of the bicycle highway between Assen and Groningen on the existing cycle network, considering travel times and distances?

- What are the benefits of the bicycle highway between Assen and Groningen on the overall cycle experience?

- Have mode preferences changed in different areas over time, and what role could establishing a bicycle highway between Assen and Groningen have played in shaping these changes?

2 Theoretical framework

2.1 Mobility

Mobility is the ability to move freely (Cambridge Dictionary, 2024). The daily lives of human beings exist in various activities and locations, all connected through mobility. Bertolini and Dijs (2010) discuss the concept of a mobility environment. This mobility environment can be defined by the external conditions that influence the presence of people at a specific location. This is linked to environmental and socio-demographic aspects that influence travel patterns. Travel patterns include human mobility, when, why, and how people move between locations(Breyer, 2021). Travel patterns have been explored extensively in the field of transportation studies. By comprehending travel patterns, travel demand (the number of people traveling between different areas) can be estimated (Breyer, 2021)

Expanding mobility broadens our choices in various facets of life, including where we live, work, recreate, and foster our social contacts (Bertolini, 2009). Throughout human history, human civilization has relied on forms of human interaction, trade, and transportation. Traditionally, the expansion of trade and political power has asked for more economical and larger-capacity forms of transportation (Kim, 2009). Over time, the evolution of transportation systems has led to significant advancements in speeds, flexibility, and quality of transportation systems. This has resulted in a manifold of individualized transportation options. The increased accessibility and efficiency expanded our geographical reach and reshaped our perception of distance and connectivity. The issue is not how far but how long it will take (Kim, 2009). The evolution of transportation has increased options and travel patterns. The analysis of travel patterns is essential in transportation research (Timmerman *et al.*, 2002). It provides information to understand better the complicated interaction between urban structure, transportation infrastructure, and household travel patterns.

2.1.1 Active Mobility

The most often defined examples of active mobility are walking and cycling. Active mobility applies not only to individual walking or cycling trips (for example) but also to trips made in combination with public transport (Koszowski *et al.*, 2019). To elaborate, Cook *et al.* (2022) argue for a broader interpretation of active transportation, including any travel involving sustained physical exercise. According to this article, the literature mainly focuses on walking and cycling; however, a broader recognition of active transportation can increase its legitimacy. According to Cook *et al.* (2022), the expansion of the term active transportation, involving running, skateboarding, and swimming, could lead to more popularity of new forms of active transportation. The growth of active travelers could receive a more significant share of policy attention and funding, leading to improved conditions for all active transportation users. Ultimately, this could start new dialogues about how transportation is more linked to health.

To elaborate on this, Rigal and Bahrami (2017) argued that cities should integrate physical activities more into urban mobility. This could be accomplished by developing attractive networks of linear public spaces that form spaces of effort. This emphasizes the need for cities to experience physical movement through diverse and engaging environments. Considering these theories, active travel is more than traveling from A to B; it is also a natural and enjoyable process that reduces the reliance on motorized traffic and promotes well-being.

2.2 Understanding travel patterns and mode selection

2.2.1 Modal split

The modal split is based on the distribution of individual trips over the number of modes of transport (European Commission, no date), mainly indicated with percentages. To some extent, a modal split reads as the usage proportion of several transportation modes at a specific geographical location. A modal split can be influenced by many factors, from individual mode preferences, mode characteristics (for example, the presence of transit service), land use, and population densities.

Measuring the modal split has various purposes, and multiple definitions can be used (Ungvarai, 2019). A modal split is often used to measure the quality of certain regions' transportation systems (Ungvarai, 2019). Moreover, according to Quandt (1967), a modal split can be formulated in terms of the probability that an individual in a particular transportation network will travel by a specific mode.

2.2.2 Socio-demographic Characteristics and Active Transportation

Multiple studies have identified different variables influencing the mode of choice for commuting and recreational purposes. Several studies identify a relationship between age and mode of choice. According to (Rodriguez and Joo, 2004), age and gender are recognized as significant demographic variables that influence, for example, cycle behavior.

Yuan *et al.* (2023) identified 14 different studies that reported that men cycle more frequently than women. A study in England and Wales analyzed the potential reasons why women cycle less frequently than men (Grudgingsa *et al.*, 2018). They found out that the attractiveness of the cycling environment primarily explains the gender gap in cycle rates. In areas with lower attractiveness of cycle infrastructure, women feel it is less convenient to cycle. Higher traffic densities and weather conditions, such as rain, negatively impact female cyclist rates. On the contrary, Dutch women use active modes of transportation (such as cycling) significantly more than men. According to Schaap et al. (2016), this could be related to several things: women more frequently work part-time and are closer to home. In addition, women more regularly use bikes for trips with the same purpose as men, for example, taking the children to school.

The mode of choice selection could also be relative to socio-cultural variables. In London, cycling is disproportionately seen as an activity for affluent white men(Steinbach *et al.*, 2011). Cycling might be less appealing to individuals from different classes or residents with other ethnic identities.

In the Netherlands, a study focused on personal characteristics associated with active mobility for trips up to 7.5 kilometers (Scheepers *et al.*, 2013). This study focused on social factors, active mode selection, but also the purpose of the trip. This study revealed that most of the in total 277.000 visits were made for shopping purposes and 25% for commuting. Additionally, the results highlighted that an increase in age was related to the rise in the use of active transportation for shopping, commuting, and sports purposes. This study also indicated that the use of active transportation differed between men and woman based on varying trip purposes.

Furthermore, this study indicated no significant differences documented in the use of active transportation between educational levels. However, this difference is addressed in other studies. De Geus *et al.* (2008) revealed that cycling commuters in Flanders (Belgium) were often more educated. This aligns with a Norwegian study by Nordengen *et al.* (2019), which indicated that people who cycled to work were more often highly educated.

Banerjee *et al.* (2021) questioned the characteristics of individuals who cycle for longer distances. For example, socio-demographic attributes are a significant contributor to cycle behavior. Hansen and Nielsen (2014) revealed that commuters in Denmark who cycle for longer distances (more than 5 kilometers) have more choices for mobility, higher incomes, and higher education.

2.2.3 Travel patterns and environmental characteristics

According to Hatami *et al.* (2023), many studies have researched the relationship between the built environment and travel patterns. Several studies have shown that travel patterns are related to the characteristics of the built environment. Density, Land-Use diversity, Design, Destination Accessibility, and Distance to transit all relate to individual travel patterns.

Studies investigating the relationship between travel patterns and residential density generally concluded that people in high-density areas use public transportation or active mobility more frequently than residents in lower-density areas (Steiner, no date). Density is related to the compactness of land use. In Sealens et al., 2003, density and land-use mix were considered to determine “proximity.” This article defines proximity as ‘the straight-line distance between land uses such as residential, office, retail, and commercial activities”. Proximity is related to non-motorized traffic, as people in high-density areas with high land use mixes are more likely to use active mobility.

Goodwin, 1975 indicated that if the residential density increases, the average length of the trip decreases, the travel speed is slower, and the use of private transportation decreases. Ewing (no date) distinguished employment density and residential density. According to this study, employment density (at destinations) may hold even greater significance for increased walking and public transportation use than residential density (at origins). Areas with a lower residential density might pose challenges faster due to longer travel distances and limited access to public transit options. In regions beyond urban boundaries, people rely more on the use of cars. Therefore, responding to travel needs with efficient public transport services and sustainable alternatives to private vehicles has been challenging.

The previously discussed proximity identifies the distances between land uses in straight lines (Sealens, Sallis, and Lawrance, 2003). However, proximity does not consider the transportation network's connectivity. Connectivity considers the grid configuration and the ease of movement between different origin and destination points. High connectivity is evident in areas that enable direct travel between origin and destination.

Proximity and connectivity are two significant aspects that were shown to be related to the use of active transportation, according to (Scheepers *et al.*, 2013). In this study, it was seen that people in low-density areas use active transportation less often. In contrast, the probability of using active forms of transportation is more significant in higher-density urban areas, which is in line with (de Geus *et al.*, 2008) and (Nordengen *et al.*, 2019). Proximity to facilities could be an essential explanation for the difference in active transportation use among residential areas.

2.2.4 Distance and Travel Mode

Several studies show that travel distance has the most impact on travel mode choice. Distance significantly affects choosing transit and walking/cycling (Ding *et al.*, 2017). Longer distances are associated with car and public transport use, while shorter distances are related to walking and cycling (Debele *et al.*, 2020). Cyclists may be willing to travel longer distances if they have access to safe infrastructure, such as dedicated bike lanes. On the contrary, barriers like fear of crime vandalism, bad weather, and hilly terrain can discourage cycling, especially for longer trips (de Nazelle, 2011).

According to (de Nazelle, 2011), to give policy regarding active mobility a reasonable chance of success, trips that could be replaced by bicycles (through policy) should be at a feasible cycling distance. In the Netherlands, 70% of all the trips made were shorter than 7,5 kilometers. Of all these trips, 36% were made by car, 34% by cycling, and 27% by walking. 7,5 kilometers is a comfortable distance for cycle trips (Banerjee *et al.*, 2021). Cycling (in the Netherlands) becomes limited beyond distances of 15km. According to Heinen et al. (2010), the mode of choice for shorter trips is affected by subjective norms. These subjective norms are related to societal expectations for a specific mode of choice. According to the same study, individual considerations become more important over longer distances. This suggests that over longer distances, commuting by bicycle is primarily based on personal preferences rather than societal expectations.

According to Hansen and Nielsen (2014), the primary motive for cycling longer distances tends to be physical exercise. Another motive is saving costs. Furthermore, Banerjee *et al.* (2021) argued several aspects influencing the choice to cycle longer distances. Among other things, habit formation, physical competency, equipment, and infrastructure are important determinants. Developing a habit could be crucial for long-distance cycling. Also, the availability of cycling infrastructure, such as bicycle highways, plays a role in encouraging people to cycle for longer distances. Additionally, the cycling equipment and the type of bicycle are essential. For example, electric bikes influence the plausibility of long-distance cycling.

2.3 Commuting

This study focuses on the Green-Axis bicycle highway between the city of Assen and Groningen. According to Benak (2020), the Green-Axis bicycle highway was predominantly realized to serve commuters willing to make a modal shift from car use to cycling.

To better understand the potential for modal shifts among commuters, this chapter will delve deeper into how mode choice is influenced and how mode selection of commuters could change. Mode selection in rural areas is an essential topic in this research, primarily as the Green Axis is mainly located beyond urban boundaries. Therefore, it is crucial to understand if rural commuting differs and if this might hamper the potential for modal shifts towards cycling in these regions.

2.3.1Commuter's mode of choice

A commuter is a person who regularly travels between home and work (Cambridge Dictionary, 2024). When commuters make the same trip every day, this often leads to a habitual and unconscious travel mode choice. If a particular mode of choice is selected, there is a significant opportunity for the commuter to make the same choice again. According to (Gardner, 2008), habits may be defined as goal-oriented behavior, strongly linked with specific cues, prompting automatic initiation. A distinction could be made between strong and weak habits. If a habit is weak, individuals tend to make reasoned choices with deliberation and consideration of available information. However, when the habit is strong, the behavior is primarily influenced by the tendencies rather than intentions formed by deliberation.

A difference could be made between habits and intentions. The habit involves a response with limited consideration of information. On the contrary, an intention is formed through deliberation over the available information. In line with that, in other articles, a distinction is made between psychological and situational perspectives on the mode of choice. Biospheric values or pro-environmental behavior are examples of psychological perspectives that could foster the option for a sustainable mode of choice. On the other hand, situational factors, such as access, cost, and time, influence the mode of choice (Collins and Chambers, 2005).

In (Klöckner and Friedrichsmeier, 2011), the psychological perspective on mode of choice is described as the underlying factors influencing why people select particular modes of transportation. In this article, two different models are discussed, and action theories are analyzed. This involves the Theory of Planned Behavior and the Norm Activation model. The theory of planned behavior assumes that intentions, perceived control over a person's behavior, attitudes, and subjective norms play a crucial role in the mode of choice. The norm activation model suggests that our behavior related to transportation is influenced by our beliefs about right and wrong. Personal norms regarding transportation modes create a moral obligation to act in a way that fits someone's values or beliefs. This personal belief is influenced by other factors such as social norms (expectations of others), perceived control over our actions, awareness of the need to act, and awareness of the consequences of our actions.

Besides the psychological factors that influence a mode of choice, a choice for a transportation mode could be influenced by situational conditions. These include, for example, the availability of the car, the purpose of a trip, disruptions, weather conditions, and duration of the trip. Furthermore, life events could affect the preferred mode of choice. Oakil et al. (2011) revealed that life events, for example, a divorce or the birth of a child, could foster a shift to commuting by car. Situational factors can be different for commuters. Heinen et al. (2010) highlighted multiple studies investigating the role of facilities at work and cycling. Facilities that support cycling, such as parking, showers, lockers, and changing rooms, appear essential for encouraging commuters to cycle. Based on this literature review, it seemed that having no facilities at work is the most critical reason for commuters not to cycle.

A study in 5 European urban regions that investigated the motivations to use active forms of transportation, revealed that motives to use active forms of transportation were generally similar for commuting and non-commuting (Charreire *et al.*, 2021). The most important underlying factor for using active forms of transportation was physical activity and the pleasure related to active forms of mobility. Hansen and Nielsen (2014), who studied the main motives for cycling for longer distances for commuting purposes, also found this.

2.3.2 Rural commuting patterns

The term 'rural often refers to areas of open country and small settlements (Dasgupta et al., no date). Researchers have increasingly indicated that the simple distinction between 'rural' and 'urban' is problematic, as there is less nuance between the boundaries of rural and urban areas. In addition to that, the definitions for the term 'rural' differ from country to country. For example, according to the OECD (Haartsen, Huigen, and Groote, 2003), there are no rural areas in the Netherlands. The Netherlands can be determined as a highly urbanized and densely populated country. However, Haartsen et al. (2003) identified the three Northern provinces of the Netherlands, Groningen, Drenthe, and Friesland, as "rural" based on the space, natural surroundings, villages, and agriculture. According to (Poltimäe *et al.*, 2022), rural areas are characterized by low population density, with less than 300 persons per km². According to this definition, the municipality of Tynaarlo (between Assen and Groningen) could be defined as 'rural,' with an average of 234 persons per km².

Rural residents may travel considerable distances to access various job sites. Hence, commuting patterns differ in rural areas. Decentralized employment results in longer commute times and higher reliance on personal vehicles. Multiple studies highlight that population density is related to commuting by bicycle. According to Scheepers *et al.* (2013), Nordengen *et al.* (2019), and Tao, Fu, and Comber (2018), urban commuters are more likely to travel to work by bicycle. The potential for commuting by bike becomes lower in areas with less density. Additionally, Jonkeren et al. (2019) (in Mobiliteit in Stedelijk Nederland) stated that the share of car users significantly increased in "non-urban Netherlands". On the contrary, in a study of the role of e-bikes, Sun *et al.* (2020) revealed that the shift from cars to e-bikes is more likely to happen in rural areas than in cities.

The commuting patterns between the cities of Groningen and Assen remain unclear. This study aims to evaluate whether commuting patterns have changed since the introduction of the bicycle highway and whether changed patterns differ between regions based on population densities. Therefore, a comparison could be made for the potential for commuting by bicycle in lower and higher-density regions.

2.3.3 Commuter's modal shift towards cycling

This study will explore to what extent the implementation of a bicycle highway can foster a modal shift for commuters. A modal shift means switching transport modes (Sinko et al., 2021). Modal shifts occur when one mode of transportation gains a relative advantage over the other modes (in, for example, the service quality) (Ahanchian *et al.*, 2019). Changing habits can activate modal shifts, which is a fundamental behavioral change. Transport policies have thus been developed to change attitudes and habits and influence travel behavior.

Transport policies directed toward shifting modes from cars to cycling primarily aim to assess health conditions (Raza *et al.*, 2018). According to (Thaler and Sunstein, 2009), policies designed to influence choices have become more prevalent in recent years. This characterizes a 'nudge' that aims to influence people's behavior without restricting other alternatives. When this "choice architecture" is designed effectively, it seeks to guide individuals toward decisions that make their lives better consciously.

Several policies are implemented to stimulate commuters to adopt active modes of transportation. Stewart et al. (2015) researched 12 studies to identify interventions that increase commuter cycling. This study revealed that several measures could lead to an increase in cycle behavior among commuters. However, there is limited robust evidence of effective interventions encouraging commuters to cycle more frequently.

According to Stewart et al. (2015), broader environmental interventions, which generally create conditions favorable to cycling, attract and benefit larger populations. A group-based approach, such as focusing on commuters, might, therefore, limit the ability to encourage a more significant number of people to integrate physical activity into their daily lives.

This study evaluates whether the bicycle highway between Assen and Groningen provides specific commuter needs. The bicycle highway's location along a canal in a natural, quiet environment suggests that recreational cyclists are also attracted. However, it is still being determined if this also fosters commuters and if the implementation of the Green Axis supports this specific target group.

2.4 Bicycle highways

Bicycle highways are a relatively new concept in spatial planning, adopted to provide better cycling conditions and to promote cycling as a competitive alternative to cars. Bicycle highways, also known as cycling superhighways, fast cycle routes, or bike freeways, are meant to travel longer distances. Bicycle highways are characterized by extra wide cycle paths with few intersections, posts, and traffic lights, which are planned to give cyclists total priority. The design of the bicycle highways encourages cyclists to ride faster and travel longer distances (Liu *et al.*, 2019), (van Lierop *et al.*, 2020) and (Banerjee *et al.*, 2021).

2.4.1 Policy and Planning

Planners are adopting the idea of "bicycle highways" more frequently, which is implemented in many northern European regions (Rayaprolu *et al.*, 2020). Bicycle highways are widely adopted to encourage the use of bikes in inter-urban transport (Pucher and Buehler, 2017). In general, bicycle highways are adopted to foster cycling. According to (Skov-Petersen *et al.*, 2017), improvements to cycle infrastructure are the main instrument to increase cyclists. Improving bicycle infrastructure through bicycle highways, in general, aims to increase the number of cyclists. However, the underlying reasons why planners aim to foster cycling can differ.

According to (de Nazelle *et al.*, 2011), cycling is increasingly seen as a solution for many (urban) problems, such as congestion, noise, air pollution, and health issues. Daily cycling increases fitness and reduces the risk of all-cause mortality (cardiovascular diseases, overweight, and colon cancer morbidity)(Oja *et al.*, 2011). According to (Davis, Valsecchi, and Fergusson, 2007), the built environment should be reorganized 'to discriminate in favor of cycling" as car use led to a decline in human energy expenditure. Sommar *et al.* (2021) agreed on that and argued that local measures to increase cycling are essential for public health.

Exposure to air pollution is associated with several non-communicable diseases (Sommar *et al.*, 2021). Forms of active mobility cause less air pollution, and more cycling significantly lead to a reduction of "mobility-related CO2 emissions' (Brand, 2019) (Jang, Yuan, and Lopez, 2021).
In Flanders (Belgium), a European hot spot for air pollution, alternatives to car use are provided to raise the daily level of physical activity while reducing air pollution (Buekers *et al.*, 2015). Two newly constructed bicycle highways near important traffic axes provide a viable alternative to car usage. The global trend towards sustainable transportation has seen bicycles emerge as a primary and sustainable vehicle in urban settings. This is also evident in the Rhine-Ruhr area in Germany. In this area, many cities experienced measures to reduce air pollution related to motorized vehicles (Haakman et al., 2019). In addition, a 100-kilometer bicycle track (Radschnellewege) will be implemented to catalyze a mode shift away from privately owned vehicles (Koska and Rudolph, 2016). The Radschnellewege is part of a larger investment plan of 370 million euros in North-Rhine Westphalia to stimulate a modal shift for tourists and commuters. A traffic demand study estimated

that this bicycle highway project could remove up to 50.000 vehicles from the road each day. Also, in Copenhagen, measures have been taken to promote cycling. In this city, bicycle highways are part of the strategy to make the city more sustainable. Cycling has been integral to urban planning and design and concepts as bicycle highways are being developed to design the city for cyclists (Municipality Copenhagen, 2014).

In the Netherlands, bicycle highways are also frequently adopted due to environmental and health consciousness (Rayaprolu, Llorca, and Moeckel, 2020). In addition, the rise of electric bikes stimulates the implementation of bicycle highways, as bicycle highways enable travel faster and longer distances. According to van Lierop et al. (2020), bicycle highways are implemented by many regions to foster the usage of 'high-speed bicycles as e-bikes' as cyclists can ride faster and travel longer distances.

Bicycle highways are increasingly becoming popular in urban infrastructure due to the time efficiency of cycling in urban settings. Dedicated lanes offer a quick and convenient route for cyclists through crowded cities. A study of the potential application of a bicycle superhighway in Patna (India) assumed that through the implementation of a bicycle highway, the bicycle becomes two times faster than before (Agarwal, Ziemke, and Nagel, 2019). According to (Dekoster and Schollaert, 1999), bicycles are more rapid than cars in short urban distances (less than 5km). The agility of bicycles could make them, especially during peak hours (in dense urban areas), more time efficient than other modes of transport. Despite the potential efficiency of bicycles in high urban areas, the bicycle could also be seen as a viable alternative in smaller cities. According to (Pucher and Buehler, 2012), the physical characteristics of smaller cities provide ideal circumstances for cyclists as the more significant portion of the town is likely to be in cycle distance, and the lower population and employment densities create more attractive conditions for cyclists.

A cost-benefit analysis of the greater Copenhagen cycle superhighway area has revealed several economic benefits to implementing bicycle infrastructure (Rich et al., 2020). Investment in bicycle highways yields substantial returns between 6% and 23%. For every unit of currency that is being invested, there is an economic gain for society. The most prominent return driver is the health benefits associated with cycling. Society saves expenses for the health system. Cycling also has financial benefits for the individual, such as a potential reduction of health care costs due to the effects of regular exercise. In addition, cycling could enable a drop in the share of household budgets devoted to the car (Dekoster and Schollaert, 1999).

In London, the cycle superhighways were aimed at providing faster, safer, and more direct cycle connections in the city(Haojie et al., 2018). Increased safety and the number of cyclists in the town were essential aims of this project. An assessment after the implementation revealed that 80 percent of the respondents experienced that the 'cycle superhighway programs' contributed to improved safety.

2.4.2 Implementation and Infrastructural Design

Bicycle highways have been implemented in different areas with different spatial characteristics. Most of the bicycle highways have been adopted in North European regions such as London (Cycle Superhighways), Germany (Radschnellwege), Belgium (Fietsostrade), Sweden (Supercykelväg), Norway (Super-Sykkelveier), Switzerland (Velobahnen) and the Netherlands (Fietssnelweg/Doorfietsroute) (Rayaprolu et al., 2020). Bicycle highways are often implemented in urban or suburban areas, but there are also examples of bicycle highways in metropolitan areas. Bicycle highways serve as a premium network from the core of an entire bicycle network. Bicycle highways are often implemented between cities to connect important origin and destination points over long distances (Grigoropoulos *et al.*, 2021).

Bicycle highways are implemented through different aims and requirements. In Denmark, the Supercykelväg must live up to four quality measures (Office for Cycle Superhighways, 2018). These include accessibility, directness, comfort, and safety. A bicycle highway should connect residential, educational, and business areas, transportation hubs, and stations. This is to improve the conditions for commuters. In addition to that, bicycle superhighways should provide commuters with the fastest possible route between home and work, being as direct as possible. Also, bicycle highways are implemented in the Netherlands according to different aims and requirements (Crow, 2014). These aims and requirements are focused on, for example, safety and speed. Bicycle highways shouldn't exceed 1,2 times the distance of other alternative routes.

Furthermore, bicycle highways should be socially safe and entirely free of cars. Additionally, there are requirements for the surrounding environment of bicycle highways. The direct environment should be attractive and varied, with changing landscapes and the opportunity to stop and experience the atmosphere. Additionally, users of the bicycle highway shouldn't be negatively impacted by noise or pollution through adjacent motorized traffic.

Design features

The bicycle highway as a concept is often seen as a Dutch invention. Several bicycle highways have been realized, and much literature on bicycle highways in the Netherlands is available. CROW, a Dutch knowledge platform focusing on infrastructure, public space, and transportation, created a manual discussing bicycle highway design and implementation (Crow, 2014) (CROW, 2016). According to this guide, the following principles are, among other things, desired for the design of bicycle highways:

- **Cohesion** The bicycle highway has a high level of continuity, meaning that cyclists can reach their destinations seamlessly.
- **Directness** The infrastructure should provide a route that is as short and direct as possible without any detours.
- **Attractiveness** The route should be attractive and incorporate the natural environment to attract cyclists.
- **Safety** The route should enhance traffic safety through multiple design elements such as good quality asphalt.
- **Comfort:** Any nuisance and delay from A to B should be minimized, for example, through priority at intersections.

Furthermore, additional requirements for designing bicycle paths associated with multiform design principles vary for each country. Therefore, bicycle highways are implemented in different forms and with other characteristics. For example, bicycle paths are designed according to a specific design speed (Ul-Abdin *et al.*, 2020). This speed indicates the maximum speed under which cycling remains safe. Typically, it means 30 km/ for main cycle routes. However, these speeds are sometimes increased for different reasons. In the Netherlands, cycle paths are designed for a maximum of 30 km/h speed. However, this speed limit rises to 10 km/h in rural areas. The speeds differ per country or type of the cycle track. Also, "stop frequencies" are calculated for bicycle highways, with a maximum of 0.4-0.5 stops per kilometer in urban areas (Grigoropoulos *et al.*, 2021). Also, waiting limits apply for bicycle highways; however, these differ according to different guidelines. The German guidelines define a maximum of 30 seconds of waiting time per kilometer in urban areas.

2.4.3 Efficiency of Bicycle Highways

Several studies have indicated that cyclists increased due to bicycle highway implementation (Hans *et al.*, no date Haojie *et al.*, 2018; Pucher and Buehler, 2017**)**. According to (Macedo *et al.*, 2022), this also applies to countries that are generally already well-equipped with cycling infrastructure, for example, the Netherlands, Denmark, and Germany. Furthermore, bicycle highways could significantly affect the promotion of a modal shift towards active mobility. New bicycle trips are mainly expected to replace trips previously made by walking or public transport (Hallberg et al.) 2021).

Furthermore, the introduction of bicycle highway infrastructure has positive effects on the efficiency of bicycle traffic, according to Grigoropoulos *et al.* (2021). The study revealed that implementing bicycle highways reduced average delays, resulting in more reliable travel times. Furthermore, there were positive effects visible on traffic flows for motorized vehicles. Alongside these observed benefits in traffic flows, it's crucial to recognize that adverse effects could occur, particularly at intersections (where cyclists have priority). This applies to bicycle highways with direct connections where interruptions to cyclists' flows are minimized. It's crucial, therefore, to consider potential conflicts between cyclists and motorized vehicles.

Furthermore, van de Coevering and Schwanen (2005) and Skov-Petersen *et al.* (2017) revealed that the overall bicyclist user experience and satisfaction increases due to the implementation of bicycle highways. These positive experiences are related to improved asphalt and lighting conditions, overall traffic safety, and personal security. An increase in safety could contribute to the overall effectiveness of bicycle infrastructure and stimulate more people to cycle. This is also evident in London, where bicycle superhighways improve the overall safety of cyclists. According to (Haojie *et al.*, 2018), 80 percent of the respondents experienced that the 'cycle superhighway programs' contributed to improved safety.

On the contrary, according to (van de Coevering and Schwanen, 2005), improved cycle infrastructure led to increased cycling volume; however, these growths are small (less than 10%). Bicycle highways alone couldn't drive significant changes, such as reducing congestion and environmental impacts. A German study revealed that solid governmental support in prioritizing bike traveling over car use is essential in bringing about changes (Rayaprolu *et al.*, 2020). In addition to that, the proximity to the bicycle highway is vital to bringing about mode shifts. This could be a critical factor for the Green Axis, located mainly in the rural area, connecting the periphery of Assen and Groningen. Therefore, this study will investigate the accessibility of the Green Axis by analyzing the existing bicycle networks.

2.4.4 Bicycle Highways Beyond Urban Boundaries

Much of the literature focuses on the urban context or metropolitan areas, and it seems that bicycle highways are often linked to the urban context. According to (Pucher and Buehler, 2017), bicycle highways are becoming increasingly popular and necessary to serve longer distances in metropolitan areas. Banerjee *et al.* (2021) argue that the very essence of bicycle highways is to provide a fast and safe connection between suburbs and city centers. According to Grigoropoulos *et al.* (2021), bicycle highways have multiple advantages in urban areas. These advantages are related to problems such as congestion, noise, air pollution, and health issues. The effects of increased cycling seem to be more significant in urban areas. It's unclear if cycling is thus also more frequently adopted as a preferred mode of transport through improved bicycle infrastructure, such as bicycle highways, in urban areas than in rural areas. Less information is available about the use and effects of bicycle highways in rural areas. According to (Tao, Fu, and Comber, 2018), urban commuters more often use active modes of commuting. However, improved cycle routes and facilities could increase the frequency of bicycle use.

It needs to be clarified if the improved bicycle infrastructure between Assen and Groningen can encourage commuters to take the bike. The 'Green Axis bicycle highway has a predominantly rural character. Although the bicycle highway connects two cities, a relatively limited part of the track is in residential areas. It's unclear how bicycle highways encourage people to cycle in rural areas and smaller villages and if time efficiency (due to cycling) is realistic for the almost 30-kilometer-long Green Axis.

2.5 Bicycle highways, benefits for commuters, and modal shifts

According to Jensen (2013), physical movements are planned, represented, and facilitated from above, performed, and lived from below. Planners, policymakers, and designers actively shape the conditions and experiences of mobility. The way how commuters experience their daily trip is thus partly shaped by institutions. According to the Province of Groningen (Provincie Groningen, 2020), commuters benefit from comfortable, safe, fast, and uninterrupted cycle routes. In addition, cycle infrastructure needs to anticipate transferring to public transportation or car usage (or the other way around). Therefore, cycle routes should facilitate parking places, shared bikes, and lockers.

This is linked closely to bicycle highways, which, according to (Rayaprolu, Llorca, and Moeckel, 2020), provide fast and safe bicycle trips that encourage commuters to work. This aligns with (Liu *et al.*, 2019), who state that commuters are the primary target group of bicycle highways. According to this article, bicycle highways suit the wishes of commuters, and this infrastructure minimizes travel times. Increased speeds and reduced travel times are essential for commuters who travel long distances. This is also discussed by (Banerjee *et al.*, 2021), who argue that bicycle highways are vital for long-distance commuting.

Furthermore, in more general terms, Jang and Joonhp (2019) described that commuters experience higher stress levels due to unpredictable travel times. Congestions and delays resulting in waiting time negatively affect commuters' satisfaction during the commute. Moreover, the text highlights the significance of the quality of the travel experience and the level of comfort during the commute. Commuters generally prefer shorter travel times (Jang and Joonhp,(2019). However, there are many variations in the interpretation of travel time. For example, additional factors such as living in a pleasant environment could compensate for a longer commuting time.

Furthermore, travel time could be perceived differently among individuals, as people with children prefer shorter commuting times than others. There is also a difference between the actual and ideal commuting time, highlighted by (Humagain and Singleton, 2020). According to this study, the difference between perfect travel time and actual travel time varies between modes of transportation. According to this study, individuals who use active forms of transportation were more satisfied with the duration of their commuting trip than commuters who use other modes of transportation. Despite that, the study revealed that most people wish to decrease the duration of their commute.

A study in Copenhagen investigated the preferences of cycling commuters in their route selection. This study revealed that commuters are willing to cycle between 1 and 1.33 kilometers longer to avoid high crowding and stops. In addition, cyclists prefer to cycle longer if this route provides an adequate cycle track and a green surrounding. This same study found that commuters prefer infrastructure only dedicated to cyclists and separated from other infrastructure, which aligns with Buehler (2016).

Modal shift

The previous text revealed that bicycle highways meet commuters' preferences due to increased comfort, speed, and safety. Furthermore, providing separate cycle facilities to connect practical, origin, and destination locations promotes cycling for commuters (Pucher and Buehler 2008). This increases the predictability of travel times. Therefore, implementing bicycle highways could stimulate more commuters to cycle instead of using other modes of transportation.

Macedo *et al.* (2022) investigated the extent to which bicycle highways could foster a modal shift for commuters in the Netherlands. The results of this study suggest that the implementation of bicycle highways is associated with an increase in commuters who cycle to work. This aligns with Mölenberg *et al.* (2019), who also stated that implementing improved cycle infrastructure leads to more people cycling. A study of the implementation of 2 bicycle highways in Denmark revealed that this construction led to significant changes in the share of 'new cyclists" (Skov-Petersen *et al.* 2017). The new cyclists included people who had used other cycle routes before and those who had previously traveled with different modes of transportation. However, according to Skov-Petersen *et al.* (2017) and Goeverden *et al.* (2015), adopting bicycle highways leads to significantly higher user rates but minimal modal shifts, as most users already cycled before implementing the new infrastructure.

Bicycle highways could foster modal shifts among commuters; however, modal shifts do not occur under all conditions. According to Macedo et al. (2022), the bicycle highway should be no further than 5 kilometers from the commuter's current trip to improve someone's journey. Furthermore, lower urbanity levels and longer distances lower commuters' probability of cycling.

Moreover, Rayaproluet al. (2020) studied the impact of bicycle highways on modal shifts. This study revealed that a modal change was seen most sharply in the commutes between zones within a one and 2-km radius of the bicycle highway. Rayaprolu et al., 2020 therefore, highlighted the importance of the density and integration of the bicycle network in fostering commuters to cycle. Crow (2014) stated that bicycle highways should link important origin and destination points such as offices, schools, hospitals, inner cities, and neighborhoods. This aligns with Hull and Holleran (2014), who stated that direct routes are necessary to encourage cyclists. Cycle routes must provide reasonable access to shopping, commuting, and education. According to Crow (2014), this is not always possible through direct connections. However, bicycle highways must be sufficiently integrated into the road network to facilitate indirect routes. This principle also extends to connections with transit hubs;

bicycle highways must be adequately connected to train stations, which are significant origin and destination locations for many cyclists.

2.6 Conceptual model

The theoretical framework investigated diverse factors influencing transport mode choice, particularly emphasizing bicycle highways' role in fostering active transportation. The theory highlighted that commuting patterns often become habitual, shaped by psychological and situational factors, while the quality of infrastructure also significantly impacts mode selection.

Understanding travel patterns and preferences is essential for estimating travel demand and effective transportation policies. The theory underpinned that enhancing cycle infrastructure, such as implementing bicycle infrastructure, could be crucial in facilitating modal shifts towards cycling.

The conceptual model (Figure 1) summarizes the theoretical framework. It represents the study framework by visualizing the main theoretical concepts (indicated in red) and their relations. The conceptual model describes the concepts necessary to understand how bicycle highways could stimulate commuters to cycle, with a specific focus on bicycle highways beyond urban boundaries.

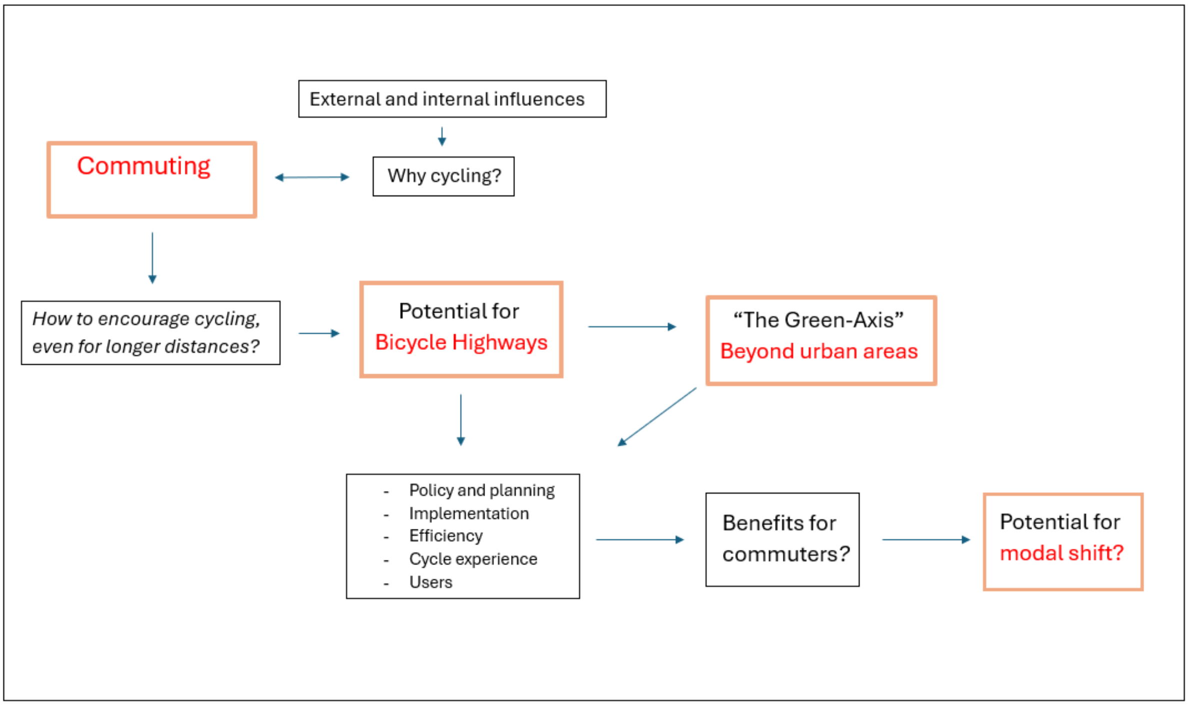

Figure 1: Conceptual model

2.6 Hypothesis

Based on the theory, improvements in cycling infrastructure, like the construction of the Green-Axis bicycle highway, offer multiple benefits for commuters. Therefore, the bicycle highway between Assen and Groningen is expected to stimulate commuters to cycle more frequently, promoting modal shifts.

3. Methodology

3.1 Research approach

Using a mixed-method approach, This research focuses on a single case, the Green-Axis bicycle highway between Assen and Groningen. A case study can be described as an intensive analysis of an individual unit, emphasizing developmental factors about the environment (Merriam-Webster Dictionary, 2024). It can serve as a tool to capture the complexity of a phenomenon, encompassing shifts and the contextual conditions of a case (Hollweck, 2016). The benefit of a case study is that a researcher can create an in-depth understanding of a single phenomenon.

This study aims to develop an in-depth understanding of the bicycle between Assen and Groningen, its benefits for commuters, and the potential for bringing about mode shifts. As discussed in the literature, bicycle highways could provide improved cycle routes that stimulate commuters to shift towards cycling. This is also aimed at the stakeholders of the Green Axis (Benak, 2020). To bring about modal shifts, the infrastructure must meet certain conditions as described by (CROW, 2016) (Crow, 2014) and (Office for Cycle Superhighways, 2018). Based on these manuals, five important guiding principles can be recognized: cohesion, directness, attractiveness, safety, and comfort.

Quantitative and qualitative methods are used to investigate the benefits the Green Axis might offer commuters. According to Mills, Durepos, and Wiebe (2010), a case study must be a variety of methods. First, the bicycle highway's efficiency (based on travel times) was investigated through a spatial analysis in ArcGIS. The location of the bicycle highway raises critical concerns about its ability to provide a short and direct route between residential areas and important points of interest for commuters. Therefore, ArcGIS analysis will be used to quantify the direct impacts of the bicycle highway on travel times, distance, and accessibility. The outcomes are critical for assessing whether the infrastructure effectively facilitates faster and shorter commuting by bicycle.

Additionally, a questionnaire has been conducted to gain insights into the experiences of current users of the bicycle highway. These insights are important for understanding commuters' needs, choices, and preferences. This research method enables to assess whether the bicycle highway between Assen and Groningen provides elements such as comfort and safety that encourage cycling.

Lastly, ODiN data will be used to understand the region's mobility trends and the bicycle highway's potential direct and indirect effects.

By employing these methods, this study aims to capture a comprehensive image of how improved cycle infrastructure can affect commuting patterns. This approach ensures that both qualitative and quantitative experiences are considered to analyze the extent to which the Green-Axis meets the condition of bicycle highways as described in the literature. Overall, this will help provide a complete understanding of the benefits and limitations of the Green-Axis bicycle highway and its ability to foster modal shifts.

3.2 Case description and selection

The Green-Axis spans almost 30 kilometers and crosses various villages and municipalities. The bicycle highway is expected to be finished by 2026 (Guit, 2024). Currently, around 2/3 of the cycle path has been realized. The route primarily consists of newly designed bike paths that meet the standards of a bicycle highway and partly of older, previously existing bike paths.

Figure 3: Priority for cyclists

Figure 2: Transition to new infrastructure

Figure 4: Route of Green Axis

This case has been selected because of its unique characteristics. The length of the bicycle path, combined with its predominantly rural character, makes this case unique. Furthermore, the location of the bicycle highway raises critical questions. The bicycle highway is situated along the edge of Assen and ends near the central station. Not all neighborhoods are near the cycle path. The same applies to Groningen, where the bicycle track ends at the city's edge (in 2026 at the central station). Lastly, alternative modes of transportation, such as a direct train connection, a highway, and different bus networks, potentially decrease the possibility that commuters will cycle along the 30-kilometer-long cycling track.

3.2.1 Study area

The study area involves the three municipalities where the bicycle highway is located (Groningen, Tynaarlo, and Assen). This area has been selected because the bicycle highway is financed with public money derived (partly) from these stakeholders. Therefore, the benefits of the bicycle highway should appeal to commuters living in these municipalities. Additionally, the impact of the bicycle highway could be best tested on regions near the infrastructure.

Study area, compared to the North of the Netherlands

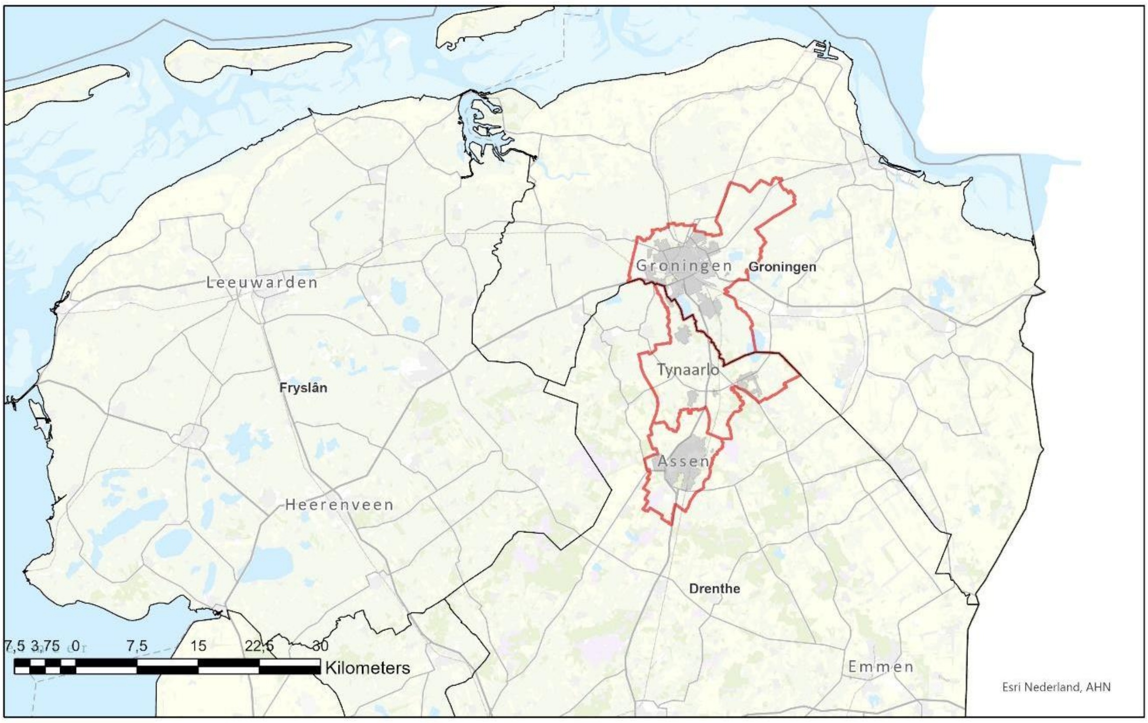

Figure 5: Study area

3.3 Data collection

3.3.1 Primary data collection

Interviews

A questionnaire and one semi-structured interview were conducted to create insights into commuters' experiences using the bicycle highway. Different methods were applied to approach respondents. First, several large companies in Assen and Groningen were approached to participate in this study. This resulted in one respondent (both spatial planner and user of the Green Axis) willing to participate in this study through a semi-structured interview. Furthermore, "Fietscommunity Groningen" was willing to share the questionnaire in their newsletter and on LinkedIn. This resulted in a few responses. In addition, actual users of the bicycle highway were approached by hanging around QR-codes of the questionnaire at various locations on the bicycle highway. That appeared to be the most successful method and resulted in several reactions. In total, 17 commuters filled out the questionnaire.

3.3.2 Secondary Data Collection

Literature review

This study started with a literature review to answer the research question. The review provided a theoretical understanding and background information on the factors that influence the adaptation of bicycle highways and the perceived benefits for commuters that are associated with them. This information was crucial in answering the main research question. The findings were synthesized to identify common themes, patterns, and insights into the adaptation of bicycle highways and perceived benefits. The literature review was also essential for setting up the interview guide. Besides the academic literature, additional literature was used to understand the "Green Axis" bicycle highway, which is the specific case of this study.

Stakeholder's questionnaire

Moreover, a study initiated by the Province of Drenthe was used. This study assessed the safety of two specific parts of the bicycle highways. This included two roads (as part of the Green Axis) designed for cyclists, while other traffic is also allowed. Quantitative and qualitative data were used for this study. Only the qualitative data was relevant to this study and involved user experiences (for cyclists and motorists). The user experiences were assessed in two different rounds. First, correspondence and questionnaires were conducted to gain insight into user experiences and potential threats. After that, a campaign started to solve the threats the trajectory users indicated. Finally, a second questionnaire was conducted to see if user experiences changed positively or negatively and whether the campaign was successful.

Travel times and distances

ArcGIS was used to answer the second and fourth research questions. To answer the second research question, data was used to analyze the impact of the bicycle highway on the existing bicycle network. The secondary data was derived from NWB (wegen—Wegvakken), which provides the current road network in the region of Assen-Groningen. Additionally, CBS data on “wijken en buurten” was used (CBS, 2023) to gain insights into further demographic characteristics in the study area.

Furthermore, data about employers in Groningen and Assen was needed. The second research question aims to discover the perceived benefits of the bicycle highway, taking into account travel times and distances. The travel times and distances were calculated from different origin locations (CBS “buurten”) to several end destinations. To make this study representative for commuters, the destinations will consist of the 10 largest employers in Groningen and Assen. A LISA dataset was used, including data about employers in Assen and Groningen, their locations, and the number of employees.

ODiN data

ODiN data was used to answer the third research question: “Have mode preferences changed in different areas over time, and what role could establishing a bicycle highway between Assen and Groningen have played in shaping these changes? The use of ODiN data for assessing the impact of bicycle highways on modal shifts is in line with Macedo *et al.* (2022).
ODiN data provides insights into daily trips, origins and destinations, mode of transport, and the purpose of the journey, as well as a multifold of additional data.
This data is crucial for defining regional commuting patterns. The “Onderzoek Onderweg in Nederland” data for 2015-2022 have been collected for this study. The months with restrictions during the COVID-19 pandemic have been removed. Only the months/weeks have been selected in which people were allowed to physically visit their work. In total, the datasets consisted of 2815 trips after selecting the purpose (commuting) and place of residence (Municipality Groningen, Tynaarlo, or Assen).

3.4 Analysis

3.4.1 methods to calculate travel times and distances in ArcGIS

Travel times and distances were calculated using a network analysis in ArcGIS. In this network analysis, the bicycle highway was pretended to be finished to better understand the impact of the infrastructure and how policymakers interpreted it. The shortest and fastest route between an origin and destination could also be calculated(Esri, no date).

Information about travel speeds per road is necessary to predict travel times based on an origin and destination. Cycle speeds can vary significantly depending on both personal and infrastructural factors. Additionally, the type of bicycle plays a crucial role in determining cycle speeds. Given that nearly one-third of the Dutch population uses an e-bike (RIVM, no date) and considering its popularity for longer distances, this study will calculate travel times for both e-bikes and traditional bikes. For e-bikes, an average speed of 22 km/h is used, and 18km/h for regular bikes (Hendriksen, 2015).

According to Romanillos and Gutierrez (2019), urban cycling speeds are influenced by various factors, including the physical design of the infrastructure, the density of traffic, and the directness of routes. These conditions determine that the average cycle speeds are lower than beyond urban boundaries. During the national “bicycle counting day” in the Netherlands, it was observed that the average speed of cyclists in Amsterdam was 14.4 kilometers and in Utrecht 14.7 kilometers. There is no data about this for Groningen and Assen; this study, therefore, assumed that the average cycle speed in Groningen and Assen is 15 km/h (19km/h for e-bikes). This is based on the size of the city and its population density. Also, between Groningen and Assen, the cycle speeds might, in reality, differ due to traffic density. However, there is no evidence of this.

Furthermore, the bicycle highway's infrastructure offers improved conditions that could stimulate faster travel speeds. According to the website of the bicycle highway between Assen and Groningen (Doorfietsroute, no date), the entire trajectory (+/—30 kilometers) could be done in 90 minutes for standard bikes and in 75 minutes for e-bikes. This means an average speed of 20 kilometers per hour for standard bikes and 24km/h for e-bikes. This study, therefore, assumes that the bicycle highway provides faster cycle speeds in line with (Rayaprolu *et al.*, 2020).

Moreover, stopping time has a significant effect on travel times. To include the stop time at intersections, this study applies the method of “congested with turn penalties travel time” (Yiannakoulias et al., 2013). This means that road and traffic conditions are taken into account. For instance, extra time is added for crossings. In this study, a divide is made between different types of crossings. Three different types of junctions are being separated: signal crossings, regular crossings, and junctions with neglectable impedance (Manum *et al.*, 2019)

According to (de Groot, 2007), the average delay for a crossing with traffic lights is 20 seconds. This delay accounts for the typical stop time at red lights based on the probability of encountering a stop. Based on data from OpenStreetMap (which provides an overview of intersections), 20 seconds of extra time is added to the junctions in the study area. A delay is added instead of a stop time for crossings without traffic lights. Manum et al. (2019) used an average speed of 4 m/s (14.4 km/h) for junctions without traffic signs, which has also been applied to this study.

When the ‘costs’ were added to the road network, single routes were generated from every PC4 location (most central point) to any of the 10 largest employers. This tool allows it to see whether the bicycle highway is the fastest/ shortest route (and the differences compared to alternative routes between origin and destination). Additionally the origin-destination cost matrix tool was used, for generating multiple routes at once.

3.4.2 methods to calculate modal split

ODiN data have been used to calculate modal splits. In Excel, a selection was first made based on the municipality of residence (Groningen, Tynaarlo, and Assen). Furthermore, a choice was made based on the purpose of the trip. Postal 4 locations were sorted, and the modal split was calculated for every postal area.

Data was collected and added to ArcGIS. In ArcGIS, a map was prepared, including all four postal regions. For every postal 4 area, the mode selection percentage was inserted per vehicle type.

Moreover, this study highlighted commuting trips where the bicycle highway was a potential alternative. To make a selection with these characteristics, commuting trips that were made within the same postal 4 area were removed. After that, every postal 4 location was linked to a coordinate. This enabled inserting origin and destination locations in ArcGIS from Excel. Based on an origin-destination analysis, it was assessed whether the bicycle highway formed an actual alternative route for the commute. The trips that were not relevant were manually removed.

3.4.3 method to analyze semi-structured interview

The semi-structured interview was recorded and transcribed afterward. This was done through the intelligent verbatim transcription method (Streefkerk, 2019), meaning that every word was written down without irrelevant fillers. After that, coding was applied to break the information down into manageable categories of data. This coding was done manually.

3.4.4 Method to Analyze Questionnaire

The questionnaire was made by Google Forms. For multiple-choice questions, Google Forms already provides graphics based on the selected answers. The open questions were coded per category. For each question, the 3 most given answers were highlighted with different colors. This provides a comprehensive overview of the answers given the most for each category.

3.5 Consent

The survey started with a consent question (see Appendix 3: Questions questionnaire). By answering “Yes,” respondents declared that they understood the purpose of this study and agreed that their responses could be used for educational purposes. They were informed that only summarized responses would be published without any link to personal data. Participants who answered “No” to the consent question were not allowed to proceed with the questionnaire. Furthermore, respondents could pass questions and leave the questionnaire at any time they wanted.

The semi-structured interview was recorded with the respondent's permission. The respondent desired to stay anonymous, which has been respected. Furthermore, the transcript of the interview was sent to the respondent who, after a few adjustments, permitted to share the responses for educational purposes.

4. Results

4.1 What are the perceived benefits of the bicycle highway between Assen and Groningen on the existing cycle network, considering travel times and distances?

This chapter will discuss the impact of the new cycle path between Assen and Groningen on commuters' travel times and distances. According to Rayaprolu, Llorca, and Moeckel (2020), the central concept of bicycle highways is to facilitate fast and safe bicycle trips, particularly to encourage commuting to work by bike. Therefore, time efficiency could play a role in fostering a modal shift among commuters.

The ArcGIS analysis indicates that travel times are expected to decrease across most regions within the study area once the bicycle highway between Assen and Groningen is fully operational. This assessment is based on calculating routes towards the ten largest employers in Assen and Groningen from every postal 4 location. Initially, these routes were calculated using the existing road network without the bicycle highway. Subsequently, the analysis was repeated with the proposed bicycle highway incorporated into the network.

Locations 10 largest employers in Groningen

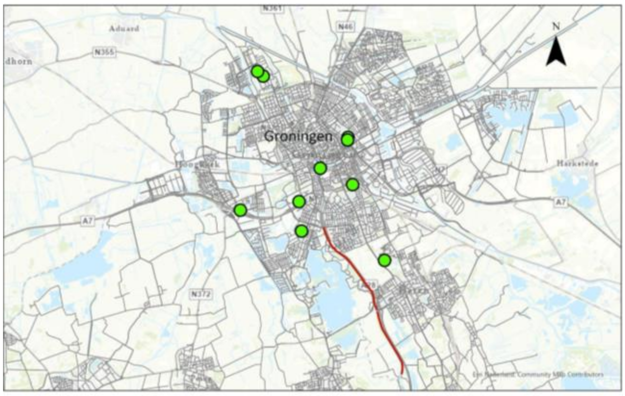

Figure 6: Largest employers Groningen

Locations 10 largest employers in Assen

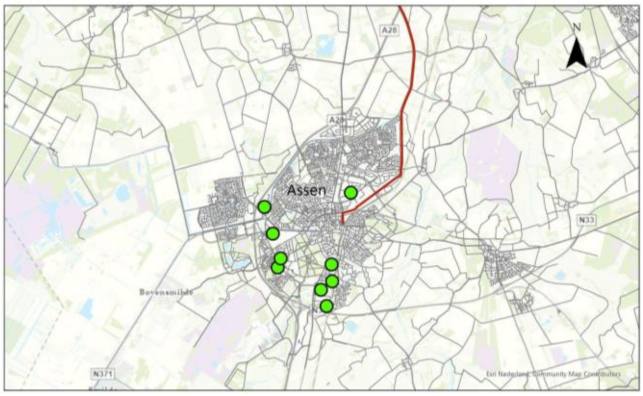

Figure 7: Largest employers Assen

The assumption underpinning this scenario is that commuters will travel faster on the bicycle highway infrastructure due to improved road conditions. In addition, ‘costs’ are added to the network analysis for junctions and traffic lights. Therefore, stop time is taken into account when calculating the fastest route. The bicycle highway provides an uninterrupted route without cars and other motorized traffic, encouraging more efficient and quicker travel.

The maps below provide an overview of postal four codes for which travel times decrease when the bicycle highway is entirely constructed. For the postal 4 locations colored green, the cycle time towards Assen or Groningen will decrease after the bicycle highway is implemented. For the red areas, no time benefit will be experienced after implementing the bicycle highway, meaning that alternative routes will be faster.

The maps below indicate that the bicycle highway will be faster for longer cycle trips. This mainly applies to commuters who cycle towards Groningen (Figure 9). For commuters living closer to Groningen, a bicycle highway does not impact travel times toward the ten most significant employers. The results could not confirm that the Green-Axis bicycle highway provides a faster connection between suburbs and essential points of interest (largest employers).

The travel time difference after the bicycle highway completion seems different for commuters who travel to Assen (Figure 8). Around the city of Assen, the bicycle highway appears to provide, particularly for areas near the bicycle highway, a more time-efficient cycle route towards Groningen and Assen. Additionally, the results indicate that the Green Axis does not enable a faster cycle route for some significant residential areas in the study region. For example, when traveling to Assen, the Green Axis won't provide a quicker route for residents in Zuidlaren and Vries, the two largest villages of Tynaarlo. For cycling to Groningen, the Green-Axis won't serve the residents of Haren with a faster cycle connection to the largest employers. According to Regio Groningen-Assen (2019), 74% of people who are employed in Haren, work in the region of Assen and Groningen, of which the city of Groningen is the main contributor. The location of the Green-Axis might, therefore, not be effective in providing a fast and direct connection for this specific population.

Cycling towards Assen

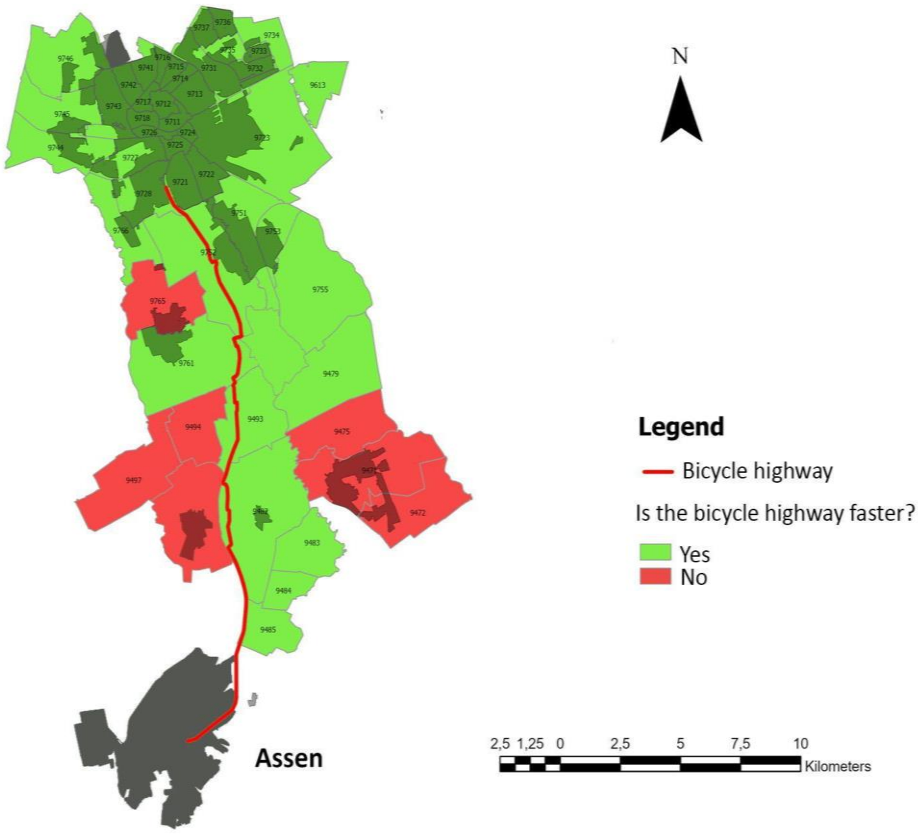

Figure 8: Is travel time reduced by the implemented bicycle highway?

Cycling towards Groningen

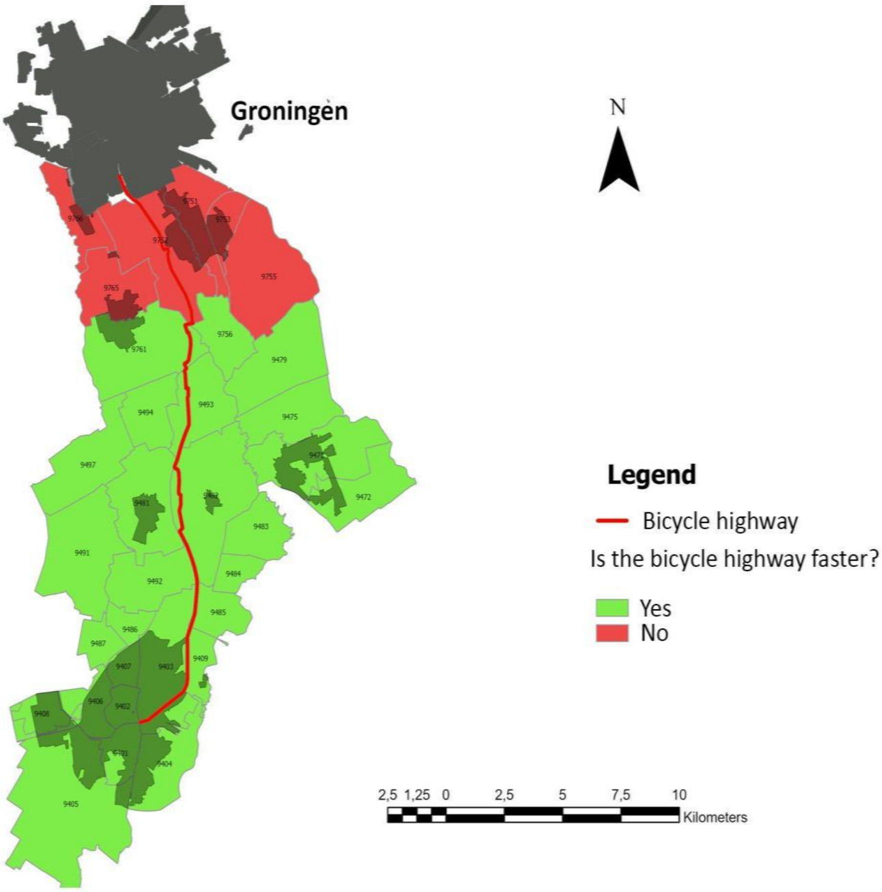

Figure 9: Is travel time reduced by the implemented bicycle highway?

The maps below illustrate the average time savings of commuting trips to Groningen and Assen for every postal 4 location (for areas that experience a time benefit in their commuting trips). The average time savings for commuters that cycle from Groningen to Assen is approximately 6,89 minutes. Similarly, for those cycling from Assen to Groningen, the travel time was reduced by an average of 6,81 minutes. The time savings that commuters will experience on an e-bike for these journeys is less than 5 minutes (approximately 4,61 minutes for commuters in Groningen and 4,74 minutes for commuters in Assen). In both cities, an average cycle trip towards one of the destinations still takes more than 1,5 hours (70 minutes with an e-bike). This means that future cycle trips are more or less reduced with 7-10 percent of the current travel time.

Commuters in Vries and Tynaarlo will generally experience a more significant reduction in travel time while cycling to Groningen than commuters in Assen (7,3 minutes). Additionally, the overall travel time to Groningen is generally around 1 hour (compared with 1,5 hours for residents in Assen). Therefore, the overall cycle time reduction is even more significant for commuters living in these areas, as their cycle trips will be reduced by approximately 12%. However, this only applies to cycle trips towards Groningen. The bicycle highway wouldn't provide any time benefits for cycle trips towards the city of Assen. However, this could vary among different origins and destinations.

Towards Groningen

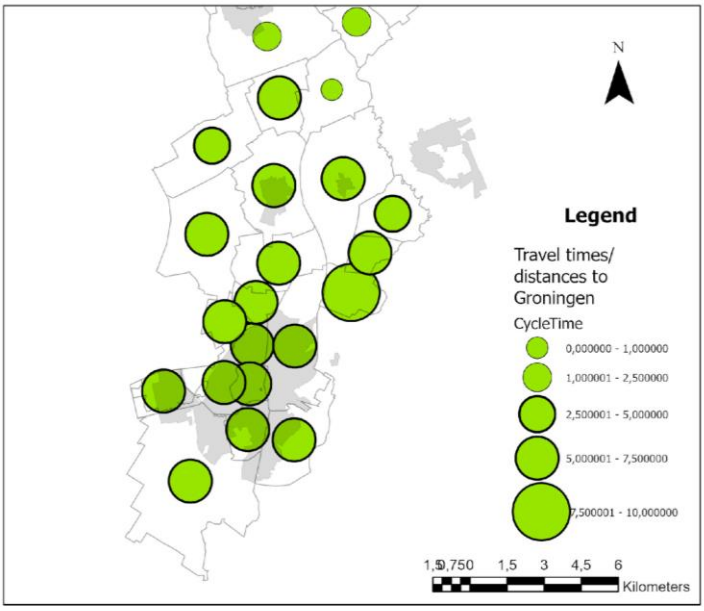

Figure 10: Reduction in travel times in minutes

Towards Assen

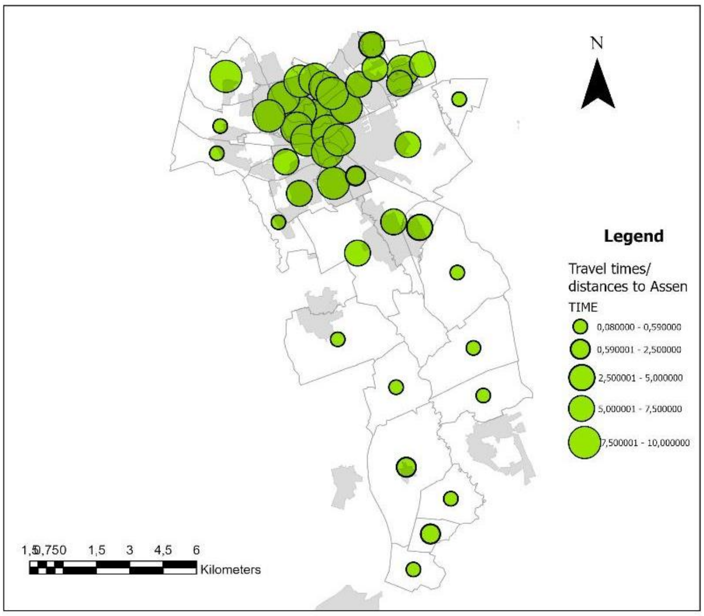

Figure 11: Reduction in travel times in minutes

The maps above highlight the decrease in travel times for commuting trips to Assen and Groningen. Only routes that experience a reduction in travel time are taken into account. The maps highlight the time benefit in minutes since the implementation of the bicycle highway.

Travel times for cycling commuters could be reduced due to the implementation of the bicycle highway. While travel time generally reduces through the implemented bicycle highway, most areas' distance towards the work locations increases. This indicates that traffic and road conditions significantly impact cycle times. The maximum increase in cycle distance will be experienced by commuters who live in Meerstad (a neighborhood in Groningen). Using the bicycle highway for commuters in Meerstad will add around 1.8 kilometers to their cycle trip.

Towards Assen

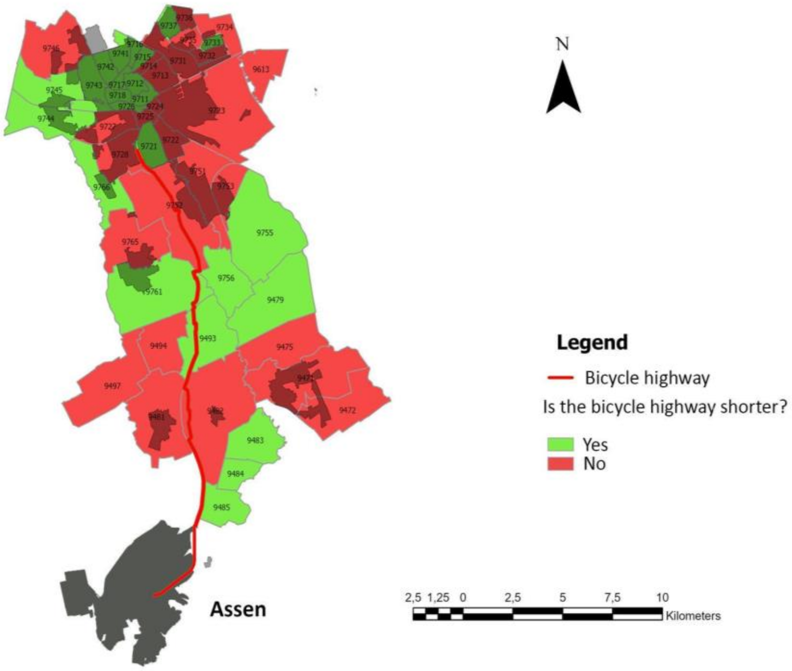

Figure 12: Is distance reduced by the implemented bicycle highway?

Towards Groningen

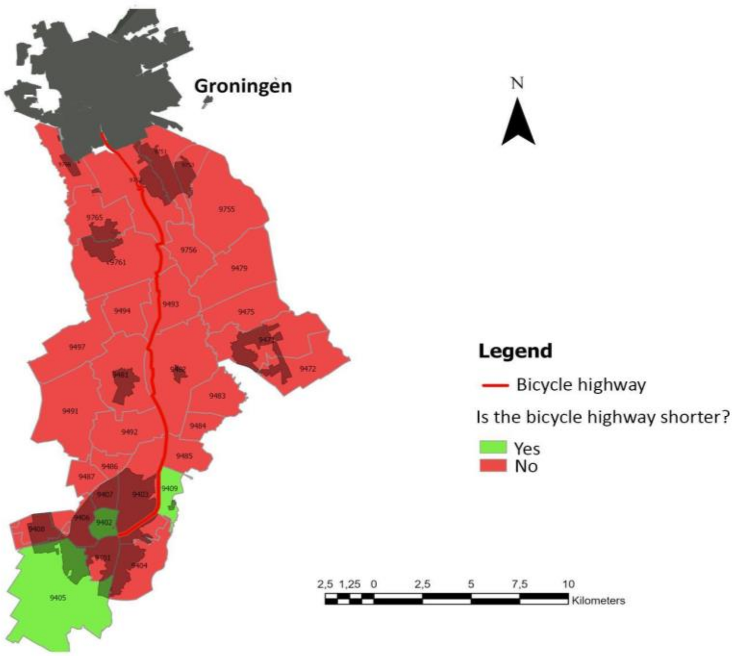

Figure 13: Is distance reduced by the implemented bicycle highway?

The maps indicate that cycling towards the 10 largest employers from any postal 4 area is related to an increase in cycle distance. As discussed in the theoretical framework, directness is an essential element that characterizes the Dutch bicycle highways (Crow, 2014), (Lagendijk and Ploegmakers, 2022). Still, it is also a significant element in the Danish bicycle highways (Office for Cycle Superhighways, 2018). The analysis highlights that the Green Axis is not facilitating a shorter cycle connection for the most significant residential areas. For cycling to Groningen, only a few postal four regions in or around Assen will experience a shorter cycle connection. Towards Assen, a shorter cycle route for main residential areas is also limited.

Drawing on Crow's theory (2014), who developed a manual for bicycle highway design and implementation in the Netherlands, bicycle highways should connect destinations on a regional scale. This means that the bicycle highway should not only connect A and B (in this case, Assen-Groningen) but also enable cyclists to cycle directly between points of interest. Additionally, in this manual, a ‘detour factor” is addressed, arguing that bicycle highways should not be 1,2 times longer in distance than alternative routes. Based on the ArcGIS analysis, it could be argued that this detour factor is more or less 1.1 for traveling between the start and end locations of the bicycle highway. However, the 1,2 threshold is not feasible for every residential area. For example, commuters living in Vries will experience a detour factor of more than 1.4 when cycling to Assen. Meaning, the bicycle highway is more than 1.4 times longer in distance than the alternative route.

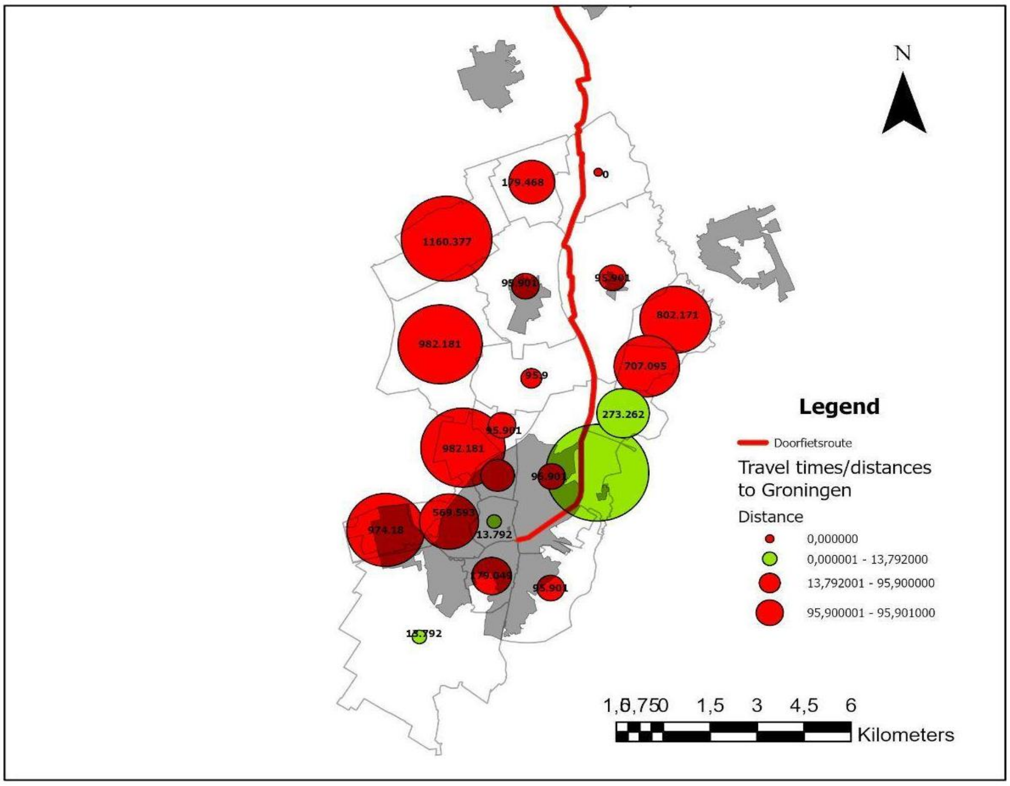

Figure 14: Difference in distance, by cycling over the bicycle highway

The map above indicates that proximity to the bicycle highway is not necessarily a factor determining a decrease in distance due to its implementation. Therefore, accessibility seems to be a more dominant factor. Beyond the urban boundaries, the bicycle highway is located in a remote area, with only a few locations where cyclists can access the infrastructure. A detour is first necessary for some regions to access the bicycle highway.

For example, for commuters living in Marsdijk (A neighborhood in Assen that borders the bicycle highway), the bicycle highway would not lead to shorter cycle trips toward Groningen. This also has to do with the accessibility of the bicycle highway. A canal is located between the neighborhood and the bicycle highway. Only two bridges enable commuters to enter the bicycle highway, which (depending on the exact location) forces cyclists to make a detour. On the contrary, commuters who live in Loon experience a reduction in cycle distance (1.3 kilometers). This village is also located near the bicycle highway; however, it is located on the other side of the channel, preventing them from making a detour.

It is important to note that calculations are based on the fastest route option. For example, cycle routes that started in Assen were not forced to use the bicycle highway from where the bicycle highway "officially starts." This means that many routes entered the bicycle highway in a later stadium and only used parts of the bicycle highway. The table below shows how often specific parts of the bicycle highway are used. This is based on the fastest route to the ten largest employers in Assen and Groningen. This table provides an insight into the time efficiency of the different segments of the bicycle highway.

Groningen-Assen	**Percentage of fastest routes using the segment**
Groningen-Haren	30,77%
Haren- De Punt	76,92%
De Punt – Tynaarlo	92,30%
Tynaarlo – Oudemolen	2,56%
Oudemolen – Assen	5,13%
Assen-Groningen	**Percentage of fastest routes using the segment**
Assen-Oudemolen	11,11%
Oudemolen-Tynaarlo	22,22%
Tynaarlo-De Punt	94,44%
De Punt- Haren	100%
Haren – Groningen	100%

Figure 15: Usage percentage of segments bicycle highway?

The table highlights that specific segments of the bicycle highway are significantly more used than others, reflecting the varying levels of time and distance efficiency. For example, the segment between De Punt and Tynaarlo is utilized by 92,30% of the routes, indicating its critical role in improving travel times for most commuters. The segment between Tynaarlo and Assen is only used by commuters who live near this part of the bicycle highway. The map below (Figure 16) provides an additional visualization of the location of the bicycle highway between Groningen and Assen and the location of alternative routes. For example, the map shows that the alternative route, which crosses both Assen and Vries, seems to be a more direct and accessible connection for most districts. Using the bicycle highway for this journey wouldn't often reduce the travel time. Around Groningen, it also seems that another cycle infrastructure better connects residential areas; however, the bicycle highway appears to be more strategically located between residential areas in this region than around the city of Assen. Still, this assumption is based on the locations of the ten largest employers. The outcomes might be different for other destinations.

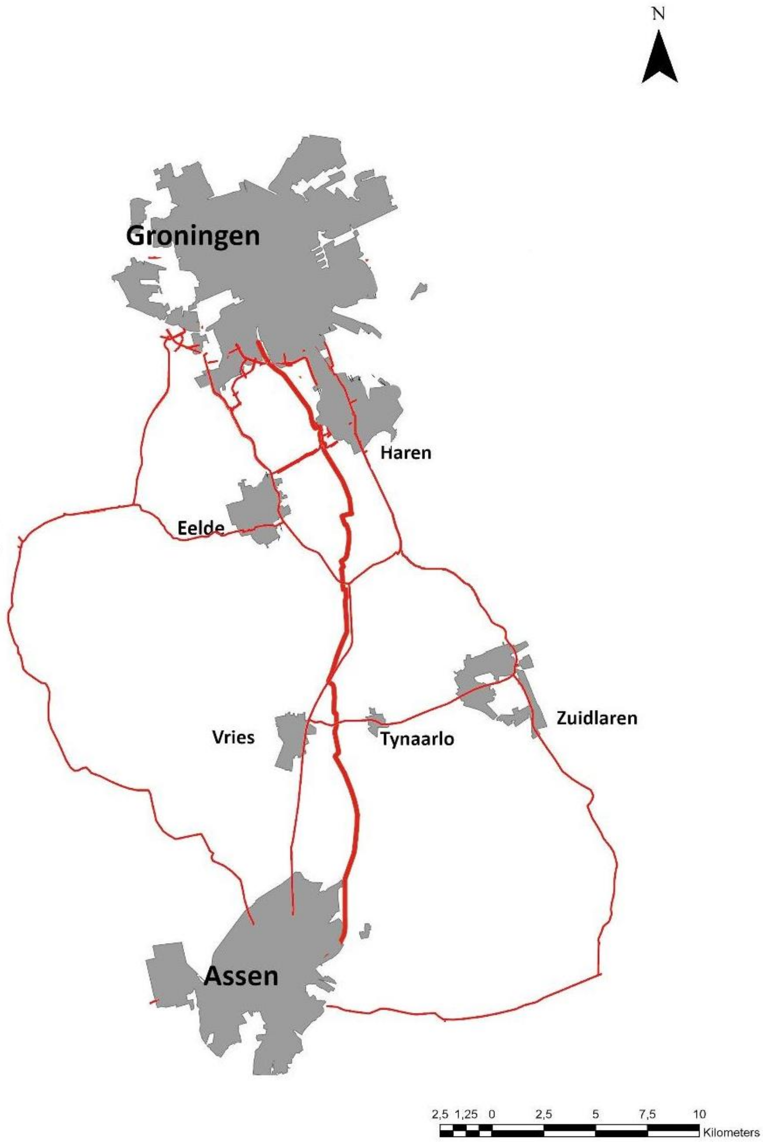

Figure 16: Alternative cycle routes and bicycle highway between Assen and Groningen

4.2 What are the perceived benefits of the bicycle highway between Assen and Groningen on the overall cycle experience?

The previous chapter highlights the impact of the bicycle highway on travel times and distances. The results indicated that the bicycle highway might lack directness and provide shorter and faster cycle route. However, it remains uncertain if this design choice (along a running canal) benefits commuters and if they are more appealing to other target groups, such as recreational cyclists. Therefore, the following chapter will investigate how commuters experience using the bicycle highway and whether the current design encourages them to adopt cycling.

User profiles and mobility patterns

Respondents' use of the bicycle highway varied significantly based on the frequency of use, the type of bicycle, and the distance traveled. Most users reported using the bicycle highway weekly, but some commuters indicated they aim to use it daily. The range of bicycles utilized included regular bikes, e-bikes, speed pedelecs, mountain bikes, Velo bikes, and racing bikes. Commuting distances on the bicycle highway ranged from 3 to 30 kilometers. The map below (Figure 17) visualize some of the cycle trips that the respondents made to their work. Not all respondents filled in their place of residence and working location, and therefore not all respondents are taken into account in the map presented below.

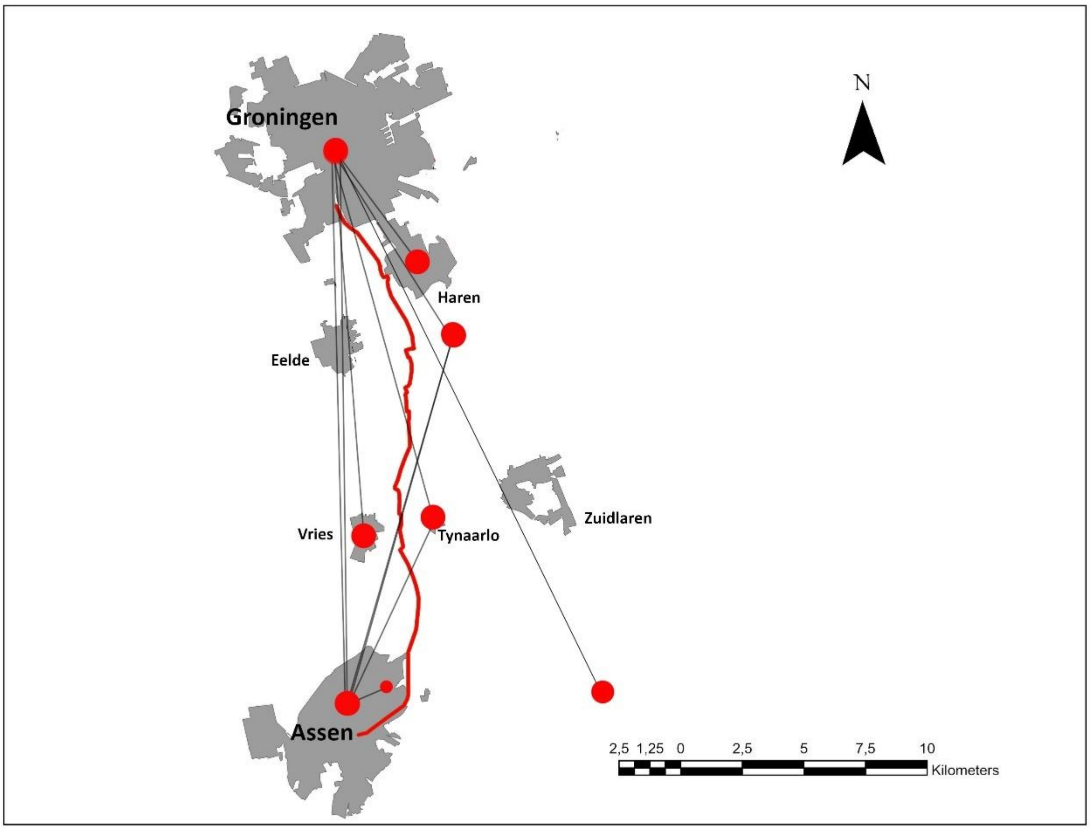

Figure 17: Origin and destination locations of some of the respondents

For most respondents, cycling to work was a well-established habit, primarily motivated by the health benefits of cycling. Sustainability was also frequently mentioned as an essential driver in adopting cycling as a preferred mode of transport. Additionally, some respondents favored cycling to avoid problems related to other modes of transportation. For example, two respondents indicated they preferred cycling over using “crowded” trains or buses, as well as the ability to avoid traffic jams. Despite a general preference for cycling, weather conditions were the most common reason for switching to other modes of transportation.

Except for two persons, all the respondents have a driving license (Figure 38). Furthermore, more than 90 percent of the respondents indicated that their working location was accessible by car (Figure 39). However, one respondent suggested that the employer did not facilitate car parking spaces, which impacted the decision to cycle. Moreover, only one-third of the respondents indicated that their working location was easily accessible by public transportation (Figure 40). Making the use of transportation less convenient for most of the respondents.

Use of the bicycle highway

The questionnaires show that the bicycle highway between Assen and Groningen appears to have minimal influence on cycling decisions.
Almost all respondents indicated they cycled to work before implementing the bicycle highway (Figure 41). Only one respondent suggested that the bicycle highway between Assen and Groningen influenced the decision to cycle. Around 30% indicated that they cycled more frequently to work due to the implementation of the bicycle highway (Figure 42)

The use of bicycle highway

Despite that, most respondents indicated that the construction of the bicycle highway improved their cycle route to work. When asked about commuters' benefits of using the bicycle highway, the most frequently mentioned answer was the absence of other traffic. Also, the lack of traffic lights and minimal intersections were cited as a benefit for commuters on the bicycle highway. Moreover, commuters experienced the road surface as comfortable and fast, making cycling at higher speeds more convenient . In summary, these characteristics increased the safety and convenience of this route. Furthermore, the word ‘quiet’ is frequently mentioned regarding the benefits of the bicycle highway. According to Kalter and Groenendijk (2018) the factors that particularly contribute to the attractiveness of cycle routes are characteristics that give cyclists a sense of calm. The location of the Green Axis, predominantly beyond urban boundaries, could contribute to the route's attractiveness, as cyclists experience fewer interactions with others. To draw on the previous chapter, attractive routes are generally perceived as being shorter (Kalter and Groenendijk, 2018) and therefore, stimulate more people to favor this route option.

Most commuters did not report reduced travel times due to the implementation of the bicycle highway. Two respondents experienced a minimal time benefit of 1-3 minutes. Some respondents indicated that they experienced a time benefit, most of which were traveling between Tynaarlo and Assen (or the other way around). As discussed in Chapter 4.2, the analyses predicted a decrease in travel time once the bicycle highway is fully completed. However, not all the respondents could confirm these benefits, as construction is ongoing and incomplete.
Consequently, cyclists must detour at some locations, negatively affecting the travel time. Moreover, most respondents also report that the travel distance towards the work location did not decrease

(Figure 43) while using the bicycle highway (which aligns with the findings in 4.2.). As a result, several respondents indicated using alternative cycle routes that are shorter and more direct to their workplaces. Another reason to take alternative routes was the need for more shelter. Some respondents argued that the bicycle highway becomes less convenient during heavy winds.

Accessibility

The bicycle highway is accessible for most commuters, however improvements need to be made to optimize accessibility for the entire route. Some of the respondents indicated that the ongoing constructions have affected its accessibility.
Three respondents appointed the constructions between Glimmen and Haren, which has been going on for five years. Due to ongoing constructions, cyclists need to make a detour over a cycle path that is poorly maintained, which negatively impacts accessibility. One respondent indicated that the bicycle highway is not accessible from Vries. Therefore, the bicycle highway becomes a valid route option at a later stadium of the commute.
This is in line with the findings presented in chapter 4.2. The ArcGIS analysis indicated that not all segments of the bicycle highway were used equally when choosing the fastest route. While the ArcGIS analysis was based on a future scenario, this accessibility of different segments might be more problematic in the current situation due to the ongoing construction.

Furthermore, one of the respondents indicated that the accessibility of the bicycle highway for Speed Pedelec users is limited. Despite the bicycle highway itself being accessible for these cyclists, speed pedestrians are often not allowed on the cycle paths that are connected to the bicycle highway. Therefore, Speed Pedelec users need to detour at some locations or use the main road, where they have to cycle between cars and other motorized vehicles. This is also discussed by Van der Salm et al, (2023) that argued that Speed Pedelec users in the Netherlands are not yet integrated into the urban mobility system and are often restricted to bicycle infrastructure.

Figure 18: Traffic sign indicating: speed-pedelecs allowed

Almost all respondents think the bicycle highway could encourage commuters to cycle more frequently. However, there were suggestions for further improvements that could stimulate commuters even more to cycle. According to most respondents, finishing the project (at a faster pace) would encourage commuters to use the bicycle highway more. Additionally, some commuters had other suggestions for improvement. Two respondents suggested that the infrastructure around the bicycle highway could be made safer and that the bicycle highway should be better marked on these roads. Moreover, one respondent indicated that the bicycle highway would improve when there is more lightning and places to shelter.

Finally, almost all commuters indicated they would use the bicycle highway more frequently when the entire trajectory was finished. The unfinished infrastructure and related limited accessibility are the most significant points of critique regarding the trajectory's accessibility.

Study Province of Drenthe

In the questionnaire conducted for this thesis, commuters often mentioned that the absence of other traffic was seen as a benefit. However, these findings somewhat contrast with the studies initiated by the Province of Drenthe. These studies were done in 2020 and 2021 and focused on two specific parts of the bicycle highway (Figure 18), implemented in 2019 and 2020. These studies analyzed the use of two “Fietsstraten” (cycle streets). This particular infrastructure is designed to favor cyclists while allowing other motorized traffic to use the infrastructure. Residents and farmers can use the infrastructure to reach their property by car or agricultural vehicles. Additionally, the road is often used for recreational purposes such as fishing. The use of “Fietsstraten” beyond urban boundaries is somewhat exceptional, as indicated by the province of Drenthe. Beyond urban cores, cars are allowed to drive 60 km/h on these cycle streets. Therefore, the speed differences between vehicles and cyclists are relatively high.

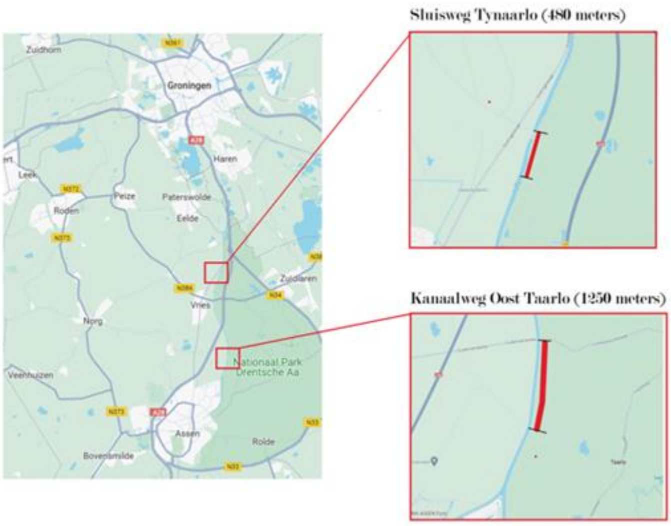

Figure 20: Study area, related research

Figure 19: Mixed use at "Fietsstraat"

The Province of Drenthe's report, which includes two primary studies, contains subjective and objective data about using the newly implemented infrastructure. This includes data from cyclists (for all purposes, including commuting), residents who live near the bicycle highway and use it to access their property, and local farmers who use the infrastructure to access their land.

First study

For the first study, the document reports mixed reactions to implementing the improved cycle infrastructure. For example, an interest group in the village of Tynaarlo raised concerns about implementing this part of the bicycle highway, which is close to their town. According to this organization, alternative locations for the bicycle highway haven't been sufficiently considered. According to the interest group, the residents of Tynaarlo do not benefit from the improved cycle infrastructure at this location as it is not a logical route to take. Furthermore, the interest group argued that using this infrastructure is unsafe due to mixed users and high-speed differences.

A questionnaire distributed among users of the previously mentioned infrastructure revealed that most cyclists indicate that "too many cars make use of the infrastructure." In particular, cyclists experience inconvenience due to fast-driving cars and car drivers who do not consider cyclists. Less inconvenience was experienced by the use of agricultural vehicles on the cycle path.

Additionally, 14 respondents indicated that the legislation around this part of the bicycle highway is unclear. It's unknown who can use the infrastructure and at what speed. For example, it is unclear if car drivers could use the infrastructure as a shortcut or if it is only meant for people who need it to access their property. Twenty respondents argued that the overall safety should be improved for the "Fietsstraat." Respondents complained about cars driving too fast and cars that insufficiently allowed cyclists space (mainly during overtaking). According to some respondents, car drivers shouldn't be allowed to use the cycle infrastructure to make a shortcut. Therefore, the use of infrastructure for these purposes should be better enforced. Furthermore, some of the complaints are in line with the input from the questionnaires. One of the respondents (from the questionnaire that was held for this thesis) indicated that the use of other traffic disturbs the function of the bicycle highway and causes mud on the surface, degrading the quality of the infrastructure.

Campaigns

The questionnaire initiated by the Province of Drenthe in 2020 resulted in specific campaigns to address the previously mentioned issues. The campaign mainly consisted of placing several traffic signs around the infrastructure to inform road users of the traffic situation (Figure 21). This was already done at another part of the bicycle highway between Haren and Groningen, focusing on the relationship between cyclists and pedestrians (Figure 22)

Figure 22: Traffic sign indicating "fietsstraat"

Figure 21: Campaign in Haren

Second study

After the campaign, an online questionnaire was held to evaluate its effects. In total, 114 respondents participated in this survey, including 67 cyclists. The majority of respondents indicated that they used the infrastructure for recreational purposes. Only 20 percent of the commuters used the cycle paths for commuting purposes.

Cyclists indicate that the overall safety was improved after the campaign. Also, car users stated that they changed their behavior after the campaign. However, a change in behavior by car drivers is more often indicated by car drivers than cyclists. In general, the campaign is experienced as being positive more often by cyclists than by motorists. A potential reason for this could be that motorists may feel that the campaign hardly represents their interests. At the same time, cyclists or pedestrians might experience more support.

Despite the campaign's effectiveness and the clarification of legislation regarding using the cycle path, cyclists still indicate some improvements. Some respondents favored restricting car use and, through enforcement, restricting only local traffic. Moreover, some respondents advocated a speed reduction for motorists (from 60 km/h to 30 km/h). Furthermore, limited lighting around the cycle track is indicated as a point of improvement, which aligns with some of the responses from the questionnaire for this thesis.

Shared use of the bicycle highway in 2024

Figure 23: Cars parked along cycle path

Figure 24: Water pipe blocking cycle path

4.3 Have mode preferences changed in different areas over time, and what role could the establishment of a bicycle highway between Assen and Groningen have played in shaping these changes?

This research studied the commuting patterns of the three municipalities where the bicycle highway is located. Therefore, ODiN data was used. This data provides travel information per postal code 4 location. This dataset provides insights into mode selection, the purpose of traveling, distance and origin, and destination location in the study area. This information is used to understand how the modal split among different places in the study area varies. In addition, it provides information about cycle behavior, the people that cycle, the distance people cycle on average, and the potential impact of the bicycle highway.

The study area showcases a diverse range of land uses and population densities. Van Acker and Witlox (2010) state that land use and population density variations significantly affect commuting patterns. The layout of residential areas, workplaces, and amenities plays a crucial role in shaping these patterns. In denser, mixed-use developments, commuters are more likely to cycle to work Scheepers *et al.* (2013), Nordengen *et al.* (2019) and Tao, Fu, and Comber, (2018).

The study area combines denser mixed-use developments and sprawling low-density regions. The map below presents the number of residents per Postal 4 locations. The study area is home to nearly 350.000 inhabitants across three different municipalities. More than 70 percent of this population lives in Groningen, where the population density reaches 1230 inhabitants per square kilometer. This contrasts sharply with Tynaarlo, which has an average density of 235 per square kilometer. In Assen, the average population density is 835 residents per square kilometer.

Population

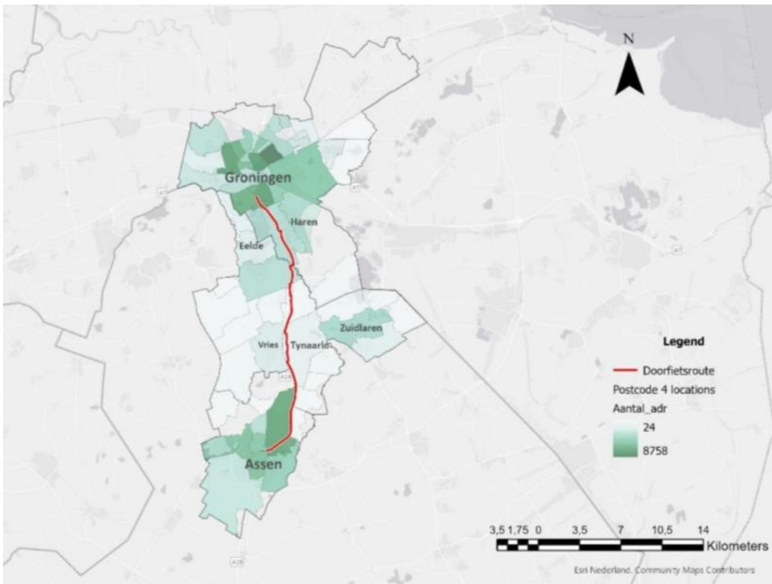

Figure 25: Population density study area

The maps below illustrate the modal split for commuting trips for postal four codes in the study area from 2018 to 2022. The maps present commuting trips of all distances. The data used to calculate the modal split per PC4 location is derived from ODiN. Not every PC4 area is included in the map. This has to do with the limited data that was available for some of the regions.

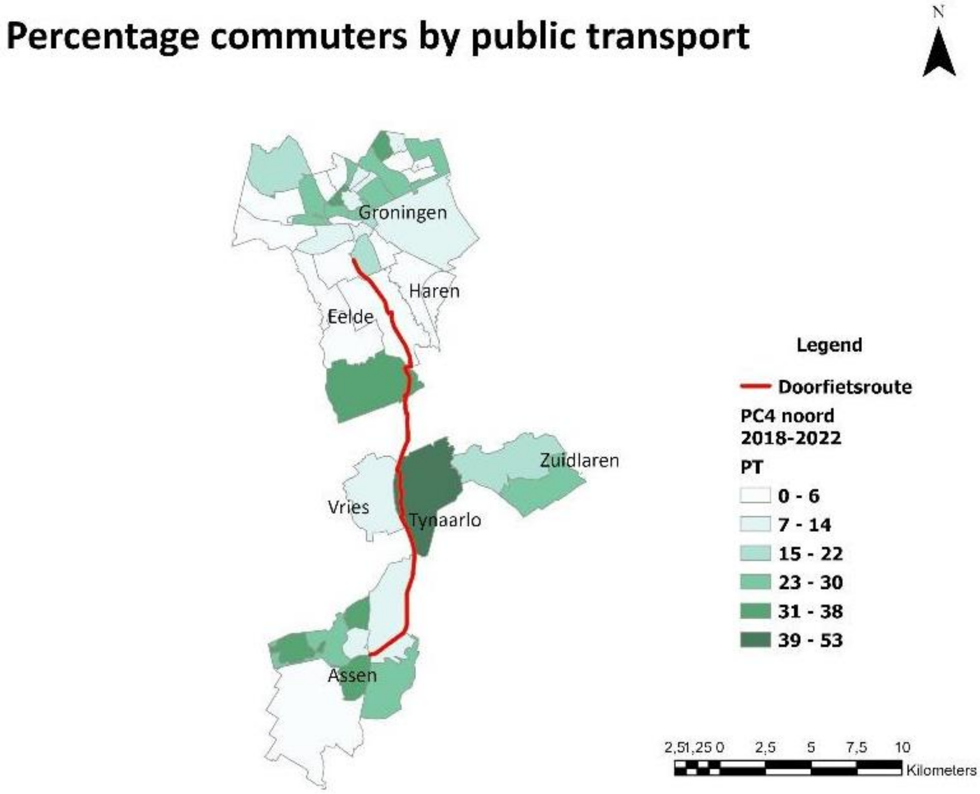

Figure 26: Use of public transportation by commuters 2018-2022

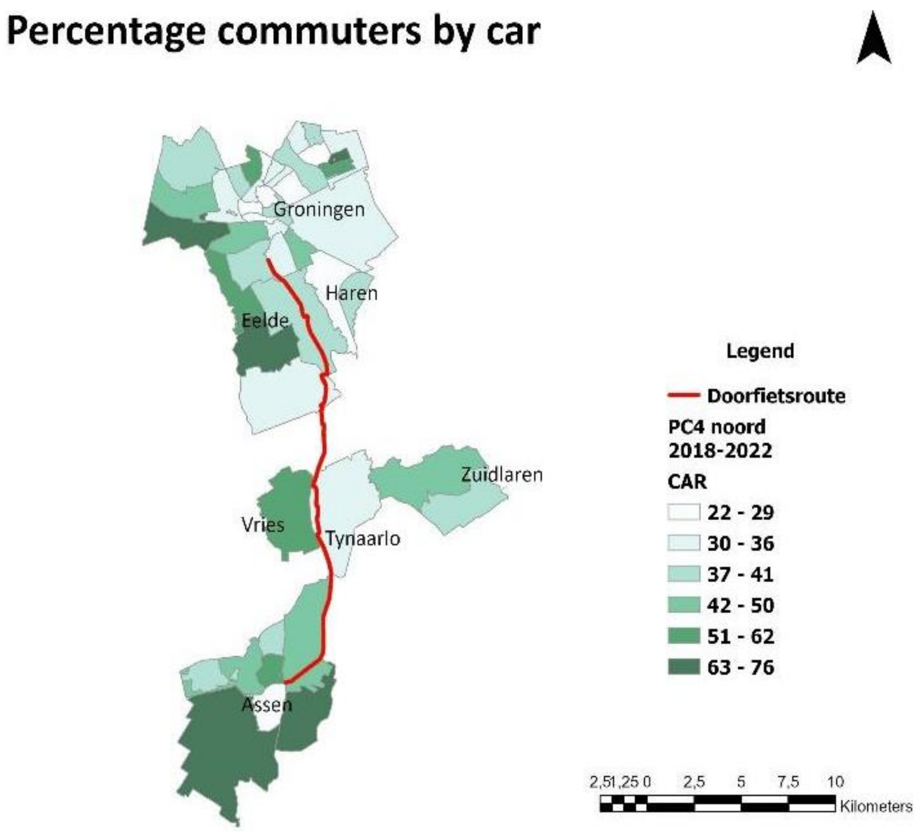

Figure 27: Use of the car by commuters 2018-2022

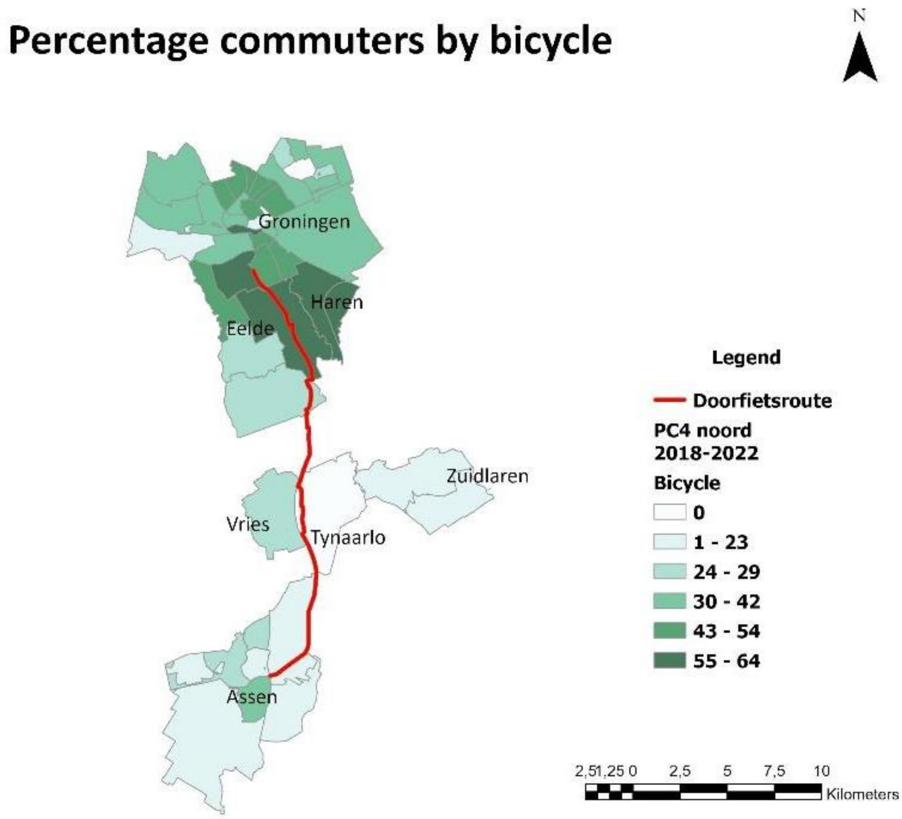

Figure 28: Use of the bicycle by commuters 2018-2022

The maps clearly show regional variations in modal split. Car use is higher in areas with lower population densities, aligning with other mobility studies in the Netherlands by Scheepers et al. (2013) and Jonkeren et al. (2019). Despite clear regional variations in mode selection based on population density, differences between urban and rural areas are not always starkly evident. For example, using a car for commuting could differ significantly for areas with comparable population sizes within the same municipality.

Furthermore, higher shares of cycling commuters and public transportation users are dedicated to areas with higher population densities and mixed land uses or areas that are in proximity to that. Furthermore, a clear difference is visible between the city of Assen and the city of Groningen. The maps indicate that the share of commuting trips by bicycle is significantly higher in Groningen. An underlying factor determining the mode choice could be the distance commuters need to travel. Regio Groningen-Assen (2019) found that commuters in Assen travel for longer distances. According to that study, commuters in Assen traveled, on average, 26,2 kilometers in 2018. The average distance between home and work was in the same year 21.9 in Groningen, 21,3 in Haren, and 23,3 in Tynaarlo. The more considerable distances for commuters in Assen could be an essential reason for the lower share of bicycle use. However, the modal split is calculated for trips longer than 7,5 kilometers. According to Banerjee *et al* (2021), 7,5 kilometers is considered a comfortable distance for cycle trips. The map below shows the percentage of commuting trips by bicycle for distances longer than 7,5 kilometers.

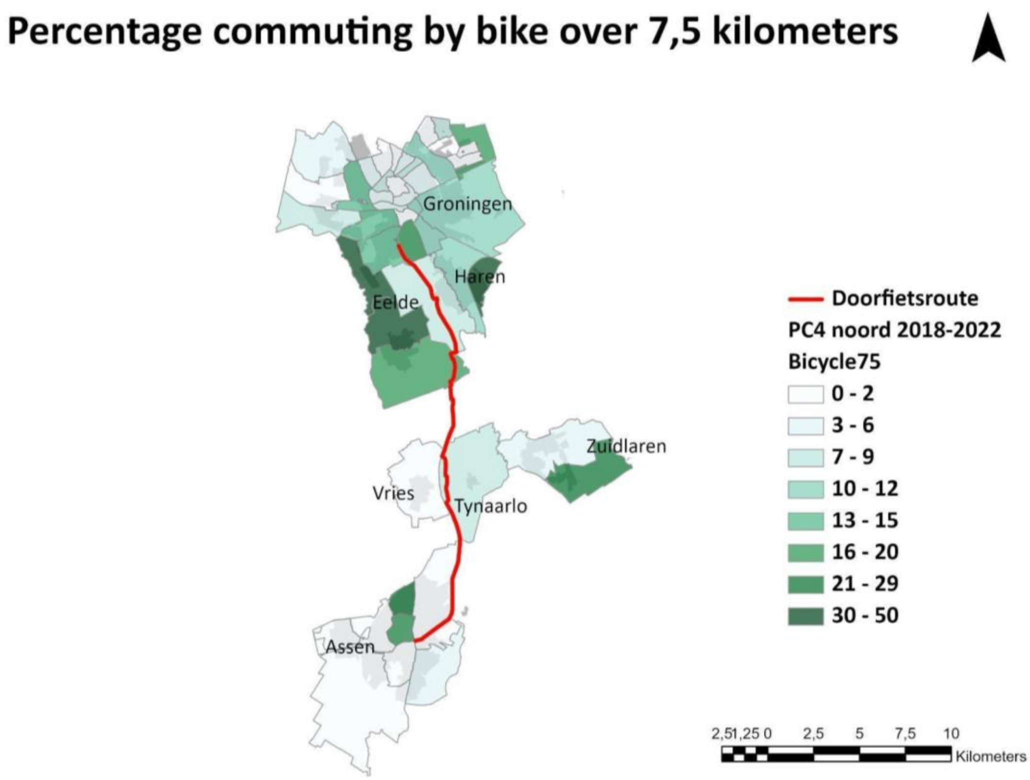

Figure 29: Commuting by bicycle for trips longer than 7,5 kilometers 2018-2022

Trips by bicycle have become more exceptional for long distances in general. In Assen, cycling has become rare for longer distances, except for two neighborhoods. The highest share of commuting trips by bicycle is visible in villages around the city of Groningen, for example (parts) of Haren, Paterswolde, Eelde, and some neighborhoods at the city's edge. Previous maps already show that the use of bicycles as a mode of transportation is generally higher in this region. Based on the ODiN data, it is evident that many people in this region work in the city of Groningen. This also means that for many people in for example Haren, the cycling trip is no longer than 7,5 kilometers, so these cycle trips are not considered. It doesn't necessarily mean that people in these areas travel with other modes of transportation for longer distances.

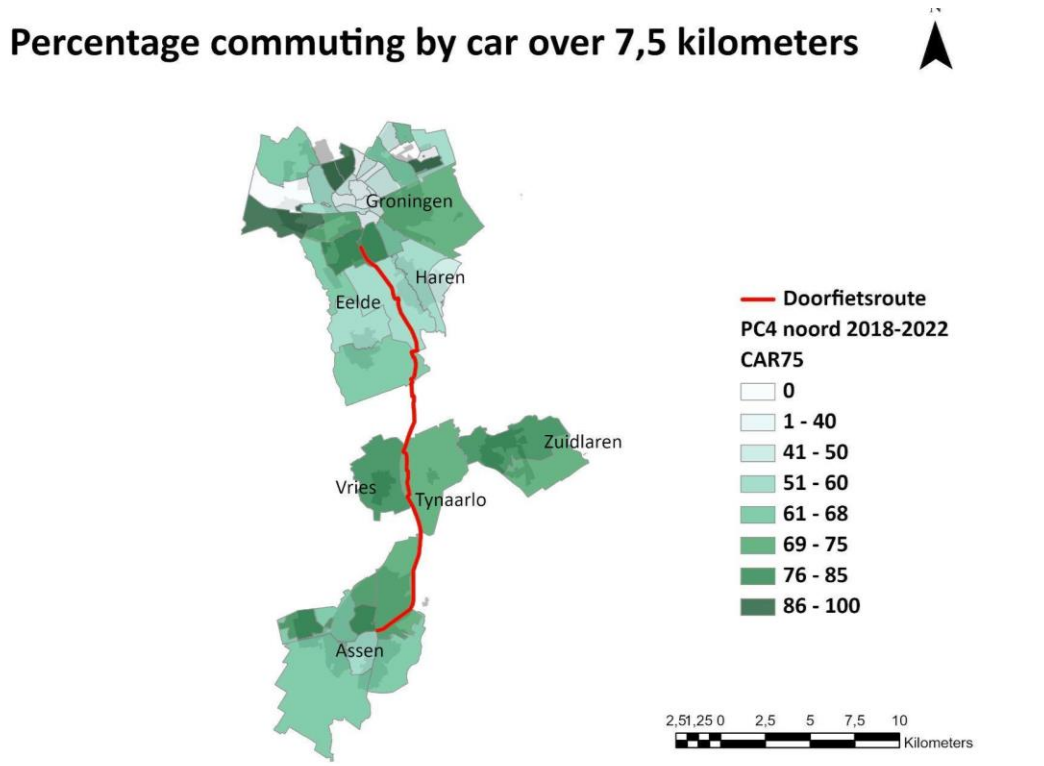

Figure 30: Commuting by car for trips longer than 7,5 kilometers 2018-2022

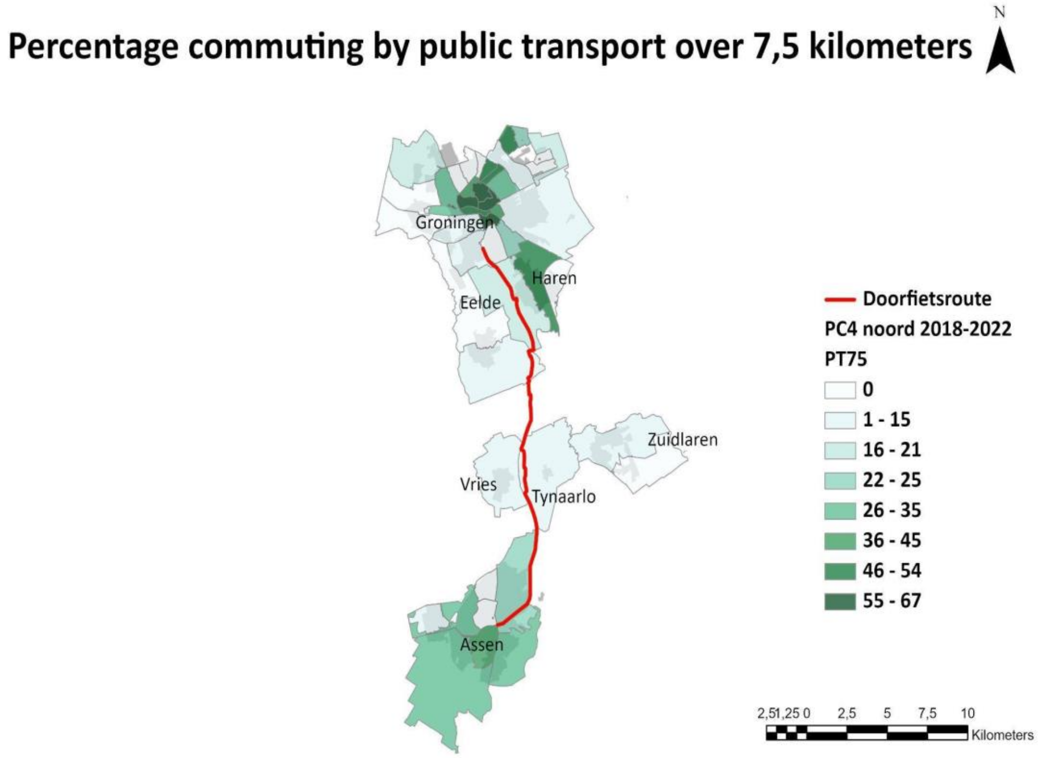

Figure 31: Commuting by public transport for trips longer than 7,5 kilometers 2018-2022

The maps above illustrate the share of car and public transportation commuting distances over 7,5 kilometers. The car is dominant for longer distances, except around key transit hubs as the translations (of Haren, Groningen, and Assen). According to Ewing (no date), public transportation usage is influenced by the origin location and the destination. According to the study, the density of employment at the point of destination has a more substantial influence on the choice of public transportation than residential density at the origin location. This might explain the higher share of public transportation use in neighborhoods on the outskirts of Groningen. In Assen, the share of commuting trips by public transportation is equally divided over the entire city. The use of public transit in any other place in the study area is generally low.

Beside the model split in 2018-2022, this study investigated the modal split in 2015-2017. Although this selection is shorter, the number of days considered is related. This is because of the Covid-19 pandemic, which is not considered (see methods). Between 2015 and 2017, there was no bicycle highway between Assen and Groningen. Therefore, a comparison could be made between the modal split before and after implementing a bicycle highway. The map below presents the percentage of commuting trips by bicycle between 2015-2017 and 2018-2022.

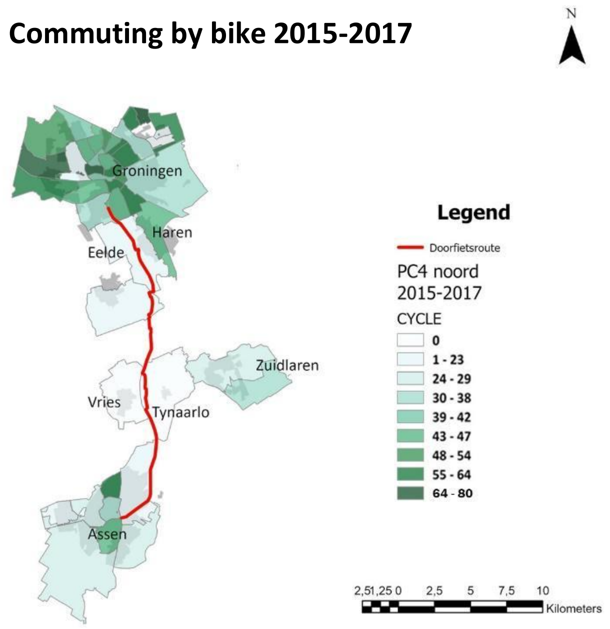

Figure 33: Use of the bicycle by commuters 2015-2017

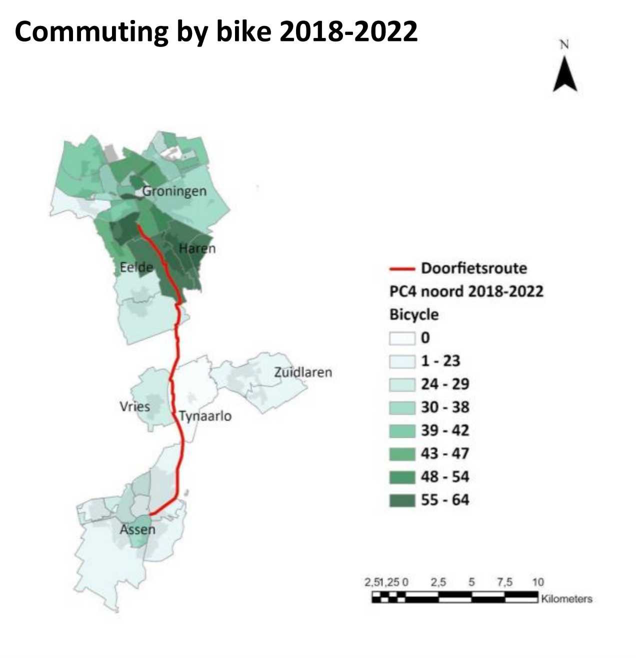

Figure 32: Use of the bicycle by commuters 2018-2022

The maps highlight that the percentage of commuters who cycle to work has increased between 2018 and 2022. In particular, in areas located beyond the urban boundaries of Assen and Groningen, commuters more often cycle to work. Also, regions close to the bicycle highway highlight increased cycle trips. This is particularly visible for the PC4 locations where Haren and Eelde are. This aligns with the findings of Regio Groningen-Assen (2019), who studied mobility patterns in the region Assen-Groningen. They reported an increase of 18,4% in cyclists between Haren and Groningen in 2019, based on traffic counts at several locations around Haren and Groningen.

Also, a slight increase in bicycle commuting is evident in Vries (located close to the bicycle highway). Notably, the increase in cycle trips is visible in areas where the first parts of the bicycle highway were constructed. This applies to the trajectory between Haren and Groningen and Tynaarlo and De Punt. Based on ODiN data, an increase in cycling commuters is not evident for both the city of Groningen and the city of Assen.

Although the maps show a comparison between a period with a bicycle highway and a period without a bicycle highway, it is still complicated to see the effects of the infrastructure. The maps represent all cycle trips to all possible locations. This means that the bicycle highway is not a potential alternative route for all commuting trips. Therefore, a selection was made based on origin and destination location to understand better the bicycle highway's ability to foster a modal shift for commuters. Only the commuting trips were selected for which cycling over the bicycle highway was a potential alternative. This means, for example, that commuting trips between locations in the city of Groningen were removed, but a commuting trip from any location in Groningen towards Haren was selected.

The maps below compare cycle trips made in areas around the bicycle highway between 2015-2017 and 2018-2022. The maps show that the number of cycle trips has increased since the implementation of the bicycle highway. In particular, in the municipality of Tynaarlo, more cycle trips were documented based on the previously noted selection. This same pattern is visible between Groningen and Haren, where more cycle trips were notable. Except for one trip, an increase in cycling is not visible from Assen to any other location around the bicycle highway.

However, based on the ODiN dataset, it is impossible to indicate if cyclists also used the bicycle highway. This is because only a Postal 4 area is indicated. Therefore, the distance indicated for the trip is difficult to track, as the exact origin and destination locations are unknown.

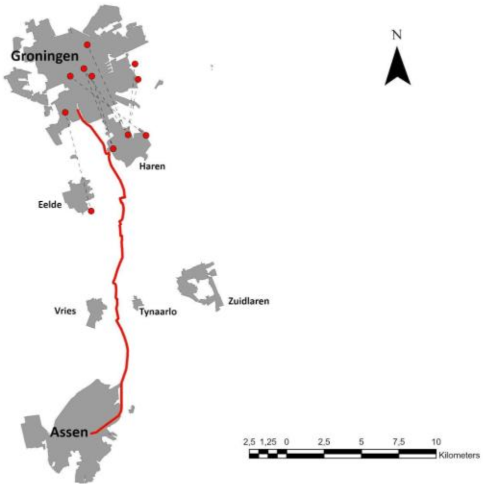

Figure 35: Cycle trips 2015-2017

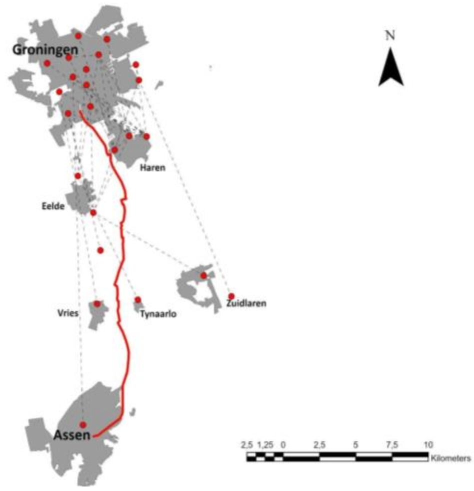

Figure 34: Cycle trips 2018-2022

The graphic below shows how mode selection changed between 2015 and 2022. Based on the ODiN data, more cycle trips have been evident in the study area since the implementation of the bicycle highway. The maps indicate that mainly cycle trips that were heading towards the city of Groningen, increased. Most commuters resided in Haren (municipality of Groningen) or in the municipality Tynaarlo. Based on the ODiN data, there is no evidence to suggest that the bicycle highway led to an increase in cycling commuters between Groningen and Assen, with only one exception. Despite the availability of more data for both cities, fewer cycle trips were documented compared to less populated villages in Tynaarlo.

Beyond the increase in bicycle commuters, a decrease in commuting by car was documented. At the same time, the graphic below highlights a reduction in commuting by public transportation. According to Hallberg et al. (2021), bicycle trips are expected to replace trips previously made by walking or public transport. The graphic below seems to support this statement. In 2018, an increase in cycle trips was visible, along with a decrease in the use of public transportation. However, this changed between 2019 and 2022. In this period, cycle trips decreased while public transportation was used more frequently.

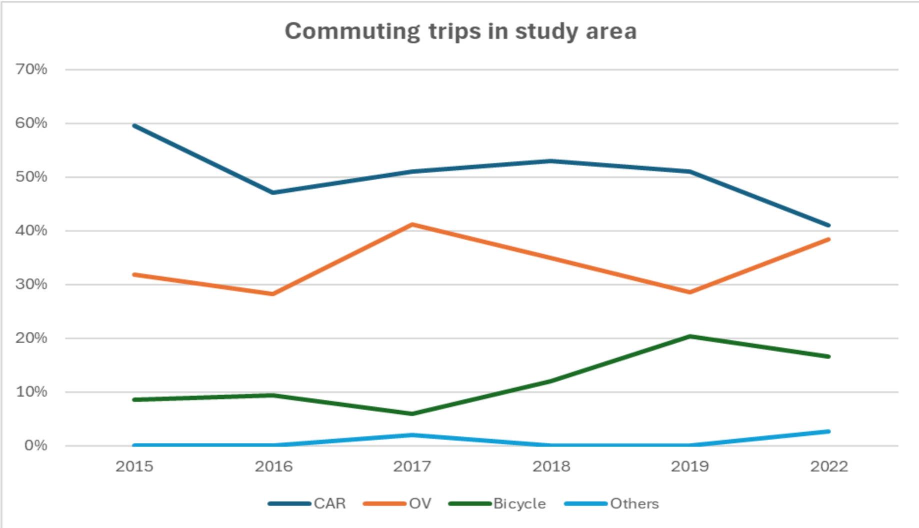

Figure 36: Modal split 2015-2022

The ODiN data revealed that the distance of cycle trips has not increased since the implementation of the bicycle highway. The map below highlights the frequency of origin locations in the dataset between 2018-2022. The greater the circle, the more frequent the Postal 4 location was documented. Only cycle trips were selected, of which the bicycle highway was a suitable alternative.

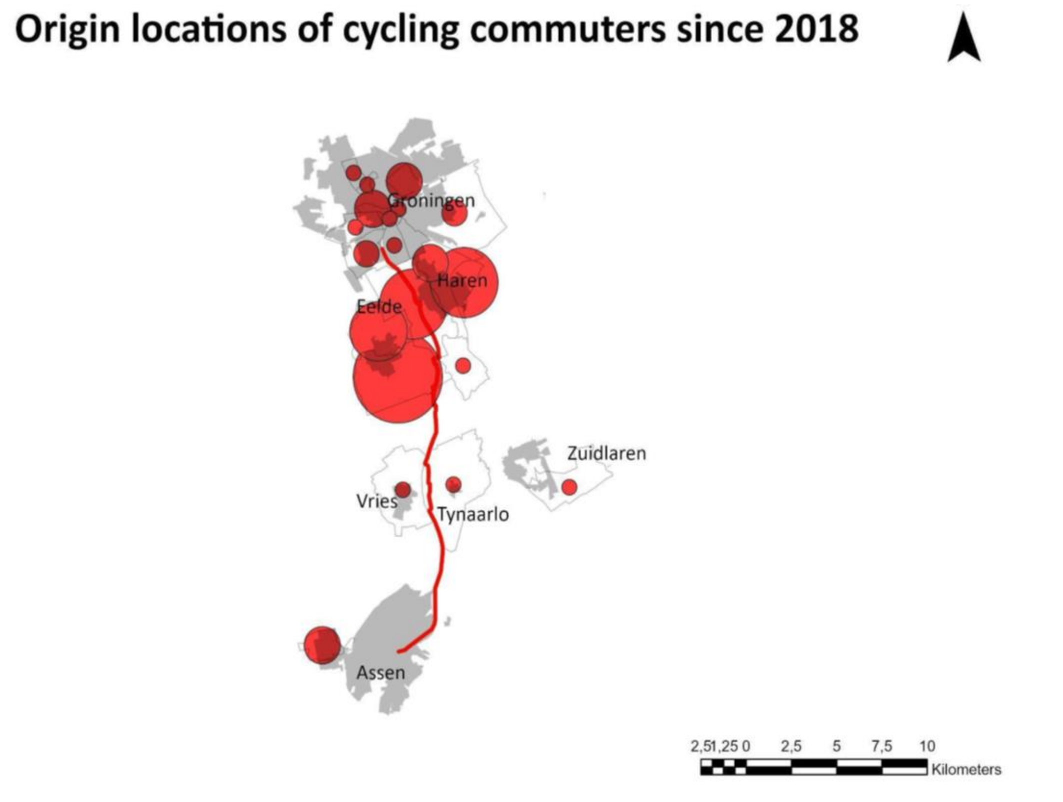

Figure 37: Origin locations of cyclists after implementation bicycle highway

Additionally, sociodemographic factors play a crucial role in cycling behavior. According to Hansen and Nielsen (2014), commuters in Denmark who cycle for longer distances (more than 5 kilometers) often have more transportation options, higher incomes, and higher education.

Odin data also provides information about socio-demographic characteristics. These characteristics were analyzed for the data that was selected to investigate cycle trips that were made between locations around the bicycle highway. The dataset highlights that in many fields, the characteristics of cycling commuters were relatively homogeneous. For example, almost all commuters have a Dutch background. All commuters that cycled had an income over 110% of the lower income threshold. This lower income threshold is based on the money needed to avoid poverty (CBS, 2022).

Furthermore, the data highlights that most commuters who cycled between 2018 and 2022 are highly educated. In 2018, more than 65% of cyclists were highly educated; in 2019 and 2022, this was even more, with 85% in 2019 and 84,6 % in 2022. Except for the homogenous characteristics in background, income, and education, the share of men and women was equally distributed, with both 50%.

The average distance of bicycle commuting trips in the study area was around 8 kilometers. Between 2018 and 2022, commuters traveled 24,5 and 30 minutes by bicycle. For most commuters by bicycle, the car was most frequently used as an alternative mode of transportation. With some exceptions, public transit was exceptional for commuters in the study area, where most commuters only used the train or bus once a year or never.

5. Discussion and Conclusion

5.1 Discussion

This study aimed to assess the benefits of the bicycle highway between Assen and Groningen for commuters. This chapter will discuss these findings in more depth and discuss existing theories.

Data summary in the conceptual framework

The study's conceptual framework is built on the theory that improved cycle infrastructure can lead to increased cycling frequency, improved commuter experiences, and modal shifts toward cycling. According to (Parkin and Koorey, 2012), improvements to cycle infrastructure are the main instrument to increase cyclists. Despite the completion of the infrastructure, early findings suggest that the bicycle highway enhances the cycling experience through safety and comfort improvements. ArcGIS analysis suggests this will not align with reduced distances toward the selected workplaces. However, the improved road conditions and traffic situation enable cyclists to cycle uninterrupted at higher speeds, improving travel times. However, time benefits are often small, with varieties over different areas. Additionally, based on ODiN data, an increase in the number of cycling commuters was evident in the region. However, this seems limited to specific areas concerning a target group with homogenous socio-demographic characteristics.

Generalizations of findings were realistically made with an explicit connection to the theory.

The effects of the bicycle highway on travel times and distances could not straightforwardly be translated into the potential for a modal shift. Additionally, there is a difference between objective travel time and perceived travel time (Kalter and Groenendijk, 2018). If routes are more convenient and enjoyable, time and distance become less critical. Kalter and Groenendijk (2018), state that cyclists perceive attractive routes as shorter. Olde Kalter and Groenendijk (2018) noted that the attractiveness of a route had the most significant impact on route decisions, followed by variety, comfort, and peace. Remarkably, the factor "speed" had the most negligible impact on route decisions, according to this study. Also, concerning distance, literature shows that commuters are willing to travel longer if this provides more convenient infrastructure (Vedel et al. 2017). The increase in distance, which is associated with using the bicycle highway for many regions, should not necessarily prohibit commuters from using the infrastructure. The ODiN data additionally revealed that the most significant increases in cycle trips were notable in regions around Groningen. The bicycle highway would generally not lead to a shorter or faster cycle route towards Groningen for these areas. If these increases are related to implementing the bicycle highway, it confirms that cyclists are willing to take longer routes if they offer other benefits.

In line with (Skov-Petersen *et al.*, 2017), this research revealed that users of bicycle highways experienced increased comfort and safety. They indicated that riding on a bicycle highway was convenient due to improved asphalt conditions and the absence of other traffic. Furthermore, the characteristics of the bicycle highway enable more predictable travel times. According to Asensio and Matas (2007), commuters valued the reduced unpredictability of travel times over the savings of travel time. Jang and Joonhp (2019) stated that commuters experience higher stress levels due to unpredictable travel times. Congestions and delays resulting in waiting time negatively affect commuters' satisfaction during the commute. Cycling over the bicycle highway minimizes the risk of experiencing delays. The questionnaire respondents also indicated that the Green Axis enabled them to cycle unhindered to their work, which was a benefit.

According to Liu et al. (2019), improved comfort and travel times associated with the construction of bicycle highways could, therefore, encourage a modal shift.

This study revealed that commuters generally experienced comfort while using the bicycle highway. However, this didn't' apply for the 'fietsstraten" (part of the bicycle highway), the allowance of cars and other traffic on these roads, negatively impacted the feeling of safety and comfort for cyclists. Due the location of these "fietsstraten" beyond urban areas, cars are allowed to drive 60 km/h, what leads to significant differences in speed between cars and cyclists. Additionally, the adjacent agricultural land ensured that farmers used the infrastructure as well, impacting the feeling of comfort for cyclists.

This study is unique in investigating the role of a bicycle highway located mainly beyond urban boundaries. Based on the results, the bicycle highway's rural character seems to provide benefits and issues for commuters.
First, much of the literature on the time efficiency of bicycle highways focuses on the time benefit that the infrastructure could provide in urban areas. For example, Banerjee *et al.* (2021) argue that bicycle highways offer a fast and safe connection between suburbs and city centers. Furthermore, Dekoster and Schollaert (1999) highlight that bicycles are more rapid than cars in short urban distances (less than 5km). The agility of bicycles could make them, especially during peak hours (in dense urban areas), more time efficient than other modes of transport. Therefore, the bicycle highway could, in particular for urban areas, provide conditions that enable cycling to be a time-efficient mode of transportation. However, the results of this study could not yet confirm these statements. For example, the maps show that the towns surrounding the city of Groningen do not directly experience a time or distance benefit due to the implementation of a bicycle highway (compared to other cycling infrastructure). Additionally, the bicycle highway won't provide a direct and efficient route for most residents in Assen and Groningen who commute within the same urban area. The analysis, therefore, suggests that the Green Axis in both urban regions insufficiently meets the design standards of bicycle highways, highlighted by (CROW, 2016) and (CROW, 2014) to provide a direct and coherent route between residential areas and points of interest.

Furthermore, the ArcGIS analysis highlighted that the bicycle highway could enable cyclists to cycle faster. The study also provided other insights. From both the questionnaires and the ArcGIS analysis, it became apparent that some parts of the bicycle highway have limited accessibility. Commuters indicated that the bicycle highway became a severe option later in their journey. This was also evident in the ArcGIS analysis. Large parts of the bicycle highway were often passed when choosing the fastest route. Using the entire infrastructure would significantly longer travel times and distances for some regions, particularly traveling to or from Assen. Therefore, commuters could not optimally experience the benefits of the bicycle highway the entire route. Rayaprolu et al., 2020 highlighted the importance of the density and integration of the bicycle network in existing cycle infrastructure for fostering commuters to cycle. The analysis of this study suggest that the placement of the Green Axis bicycle highway outside urban boundaries, alongside a running channel, seems to restrict its ability to link critical destinations directly. The infrastructure is mainly placed outside residential areas and therefore the ability to provide a fast and direct route between home and work is not optimized for all commuters in the study area.

Moreover, the analysis indicated that the car was mainly dominant in lower-density areas and that commuters in higher-density areas cycled more frequently, which is in line with Scheepers *et al.* (2013), Nordengen *et al.* (2019) and Tao, Fu, and Comber, (2018). Also, the increase in cycling since implementing the Green Axis was mainly evident in areas where commuters generally cycled more frequently. Minimal modal shifts have been obvious in lower populated areas since the implementation of the Green Axis. Additionally, the ODiN data revealed that commuters who cycled between locations where the bicycle highway was a potential alternative had more mobility choices, higher incomes, and higher education. These findings align with Hansen and Nielsen (2014). Also, the motives to cycle, which derive from the questionnaires, align with Hansen and Nielsen (2014), who argue that the primary motive for cycling longer distances tends to be physical exercise. Commuters also indicated that cycling to work was part of a habit formation, which aligns with Banerjee *et al.* (2021).

This study highlighted that commuters in many regions in the study area will experience a reduction in cycle time when the bicycle highway is operational. However, despite improving travel time, cyclists will still experience long commuting times. To cycle from start to end (train stations Groningen and Assen), the journey will still take more than 1,5 hours (70 minutes with an e-bike). For example, this journey will take less than 20 minutes by train. Therefore, for most regions, the bicycle highway would not enable cycling to be the most time-efficient mode of transportation.

Nevertheless, it is essential to consider that this bicycle highway enhances the attractiveness of the cycling experience. Attractive routes are perceived as being shorter (Kalter and Groenendijk, 2018). Despite increased travel times and distances, commuters in the study area might favor cycling along the Green Axis, as this route is more enjoyable and perceived as being shorter. Consequently, through its natural and rural character, the Green Axis could benefit commuters by linking transportation more to health (Cook *et al.*, 2022). Therefore, commuters could experience physical movement through diverse and engaging environments by taking this route (Rigal and Bahrami, 2017). From that perspective, the Green Axis is more than a route from A to B; it also makes commuting a natural and enjoyable process that reduces reliance on motorized traffic while promoting well-being.

Opportunities for modal shift

The question at the heart of this research is: To what extent could the previously mentioned benefits influence the decision-making to cycle to work?

Skov-Petersen *et al.* (2017) investigated the effects of improved bicycle infrastructure that targeted commuters to cycle more frequently. The investments resulted in significant increases in cycle volumes and satisfaction with the improved infrastructure. However, this study revealed the rise in cycle flows attributed to cyclists switching from other alternative routes. Therefore, modal shifts due to the improved cycling conditions were modest (4-6%). This aligns with van Goeverden *et al.* (2015), who argue that improved cycling infrastructure has a limited effect on modal change (2-3%). Also, the questionnaire in this study highlighted that almost all commuters indicated that implementing the bicycle highway did not influence their decision to cycle. Expect one respondent; all commuters cycled before implementing the bicycle highway.

Additionally, Song et al. (2017) provided evidence that new cycling infrastructure can significantly encourage modal shifts from car use to cycling. However, this study revealed that potential exposure, defined as the distance from the intervention, did not directly predict modal shifts. So, living close to the bicycle highway (with potential benefits such as decreased travel time and distance), is not necessarily bringing about mode shifts (drawing on the theory of, Song et al, 2017). According to this study, passive exposure could stimulate an increased use of recreational values. To bring about mode shifts, actual exposure is crucial, defined by experiencing the infrastructure (making use of it).

Furthermore, based on the questionnaire, this study revealed that cycling for longer distances was a habit for most commuters, and it was supported by advanced equipment such as racing bikes, mountain bikes, and speed pedelecs. Literature shows that individual considerations become more critical over longer distances (Banerjee *et al.*, 2021). This suggests that over longer distances, commuting by bicycle is primarily based on individual preferences rather than societal expectations. This also became evident in the questionnaires, where multiple respondents indicated that sustainability was also an essential driver in adopting cycling beyond the health benefits associated with cycling. Therefore, commuting by bicycle still stimulates specific target groups with particular values for cycling. Additionally, the increase in cycle trips over large distances would be modest as cycling (in the Netherlands) becomes limited beyond distances of 15km (Banerjee *et al.*, 2021).

Based on the ODiN data, it could be suggested that cycle trips have increased since implementing the bicycle highway. However, these increases were regional and dedicated to specific parts of the bicycle highway. An increase in cycle distance was not evident. Due to the methods applied, it is complicated to discuss whether the increase in cycle trips documented in Chapter 4.3 relates to implementing improved cycle infrastructure. Other literature highlights some trends that could have contributed to the changes in mobility patterns.

First, according to Regio Groningen-Assen (2019), the distance commuters travel decreased in Assen-Groningen between 2014-2018. In Groningen, commuters traveled on average 5.8 kilometers shorter to their work. Reducing travel distance could create more favorable conditions for active mobility.

Furthermore, regio Groningen-Assen (2019) documented an increase in the number of speed pedelecs in the region between 2018 and 2019. The most significant increase (+38%) was reported in the municipality of Assen. This same pattern was visible in the municipalities of Groningen (+29%) and Tynaarlo (+20%). The speed pedelec is an effective mode of transportation that encourages fast traveling. Groningen Bereikbaar investigated the use of speed pedelecs and e-bikes (Eemskrant, 2017). A questionnaire with ebike and speed pedelec users revealed that 60% of the respondents indicated that they made a modal shift towards cycling due to the time advantage they experienced.

Moreover, beyond the development of new cycle infrastructure and equipment, commuting by bicycle also receives much media attention. The same is evident for the bicycle highway, which caused a lot of regional media attention. This media attention could have created awareness for commuting by bicycle and cycling longer distances. Buck and Nurse (2021) state that marketing campaigns could change attitudes and behavior. A previously mentioned “choice architecture” towards cycling could lead individuals to decisions that can improve their lives. Therefore, implementing the bicycle highway could positively influence commuters' cycle decisions and potentially for other regions.

5.2 Limitations and further research

This thesis added some valuable insights to science and regional planning practice. This study examined the implementation and effects of improved cycle infrastructure in a predominantly rural setting. Evaluating a rural bicycle highway broadens understanding of how such infrastructure functions in less densely populated areas, addressing unique challenges and opportunities. The emphasis on particularly commuters provides additional insights into how improved infrastructure could serve the wishes of commuters, fostering a modal shift towards cycling. Moreover, for local planning authorities, this study offered valuable insights into the experiences of current users of the bicycle highway. Additionally, the maps highlight apparent regional differences in the impact of the bicycle highway, which could help to apply a location-oriented approach in understanding and improving the impact of the infrastructure.

Nevertheless, this study also has some limitations. First, the ArcGIS analysis regarding travel times and distances is based on assumptions (supported by literature). The trajectory still needs to be finished, so it was necessary to assume the exact location of the future track. This prediction is based on information provided by the province of Drenthe (a stakeholder in this project). Furthermore, due to improved asphalt conditions, cyclists are assumed to cycle faster on the bicycle highway, supported by Doorfietsroute.nl (no date). However, no evidence exists that cycle speeds increase on the Green-Axis bicycle highway.
Moreover, in ArcGIS, a stop time was added at crossings based on the information from Groot (no date). The exact stop time is added to every traffic light; however, the stop time might differ between locations. Lastly, the origin and destination locations were used to make a general assumption. Variations in origin and destinations (within the same residential area) might provide other outcomes. Furthermore, it was challenging to find respondents for this study. Large companies in Assen and Groningen were emailed, the link to the questionnaire was spread in newsletters and on social media, and QR codes were placed across the bicycle highway. This often led to limited responses, which, therefore, limited the representativeness of the involved population. The same was experienced by the province of Drenthe (of which the questionnaire is included in this thesis). Therefore, the minimal response rate might also indicate the use of the trajectory (for commuters).
Another limitation is the use of ODiN data. The datasets often consisted of more than 200.000 travel moments; however, data became limited for some postal 4 locations in the study area. Furthermore, the impact of the bicycle highway is difficult to measure based on ODiN data because the data doesn't provide insights into the reasons for mode selection and route characteristics. Therefore, other methods might offer deeper insights into place-based characteristics and the considerations for mode selection.

Future research should be conducted when it is fully operational to understand the bicycle highway fully. Additionally, this research could benefit from the application of new methods. For example, GPS tracking could analyze travel times more precisely.
Furthermore, focusing on the region's commuters instead of cycling commuters would provide more comprehensive insights, such as motivations not to cycle to work (or to use alternative cycle routes). Additionally, this would help find more respondents. Lastly, by using ODiN data, travel patterns for other bicycle highways could also be assessed. This would provide more comprehensive insights into how bicycle highways might affect travel patterns and how this differs between several areas.

5.3 Conclusion

The findings of this study underscore that the Green-Axis bicycle highway benefits commuters. Commuters in most regions will benefit from a faster cycle route due to better asphalt conditions and fewer stops; however, these time benefits will be small. Moreover, for commuters in most areas, the distance to the working location will generally increase when using the bicycle highway.

Questionnaire responses indicated that commuters experienced improved cycle conditions due to the construction of the bicycle highway. The bicycle highway adds value by providing an unhindered, save, and more convenient cycle route. However, the allowance of cars at some specific locations on the bicycle highway creates more challenging conditions for cyclists.
Additionally, further analysis highlighted that some areas closer to the bicycle highway saw a slightly higher uptake in cycling since the bicycle highway became operational. This is mainly related to areas near the city of Groningen. For other regions, increased cycle trips among commuters were barely documented. Lastly, the ODiN data revealed that commuters who cycled showed relatively homogeneous characteristics, as most had a Dutch background and were highly educated.

In conclusion, while the bicycle highway enhances commuter experiences by providing a faster, more convenient, and safer cycle route to the working location, it is assumed that significant shifts in transport modes will remain modest.
The benefits of bicycle highways might be more appealing to commuters who already cycled on alternative routes. Skov-Petersen *et al.* (2017) and Goeverden *et al.* (2015) indicated that the users of improved cycle infrastructure mainly attribute people who already cycled before implementing the new infrastructure. This is in line with the results of the questionnaire. According to (Liu et al. (2019), achieving a mode shift towards cycling might be expected to be limited through implementing a bicycle highway. However, the higher quality of cycling still benefit commuters, and could make commuting a more enjoyable and healthy experience.

6. References

Agarwal, Ziemke and Nagel (2019) ‘Bicycle superhighway: An environmentally sustainable policy for urban transport’.

Agrawal and Schimek (2007) ‘Extent and correlates of walking in the USA’.

Ahanchian *et al.* (2019) ‘Analyzing effects of transport policies on travelers’ rational behaviour for modal shift in Denmark’.

Asensio and Matas (2007) ‘Commuters’ valuation of travel time variability’.

Banerjee *et al.* (2021) ‘Facilitating bicycle commuting beyond short distances: insights from existing literature’.

Bertolini and Dijs (2010) *Mobility Environments and Network Cities*. Available at: https://doi.org/10.1080/1357480032000064755.

Bertolini, L. (2009) *De planologie van Mobiliteit*. Amsterdam University Press.

Brand (2019) ‘The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities’.

Burian *et al.* (2018) ‘Attitudes and Motivation to Use Public or Individual Transport: A Case Study of Two Middle-Sized Cities’.

Buck, M. and Nurse, A. (2021) ‘Cycling in an“ordinary city”: A practice theory approach to supporting a modal shift’.

Breyer, N. (2021) *Methods for Travel Pattern Analysis Using Large-Scale Passive Data*. Linköping: Linköping University Electronic Press (Linköping Studies in Science and Technology. Dissertations). Available at: https://doi.org/10.3384/diss.diva-175347.

Buehler, R. (2011) ‘Determinants of transport mode choice: a comparison of Germany and the USA’.

Buekers *et al.* (2015) ‘Health impact model for modal shift from car use to cycling or walking in Flanders: application to two bicycle highways’.

Burian *et al.* (2018) ‘Attitudes and Motivation to Use Public or Individual Transport: A Case Study of Two Middle-Sized Cities’.

Cambridge dictonairy (2024) *commuter*. Available at: https://dictionary.cambridge.org/dictionary/english/commuter (Accessed: 5 February 2024).

Cambridge dictonairy (2024) *mobility*. Available at: https://dictionary.cambridge.org/dictionary/english/mobility (Accessed: 5 March 2024).

Charreire *et al.* (2021) ‘Walking, cycling, and public transport for commuting and non-commuting travels across 5 European urban regions: Modal choice correlates and motivations’.

Clark, Chatterjee and Melia (2016) ‘Changes to commute mode: The role of life events, spatial context and environmental attitud’.

van de Coevering, paul and Schwanen (2005) ‘Re-evaluating the impact of urban form on travel patterns in Europe and North-America’.

Collins and Chambers (no date) *Psychological and Situational Influences on Commuter-Transport-Mode Choice*. Available at: https://doi.org/10.1177/0013916504265440.

Cook *et al.* (2022) 'More than walking and cycling: What is "active travel"?' Available at: https://doi.org/10.1016/j.tranpol.2022.07.015.

CROW (2014) *Inspiratieboek snelle fietsroute*.

CROW (2016) *Design Manual for Bicycle Traffic. Ede: CROW.*

Dasgupta (no date) 'Rural Area'.

Dalvi and Martin (1978) 'The measurements of accessibility: some preliminary results.' Available at: doi:10.1007/BF00165245

Davis, A., Valsecchi, C. and Fergusson, M. (2007) 'Unfit for purpose: How car use fuels climate change and obesity'. Available at: https://trid.trb.org/View/847092 (Accessed: 17 January 2024).

Debele *et al.* (2020) 'Dependence between travel distance, individual socioeconomic and health_related characteristics, and the choice of the travel mode: a cross-sectional study for Kaunas, Lithuania'.

Dekoster, J. and Schollaert, U. (1999) *Cycling: the way ahead for towns and cities*. Luxembourg: Office for Official Publications of the European Commission.

de Geus, B. *et al.* (2008) 'Psychosocial and environmental factors associated with cycling for transport among a working population', *Health Education Research*, 23(4), pp. 697–708. Available at: https://doi.org/10.1093/her/cym055.

de Groot (2007) 'Design manual for bicycle traffic, CROW (Centrum voor Regelgeving en Onderzoek in de Grond-, Water-, en Wegenbouw en de Verkeerstechniek), The Netherlands.'

Ding *et al.* (2017) 'Exploring the influence of built environment on travel mode choice considering the mediating effects of car ownership and travel distance'.

Djurhuus *et al.* (2014) 'Individual public transportation accessibility os postively associated with seld-reported active commuting'.

Doorfietsroute (no date) *Assen*. Available at: https://www.doorfietsroute.nl/assen (Accessed: 17 April 2024).

Drenthe (2019) *Over de provincie*, *Provincie Drenthe*. Drenthe. Available at: https://www.provincie.drenthe.nl/organisatie-bestuur/over-de-provincie/ (Accessed: 17 March 2023).

Eemskrant (2017) *Elektrische fiets voor veel forenzen Groningen goed alternatief*, *Eemskrant.nl | Nieuws uit de regio Eemsdelta*. Available at: https://www.eemskrant.nl/elektrische-fiets-forenzen-groningen-goed-alternatief/ (Accessed: 22 June 2024).

Esri (no date) *Find the shortest path and generate directions with Route—ArcGIS Pro | Documentation*. Available at: https://pro.arcgis.com/en/pro-app/3.1/help/analysis/networks/route-tutorial.htm (Accessed: 17 April 2024).

European Commission (no date) *Glossary:Modal split of passenger transport*. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Modal_split_of_passenger_transport (Accessed: 12 March 2024).

Ewing and Cervero (no date) *Travel and the Built Environment: A Synthesis*. Available at: https://doi.org/10.3141/1780-10.

Ewing, Schoeer and Greene (2004) *School Location and Student Travel Analysis of Factors Affecting Mode Choice*. Available at: https://doi.org/10.3141/1895-08.

Gallimore, Brown and Werner (2011) 'Walking routes to school in new urban and suburban neighborhoods: An environmental walkability analysis of blocks and routes'.

Gardner (2008) 'Modelling motivation and habit in stable travel mode contexts'.

van Goeverden, K. *et al.* (2015) 'Interventions in bicycle infrastructure, lessons from Dutch and Danish case'.

Goodwin, P. b. (1975) 'Variations in travel between individuals living in areas of different population density', *Proceedings of the International Research Council on the Biomechanics of Injury conference*, 3, pp. 256–370.

Goudappel Coffeng (2018) *ONDERZOEK REISTIJDBELEVING FIETSERS*. Available at: https://rwsenvironment.eu/subjects/sustainable-mobility/toolbox-smart-mobility-management/bicycle/map/fact-sheet-cycling-infrastructure/ (Accessed: 7 June 2024).

Grigoropoulos, G. *et al.* (2021) 'Traffic Simulation Analysis of Bicycle Highways in Urban Areas'.

Grudgingsa *et al.* (2018) 'Why don't more women cycle? An analysis of female and male commuter cycling mode-share in England and Wales.

Guit, H. (2024) 'Asser gedeelte fietssnelweg naar Groningen feestelijk geopend met taart en smoothies'.

Ha, Lee and Ko (2020) 'Unraveling the impact of travel time, cost, and transit burdens on commute mode choice for different income and age groups'.

Haakman, Beenakker and Geerlings (2019) 'Reducing vehicle-related NOx and PM emissions in metropolitan areas: A comparison between the Randstad and the Rhine-Ruhr area'.

Haartsen, T., Huigen, P.P.P. and Groote, P. (2003) 'Rural Areas in the Netherlands', *Tijdschrift voor Economische en Sociale Geografie*, 94(1), pp. 129–136. Available at: https://doi.org/10.1111/1467-9663.00243.

Hallberg, M., Rasmussen, T.K. and Rich, J. (2021) 'Modelling the impact of cycle superhighways and electric bicycles', *Transportation Research Part A: Policy and Practice*, 149, pp. 397–418. Available at: https://doi.org/10.1016/j.tra.2021.04.015.

Hansen and Nielsen (2014) 'Exploring characteristics and motives of long distance commuter cyclists'.

Haojie, L. *et al.* (2018) 'Effects of the London Cycle Superhighways on the usage of the London Cycle Hire'.

Hatami *et al.* (2023) 'Non-Linear Associations Between the Urban Built Environment and Commuting Modal Split: A Random Forest Approach and SHAP Evaluation'.

Haustein (2011) 'Mobility behavior of the elderly: an attitude-based segmentation approach for a heterogeneous target group'.

Heinen, Maat and Wee (2010) ‘The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances’.

Hendriksen, I. (2015) ‘Elektrisch fietsgebruik in het woon-werkverkeer ter vervanging van de auto’:

Hollweck, T. (2016) ‘Robert K. Yin. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage. 282 pages.’, *The Canadian Journal of Program Evaluation*, 30. Available at: https://doi.org/10.3138/cjpe.30.1.108.

Humagain and Singleton (2020) ‘Investigating travel time satisfaction and actual versus ideal commute times: A path analysis approach’. Available at: https://doi.org/10.1016/j.jth.2020.100829.

Hull and Holleran (2014) ‘Bicycle infrastructure: can good design encourage cycling?’

Jang and Joonhp (2019) ‘Factors associated with commuter satisfaction across travel time ranges’. Available at: https://doi.org/10.1016/j.trf.2019.09.019.

Jang, Yuan and Lopez (2021) ‘Investigating Sustainable Commuting Patterns by Socio-Economic Factors’.

Jensen, O.B. (2013) *Staging Mobilities*. Routledge.

Jonkeren, Wust and de Haas (2019) ‘Mobiliteit in stedelijk Nederland’. Kennisinstituut voor Mobiliteitsbeleid.

Kaszczyszyn and Dutkowska (2019) ‘Walking Access to Public Transportation Stops for City Residents.’

Kim, T.J. (2009) *Transportation Engineering and Planning - Volume I*. EOLSS Publications.

Klöckner and Friedrichsmeier (2011) ‘A multi-level approach to travel mode choice – How person characteristics and situation specific aspects determine car use in a student sample’.

Koska, T. and Rudolph, F. (2016) ‘The Role of Walking and Cycling in Reducing Congestion’.

Koszowski, *et al.* (2019) ‘Active Mobility: Bringing Together Transport Planning, Urban Planning, and Public Health’.

Lipps and Kunert (2005) ‘Measuring and explaing the increase of travel distance: A multilevel analysis using repeated cross sectional travel surveys’.

Liu *et al.* (2019) ‘Practitioners’ perspective on user experience and design of cycle highways’.

Macedo *et al.* (2022) ‘Cycle Highway Effects: Assessing Modal Shift to Cycling in the Netherlands’.

Manum, B. *et al.* (2019) *Using Realistic Travel-time Thresholds in Accessibility Measures of Bicycle Route Networks*.

Merriam-Webster dictonairy (2024) *Definition of CASE STUDY*. Available at: https://www.merriam-webster.com/dictionary/case+study (Accessed: 5 March 2024).

Mills, A., Durepos, G. and Wiebe, E. (2010) *15. Mills, A. J., Durepos, G., and Wiebe, E. [Eds.] (2010) Encyclopedia of Case Study Research, Volumes I and II. Thousand Oaks, CA: Sage*.

Mölenberg *et al.* (2019) ‘A systematic review of the effect of infrastructural interventions to promote cycling: strengthening causal inference from observational data’. Available at: https://doi.org/10.1186/s12966-019-0850-1.

Municipality Copenhagen (2014) 'COPENHAGEN SOLUTIONS FOR SUSTAINABLE CITIES'.

de Nazelle, A. (2011) 'Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment'.

Nordengen, S. *et al.* (2019) 'Correlates of Commuter Cycling in Three Norwegian Counties', *International Journal of Environmental Research and Public Health*, 16(22), p. 4372. Available at: https://doi.org/10.3390/ijerph16224372.

Oakil, A.T. *et al.* (2011) 'A longitudinal analysis of the dependence of the commute mode switching decision on mobility decisions and life cycle events.', in.

Oja, P. *et al.* (2011) 'Health benefits of cycling: a systematic review', *Scandinavian Journal of Medicine & Science in Sports*, 21(4), pp. 496–509. Available at: https://doi.org/10.1111/j.1600-0838.2011.01299.x.

Office for cycle superhighways (2018) 'Cycle superhighways'.

Olde Kalter and Groenendijk (2018) 'Nationaal verkeerskundecongres 2018 Aantrekkelijkheid en afwisseling routes meer sturend in keuzegedrag fietsers dan snelheid'.

Poltimäe *et al.* (2022) 'In search of sustainable and inclusive mobility solutions for rural areas'.

Pourhashem *et al.* (2022) 'Gender Difference in Perception of Value of Travel Time and Travel Mode Choice Behavior in Eight European Countries'.

Provincie Groningen (2020) 'Verbinden met de fiets | Uitvoeringsprogramma Fiets 2020-2023'.

Pucher, J. and Buehler, R. (2008) 'Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany', *Transport Reviews*, 28(4), pp. 495–528. Available at: https://doi.org/10.1080/01441640701806612.

Pucher, J. and Buehler, R. (2012) *City Cycling*. MIT Press.

Quandt (1967) 'Estimation of modal split'.

Rayaprolu, Llorca and Moeckel (2020) *Impact of bicycle highways on commuter mode choice: A scenario analysis*. Available at: https://doi.org/10.1177/2399808318797334.

Raza *et al.* (2018) 'Air pollution as a risk factor in health impact assessments of a travel modeshift towards cycling'.

Rich, J. *et al.* (2020) 'Cost-benefit of bicycle infrastructure with e-bikes and cycle superhighways'.

Rigal, A. and Bahrami, F. (2017) 'Spaces of effort, exploration of an experience of mobility', *Applied Mobilities*, 2, pp. 85–99. Available at: https://doi.org/10.1080/23800127.2017.1285195.

RIVM (no date) *Bijna een derde van fietsers in Nederland gebruikt een elektrische fiets | RIVM*. Available at: https://www.rivm.nl/nieuws/bijna-derde-van-fietsers-in-nederland-gebruikt-elektrische-fiets (Accessed: 17 April 2024).

Rodriguez and Joo (2004) 'The relationship between non-motorized mode choice and the local physical environment'.

Romanillos and Gutierrez (2019) *Cyclists do better. Analyzing urban cycling operating speeds and accessibility*. Available at:

https://www.tandfonline.com/doi/epdf/10.1080/15568318.2019.1575493?needAccess=true (Accessed: 17 April 2024).

Schaap, Kansen and Harms (2016) 'Cycling and walking: the grease in our mobility chain'.

Scheepers, E. *et al.* (2013) 'Personal and Environmental Characteristics Associated with Choice of Active Transport Modes versus Car Use for Different Trip Purposes of Trips up to 7.5 Kilometers in The Netherlands', *PLoS ONE*. Edited by N.C. Barengo, 8(9), p. e73105. Available at: https://doi.org/10.1371/journal.pone.0073105.

Sealens, Sallis, J.F. and Lawrance (2003) 'Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literature'.

Sinko, Prah and Kramberger (2021) 'Spatial Modelling of Modal Shift Due to COVID-19'.

Sivasubramaniyam, Charlton and Sargission (2019) 'Mode choice and mode commitment in commuters'.

Skov-Petersen *et al.* (2017) 'Effects of upgrading to cycle highways - An analysis of demand induction, use patterns and satisfaction before and after'.

Snellen, Borgers and Timmermans (2002) *Urban Form, Road Network Type, and Mode Choice for Frequently Conducted Activities: A Multilevel Analysis Using Quasi-Experimental Design Data*. Available at: https://doi.org/10.1068/a349.

Sommar, J.N. *et al.* (2021) 'Potential for reduced premature mortality by current and increased bicycle commuting: a health impact assessment using registry data on home and work addresses in Stockholm, Sweden', *BMJ Open Sport — Exercise Medicine*, 7(1), p. e000980. Available at: https://doi.org/10.1136/bmjsem-2020-000980.

Song, Y., Preston, J. and Ogilvie, D. (2017) 'New walking and cycling infrastructure and modal shift in the UK: A quasi-experimental panel study', *Transportation Research. Part A, Policy and Practice*, 95, pp. 320–333. Available at: https://doi.org/10.1016/j.tra.2016.11.017.

Statistiek, C.B. voor de (no date) *Wijk- en buurtkaart 2023*, *Centraal Bureau voor de Statistiek*. Available at: https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische-data/wijk-en-buurtkaart-2023 (Accessed: 5 March 2024).

Steg, L., Vlek and Slotegraaf (2001) 'Instrumental-reasoned and symbolic-affective motives for using a mtor car'.

Steinbach *et al.* (2011) 'Cycling and the city: A case study of how gendered, ethnic and class identities can shape healthy transport choices'.

Steiner (no date) 'Residential Density and Travel Patterns: Review of the Literature'.

Stewart, Anokye and Pokhrel (2015) 'What interventions increase commuter cycling? A systematic review'.

Streefkerk, R. (2019) *Transcribing an Interview | 5 Steps & Transcription Software*, *Scribbr*. Available at: https://www.scribbr.com/methodology/transcribe-interview/ (Accessed: 2 July 2024).

Sun, Q. *et al.* (2020) 'Modal shift implications of e-bike use in the Netherlands: Moving towards sustainability?', *Transportation Research Part D: Transport and Environment*, 78, p. 102202. Available at: https://doi.org/10.1016/j.trd.2019.102202.

Tao, Fu and Comber (2018) ‘An analysis of modes commuting in urban and rural areas’.

Thaler, R. and Sunstein, C. (2009) *NUDGE: Improving Decisions About Health, Wealth, and Happiness*, *Nudge: Improving Decisions about Health, Wealth, and Happiness*.

Timmerman *et al.* (2002) ‘Spatial context and the complexity of daily travel patterns: an international comparison’.

Ul-Abdin, Z. *et al.* (2020) ‘Analytical geometric design of bicycle paths’, *Proceedings of the Institution of Civil Engineers - Transport*, 173(6), pp. 361–379. Available at: https://doi.org/10.1680/jtran.17.00162.

Ungvarai, A. (2019) ‘Modal Split – Different Approaches to a Common Term’.

Van Acker, V. and Witlox, F. (2010) ‘Commuting trips within tours: how is commuting related to land use?’

van Lierop *et al.* (2020) ‘Wayfinding for cycle highways: Assessing e-bike users’ experiences with wayfinding along a cycle highway in the Netherlands,’.

Vanoutrive and Huyse (2023) ‘Revisiting modal split as an urban sustainability indicator using citizen science’.

Vedel, Jacobsen and Skov-Petersen (2017) ‘Bicyclists’ preferences for route characteristics and crowding in Copenhagen – A choice experiment study of commuters’. Available at: http://dx.doi.org/10.1016/j.tra.2017.04.006 d.

Wesley, Marshall and Norman (2024) *Effect of Street Network Design on Walking and Biking*. Available at: https://doi.org/10.3141/2198-12.

Williams (1971) ‘The Modal Split: The Relevance of American Experience for Britain’.

Yang *et al.* (2018) ‘Understanding the determinants of travel mode choice of residents and its carbon mitigation potential’.

Yiannakoulias, Bland and Svenson (2013) ‘Estimating the effect of turn penalties and traffic congestion on measuring spatial accessibility to primary health care’. Available at: https://www.sciencedirect.com/science/article/pii/S0143622812001683.

Yuan *et al.* (2023) ‘Intersectionality and urban mobility: A systematic review on gender differences in active transport uptake’.

Appendix 1: Transcription semi-structured interview

Interviewer:
Kunt u mij wat vertellen over uw achtergrond, plek waar u werkt, plek waar u woont, wat voor uw werk u doet.

Respondent:
Mijn werkplek is al langere tijd in het centrum van Groningen. Ik woonde 5 jaar geleden nog in Hoogezand op 15 kilometer van mijn werk. Toen ik voor het eerst in de stad ging werken (want ik werkte eerder in dorpen) werd ik gedwongen om na te denken over hoe ik reis. Dat begon er eerst mee dat ik niet van het OV houd. Als reiziger maak ik niet graag gebruik van het openbaar vervoer. Eerder ging ik met de auto naar een P+R locatie in de stad (waar ik dan een fiets had staan) en dan fietste ik het laatste stukje naar mijn werk toe. Alleen toen zijn er op een gegeven moment 3x fietsen gestolen, waardoor de betrouwbaarheid een probleem werd. Via een campagne ben ik vervolgens op het idee gekomen om een speedpedelec te kopen. Via Hoogezand fietste ik toen 15 kilometer, wat ongeveer 25 minuten fietsen was. Toen ben ik 5 jaar gelegen terug naar Eext verhuisd. Eext is een dorpje in de buurt van Gieten. Eext is 28 kilometer fietsen naar Groningen, 28 kilometer zonder een stoplicht. Dat fiets ik in ongeveer 3 kwartier.

Interviewer:
Dat is snel.

Respondent:
Ja en dat is ook wat ik leuk vind, het snelle. Wat ik met name van belang vind is de betrouwbaarheid van de reistijd. Als ik een enkele keer gebruik maak van de auto dan parkeer ik niet bij mijn werk, want dat kost mij 22 euro per dag. De werkgever faciliteert het parkeren niet dus als ik met de auto ga dan parkeer ik bij P+R Haren en dan pak ik de bus, waardoor ik ook 45 minuten onderweg ben. Als ik helemaal met de bus ga moet ik eerst 10 minuten fietsen, heb ik een beetje wachttijd , moet ik vervolgens 25 minuten met de bus waardoor ik uiteindelijk weer 3 kwartier onderweg ben. Qua tijd is het allemaal ongeveer het zelfde. Dat vind ik altijd wel een leuke vergelijking.

Interviewer
Alleen de fiets is dus qua betrouwbaarheid wel een stuk prettiger?

Respondent:
Ja er moet iets heel geks gebeuren wil je 10 minuten vertraging hebben. Dat gebeurt eigenlijk nooit. Terwijl dat met de bus of met de auto eigenlijk wel vrij makkelijk zou kunnen. Daarnaast is voor mij het fysieke ook wel erg belangrijk. Ik vind het fysieke en psychische erg prettig, dat zodra ik thuis kom, ik een leeg hoofd heb en ik niet meer weet wat ik op het werk heb gedaan, dat vind ik fijn. Ik ben wel bijna 2 uur per dag aan het fietsen, dat vind ik een belangrijk onderdeel.

Interviewer
Dat zijn direct ook wat antwoorden op de volgende vragen die ik had. Mijn volgende vraag die ging over het reisgedrag ging over de alternatieve vervoersmiddelen. Ik begrijp dat die er nog steeds zijn zoals bijvoorbeeld het gebruik van de auto.
Is het wel het vanuit een bepaald gedrag dat de voorkeur uit gaat naar de fiets, of hangt dit nog wel af van de situatie?

Respondent:
Ik ga eigenlijk altijd met de fiets, het weer maakt mij eigenlijk niet uit. Zelfs met sneeuw fiets ik ook gewoon. Wanneer er ijzel ligt werk ik thuis, ik kan ook gewoon thuis werken. Eigenlijk is het weer geen factor.

Interviewer
Alleen een factor die bepaalt of u wel of niet fysiek naar uw werk gaat dus?

Respondent:
Precies. Als ik een keer met de auto ga dan moet er echt een speciale reden voor zijn, dat ik bijvoorbeeld eerst naar werk ga en vervolgens naar een bepaalde locatie moet die heel erg moeilijk te bereiken is met het OV. Met het OV ga ik eigenlijk alleen als mijn fiets kapot is of wanneer ik geblesseerd ben.

Interviewer
Precies, en de motivatie om te fietsen komt dus ook wel voort uit het fysieke aspect en het hoofd willen leegmaken.

Respondent:
Ja en ook wel de onafhankelijkheid. Als ik naar huis ga kan ik direct op de fiets stappen en hoef ik niet te denken qua timing, ik heb een hekel aan wachten. Met het OV moet je altijd iets van wachttijd incalculeren of je moet rennen. Dat vind ik altijd erg vervelend. Alleen met de auto kan eigenlijk ook niet, want dan moet ik alsnog met het openbaar vervoer. Dan pak ik alsnog dezelfde bus die ook vanuit Gieten vertrekt, dat voelt dan een beetje dubbel.

Interviewer
Zou je de keuze voor de auto wel kunnen maken als er genoeg parkeerplekken zouden zijn, of wanneer dit makkelijker is?

Respondent:
Dat vind ik een heel interessant gedachte experiment. Stel dat we hier parkeerplekken zouden hebben dan denk ik dat ik iets vaker met de auto zou gaan alleen doordat ik het fietsen nu zo gewend ben, denk ik dat dat niet vaak zou zijn.

Interviewer
Heeft de fietssnelweg enige vorm van beïnvloeding gehad voor de keuze om de fiets te pakken?

Respondent:
Nee, nee. Want zoals die er op dit moment is, is het nog steeds erg matig. De stukken die klaar zijn, zijn heel mooi, maar er zijn hele grote stukken nog niet klaar. Wel vervelend dat het zo lang duurt. Maar als je 4 m breed beton pad kan hebben en verderop moet je over een modderig stukje schelpenpad, dan kies ik per saldo liever voor mijn gewone kortste fietsroute en voor mijzelf is het ook nog van belang dat de kortste route gewoon die ik nu fiets 28 km is en via de fietssnelweg is het 33 kilometer. Dat is 5 kilometer om. Soms doe ik het wel voor de afwisseling, omdat het wel een mooie leuke route is maar niet voor de snelheid.

Interviewer:
Dan begin je wel in Assen wanneer je de fietssnelweg gebruikt?

Respondent:
Nee dan fiets ik via Eext, Anloo, Gasteren en dan naar die brug bij Oude Molen daar. Vanaf daar pak ik de fietssnelweg. Via Assen zou echt 15 kilometer om zijn denk ik.

Interviewer:
Wat zijn de voordelen die je ervaart tijdens het fietsen over de fietssnelweg, ten opzichte van andere fietsinfrastructuur?
Die zijn heel groot. 'Andere fiets infrastructuur' is natuurlijk maar net wat je als voorbeeld neemt. Als ik het met mijn dagelijkse route vergelijk, dan mag ik alleen binnen mijn eigen gemeente op het fietspad in AA en Hunze. En zodra ik in de gemeente Tynaarlo en Groningen fietst, dan moet ik op de rijbaan met mijn speedpedelec. Als ik daar over die fietssnelweg moet dan heeft het als voordeel gehad dat je bijna geen kruisend verkeer hebt. Geen erfinritten dus. Als ik bijvoorbeeld bij Noordlaren een smal fietspad heb met bomen en auto's die van hun eigen oprit rijden of erin rijden heb je een groot risico op ongelukken. Maar vergeleken met de rijbaan is het grote voordeel dat je geen auto's hebt. Als je een speedpedelec hebt kies je er wel voor maar je fietst wel tussen de auto's, vrachtwagens en bussen. De wegen in de gemeente Tynaarlo zijn nog eens niet erg breed, waardoor het erg gevaarlijk kan zijn.

Interviewer:
Dus de fietssnelweg verhoogt dus ook wel echt het veiligheidsgevoel?

Respondent:
Ja klopt, veiligheid en comfort. Dat wat er is, is wel heel mooi glad zowel voor de racefiets als de Speed Pedelec. Dat is wel heel fijn, je hoeft niet continu op te letten op verkeer want dat is er gewoon veel minder

Interviewer:
Het is ook nog een stuk breder dan een normaal fietspad wat wellicht comfort maar ook veiligheid vergoot?
Op bepaalde stukken heb je nog wel woningen staan, direct aan de fietssnelweg. Wellicht dat je daar af en toe nog een auto ziet?

Respondent:
Jawel, alleen dat vind ik geen bezwaar, het is in ieder geval al een stuk beter dan wat ik normaal op de route heb.

Interviewer:
Ervaar je enige verandering in rijstijl door de fietssnelweg, stimuleert het bijvoorbeeld dat je harder fietst en daardoor ook minder lang over je reis doet, ondanks dat de route niet korter is dan andere alternatieven?

Respondent:
Dat ik de route toch af en toe gebruik, dat zegt ook wel genoeg, dat ik er 5 kilometer voor om fiets. Mijn rijstijl is niet anders, want ik fiets altijd zo snel als ik kan, dat is 42/43 kilometer per uur

Interviewer:
Want dan blokkeert het systeem?

Respondent:
Dan stopt de ondersteuning. Ik kan wel harder maar dan moet ik heel hard trappen. Mijn rijstijl verandert in de zin dat ik minder hoef op te letten. Dan ben je lekkerder aan het fietsen. Het zit het hem vooral in de kruizingen.

Interviewer:
Dat je overal voorrang hebt dat beïnvloedt eigenlijk je reistijd.

Respondent:
Niet eens dat je voorrang hebt want ik ga er ook bij de fietssnelweg altijd van uit dat wanneer je voorrang hebt, niet iedereen dat weet of geeft. Dus ik ben dan altijd wel heel alert, maar van wat ik mij zo even voor de geest kan halen, de kruisingen die er zijn, zijn zo overzichtelijk dat je al snel ziet of er een auto aan komt. Dat is bij mijn dagelijkse fietsroute niet zo. Daar moet je wel continue opletten, omdat er altijd een auto uit een zijstraatje kan komen. Dat is bij de fietssnelweg wel echt beter.

Interviewer:
Dat geldt dan alleen voor de nieuwe stukken?

Respondent:
Ja

Interviewer:
De andere stukken die nog ontwikkelt moeten worden, daar zou je dan wellicht iets alerter moeten zijn?

Respondent:
Er zijn sowieso kruisende wegen, er zijn ook weinig woningen vergeleken met de route die ik normaal fiets. Het is daardoor wel veel veiliger en comfortabeler.

Interviewer:
Vind je dat de fietssnelweg in de huidige situatie toegankelijk is en dat de fietssnelweg goed aansluit op belangrijke locaties? *Want als je bijvoorbeeld bij Assen Noord had gelegd waar nu ook een fietspad ligt dan denk ik dat dat veel efficiënter zou zijn?*

Respondent:
Omdat ik de fietssnelweg alleen gebruik vanuit mijn eigen huis naar mijn eigen werk denk ik daar verder niet zo heel veel over na. Als je hebt over voorzieningen bedoel je ook anderen fietspaden of ook bijvoorbeeld een ziekenhuis?

Interviewer:
Nou wat er zeg maar in literatuur vaak gezegd wordt is dat het een soort hoofddader moet zijn in het fietsnetwerk, die belangrijke locaties moet verbinden, niet perse direct maar wel indirect ,dus goed aan moet sluiten op andere fietspaden.

Respondent:
Ik denk dat het belangrijk is dat je in Assen of Groningen of in het dorp richting het begin van die doorfietsroute begeleid wordt. Hier heb je ook op het Damsterplein iets op de weg getekend met 'doorfietsroute naar Ten Boer' dat je daar langs het water moet. Dat helpt dan als je mensen daar

heen wilt krijgen. Stel: ik ga ook vaak die speedpedelec na overleggen in Assen, als je gebruik wilt maken van de fietssnelweg kom je vaak uit bij een moeilijker te vinden deel van de fietssnelweg. Voor mij is dat persoonlijk geen probleem, alleen je wordt dan wel meer overgeleverd aan de wegbewijzering die je daar hebt.

Interviewer:
Wanneer de fietssnelweg helemaal gerealiseerd is moet die natuurlijk van station naar station liggen. Misschien dat dit dan wel wat verbetert. Momenteel eindigt de fietssnelweg heel abrupt in Groningen. Je komt direct op een druk punt uit.
Heb je wel het idee dat de fietssnelweg forenzen stimuleert om de fietssnelweg, of dat de huidige opzet meer mensen aantrekt die gewoon recreëren.

Respondent:
Wat ik zie, dat de route op veel verschillende manieren wordt gebruikt. Bijvoorbeeld recreatief doormiddel van ouderen op een e-bike, maar ook sportief doormiddel van racefietsen. Forenzen zie je ook wel, maar ook bijvoorbeeld mede gebruik roeicoaches van de roeivereniging. Er zijn altijd wel mensen die mee fietsen. Ik denk ook niet perse dat het belangrijk is dat je van Assen naar Groningen van A naar B kan, maar dat er een bepaalde symboliek is, vanwege media aandacht. Dat je ook gebruik krijgt van mensen die wat verder van de fietssnelweg af wonen, die ook eens gaan nadenken om met de fiets naar werk te gaan.

Interviewer:
Ja de fietssnelweg zorgt wellicht voor wat bewustwording. Dat de fiets een alternatief is.

Respondent:
Dat is bij mij in het dorp ook zo, waar zeker niet veel gefietst wordt, zeker niet naar Groningen. Iedereen vraagt dan "Oh ga je over de fietssnelweg" dat weten de mensen dan wel, de fietssnelweg is wel erg bekend.

Interviewer:
Ik vraag mij dan wel af hoe dat bijvoorbeeld in Assen is, aangezien er ook andere alternatieve fietsroutes zijn. Zal de fietssnelweg daar ook voor meer bewustwording hebben gezorgd.
Volgende vraag: Zie je verder veel andere mensen gebruik maken van de fietssnelweg?

Respondent:
Dat is moeilijk te zeggen. Ik fiets ook niet dagelijks naar Groningen en ook niet altijd over de fietssnelweg. Daardoor is het niet betrouwbaar genoeg om er iets over te zeggen.

Interviewer:
Je ziet ook niet bijvoorbeeld een duidelijk verschil in verschillende trajecten van de fietssnelweg. Dat bijvoorbeeld Groningen-Haren drukker is dan andere trajecten.

Respondent:
Jawel, maar ook daarin zou ik voorzichtig zijn met het trekken van een conclusie. In dat traject wonen namelijk veel meer mensen. Voor mijn dagelijkse route, via Zuidlaren, Midlaren, Haren en Groningen ga, hoe dichter je bij de stad komt hoe meer mensen er fietsen. Ik fiets ook vaak erg vroeg om een beetje voor de spits aan te komen. Ik ben dan 45 minuten aan het fietsen, hoe verder ik kom hoe later het is en dus ook hoe drukker het is. Dat is moeilijk te zeggen dus.

Interviewer:
Heb je suggesties voor verbetering van de fietssnelweg?

Respondent:

Eerst afmaken. Sowieso zou ik denken eerst afmaken dus de steden en ook de aanlanding in de steden zoals ze dat noemen, dus zorgen dat het ook op het stedelijke fiets netwerk aansluit. Een andere verbetering zou zijn dat je geen medegebruikers meer hebt, of minder medegebruik. Daar waar mensen langs de route wonen snap ik dat je dat nooit zal bereiken, maar zeker tussen Tynaarlo en de De Punt zie je dat veel autoverkeer gebruik maakt van de fietssnelweg. Dat zou een verbetering kunnen zijn.

Interviewer:
Dus echt alleen gericht op autoverkeer of ook ander verkeer?

Respondent:
Nee vooral autoverkeer. Mensen die er gewoon langs rijden en ook erg hard rijden. Een verbetering zou zijn om te kijken of je daar wat aan kan doen. Voor de rest als het erg ligt breed en goed onderhouden. Richting Hoogezand bijvoorbeeld heb je een redelijk fietspad, maar op het gegeven moment staat het gras zo hoog dat het fietspad erg smal wordt. Zorg ervoor dat je bermen goed maait. Dan heb ik verder niet zoveel nodig.

Interviewer:
Is dat op dit moment wel goed georganiseerd?

Respondent:
Dat kan wel beter

Interviewer:
En met gladheid, wordt daar direct op gereageerd?

Respondent:
Dat verschilt per gemeente, maar dat kan ook beter
En nog een ding, medegebruik door landbouwverkeer betekent ook dat er vaak veel modder ligt en dat is vaak irritant maar ook gevaarlijk. Als dat nat wordt dan wordt het gewoon erg glad.

Interviewer:
Ja precies, dat richt zich dan weer op het medegebruik.
Ik vroeg mij ook nog af of er dan nog een duidelijk verschil zit voor verschillende locaties van de fietssnelweg. Ik denk echter dat dat wel afhankelijk is van de delen die nog niet gerealiseerd zijn en de delen die al wel af zijn.

Respondent:
Ik denk dat wat juist goed is, dat je overal het zelfde ontwerp na streeft. Voorspelbaarheid is daarin erg belangrijk, dat je weet dat je bij elke kruising voorrang hebt, zodat je daar niet over na hoeft te denken. Een belangrijk voorbeeld is dat, de fietser in Groningen op rotondes bijna altijd voorrang

heeft, maar in Drenthe bijna nooit. Als je dan de provinciegrens over gaat en ineens is die situatie anders, dat is niet optimaal.

Interviewer:
Ja precies en dat zou misschien ook voor het onderhoud kunnen gelden dat er overal het zelfde beleid wordt gevoerd zonder duidelijke verschillen tussen gemeentes.
Volgende vraag: Denk je dat je in de toekomst nog veel gebruik gaat maken van de fietssnelweg?

Respondent:
Ja.

Interviewer:
En gaat dat ook toenemen wanneer de fietssnelweg helemaal af is?

Respondent:
Jazeker. Als je in ieder geval de gevaarlijke kruisingen weg kunt nemen, zoals bijvoorbeeld bij Ketwich Verschuurbrug of de Van Iddekingeweg dan vind ik dat al goed genoeg. Dan hoeft voor mij de fietssnelweg nog niet eens tot aan het station gelegen te zijn. Als je alleen maar fietst is dat in principe niet een hele belangrijke bestemming.

Interviewer:
Nog een laatste vraag: zou je het fietsen naar werk ook doen op een normale fiets? Nu heb je een speedpedelec, wat denk ik wel een belangrijke rol speelt in uw reisgedrag.

Respondent:
Ik zou dat niet altijd doen. Als ik op een gewone fiets zal gaan zal ik ongeveer tussen de 22-23 kilometer per uur fietsen. Als ik een gewone e-bike zal nemen dan zal ik ongeveer 3 kilometer per uur sneller gaan, terwijl mijn conditie achteruit gaat. Met de speedpedelec moet ik wel echt hard trappen en gaat de snelheid wel echt vooruit. Maar op een gewone fiets zal ik zeker niet altijd gaan fietsen. Ik pak in de zomer ook regelmatig de racefiets. Het is dan wel belangrijk dat je op je werk een kleedruime en douche hebt.

Appendix 2: Transcription semi-structured interview (translated)

Interviewer:

Could you share some insights about yourself, including your work location and the nature of your work?

Respondent:
My workplace has been in the center of Groningen for a long time. Five years ago, I lived in Hoogezand, 15 kilometers from my work. When I started working in Groningen (previously, I worked mainly in villages), I had to think about my daily travel. For commuting purposes, I don't prefer public transportation. I used to drive to a P+R location in the city (where I placed a bicycle) and then cycled the last part to work. But then, my bikes were stolen three times, making it unreliable. Through a campaign, I got the idea to buy a Speed Pedelec. Then, I cycled 15 kilometers from Hoogezand, which took about 25 minutes. Five years ago, I moved back to Eext (Drenthe). Eext is a village near Gieten. Eext is 28 kilometers from Groningen, 28 kilometers without a traffic light. I cycle for about 45 minutes.

Interviewer:
That is fast.

Respondent:
Yes, and that's also what I like, the speed. What I prefer is the reliability of the travel time. If I usually use the car, I don't park at my work because it costs me 22 euros per day. The employer does not facilitate parking, so if I go by car, I park at P+R Haren and then take the bus, which also takes me 45 minutes. If I take the bus for the entire journey, I have to cycle for 10 minutes first, then I have to wait, and then afterward, I have to travel by bus for 25 minutes. This makes the total travel time again around 45 minutes. Timewise, it's all similar. I like that comparison.

Interviewer:
So, is the bike the most reliable option?

Respondent:
Yes, because something strange must have happened to delay me by 10 minutes by bicycle. That rarely happens. However, delays can happen quickly if I take the bus or car. Additionally, the physical aspect is essential to me. I like the physical and psychological benefits. When I come home, my mind is clean, and I don't think about my working day any more, which is a pleasure. I cycle for almost two hours per day.

Interviewer
That already answered some of the following questions. The next question I had was about travel behavior and alternative modes of transportation. I understand that alternatives like the car are still available. Is bike use habitual, or does it depend on the situation?

Respondent:
I almost always go by bike; the weather doesn't matter. Even in snowy conditions, I still cycle. When there is ice, I work from home, which I can do. So, the weather is not a factor.

Interviewer:
So, the weather determines if you go physically to work or not.

Respondent:
Exactly. If I use the car, there has to be a particular reason, such as when I have a meeting after work at a location that is difficult to reach by public transportation. I only use public transit if my bike is broken or when I'm injured.

Interviewer:
So, to summarize, the primary motivation to cycle is the physical and psychological aspects.

Respondent:
Yes, and also the independence. Going home, I can immediately get on the bike without worrying about timing. I hate waiting. With public transportation, you must always account for waiting time, or you have to run. I find it very annoying. The same applies to using the car because I still have to use public transport for the journey.

Interviewer:
Would you consider car use more often if there were enough parking spaces or if this was less complicated?

Respondent:
That's an interesting experiment. If there were more parking spaces here, I might use the car more often, but since I'm used to cycling, I don't think that would be very frequent.

Interviewer:
Did the bicycle highway influence your decision to cycle?

Respondent:
No, not the current state is still lacking. The finished sections are beautiful, but significant sections are still unfinished. It is frustrating that it takes so long.

Even though there are four-meter white concrete cycle paths, I still prefer to take my usual shortest bike route due to the muddy shell paths that are also part of the bicycle highway route. My usual shortest bike route takes 28 kilometers, compared to 33 kilometers if I take the bicycle highway. Sometimes, I use the bicycle highway for variety because it is an excellent route, but not for the speed.

Interviewer:
Do you then start in Assen?

Respondent:
No, I go through Eext, Anloo, Gasteren, and then to the bridge at Oude Molen. From there, I take the bicycle highway. Via Assen would be a 15-kilometer detour.
Interviewer;
What benefits do you experience when cycling on the bicycle highway compared to other cycling infrastructure?

Respondent:
The benefits are significant. On my daily route, I can only use the bike path in the municipality of AA en Hunze. Once I enter the municipalities of Tynaarlo and Groningen, I have to bike on the road with my speed pedelec. The advantage of the bicycle highway is that there is almost no crossing traffic and no driveways; for example, in Noordlaren, there is a narrow path with trees and cars entering and exiting their driveways, posing a higher accident risk. Compared to other roads, the advantage is that there are no cars. With a speed pedelec, you choose to cycle among cars, trucks, and buses; however, if the roads are narrow, this becomes dangerous.

Interviewer:
So, does the bicycle highway increase safety?

Respondent:
Yes, and comfort. The smooth, well-maintained surface is excellent for racing bikes and speed pedelecs. It's nice that you do not have to watch out for traffic constantly.

Interviewer:
The path is also wider than a standard bike path, which might enhance comfort and safety.

Still, in some locations, houses are near the bicycle highway. Does that result in any traffic on the bicycle highway?

Respondent:
Yes, houses still line the bicycle highway in certain sections, so you might occasionally see a car, but it is still much better than my usual route.

Interviewer:
Have you noticed any change in your cycling style on the bicycle highway? Do you drive faster, and is it shortening your travel time even though the route is not shorter than the other alternative?

Respondent:
The fact that I use the route sometimes says enough, as I have to cycle 5 kilometers extra. My riding style doesn't change; I always cycle as fast as possible, around 42 / 43 kilometers per hour.

Interviewer:
Because the system blocks at that speed?

Respondent:
Yes, I can go faster, but I have to pedal very hard when the assistant stops. My driving style changed because I have to pay less attention, which made cycling more enjoyable. This is mainly due to the decrease in intersections.

Interviewer:
Having priority everywhere, does this influence the cycle time?

Respondent:

It's not necessarily about the priority because I always assume that not everyone knows or gives it even if I have priority. I stay alert, but the intersections on the bicycle highway are clear, so you quickly see if a car is coming. That's not the case on my daily route, where you always have to watch for cars coming from the side streets. That is a real improvement of the bicycle highway.

Interviewer:
So, does that only apply to the newly constructed parts?

Respondent:
Yes.

***Interviewer**:*
You might have to be more alert on the other sections that need development.

***Respondent**:*
There are still fewer crossing roads and houses than on my usual route, which makes it much safer and more comfortable.

***Interviewer**:*
Do you think the bicycle highway is accessible in its current state, and are we connected to import locations?

***Respondent**:*
I don't think much about this since I used to bicycle from home to work. When we talk about facilities, do you mean other infrastructure or facilities such as hospitals?

***Interviewer**:*
Literature often says it should be the main route in the bicycle network, connecting important locations not necessarily directly but indirectly while connected to other cycle infrastructure.

***Respondent**:*
I think it's essential to be guided towards the start of the bicycle highways in Assen, Groningen, or any other village. For example, signage on the road at Damsterplein indicates the bicycle Highway to Ten Boer. That helps to guide people. Finding the bicycle highway can be complicated if you are somewhere in Assen. It is not a problem for me; however, other people might rely on the signage there.

Interviewer
When the bicycle highway is fully operational, it should ideally connect stations. This might improve things. Nowadays, the infrastructure ends abruptly in the city of Groningen at a buzzy crossing. Do you think the bicycle highway encourages commuters to use it, or does the current bicycle highway attract more recreational users?

Respondent:
I see many users on the route, such as older people using e-bikes for recreational purposes and other cyclists using them for sporting purposes. Commuters use it too, and rowing coaches from the rowing club also bike along the bicycle highway. I also don't think it's necessarily about getting from Assen to

Groningen but about the symbolic awareness. It also encourages people living further away from the bicycle highway to consider biking to work.

Interviewer:
Do you think the bicycle highway has raised more awareness, making cycling a more valid alternative?

Respondent:
I see it in the village where I live, where not many people cycle, particularly not to Groningen. Everyone asks me, "Do you use the bicycle highway to Groningen?". The bicycle highway is pretty famous.

Interviewer:
Do you see many other users making use of the bicycle highway?

Respondent:
It's hard to say. I do not travel daily to Groningen, and I do not always use the bicycle highway. I cannot make a reliable statement about that.

Interviewer:
Do you know there's a clear difference in usage between different sections of the bicycle Highway? For example, is Groningen-Haren busier than other sections?

Respondents:
Yes, but I would be cautious about concluding. More people live in that area. On my daily route through Zuidlaren, Midlaren, Haren, and Groningen, the closer I get to the city, the more people I see cycling. However, I often cycle early to avoid peak hours. I cycle for 45 minutes, so the closer I get, the later it is and the busier it gets. Therefore, it is hard to say.

Interviewer:
Do you have suggestions for improving the bicycle Highway?

Respondent:
Yes, first, finish it. Complete it first, including the connections with other cycle infrastructures in the city. Another improvement would be to reduce mixed-use. It's understandable where people live along the route, but especially between Tynaarlo and De Punt, there's a lot of car traffic using the bicycle highway. Reducing this would be an improvement.

Interviewer:
So only car use or also other types of traffic

Respondent:
There is mainly car traffic, with people driving along often at high speeds. Reducing this would help. Besides that, the cycle path needs to be well-maintained. For example, the path to Hoogezand is reasonable, but the grass grows so high that the path becomes narrow. The roadsides need to be well mowed. Furthermore, I don't need so much.

Interviewer:

Is that currently well organized?

Respondent:
That could be better.

Interviewer:
Is there an adequate response to slippery conditions?

Respondents:
This varies by municipality but could also be better. Another issue is mud caused by agricultural traffic, which is annoying and dangerous when it rains. It can become very slippery.

Interviewer:
I also wonder if there are apparent differences between the sections of the bicycle highway. I think it depends on which parts are completed.

Respondent:
It is essential to strive for the same design everywhere. Predictability is key, knowing you have priority at every crossing; you don't need to consider that. For example, cyclists in Groningen usually have priority at roundabouts, but in Drenthe, this is rarely the case. When you cross a provincial border, and the situation changes, that is not optimal.

Interviewer:
Exactly, and that could apply to maintenance as well. The same policy should be adopted everywhere without apparent differences between municipalities.

Interviewer:
Next question: do you think you will use the bicycle highway more often once the infrastructure is fully completed?

Respondent
Yes, if dangerous crossings like Ketwich Verschuurbrug or Van Iddenkingeweg are improved, that's good enough for me. The bicycle highway doesn't need to go to the Central Station, which is not an essential destination for commuters who only cycle.

Interviewer:
One last question: You regularly cycle on a speed pedelec, significantly influencing your travel behavior. Would you also cycle to work on a regular bike?

Respondent:
I wouldn't always do that. Then, I would cycle about 22 / 23 kilometers per hour. On a regular e-bike, I would be about three kilometers per hour faster, but my condition would deteriorate. With the speed pedelec, I'm working on my conditions while cycling at a higher speed. I wouldn't always commute by bicycle on a regular bike. In the summer, I also sometimes use my racing bike. However, having a changing room and a shower at work is also essential.

Appendix 3: Questions questionnaire

Consent:

- I have read the information and I give my consent to participate in this study.

Commuter's profile

- Can you tell me about your background, where you work, where you live, and what kind of work you do?
- In what ways do you travel to work?
- What is the distance you need to travel to work?
- Do you have a driving license
- How long does it take to commute to work on average, and does the travel time vary significantly by mode of transportation?
- Do you have a driving license?
- Is the place where you work accessible by car (from where you live?
- Is the place where you work accessible by public transport (from where you live?

Cycling to work

- What motivates you to cycle to work
- When you cycle to work, what type of bike do you use?
- Is cycling to work a habit, or does it strongly depend on the situation?
- Has the bicycle highway between Assen and Groningen influenced your decision to cycle to work? If yes, in what way?
- Did you cycle to work before the construction of a bicycle highway between Assen and Groningen?
- Do you cycle more often to work due to the construction of a bicycle highway between Assen and Groningen?

Use of the bicycle highway

- How often do you use the bicycle highway between Assen and Groningen?
- Does the bicycle highway between Assen and Groningen benefit you as a commuting cyclist, and if so, what are they?
- Did the bicycle highway between Assen and Groningen reduce the distance and travel time to your work?
- Do you use other cycling routes to your work?
- If you answered 'yes' to the previous question, what are your reasons for using the bicycle highway instead of the alternative routes?

Evaluation

- Do you think the bicycle highway is accessible in its current state, and does it connect well to key locations?
- Do you think the bicycle highway especially encourages commuters to cycle (or does the current route target other types of users)
- Do you have suggestions for improvements to the bicycle highway that could further promote its use (perhaps especially for commuters)?

Future

- Will you use the bicycle highway more frequently when the route is finished?

Appendix 4: Responses questionnaire

In this appendix the results of the questionnaire are presented. In total 17 commuters responded to the questionnaire. However, not all questions were required to answer, therefore some questions have more responses than others. Additionally, some answers are removed as people misinterpreted the question, which not provided a useful answer. The 3 most frequently mentioned answers are highlighted for each question.

Wat is de afstand die u moet afleggen naar werk?
What is the distance you have to travel to work?

- 20 kilometer
- 24 km
- 12 km (x2)
- Wisselend tussen ca 10 en 100 km.
- 4 km
- 11km
- 24 kilometer
- 13 kilometer
- 8km
- 5 kilometer
- 3 km
- (School) 6,6km
- 7,5 km fiets, 11 km auto
- 30
- 30km

Hoe lang bent u gemiddeld onderweg naar uw werk en verschilt de reistijd duidelijk per type vervoersmiddel?
How long does it take to commute to work on average, and does the travel time vary significantly by mode of transportation?

- 50 minuten met e-bike. In de wintermaanden gebruik ik het openbaar vervoer en is de reistijd 40 minuten van deur tot deur.
- Op de fiets 60 minuten, met de auto 30 minuten
- 35 min
- Ongeveer 45 - 60 minuten
- 10 min
- 20 minuten per velomobiel, verschil met auto ca 5 minuten.
- Met de trein ben ik gemiddeld een halfuur onderweg. Met de fiets is dit 45 minuten
- Op mijn e-bike ben ik 25 minuten onderweg en met de auto 15 minuten.
- 20m
- 10-15 minuten
- 8 min, qua tijd geen verschil welk vervoermiddel
- 20-25 minuten. Ik gebruik alleen de fiets
- 25 minuten fietsen, auto 10 minuten korter
- fiets: 45-50 minuten auto: 30 minuten
- Met de fiets 90 min. Met deels auto en fiets 60 min.
- 30 minuten. Met de auto steeds in file met fiets kun je mooi doorrijden.

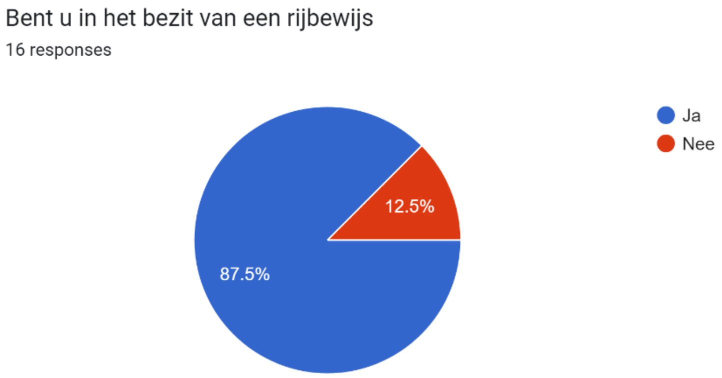

Figure 38: Do you have a driving lisence

Figure 39: Is your work location accessible by car?

Figure 40: Is you working location accessible by public transport (from where you live)

Wat is uw motivatie om de fiets te pakken naar werk?
What is your motivation to cycle to work?

- Buiten zijn, fietsen is ontspanning voor mij. Geen last van overvolle bussen.
- Gezondheid
- Dagelijkse beweging als onderdeel van vast patroon, bijna net zo snel als auto
- Duurzaam en gezond, voorbeeld zijn.
- Sneller, geen file, kan altijd parkeren en het is gewoon leuker. In de auto verveel ik me snel
- Klimaat, gezondheid
- Gezondheid, goed begin van de dag
- Ik vind het fijn om te fietsen voor en na werktijd, lekker in de buitenlucht en in beweging.
- geen rijbewijs
- Gezond voor lichaam en geest
- Zoveel mogelijk alles op de fiets.
- Het is gemakkelijk en het is rustgevend.
- Gezondheid, rust, besparing (daardoor 1 auto ipv 2),
- Omdat het leuk is, daarnaast duurzaam en gezond
- Lekker buiten zijn en bewegen. Eigen vertrektijd bepalen
- Sneller, gezond en milieu

Health/physical exercise = Colored yellow
Relaxing/fun = Colored blue
Sustainability = Colored green

Wanneer u naar werk fietst, wat voor type fiets gebruikt u dan?
When you cycle to work, what type of bike do you use?

- E-bike
- E bike
- stads/toer fiets
- Gewone fiets, vouwfiets en MTB.
- Speed Pedelec
- Velomobiel
- Elektrische fiets
- Een e-bike
- Bikepacking/tourfiets
- Normale fiets zonder ondersteuning
- E-bike
- Een normale fiets
- Normale fiets
- Speed pedelec
- Tour fiets

Regular bike = Colored yellow
Speed pedelec = Colored green
Regular e-bike = Colored blue

Is de keuze voor de fiets een gewoonte of hangt dit sterk af van de situatie?
Is cycling to work a habit, or does it strongly depend on the situation?

- gewoonte
- Gewoonte
- Wel gewoonte, maar ook weersafhankelijk. Regen en winterkou laten mij voor de bus kiezen.
- Gewoonte. Behalve in de winter
- Afhankelijk van de situatie. Korte stukjes binnen dorp niet per velomobiel.
- Situatie, het hangt af van de werkdag en het weer. Op een rustige vrijdag met lekker weer pak ik bijvoorbeeld sneller de fiets.
- Als het regent pak ik wel sneller de auto, al probeer ik dit wel te vermeiden.
- Dagelijkse fiets
- Het is een gewoonte
- De fiets is de standaard. De auto is de uitzondering waarbij tijd en weer een rol spelen in de afweging om met de auto te gaan.
- vooral gewoonte
- Keuze
- Gewoonte

Habit = Colored yellow
Situational = Colored green

Heeft de doorfietsroute tussen Assen en Groningen geleid tot een beïnvloeding van uw keuze om de fiets te pakken? Indien ja, op welke manier?
Did the bicycle highway between Assen and Groningen influenced your decision to cycle to work? If yes, in what way?

- Nee
- Nee
- Nee, maar het is wel een verbetering van de route.
- Nee. Het fietspad tussen Eelde - Vries en Assen was al prima. De doorfietsroute is wel 'lekker rustig' overdag en in het weekend
- Ja, ik heb een tijd in Tynaarlo gewerkt en toen de auto weggedaan voor een fiets. Elke dag 18 km heen en 18 terug
- Nee. Ik fietste altijd al.
- Ja, het is voor mij de snelste manier om naar werk te fietsen en het is een rustige omgeving om langs te fietsen.
- Nee, ik ging altijd wel op de fiets. Mijn route is nu wel een stuk veiliger.
- Nee, ik pak altijd de fiets
- Nee, voorheen pakte ik de andere kant van het kanaal en koste het me 5 minuten extra fietsen.
- Nee, fietste daarvoor al, heeft wel het plezier verhoogd
- Nee, dat deed ik al. Maar is wel prettig.
- Nee ik fietste altijd al naar werk

No = Colored red
Yes = Colored Green

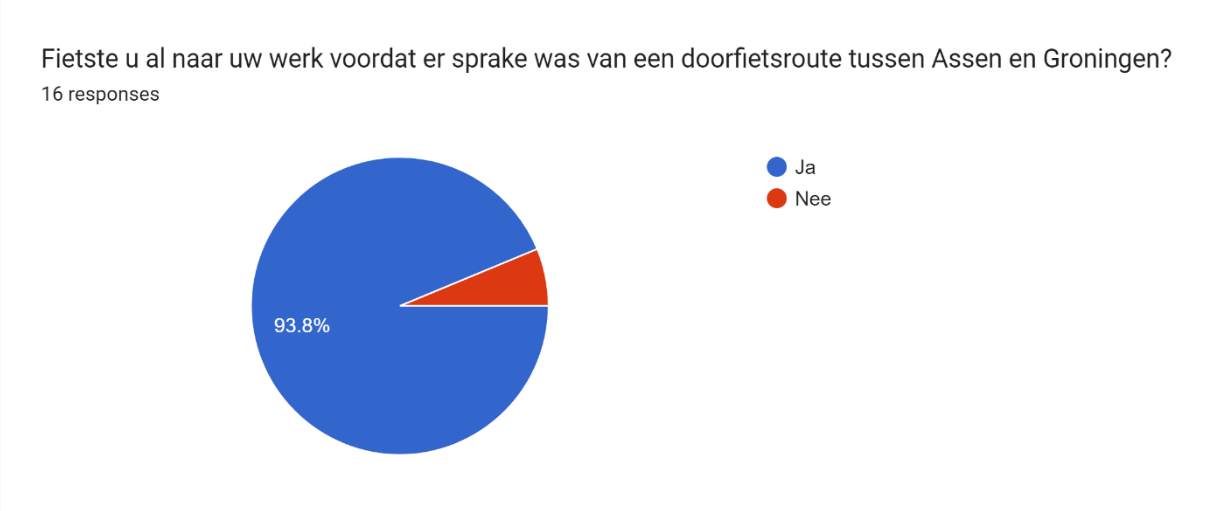

Figure 41: Did you already commute by bicycle before the bicycle highway?

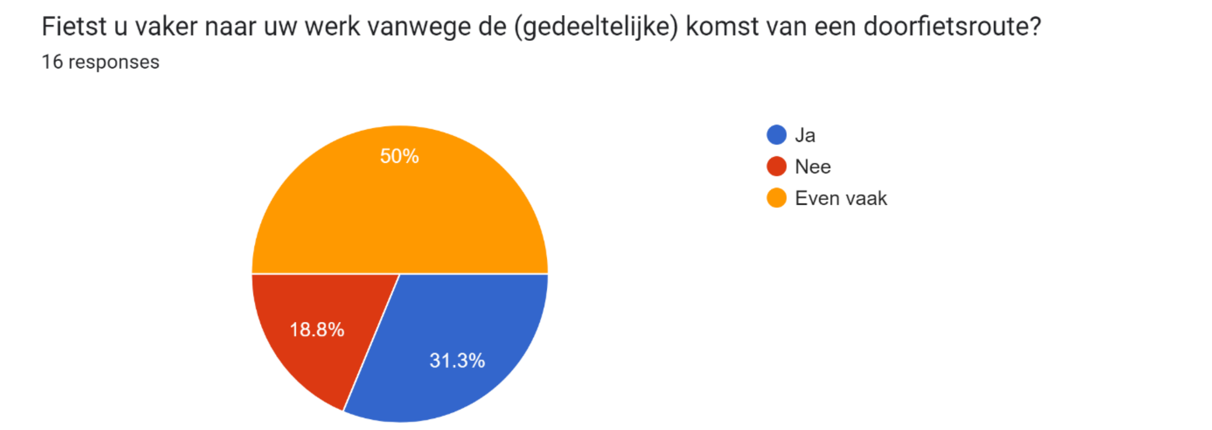

Figure 42: Do you cycle more often to work do to the bicycle highway?

Hoe vaak maakt u gebruik van de doorfietsroute Assen-Groningen?
How often do you use the bicycle highway?

- 2 tot 3 dagen per week, andere dagen werk ik thuis.
- Twee tot drie keer per week
- 2 x maand
- 1x per twee weken
- Nu 1 keer per maand. Dat was 4 keer per week
- 1x per maand
- Gemiddeld 1x in de 2 weken
- Gemiddeld 3/4 dagen in de week.
- 4 dagen per week
- 5 dagen per week
- Als het kan iedere werkdag
- Elke dag
- Twee tot drie keer per week naar werk en zelfde route terug.
- 3-4 keer per week3 x per week

- 4 dagen in de week

Biedt de doorfietsroute Assen-Groningen voordelen voor u als fietsende forens en zo ja op welke manier?

Does the bicycle highway provide benefits for commuters, and if yes, which?

- Ja, beter wegdek. Geen fietspaden die hobbelig zijn door boomwortels en slecht onderhoud.
- Gezondheid. Rust.
- nee (veel wind,beetje om)
- Nauwelijks. Voor training met de MTB of racefiets wel prettig strak asfaltbeton
- Enigszins. Het wordt er makkelijker op
- Sommige stukken fietsen prettig door, maar wisselingen kant van het kanaal etc zijn vervelend voor de velomobiel
- Ja, het wegdek is erg comfortabel. Daarnaast kom je niet tot weinig in aanraking met andere weggebruikers. Dit maakt het fietsen ontspannender.
- Ja, de route is sneller en rustiger. Geen last van auto's die voorbij scheuren.
- snelste route
- Ja, rustig ongestoord en veiliger , geen hinder van verkeerlichten/druk vrachtverkeer etc
- Veiligheid onderweg weinig kruizing met drukke auto route in de ochtend of middag
- Ja, het is een snellere route
- Het scheelt mij 5 minuten ten opzichte van voordat de route was opgeleverd. De weg rijdt fijner dan de oude route.
- veel veiliger en veel fijner qua doorfietsen en betere wegoppervlak
- Betere verbinding en auto vrij
- Rustiger je kunt goed doorfietsen

Quiet route/ absence other traffic= Colored Yellow

Safe route = Colored Blue

Fast route = Colored Green

Is door de komst van de doorfietsroute tussen Assen en Groningen de afstand en reistijd naar uw werk korter geworden?

Did the bicycle highway between Assen and Groningen reduce the distance and travel time to your work?

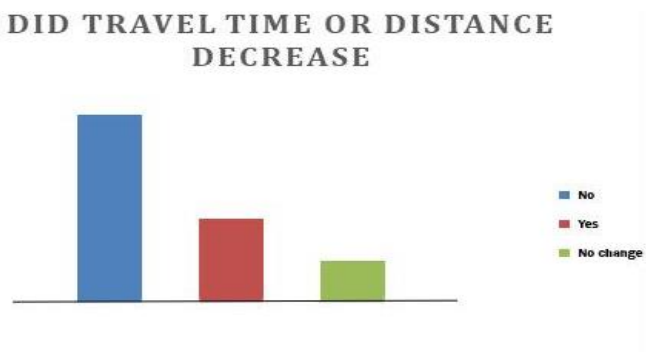

Figure 43: Decrease in travel time?

Figure 44: Do you use alternative cycle routes to work?

(Indien u de vorige vraag met "ja" heeft beantwoord) Wat zijn beweegredenen om gebruik te maken van alternatieve routes?

If yes, why do you sometimes chose for alternative routes?

- Soms neem ik andere route voor afwisseling
- Een ander alternatief is duidelijk korter, misschien wel 3 kilometer. Dit maakt het wel aantrekkelijker om deze route te nemen.
- ik fiets tot de Punt op de doorfietsroute, daarna andere route vanwege vermijden van stad Groningen
- Soms is afwisseling ook fijn
- Kortste weg gevoel.
- Mijden van Groningse binnenstad (is niet mijn bestemming)
- Behoefte aan afwisseling
- Mooiere route
- Doorfietsroute is wegdek comfortabeler. Bij veel tegenwind is de oude route langs de rijksstraatweg en helperzoom meer beschut.
- route is meer beschut, korter, en vriendelijker
- Als er harde tegenwind is bij slecht weer
- Veiligere route.

Shorter = colored yellow

More sheltered = colored green

Vindt u de fietssnelweg in de huidige situatie toegankelijk en heeft u het idee dat de fietssnelweg goed aansluit op belangrijke locaties?

- Ja
- Ik heb hier niet uitgebreid onderzoek naar gedaan. Ik vind de fietssnelweg zelf wel toegankelijk
- In de huidige situatie niet. Het traject is nog niet af en dat beperkt de bereikbaarheid. Het traject stopt abrubt in Groningen waardoor de voordelen van de doorfietsroute direct vervallen
- nee, want veel fietspaden die leiden naar de doorfietsroute zijn officieel verboden voor speed pedelecs, zowel in Assen als in Groningen. Dus bij aankomst in Groningen heb je eigenlijk geen goede route omdat je dan op de weg moet
- Met het nieuwe gedeelte van de fietssnelweg bij Assen ben ik helemaal tevreden.
- Ja hoor
- kan beter
- Hmm ja, maar kan beter. Het stuk langs de witte molen zou fijn zijn als dat af is. Nu moet je bij Haren onder de a28 door en later weer
- Voor mij vanuit Vries is de fietssnelweg pas interessant vanaf De Punt. Aansluiting op dorp Vries is niet ideaal. Als ik eerst naar de vriezerbrug moet fietsen rijd ik al gauw 1,5 km om.
- de route is nog steeds niet af. Werkzaamheden al 5 jaar ofzo stuk glimmen-haren
- Hij is toegankelijk
- Stuk van Tynaarlo is nog niet prettig
- Ja, dat denk ik wel.

Yes = Colored green
Could be better = Colored grey

Heeft u suggesties voor verbeteringen van de doorfietsroute die het gebruik van de route kunnen bevorderen (en wellicht specifiek voor forenzen)?

Do you have suggestions for improvements to the bicycle highway that could further promote its use (perhaps especially for commuters)?

- Het eindelijk voltooien fietssnelweg tussen De Punt en Haren (meerweg). Duurt veel te lang. Zorg ook voor verlichting van de fietsnelweg (via sensoren oid) En als laatste: zorg ook voor een veilige oversteek bij de brug bij De Punt.
- De route binnen de gemeente Tynaarlo eindelijk eens in orde maken
- sneller aferonden, knelpunten (tynaarlo) oplossen
- Nee
- Ja, dus bij witte molen langs
- Minder wisselingen kanaalzijde.
- Het traject afmaken. Daarnaast de aansluitingen rondom de fietssnelweg sterker maken. Als laatste is de weggebewijzering in Groningen richting de fietssnelweg erg beperkt.
- Nee, het is goed naar mijn idee
- route er naar toe kan duidelijker en veiliger
- Geen suggesties
- Op dit moment even geen idee, misschien over een tijd, als het fietspad wat langer wordt gebruikt.
- Diversiteit in natuur
- Twee ideeën: meer verlichting voor de maanden waar de dagen korter zijn en op verschillende plaatsen langs de route een afdak te plaatsen om te schuilen tegen de regen.
- zo snel mogelijk afmaken!! Het stuk bij Vries en vooral het stuk tussen de Punt en Haren zijn een drama
- Ja, de F28 geheel doortrekken. Verlichting hier en daar zou fijn zijn.
- Ms meer bankjes aan route voor degenen die tussendoor uit willen rusten

Finish the construction = Colored blue

Lightning around the cycle path = Colored Yellow

Better accessibility towards the bicycle highway = colored green

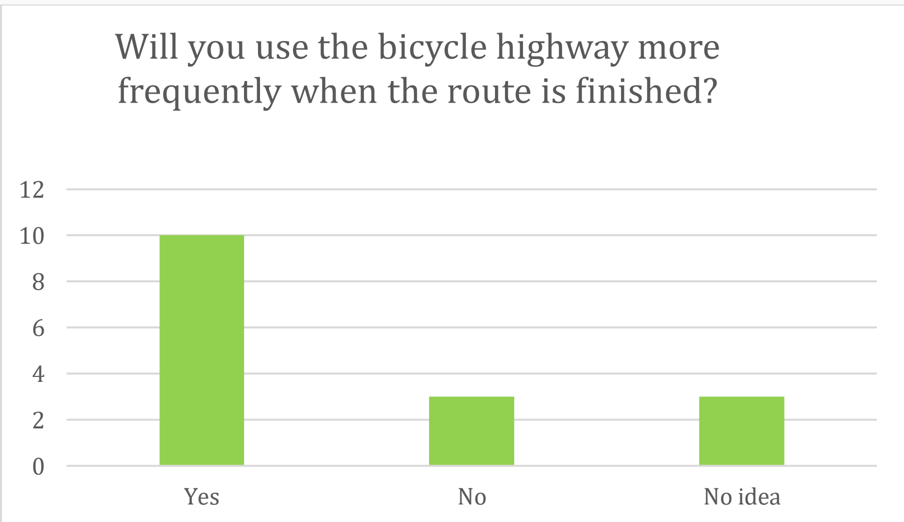

Figure 45: Future use of bicycle highway

Appendix 5: Poster Graduate Research Day

Figure 46: Poster (and link to video) with research summary