# Cycling Dissonance in the Netherlands

***Exploring Employer Influence, Spatial Barriers, and the Health Potential of a Shift to Bicycle Commuting***


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*August 2025*

*Cover illustration created with AI-generated imagery*

# Preface

Before you is my thesis about cycling dissonance in the Netherlands. This thesis is the final assignment for the Master's program in Complex Systems Engineering and Management at TU Delft. This thesis was also made for 'Coalitie Anders Reizen'. This is a coalition between more than 70 big organisations in the Netherlands with the goal of making mobility in the Netherlands more sustainable.

I have a few people I would like to thank for helping me complete this thesis. First, I want to thank my supervisors from the TU Delft, Maarten Kroesen and Karolien van Nunen, for the feedback they have given me during my thesis. Secondly, I would like to thank Hugo Houppermans and Tamara Boonstra from 'Coalitie Anders Reizen'. They have helped me with the subject and goal of this thesis. Also, through the regular meetings, they have helped me with feedback and guidance for the focus of this thesis.

By completing this thesis, I have learned a lot about myself by independently working on such a big project. While at times challenging, I think it was an interesting subject and I am glad to have explored the topic of bicycle commuting in the Netherlands.

Stefan Bentvelsen
*Delft, August 2025*

# Abstract

Although the Netherlands is known as a cycling country, many people still commute by car or public transport for distances that could realistically be covered by bicycle. This has negative consequences, including traffic congestion, increased greenhouse gas emissions, capacity issues in public transportation, and a decline in physical activity. Alternatively, commuting by bicycle would present considerable health benefits, including fewer sick days, improved mental health, and even reducing mortalities.

The gap between commuters who could cycle to work and those who actually cycle to work introduces an important problem and concept: *cycling dissonance*. This term refers to: “The mismatch between the potential that commuters might cycle to work given a cyclable distance from home to work and the reality that they commute by non-cycling modes” (Zhang, 2021). This concept has not yet been studied in the Netherlands. However, it is a very relevant concept, as reducing cycling dissonance could yield many benefits, including the possible health gains for society.

It is important to know what causes people to refrain from cycling to work, even when distance is not a barrier. The role of employer policies, spatial and infrastructural factors, and demographic characteristics in the Netherlands on cycling dissonance should be further studied to reduce cycling dissonance effectively. To address these unknowns, the following research question is formulated: *To what extent can cycling dissonance in the Netherlands be explained by employer policies, spatial factors, and demographics, and what are the potential health gains from reducing it?*

The cycling dissonance in this study has been operationalised as commuter trips within a cyclable distance. A cyclable distance for commuting is defined as 7.5 kilometres when using a ‘conventional’ bicycle and 15 kilometres for an e-bike. Using data from CBS’s yearly ODiN mobility survey, the cycling dissonance across the Netherlands has been estimated to be 48.4% nationally. This represents a daily group of 480,694 people who are cycling dissonant. For longer distances (7.5 – 15 km), which can be travelled by e-bike, another 409,621 people (74.9%) currently do not use a bicycle to get to work. The cycling dissonance is also calculated and visualized for COROP areas in the Netherlands. The regions in the south and east of the Netherlands show higher cycling dissonance. The cycling dissonance seems to be lower in the Randstad area, except for the Rijnmond area. The 10 biggest municipalities all seem to score below average for cycling dissonance, except for Rotterdam and Almere. The presence of a large number of people who are cycling dissonant on a day-to-day basis shows the potential for reducing cycling dissonance.

After complementing the ODiN data with data from Fietsersbond their Fietsgemeente research, a linear regression model was estimated. This model includes employer policies, spatial & infrastructure factors, and social demographic variables to examine how the cycling dissonance is influenced. The dependent variable of the regression model was the *average cycling dissonance level of an individual*. The regression analysis revealed that several factors significantly contribute to cycling dissonance. The variables with the biggest impact were owning a lease car and receiving a variable travel reimbursement, both of which increase the likelihood of commuting by non-cycling modes. Variables that were associated with a lower cycling dissonance were higher urbanity levels, separated cycling lanes along 50 km/h roads, and roundabouts that give way to cyclists. Gender and age also had a significant effect, with women and older individuals being more likely to exhibit cycling dissonance.

The HEAT tool, developed by the World Health Organisation, was used to estimate the health benefits of a potential reduction in cycling dissonance. It was estimated that a potential reduction of cycling dissonance by 50% would lead to 89.5 prevented mortalities per year. When converted to an economic value using the economic value of a statistical life, this would represent €5 billion over a period of 10 years. The HEAT model only provides the prevented mortalities as a result of increased physical activity; however, there are many other positive health effects related to a reduction in cycling dissonance. The prevented mortalities are merely an indicator of the total health effects, which also consist of fewer sick days, better mental health, and lower morbidity.

The findings highlight the potential and incentives for reducing cycling dissonance for employers and the government. The municipalities should invest in separated cycling lanes and roundabouts that give way to cyclists, as this has a significant effect on cycling dissonance. The central government can also promote commuting by bicycle through regulations. In addition to the already existing regulations, the government could make it possible to have higher tax-free travel reimbursements for cycling compared to other modes.

For employers, there is still much potential within already existing government regulations. Currently, the tax-free travel reimbursement is not fully utilized. Furthermore, policies regarding the leasing and provision of e-bikes or normal bicycles are not present at many employers. Further exploitation of these regulations by employers could help cycling dissonance be reduced.

It is recommended that further research investigate the relationship between cycling dissonance and other employer policies. Including more employer policies in the model will help determine which policies are most effective in reducing cycling dissonance. This study specifically focused on the health benefits of reducing cycling dissonance for short distances (<7.5km), for longer distances, e-bikes will be a logical transport mode. The potential health benefits of more people commuting longer distances (7.5 -15 km) by e-bike are still unknown. Finally, health is not the only positive effect related to the reduction of cycling dissonance. Fewer emissions, less congestion, and less stress on the public transport systems are also positive effects related to more people commuting by bicycle. These effects were not quantified. Further research could quantify these effects and create a more holistic picture of the positive effects of a reduction of cycling dissonance.

# Contents

# Chapter 1: Introduction

Car usage has several negative effects in the Netherlands. Firstly, cars on the road produce significant greenhouse gas emissions. The Dutch government has set goals to become climate-neutral in 2050 and reduce its $CO_2$ emissions by 55% in 2030 (Rijksoverheid, n.d.). Cars are responsible for 15.3 billion kilograms of CO2 emissions, significantly contributing to the climate crisis (Centraal Bureau voor de Statistiek, 2024b). Nearly a quarter of all travel kilometres by car are made during commutes (Centraal Bureau voor de Statistiek, 2023). This indicates substantial potential for reducing emissions during commuting by reducing car use. Many people in the Netherlands commute to work every day by car. Even if the distance from home to work is less than 7.5 km, more people take the car (44%) than go by bicycle (40%) (Vliet et al., 2023).

In addition to the problems regarding greenhouse gas emissions, commuting by car is also unsustainable due to the increasing congestion and limited space. In 2016, an analysis of CROW showed that the traffic in Dutch cities would become unbearable in 5 years (NOS, 2016). The COVID-19 pandemic initially caused traffic to decrease in the Netherlands. However, since the end of the pandemic, traffic has worsened and led to even more congestion on Dutch roads. The ANWB has reported that the 'filezwaarte', congestion length times the duration, has increased by 7% in 2024 relative to pre-COVID levels (Müller, 2024). Data from CBS showed that the distance driven in cars in the Netherlands has only increased in the last few years (Centraal Bureau voor de Statistiek, n.d.).

Not only does commuter travel by car cause problems, but public transport in the Netherlands also faces capacity problems with the large number of commuters during rush hours. NS, the Dutch railway organisation, mentions that the capacity problems they face are primarily during the rush hours (RADAR, 2024). Due to many commuters having the same rhythm, travel peaks are extreme during rush hour in the Netherlands. The Dutch railway cannot deal with this huge demand during those hours (Nandram & Dekker, 2024). NS is already trying methods to decrease the demand for rush hour travel with public transport, but it is not having a sufficient impact. An increase in public transport commuting is therefore not a viable solution for the problems caused by commuters going by car.

Current commuting patterns in the Netherlands are not sustainable due to capacity problems and emissions. However, cycling as a commuter mode does not have these problems. Around 44% of the population in the Netherlands lives within 7.5 kilometres of their workplace (MuConsult, 2022). The knowledge institute for mobility in the Netherlands (KiM, 2016), classifies 7.5 kilometres as a cyclable distance for commuting with a conventional bicycle, and 15 kilometres as an acceptable distance for e-bikes. In big and medium-sized cities, where more than 60% of the Dutch population lives, between 60% and 80% of commuters live within a distance of 15 kilometres of their workplace (Wiersma, 2020). Commuting by bicycle has great potential to make commuting in the Netherlands more sustainable. More people in the Netherlands who live close to their workplace should start commuting by bicycle. Choosing another mode of transport, while living close to the workplace, is called cycling dissonance: "The mismatch between the potential that commuters might cycle to work given a cyclable distance from home to work and the reality that they commute by non-cycling modes" (Zhang et al., 2022). A reduction of cycling dissonance in the Netherlands is desirable as it reduces emissions, congestion, and public transport capacity problems.

Even though the mode share of cyclists in the Netherlands is already high, there is still more potential for this travel mode. Encouraging more people in the Netherlands to commute short distances by bicycle is essential for creating more sustainable commuter patterns. Almost half of the population in the Netherlands lives within a cyclable distance of their workplace. This highlights the significant potential for shifting travel behaviour. Promoting cycling for short commutes, and thus reducing cycling dissonance, would not only help reduce greenhouse gas emissions, congestion, and crowded public transport, but it would also contribute to public health. Making better use of this potential aligns with national climate goals and can help address both environmental and infrastructural challenges.

The current mismatch between potential bicycle commutes and actual bicycle commutes is partly related to employer policies. Braun et al. (2016) showed a clear relationship between employer policies and the selected transport mode for commuting. The paper showcased a clear competition between commuting by public transport and by bicycle. Public transport benefits given by employers lead to fewer employees using a bicycle for commutes. Bueno et al. (2017) also researched how employer policies can affect the mode choice of commuters. Their results show how employer policies that pay for car expenses, such as free parking, toll payments, and mileage reimbursements, lead to more people commuting by car and fewer people choosing sustainable commuter modes such as cycling or public transport. However, they also find that employer benefits that stimulate sustainable commuter modes (cycling and public transport) steer commuters towards these transport modes. The benefits that employers offer impact the mode choice that employees make for commuting.

In addition to employer policies, the available cycling infrastructure and the surrounding environment also influence commuters' mode choice. Zhang et al. (2021; 2022; 2023) show that the perceived built environment greatly influences cycling dissonance. More specifically, the inclusion of cycling lanes and flat terrain both influence cycling dissonance. Other papers (Grudgings et al., 2021; Braun et al., 2016) found that the presence of good cycling infrastructure encourages commuting by bicycle. In this case, it is not just about flat roads, but designated cycling paths separated from cars. A more specific example of the impact of cycling infrastructure on a commuter's choice to potentially cycle is given by Panter et al. (2016). They compare the number of commuters going by bicycle in the Cambridge municipality before and after creating safer and traffic-free cycling routes. They found that the number of commuters going by bicycle significantly increased after implementing these routes. The cycling infrastructure that is present influences a commuters choice to potentially cycle.

Bicycle usage could also be related to several social demographic attributes. For example, a study (Larriva et al., 2024) found that both a person's education level and income impact the odds of cycling. In a case study examining transport in the Munich area, the researchers found that higher education and income levels exhibited higher odds of cycling. A person's age is also related to cycling. A study (Van Amen et al., 2017) of transport in the greater Rotterdam area found that elderly people, when compared to younger people, are more inclined to travel by car instead of bicycle. Another example of social demographic attributes impacting cycling is gender. MacBride-Stewart et al. (2020) found that in New Zealand, men are more likely to cycle compared to women.

Commuting by bicycle is also related to many positive health benefits. A reduction in cycling dissonance would lead to increased physical activity as more people start cycling. In a general study calculating the health benefits of cycling, Fisherman et al. (2015) found that cycling in the

Netherlands prevents around 6500 yearly deaths due to the positive effects of physical activity. With obesity levels in the Netherlands tripling in the last 40 years, cycling as a commuter mode could help make Dutch people healthier. In 1981, only 5% of the population was classified as being obese; now that percentage has risen to 15% of the population (Centraal Bureau voor de Statistiek, 2024a). The Dutch Research Institute for Health and Environment (RIVM) also predicts that obesity in the Netherlands will keep rising until 2050 (Spijkerman et al., 2024). This is mainly due to people in the Netherlands moving too little. The World Health Organisation recommends that adults have at least 150 to 300 minutes of medium intensity physical activity (WHO, 2020). The WHO categorizes cycling as a form of medium-intensity physical activity. Reducing cycling dissonance by increasing physical activity would have positive health effects that could combat these negative health trends in the Netherlands.

This is not only an incentive for the Dutch government to try and reduce cycling dissonance, but also for employers. Research by Kalliolahti et al. (2024) shows that employees who commute by bicycle or on foot report fewer sick days. Other research also finds a link between commuting by bicycle and fewer sick days among employees (Hendriksen et al., 2010; Mytton et al., 2016). Not only do employees report fewer sick days, but they also improve their work performance as they get healthier (Chang, 2024). This illustrates how employees commuting by bicycle could also be beneficial to employers.

While much is already known in current literature about cycling in the Netherlands, the cycling dissonance, cyclable distance commutes taken by another mode of transport, have not been studied. Specifically, a study of the impact of employer policies, spatial & infrastructure factors, and social demographic variables on cycling dissonance in the Netherlands has not yet been conducted. This leads to the following research question(s).

## Research questions

As cycling is a more sustainable travel mode for commuting than car or public transport for short distances and could potentially have great health benefits, the following research question arises:

***To what extent can cycling dissonance in the Netherlands be explained by employer policies, spatial factors, and demographics, and what are the potential health gains from reducing it?***

To correctly answer this research question, several sub-questions have been formulated. These sub-questions will help to answer the main research question in a structured manner. First, getting a good overview of the cycling dissonance in the Netherlands is important. This leads to the following sub-question:

***What is the estimated cycling dissonance in the Netherlands, and how does it vary across different regions?***

To answer this sub-question, a data analysis will be done based on mobility data collected for the yearly ODiN research. This will result in an overview of how many daily commuters can be classified as cycling dissonant. The cycling dissonance will also be calculated for different regions across the Netherlands to make potential regional differences insightful.

After calculating the cycling dissonance for ‘conventional’ bicycles, the question arises how many people would be able to commute by bicycle if they had access to an e-bike. As e-bikes are generally faster and need less physical effort, longer distances can be covered by e-bikes. This leads to the following sub-question:

***How many people in the Netherlands, if given access to an e-bike, would be able to commute by bicycle?***

To answer this sub-question, another data analysis will be conducted using the ODiN research. However, this time it will look at commutes that are too long for a 'conventional' bicycle, but are doable with an e-bike.

After identifying the scope of cycling dissonance in the Netherlands, the question arises as to what impact this behaviour.

***What is the impact of mobility policies of employers and spatial & infrastructure factors, controlled for social demographic variables?***

This sub-question will be answered by creating a multivariate model in SPSS. This model will use the same ODiN data as the first sub-question. However, the model will also include data from the Fietsersbond yearly 'fietsgemeente' research. This will provide variables on cycling infrastructure in different municipalities.

Finally, there is potential for health benefits if cycling dissonance is reduced and more people commute by bicycle.

***Given the previously calculated cycling dissonance, what potential health effects could result from its reduction in the Netherlands?***

To answer this sub-question, the HEAT tool, developed by the World Health Organisation will be used. This tool is created to assess the impact of an increase in physical activity due to transport policies on mortalities. Using earlier results regarding the cycling dissonance in the Netherlands as input, an estimation of prevented mortalities due to an increase in physical activity can be given. The prevented mortalities will be used as an indicator of the health benefits of reducing cycling dissonance. This indicator will be supported with findings of the relationship of bicycle commuting and health from the literature.

More information and specifications about the methods used to answer the research questions will be given in Chapter 3.

## Scope of study

While existing literature has mainly investigated cycling in general or commuting by bicycle, this study will specifically focus on cycling dissonance. This differs from existing research as it checks for commuting trips within a distance that could realistically be taken by bicycle. Studies in the Netherlands, by organisations such as RIVM or KiM, mainly investigate the general number of commuters going by bicycle or bicycle users. There are no studies that specifically focus on cycling dissonance in the Netherlands. It is useful information to know what impacts the cycling dissonance in the Netherlands. This creates opportunities to reduce this cycling dissonance, which will present many benefits.

When assessing the benefits of commuting by bicycle, only health benefits are taken into account. There are a lot of other benefits to society and individuals related to a reduced cycling dissonance, but these are beyond the scope of this study. These benefits include, for example, a reduction of emissions, less congestion, and less space needed for parking. These are all positive effects related to a modal shift towards more cycling, but not included in this study.

This study is set in the context of the Netherlands, a country known for its strong cycling culture. For example, 27% of all trips in the Netherlands were made by bicycle in 2012 (CROW, 2012). This is much higher than in other countries. Although the results may be interesting for other places too, the focus is on the Dutch situation. As shown by O'Reilly et al. (2024), differences in cycling levels across Europe cannot be explained by infrastructure alone, which supports the importance of country-specific research like this.

## Outline of the report

In the next chapter, a literature review will be conducted, and following that, a conceptual model will be presented. Chapter 3 will contain further explanation of the operationalisation of variables used for answering the sub-question. Also, a more detailed research approach will be given. In Chapter 4, the results will be presented. In Chapter 5, the results will be discussed. Here, possible explanations for the results will be given, and the results will be compared to existing findings from the literature. In Chapter 6, a conclusion will be presented. This will be done by first answering the sub-questions and finally answering the main research question. This chapter will also contain policy recommendations, further research recommendations, and the limitations of the study will be discussed.

# Chapter 2: Literature

In this chapter, literature relevant to the research questions will be discussed. By examining existing studies and theories, a solid foundation for the analysis will be built. At the end of this chapter, a conceptual model based on the insights of the literature will be presented.

## Cycling dissonance

The concept of cycling dissonance entails: “The mismatch between the potential that commuters might cycle to work given a cyclable distance from home to work and the reality that they commute by non-cycling modes” (Zhang et al., 2022). For someone to be cycling dissonant, the trip has to be a commute and the trip has to be cyclable. The researchers argue that a cyclable distance is not a fixed number, but is context-specific. A report by Kennisinstituut voor Mobiliteit (KiM, 2015) found that in the Netherlands, 91% of trips taken by bicycle are less than 7.5 kilometres. Of the working population in the Netherlands, around 40% live less than 7.5 kilometres from their workplace (MuConsult, 2022). In an RIVM report (Vliet et al., 2023), 7.5 kilometres was also used as a benchmark for a cyclable distance.

## E-bikes

A study by Plazier et al. (2023) showed that e-bikes are a great substitute for cars for up to 15 kilometres. The e-bike mainly replaces current car commuters. A qualitative study also showed that e-bike usage was not only replacing conventional bicycle trips but also car trips (Jones et al., 2016). However, another paper by De Haas et al. (2021) did not find a significant substitution effect of e-bikes for the car when not making a distinction for the trip purpose. They did find that the e-bike has a significant substitution effect for cars when specifically looking at commuter trips. This illustrates that e-bikes are an excellent commuter mode for more sustainable travel. Wiersma (2020) used 7.5 kilometres and 15 kilometres as acceptable distances for commuting by (e-)bicycle. He based these distances on a mobility report by the Knowledge Institute for Mobility in the Netherlands (KiM, 2016). He also found that in the Netherlands, in big and medium-sized cities and suburban areas (>60% of the population), 60-80% of the commuters lives within the distance of 15 kilometres. This illustrates the potential for commuting longer distances by e-bike.

## Employer policies

Braun et al. (2016) showed a clear relationship between employer policies and the selected transport mode for commuting. The paper showcased a clear competition between commuting by public transport and bicycle. Public transport benefits given by employers lead to fewer employees using the bicycle for commutes. The incorporation of bicycles into the mode choice set for commuting is dependent on different determinants. The most important determinant is employers' reimbursement for the specific modes, followed by characteristics such as urban density and mode ownership (Ton et al., 2020). Bicycle benefits provided by the employer in a pilot led to increase usage of the commuter mode, even after the pilot ended (Hämäläinen, 2023). This showcases how big of an impact the employer policies can have on the mode choice for commuting.

Bueno et al. (2017) also researched how employer policies can affect the mode choice of commuters. Their results clearly show how employer policies that pay for car expenses, such as free parking, toll payments, and mileage reimbursements, lead to more people commuting by car and fewer people choosing sustainable commuter modes such as cycling or public transport. They also find that employer benefits that stimulate sustainable commuter modes (cycling and PT) help commuters choose these modes. They conclude that employer policies have a large impact on commuter mode choice and could be crucial in encouraging commuters to choose sustainable modes.

Not only promoting bicycle usage through employer policies, but also facilitating the use of bicycles for commuting increased its usage (Porter et al., 2019). Employers can facilitate bicycle usage through the presence of, f.e, good bicycle parking, clothes storage, and showers. Shin (2020) illustrates that employer policies not only affect the mode choice for commuting but also impact overall mode choice. This illustrates that there is a clear spillover effect of employer policies on mode usage. This emphasizes even more the possible impact of employer policies. Lastly, Van Malderen et al. (2012) found that both financial incentives offered by the employer and environmental characteristics impact commuters' mode choice. Offering financial incentives for the use of bicycles has a positive impact on the mode share of bicycles for commuting.

### Infrastructure & spatial factors

Infrastructure & spatial factors also impact bicycle usage. Firstly, it is evident that distance is the most significant factor in selecting cycling as the preferred mode of commuting (Melin et al., 2024; Makkonen et al., 2024). However, the environment of the trip is also important for accounting for the mode choice. Zhang et al. (2021; 2022; 2023) show that the perceived built environment greatly influences cycling dissonance. The cycling dissonance in Australia seems to be largely influenced by the environment. For example, the hilliness of terrain and the presence of good cycling infrastructure. Lu & Gan (2024) found that the impact of the built environment on mode choice is more dependent on the residence area of the commuter than the working area. The presence of good cycling infrastructure is thus more valuable in residential areas to stimulate cycling. Other papers (Grudgings et al., 2021; Braun et al., 2016) also found that the presence of good cycling infrastructure encourages commuting by bicycle. More specifically, they show that separated cycling lanes increase the number of bicycle commuters. Another study also found that creating more cycling-specific routes in the UK will lead to more people choosing to cycle to work (Brand et al., 2014). Studies conducted in the Netherlands have reviewed the impact of urban density on travel mode choice. Scheepers et al. (2013) found that people living in more urban areas are more likely to cycle. The authors do wonder if the environment causes this correlation, or if people who want to cycle choose to live in a more urban area.

### Health benefits

The potential health benefits of employees commuting by bicycle could be a big incentive for employers to stimulate their employees via employer policies to start commuting by bicycle. As mentioned in the introduction, employees who cycle to work report fewer sick days (Kalliolahti et al., 2024; Hendriksen et al., 2010; Mytton et al., 2016). Neumeier et al. (2020) found that active commuting, and especially cycling, improves health-related quality of life and reduces sick days. Synek & Koenigstorfer (2019) also found that the use of company-leased bicycles has a positive impact on both physical and mental health. This highlights how employer policy can create healthier employers.

Scientific papers suggest that there is a clear relationship between commuting by bicycle and a lower BMI (Makkonen et al., 2024; Echeverría et al., 2023; Useche et al., 2024; Wen & Rissel, 2007). While BMI is not necessarily an accurate indicator of health, a paper by Stenholm et al. (2017) states that excess BMI is associated with substantially shorter healthy and chronic disease-free life expectancy when generalized for a population. A more detailed relationship between commuting by bicycle and

BMI is given by Dons et al. (2018). They show that the BMI of a commuter was, on average, 0.010 $kg/m^2$ lower for every day in the month that somebody commutes by bicycle instead of by car. More concretely, this means that the average person who switches from commuting by car to commuting by bicycle loses 0.75 kg of body weight. While these are positive effects for commuting by bicycle, the same paper also shows that these effects are not present for commuters who use an e-bike. While these papers mainly focus on the positive effects on health of cycling by the reduction of BMI, there are also negative effects. A paper by Götschi et al. (2015) highlights that cyclists could experience negative effects such as injuries due to crashes and air pollution. However, the same paper also highlights that these effects are minimal compared to the impact of the health benefits of commuting by bicycle. A report by De Haas (2021) also showed that the distance travelled per three days in kilometres by bicycle has a significant impact on the perceived health of a person. De Hartog et al. (2010) mention that a person should have at least 500-1,000 MET (metabolic equivalent of task) minutes per week. They mention that cycling at 15 km/h has a MET value of 4. Cycling to work could help achieve enough active minutes in a week.

The health effects of commuting by bicycle are not only restricted to direct physical effects, but also to mental health. Company leasing bicycles positively impacts both physical and mental well-being (Synek et al., 2019). Commuting by bicycle is associated with higher mental well-being scores than those who commute by public transport or car (Mytton et al., 2016; Singleton, 2018). This leads to people who commute by bicycle having significantly lower risk of being stressed (Avilla-Palencia et al., 2017). This effect is big enough that it even leads to bicycle commuters having 16% lower mental prescriptions than those who use other forms of transport (Berrie et al., 2022). An increase of 10 kilometres of cycling per week is also associated with a higher self-rated health (Gluschkoff, 2023). Furthermore, longer commutes by bicycle have a significant impact on the subjective health of a person (Echeverría, 2023). People who commute by bicycle have a lower BMI, report fewer sick days, have better mental health and experience higher subjective health levels.

While the research shows many positive and desirable health effects of commuting by bicycle, there are also negative health effects. Nilsson et al. (2017) found that a switch of travellers going by bicycle instead of car in Sweden increases the number of road fatalities and injuries. De Hartog et al. (2010) mention that commuting by bicycle is related to bigger risks regarding air pollution and traffic accidents. Cole-Hunter et al. (2015) found that commuting by bicycle leads to an increase of the negative effects of air pollution. While these papers find that there are negative health effects related to commuting by bicycle, they all state that the positive health effects of commuting by bicycle outweigh the negatives.

### Social demographic attributes

As mentioned in chapter 1, social demographic attributes also could impact commuting by bicycle or cycling in general. Firstly, a study conducted in Bogotá towards commuting by bicycle (Medaglia et al., 2021) found that factors that impact bicycle commuting differ per gender. This is supported by a study in 1997 (Niemeier & Shafizadeh) about travel behaviour in Seattle, USA. They also found socioeconomic information such as age, gender and income is related to bicycle commuting. With some social groups commuting more often by bicycle. However, a study by Lu et al. (2010), conducted in Nanjing, China, did not find any significant effects of gender and age on bicycle commuting. The findings of these studies thus show that socio demographic attributes do not have a uniform effect on bicycle commuting across the world. In a study conducted in Canada (Harris et al., 2021), there was a strong relationship between cycling and gender. Especially for commuting, men were twice as likely to go by bicycle. Finally, a study by Heydari & McCreery-Phillips (2023) showed that bicycle commuting is positively impacted by employment rate and negatively by the absence of academic qualifications.

## Conceptual model

As a result of the literature review, a conceptual model has been created. The model in Figure 1 shows how the different concepts interact. The conceptual model will guide as a structure for answering the research questions.

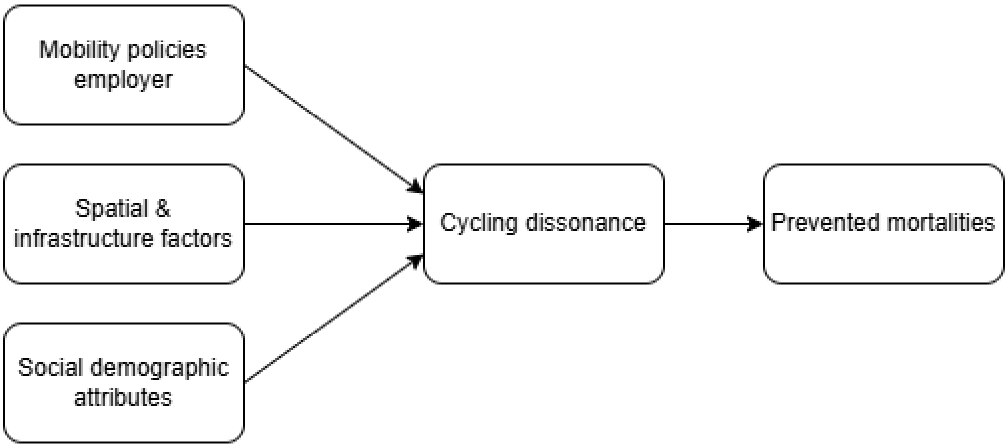


*Figure 1: Conceptual model*

The literature has shown that socio-demographic variables such as age, gender, education, and income are related to cycling levels. These attributes will be checked for their impact on cycling dissonance in the Netherlands. The literature also showed that a wide variety of mobility policies by employers can affect commuting by bicycle. In this study, employer policies for fixed travel reimbursement, variable travel reimbursement, and lease cars will be checked for their impact on cycling dissonance. O'Reilly et al. (2024) have found that countries with high rates of bicycle commuting are more responsive to changes in cycling infrastructure. As the Netherlands already has a high rate of bicycle commuting, it is hypothesized that spatial & infrastructure factors impact the cycling dissonance in the Netherlands. This leads to the inclusion of spatial & infrastructure factors. This includes urban density, design of roundabouts, design of cycling lanes, and cycling infrastructure directness.

Literature has shown that commuting by bicycle is a form of physical activity that can have health benefits. Reducing cycling dissonance will present health benefits. These benefits range from mental wellbeing, fewer sick days, and better physical health. For this study, the health benefits will be indicated by the prevented mortalities related to an increase of physical activity.

In the next chapter, the concepts of this conceptual model will be operationalised, and the research approach will be discussed.

# Chapter 3: Research data & methods

This chapter will first discuss the design of the study. Then, the data used in this study will be described and elaborated on. After discussing the data, the concepts of cycling dissonance and those that impact cycling dissonance according to the conceptual model will be operationalised. The analytical approach to answering the research questions will then be explained. The descriptive statistics of the dataset and specifically the model will be shown and discussed. Finally, the concept of health benefits will also be operationalised, and the approach to answering this sub-question will be outlined.

## Research design

To answer the research questions, a quantitative study was conducted. To answer sub-questions 1 and 2, the number of cycling-dissonant people had to be calculated for distances deemed cyclable for 'conventional' bicycles and for e-bikes. These results were also presented for different regions to highlight potential regional differences.

To address the third sub-question, a regression model was estimated to assess the influence of the various operationalised variables corresponding to the concepts outlined in the conceptual model. With a regression model, the effects of the independent variables on cycling dissonance can be made insightful. Finally, using the results of the first sub-question, the final sub-question can be answered. Here, the health benefits were calculated by estimating the increased physical activity if current cycling-dissonant people began commuting by bicycle. A more in-depth discussion of the specific methods used to answer the sub-questions is presented later in this chapter. First, the data used for answering these research questions will be discussed.

## Data sources

Two different data sources were used for this study. The main source is the data from the ODiN study of Centraal Bureau voor de Statistiek (CBS). This data was complemented with data from the Fietsersbond's Fietsgemeente study.

### ODiN data

To gather data, the CBS selects a sample of the population to invite to participate in the survey. They also assign a specific weekday to every respondent to track their trips. This ensures equal representation of weekdays in the dataset. The target population of the research is people who reside in the Netherlands aged 6 years and older. The sample is created using the 'Basisregistratie Personen', which is the Dutch population register. People living in mental health hospitals were not included in the sample. People who participated to a CBS survey in the last 12 months were also excluded from the sample. To get a good representation of the population, sociodemographic groups that are less likely to respond to surveys were oversampled. This mainly consists of people in lower income groups and with non-Western backgrounds. By sending more survey invitations to these social groups, CBS aimed to obtain a representative sample group of the population. After a screening and thinning of the sample group, the final group is created.

Even though CBS tried to compensate for non-responses by including more people from some social groups, the sample is not perfectly representative for the target population. This is partly due to the sampling, but mainly due to selective non-response. Some groups are more or less likely to partake in surveys. To still be able to scale the data of ODiN to the population, CBS included weight factors.

These factors are specific to every person represented in the dataset. This way, the data can be scaled to the population as accurately as possible. The weight factor for every respondent is based on the socio-demographic attributes of the respondent and their residential location. The weight factors are calculated in such a way that every social group and region is represented accurately. This is done based on the information that CBS has about the population in the Netherlands. They can check which groups in the data are over- or underrepresented compared to the real population and create weight factors accordingly. The weight factors are created in such a way that, in total, they encapsulate the target population of the ODiN research

A big part of the research is done using data from CBS, their yearly ODiN research (Centraal Bureau voor de Statistiek, 2024c). The data from their 2022 and 2023 research have been used for this thesis. These are the two most recent datasets that both use the same questionnaire. Using two datasets increases the number of respondents and thus reduces the standard deviation of results. As the CBS only included people who did not partake in CBS studies in the last 12 months, double respondents in these two consecutive studies are not present. In total, the combined dataset of 2022 and 2023 included 92,442 unique respondents. The choice has been made not to include datasets from 2021 or earlier. This is related to the COVID-19 pandemic, which had a big impact on mobility in these years. The data from the ODiN research has been chosen due to its large number of respondents, allowing for specific research questions to be answered. The ODiN research survey asks respondents about all the trips they have taken that day. This contains information about the transport mode used, length of the trip, and motive of the trip (f.e. commuting). With this specific data, it is possible to determine if trips can be classified as cycling dissonance. The ODiN dataset also contains general information about the respondents and the location where they live and travel. This allows for the possibility of finding out what impacts cycling dissonance. This allows for answering the research questions.

### Fietsersbond data

To improve the model for explaining the cycling dissonance in the Netherlands, the ODiN dataset was enriched with data from the Fietsersbond. Fietsersbond is a Dutch association that champions the interests of cyclists in the Netherlands. The association tries to influence transport policy by lobbying for traffic regulations and cycling facilities.

The Fietsersbond has conducted a study ranking municipalities in the Netherlands for cycling friendliness (Fietsersbond, 2024). For this study, they scored every municipality on several factors about cycling. The objective of the study by the Fietsersbond is to raise awareness for cycling. They try to stimulate municipalities to promote cycling actively and reward the municipalities that do this well. With the results of the study, volunteers can go to their local municipality and ask for specific improvements related to the results of the study. The ranking of the municipalities is based on scores from a survey and objective data. The survey they conducted had more than 46.000 respondents, mostly members of the Fietsersbond. Other variables were objective data that the researchers had collected about cycling in the municipalities. There is not much clarity about the representativeness and relevance of the subjective data. Because of this, only objective data from their Fietsgemeente study has been included in this study.

The objective data is added to the existing ODiN dataset. This allows for more variables regarding spatial and infrastructure to be included in the model. The specific variables will be discussed and explained in detail later in this chapter. These are variables scoring cycling infrastructure in municipalities.

## Operationalisation of variables

To get a clear and concise answer to the research questions, the concepts introduced in the previous chapter have to be operationalised. Not only the concept of cycling dissonance, but also the independent variables will have to be operationalised.

### Cycling dissonance

To get a good answer to the first sub-question, the concept of cycling dissonance has to be operationalised. As mentioned earlier, the concept of cycling dissonance entails: "The mismatch between the potential that commuters might cycle to work given a cyclable distance from home to work and the reality that they commute by non-cycling modes" (Zhang et al., 2022). The cycling dissonance will be calculated using the ODiN data.

With the ODiN data, every trip of a respondent can be classified as a potential commute by bicycle. When classifying a trip as potentially cycling dissonant, the trip has to be a commute and be within a cyclable distance. Existing scientific literature discussed in Chapter 2 suggests that distances up to 7.5 kilometres could be taken with a 'conventional' bicycle. This distance can be increased to 15 kilometres if an e-bike is used. The cycling dissonance will be calculated for both of these distances to show which group of people could start commuting by 'conventional' bicycle or longer distances with an e-bike. This will illustrate the potential of e-bikes. For every trip that fulfils these criteria, it will be determined if it is cycling dissonance based on the transport mode taken. If taken by bicycle, it is not cycling dissonance, but if taken by a non-cycling mode, it is cycling dissonance. It is important to note that trips taken on foot have been left out of the analysis. As this is only a small part of commuter trips of less than 7.5 kilometres (13%), and it is not the goal to get these people to start cycling. Commuting by foot is already good for the environment, does not cause congestion on roads, and is also a form of physical commuting (Neumeier et al., 2020). There is no clear advantage for society or employers to get commuters who go by foot to start cycling.

The analysis will be done using the ODiN data in a SPSS file. Every trip taken will be determined to be either cycling dissonant or not. While this would suggest that cycling dissonance will be a binary variable, this will not be the case. The dataset will be aggregated to an individual level to treat every respondent equally, regardless of the number of trips they have taken. This will result in respondents who have taken at least one commute within a cyclable distance receiving a mean cycling dissonant score. Cycling dissonance will thus be a proportion. Further explanation on the effect of this on the interpretation will be given later in this chapter.

### Spatial & infrastructure factors

As mentioned earlier, the ODiN dataset has been complemented with data from the Fietsersbond's 'Fietsgemeente' study. This contains data about the cycling infrastructure of municipalities. As the exact routes that a respondent takes during their commute are unknown in the ODiN data, an assumption is made. As cycling dissonance only looks at cyclable trips (<7.5 km), it is assumed that for most respondents, at least a large part of the trip takes place in their municipality of residence. The infrastructure in this municipality likely has the biggest impact on choosing whether or not to commute by bicycle. Furthermore, Lu & Gan (2024) have found that the choice to commute by bicycle is more related to the area of residence than to the area of the workplace. Because of this, the Fietsersbond's data is linked with the municipality of residence of respondents in the ODiN dataset.

All the variables included for the concept 'spatial & infrastructure factors' are shown and explained in Table 1. The source of the urbanity variable is from the original ODiN dataset. The other three variables are created by the Fietsersbond. The scoring methods of the Fietsersbond data are retrieved via personal communication with an employee of Fietsersbond (J. Kamminga, personal communication, 25-07-2025).

**Spatial & infrastructure factors**

| Variable | Explanation |
| --- | --- |
| *Urbanity (1-5)* | Classification of urbanity of the municipality of residence. This is based on the number of addresses per square kilometre:<br>1 = less than 500 addresses/km$^2$<br>2 = 500 – 1000 addresses/km$^2$<br>3 = 1000 – 1500 addresses/km$^2$<br>4 = 1500 – 2500 addresses/km$^2$<br>5 = more than 2500 addresses/km$^2$ |
| *Detourfactor (1-5)* | If we plan trips from a central point to points that are one kilometre away as the crow flies, how much more do we have to cycle than that one kilometre? The shorter the distance, the better the score. The Fietsersbond identifies the central location of all settlements within a municipality and analyses the distance to cycling lanes that are precisely one kilometre from this central point. The actual distance required to reach this point determines the detour factor. Ultimately, the municipality's score is derived by weighting the scores of its settlements according to their relative population sizes.<br>1 = 1.6 or higher<br>5 = 1.1 or lower |
| *Roundabouts (1-5)* | Are the roundabouts in the municipality designed to give way to cyclists? Higher scores are more cycle-friendly.<br>1 = 0% of roundabouts give way to cyclists<br>5 = 100% of roundabouts give way to cyclists |
| *50 km/h (1-5)* | Are cycling lanes separate from 50 km/h roads? A higher score means that cycling lanes are more often separated from cars. Based on the total length of 50 km/h roads in a municipality, and the % of this length where the cycling lane is separated. The scores are scaled accordingly:<br>1 = 0% separation<br>5 = 100% separation |

*Table 1: Spatial & Infrastructure variables*

The variables of the Fietsersbond have been linked with the respondents of the ODiN dataset. The Fietsersbond data is related to municipalities. Every respondent also has a municipality of residence included in the ODiN dataset. The Fietsersbond data has been linked to the respondents using their municipality of residence. This way, the data from Fietsersbond can be used in the model.

## Employer policies

For the employer policies, there are three variables from the ODiN dataset that are included. These are shown in Table 2.

**Employer policies**

| **Variable** | **Explanation** |
|---|---|
| *Lease car (#)* | The number of lease cars and/or company cars in a household. |
| *Variable travel reimbursement (yes/no)* | Does the respondent get a variable travel reimbursement from the employer for commuting related to the actual distance covered? |
| *Fixed travel reimbursement (yes/no)* | Does the respondent get a fixed travel reimbursement per period? |

*Table 2: Employer policy variables*

For the variable 'lease car', it is not clear what part of the respondents have a car leased privately and what part have a car through their employer, either a business lease or a company car. However, in the Netherlands, most leased cars are business leases. The latest data shows that around 20% of leased cars in the Netherlands are leased privately (VNA, n.d.). This excludes company cars that are not leased. The number of company cars that are used for commuting is more difficult to estimate. However, the number of company cars in the Netherlands is around 1.3 million (BOVAG & RAI, 2024). While not all cars included in this variable are employer policy, the variable is included as the influence of private lease cars on the variable is assumed to be small. While the ODiN dataset does include more employer policies, these cannot be used due to the way they were asked of respondents. These employer policy variables were only asked to respondents based on their most used transport mode for commuting. This made these variables unsuited for this analysis.

## Social demographic variables

As shown in the conceptual model in Chapter 2, to accurately check the impact of the concepts on cycling dissonance, the model has to be controlled for social demographic variables. For the social demographic variables, the model is restricted to those that are available in the ODiN dataset. From this dataset four different social demographic variables have been selected to implement in the model. These variables are shown and explained in Table 3.

**Social demographic variables**

| Variable | Explanation |
|---|---|
| *Gender* | Gender of respondent. Dataset only contains the classification of male and female. Male is coded as 1 and female is coded as 2. |
| *Age* | Age of respondent. Respondents start at age 6 up to age 99. |
| *Education (1-5)* | The highest level of education that the respondent has completed. Classified in 5 levels of education. Level 5 being the highest level of education. |
| *Income level household (1-10)* | Income of the household classified in percentile groups of 10%. |

*Table 3: Social demographic variables*

## Analytical approach

First, the cycling dissonant population for distances up to 7.5 and 15 kilometres will be calculated. This will be done accurately by using the weight factors included in the ODiN datasets. The weight factor of a respondent indicates how many people a respondent represents. The weight factor is multiplied by the respondent's cycling dissonance score. By adding these numbers, the total cycling dissonant population is estimated. As this study uses the data of two different years of the ODiN research, the weight factors are divided by two.

To make the cycling dissonance across the Netherlands more insightful, the regional differences will be calculated. To create an insightful visualization of the cycling dissonance in the Netherlands, a map will be created. Using ArcGIS, the cycling dissonance for the different COROP areas in the Netherlands will be presented. ArcGIS is a geospatial platform that can be used to combine maps and data in order to create a good visualization of the cycling dissonance across the Netherlands. The regional differences will be shown using COROP areas, as these will likely have enough respondents per area to present representative results, while being as detailed as possible. The COROP areas are regional divisions that are smaller than provinces and bigger than municipalities. They are created and used for analytical purposes (Centraal Bureau voor de Statistiek, n.d.-c).

To explore the effects of the concepts on cycling dissonance, a regression model will be estimated. In this model, the variable 'cycling dissonance' will be the dependent variable, and the variables that have been identified in the operationalisation will be the independent variables. With the regression model, the strength of the association and direction can be explained. This gives insight into how cycling dissonance can be influenced and what has to change to reduce cycling dissonance.

A linear regression model estimates the relationship between the dependent variable and the explanatory variables. The goal of the model is to explain variation in the dependent variable that can be attributed to variation in the explanatory variables. This way, linear relationships between the dependent variable and the explanatory variables can be identified. The model's output can explain variation in cycling dissonance based on spatial and infrastructure factors, employer policies, and social demographic variables. These three groups of variables will be used for the model. Finally, the model's output can be used to predict the impact of policy decisions. The impact of better cycling infrastructure on cycling dissonance will become more clear to policymakers.

Although cycling dissonance was originally a binary variable, with each trip classifying as either cycling dissonant (1) or not cycling dissonant (0), a linear regression model was used to estimate the effects of the independent variables. The choice for linear regression, instead of a binomial or logistic regression, was made due to an aggregation to an individual level. Specifically, for every respondent, the mean cycling dissonance was calculated. This resulted in the cycling dissonance variable becoming a proportion between 1 and 0. This average cycling dissonance score represents the share of dissonant trips taken by a respondent. An important reason for this approach is that it allows each respondent to be treated equally in the analysis, regardless of how many trips they reported.

It is important to note that this changes the interpretation of the dependent variable: the regression now estimates the effects of predictors on the *average level of cycling dissonance per individual*, rather than on *the probability of a single trip being cycling dissonant*. This is important when interpreting the results of the model.

Although cycling dissonance is a proportion between 0 and 1, a linear regression was chosen for estimating the impact of the independent variables on cycling dissonance. This method can, in theory, predict values that are bigger or smaller than 0 and 1. However, due to the straightforward interpretation and widespread use of linear regression, this method is chosen. It is important to keep this in mind when interpreting the results.

## Descriptive statistics model

To demonstrate the representativeness of the data for the population, a table has been created to display the descriptive statistics of the variables entered into the models. The statistics are shown for the full ODiN dataset, and the cases used in the model. The population which the data in the model should represent is the Dutch working population, as the model only looks at commutes. The model only includes respondents who have made at least one commute of a cyclable distance. These respondents have a value for cycling dissonance and are included in the model. The whole dataset should represent the general population in the Netherlands from age 6+. This is population under which the survey has been spread.

| Variable | Full sample ODiN dataset (N = 92,442) | Model (N=12,807) |
|---|---|---|
| *Lease car (% Yes)* | 18.5% | 18.1% |
| *Fixed travel reimbursement (% Yes)* | 12.3 % | 13.0% |
| *Variable travel reimbursment (% Yes)* | 14.2 % | 12.6% |
| *Urbanity (mean, SD)* | 3.5 (1.2) | 3.7 (1.2) |
| *Detour (mean, SD)* | 2.8 (0.7) | 2.9 (0.6) |
| *50 km/h (mean, SD)* | 2.2 (0.6) | 2.2 (0.6) |
| *Roundabout (mean, SD)* | 4.1 (1.1) | 4.1 (1.1) |
| *Education* | No education, n/a = 13.4% | 4.2% |
| | Primary education = 3.3% | 3.6% |
| | Lower vocational education = 13.8% | 14.1% |
| | Intermediate vocational education = 28.6% | 35.6% |
| | Higher education = 40.8% | 42.5% |
| *Gender (male %)* | 51.4% | 50.4% |
| *Income level household (mean, SD)* | 6.4 (2.7) | 6.5 (2.6) |
| *Age (mean, SD)* | 44.2 (21.4) | 42.8 (17.3) |

*Table 4: Descriptives dataset & model*

As Table 4 shows, most data in the model does not differ a lot from the full dataset. However, for the education variable, there is a big difference. While in the full dataset, the lowest group for education is more than 13%, in the model, this drops to 3-4%. There is a clear explanation for this. As the model looks at the impact of these variables on commuting by bicycle, only the working population, who commute, are included in these models. Due to the same reason, the standard deviation of the age variable also decreases. Only people who work, mostly in between the ages of 18 and 67, are included in the model.

Something else that stands out is the high representation of highly educated people in the dataset. While the Netherlands is a relatively high educated country, these statistics are even higher than reported by the government (Ministerie van Onderwijs, Cultuur en Wetenschap, 2021). Higher-educated people are thus overrepresented in both the model and the dataset in general. The percentage of male respondents versus female respondents is close to the population level. The Working population encompasses a bit more males than females (Centraal Bureau voor de Statistiek, 2024d). In the model, this is also true with a male percentage of 50.4%. The mean age of the working population in the Netherlands is around 43 years old (Ebregt et al., 2019). Finally, the income level of the household variable is already standardized by CBS. If there were to be a good representation in this dataset, the mean value of this variable would be exactly in the middle as every group would be perfectly represented. This would result in the mean income level being 5.5. The mean value of income level household in the sample is 6.5. This shows that there are relatively more respondents from high-income households included in the sample. This group is thus overrepresented in the model and dataset.

To summarize, the dataset is mostly representative for the (working)population. However, both higher-educated and higher-income level households are a bit overrepresented in the data. Since the influence of other factors on cycling dissonance can vary for different education groups and income levels, the results may disproportionately reflect the patterns of the higher educated and richer population. This should be kept in mind when interpreting the results and drawing conclusions about the general Dutch working population. For the estimation of the size of cycling dissonant people, this misrepresentation is corrected by the weight factors included by CBS in the dataset. However, these were not used for the regression model.

## Health benefits

To calculate the potential health benefits of a reduction of cycling dissonance in the Netherlands, the HEAT tool of the World Health Organisation will be used. With this tool, urban planners, traffic engineers and special interest groups working on transport can mortality benefits of increased cycling and/or walking. The tool is suited for creating a quantitative Health Impact Assessment (HIA). The HEAT model quantifies the health benefits of cycling into prevented premature mortalities through changes in physical activity levels. The main question that HEAT model is supposed to answer is: If x people regularly walk or cycle an amount of y, what is the economic value of the health benefits resulting from the reduction in mortality caused by their physical activity? (World Health Organisation, 2017).

The Pan-European Master Plan for Cycling Promotion also recommends the use of this tool for calculating the mortality effects of transport policies (THE PEP – UNECE, 2021). HEAT is very user friendly, but therefore does make a few assumptions and does only apply in the following cases (World Health Organisation, n.d.):

- The HEAT model is a population model, making it only suited for estimating the broad effects on the total population.
- The HEAT model is only applicable for the age group of 20 up until 64. In this case the model will be used to estimate the effects of increased commuting by bicycle. The working population in the Netherlands finds itself largely in this group.
- The HEAT model is made for habitual behaviour. This makes it only suited for a structural increase in active transport. Commuting is a structural behaviour as people routinely have to travel to work.
- The HEAT model only presents mortality changes. The model does not include morbidity.

The tool needs input parameters that are possible to calculate using the ODiN dataset or have been gathered from literature.

The input parameters that will be used in the HEAT model are shown in Table 5.

**HEAT model World Health Organisation**

| Parameter | Input | Explanation |
|---|---|---|
| *Transport modes* | Cycling | As the research is about a reduction of cycling dissonance, only the health benefits of cycling are taken into account |
| *Country* | The Netherlands | The data used is specifically about Dutch commuters |
| *Year* | 2025 | - |
| *Number of years to be calculated* | 10 | The model also provides a constant yearly number of prevented mortalities |
| *Cycling data amount* | 7.56 km/day | The model allows to input the increase of cycling in various ways. With the ODiN data is is possible to calculate the total distance of cycling dissonance per person. This number is thus the mean cycling dissonance of people who have experienced at least one trip that can be classified as cycling dissonance. |
| *Average cycling speed* | 17.6 km/h | Average cycling speed on a conventional bicycle in the Netherlands (SWOV, 2022). |
| *Population size of country* | 18,078,745 | The most recent population data of CBS when running the model (Centraal Bureau voor de Statistiek, n.d.-b) |
| *Population size of assessment* | 480,694.25 | Using the ODiN dataset, the cycling dissonant population has been calculated. This is explained more thoroughly in chapter 4. |
| *All-cause mortality for cycling* | 213/100,000 inhabitants | To compare the reduction of mortalities due to more cycling, the WHO has a reference mortality rate for the Netherlands (World Health Organisation, 2025). This is the mortality in the Netherlands in the reference case. |
| *Economic value of life* | €6,300,000 | Research conducted by the governments of the Netherlands, Belgium, France and Germany calculated the value of a statistical life to monetize the effects of safer road policies (Schoeters et al., 2021). |
| *Discount rate* | 2.25% | The current discount rate for the Netherlands has been set by different government organisations (Rijkswaterstaat, n.d.). |

*Table 5: Input HEAT*

After the input parameters have been entered in the HEAT model, a calculation will be done and the estimated prevented mortalities and related economic value will be presented. The HEAT does this by applying a comparative risk assessment approach. The risk of mortality or premature death is compared between two cases; a reference case and a comparison case. The difference between these cases is the contrast in physical activity due to an increase in cycling and/or walking (World Health Organisation, 2021). To calculate this impact, HEAT uses well established relationships from epidemiological research between walking or cycling and health outcome. This relationship is then quantified based on literature. In Figure 2 a visual representation of HEAT is given.

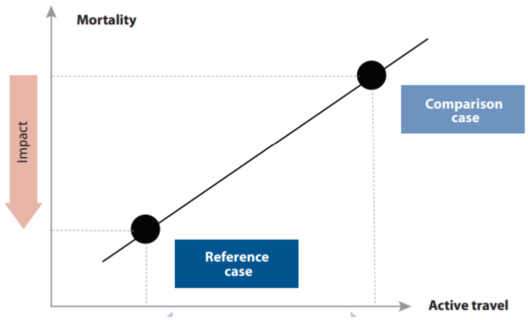

*Figure 2: Visual representation of HEAT (World Health Organisation, 2021)*

After quantifying the effects of increased physical activity on health, HEAT also calculated the related economic value of this change. This is calculated by multiplying the prevented mortalities with the statistical economic value of a life. For years in the future, this number is discounted by the discount percentage for the selected country.

# Chapter 4: Results

In this chapter, the results for every sub-question will be presented. The results of the first two sub-questions are presented together as they are both about cycling dissonance, but for different distances. At the end of the chapter, some results will be briefly discussed and compared to the current literature.

## Cycling dissonance in the Netherlands

The cycling dissonance in the Netherlands, commuter trips of less than 7.5 kilometres not taken by bicycle, was 48.4%. This represents a population of 480,694 people in the Netherlands. These people commuted without using any form of bicycle (bicycle, e-bike, or speedpedelec). When examining commuter trips with a distance of up to 15 kilometres, the percentage of people not cycling increases to 57.8**%**. This is further shown in Table 6. The population size of the cycling dissonant people is calculated using the weight factors discussed in chapter 3. This is the daily number of people who show cycling dissonant behaviour. As the ODiN research equally assigned every weekday the same number of respondents, and every respondent reported that single day. The number is thus the average number of daily cycling dissonant people. In reality, the number of people would probably be larger during the week and lower on weekends. More people in the Netherlands work during the week than on weekends.

| **Variable** | **Dissonant Percentage** | **Dissonant population** | **Total working population** |
|---|---:|---:|---:|
| *Commuter trips < 7.5km* | 48.4% | 480,694.25 | 993,450.45 |
| *Commuter trips 7.5 -15km* | 74.9% | 409,621.40 | 546.725.09 |
| *Commuter trips < 15km* | 57.8% | 890,315.65 | 1,540,106.52 |

*Table 6: Cycling dissonance in the Netherlands*

The cycling dissonance has also been calculated for regional levels. The regional levels for which the cycling dissonance has been calculated are COROP areas and municipalities. COROP area is a regional area within the Netherlands created for analytical purposes. The score of a respondent for cycling dissonance has been coupled the area of residence. Due to the distance cap for cycling commutes at 7.5 kilometres, a significant portion of the trip likely occurred in the respondent's area of residence.

In Figure 3 the cycling dissonance for the COROP area across the Netherlands is visualized for both distances up to 7.5 km (left) and 15 km (right).

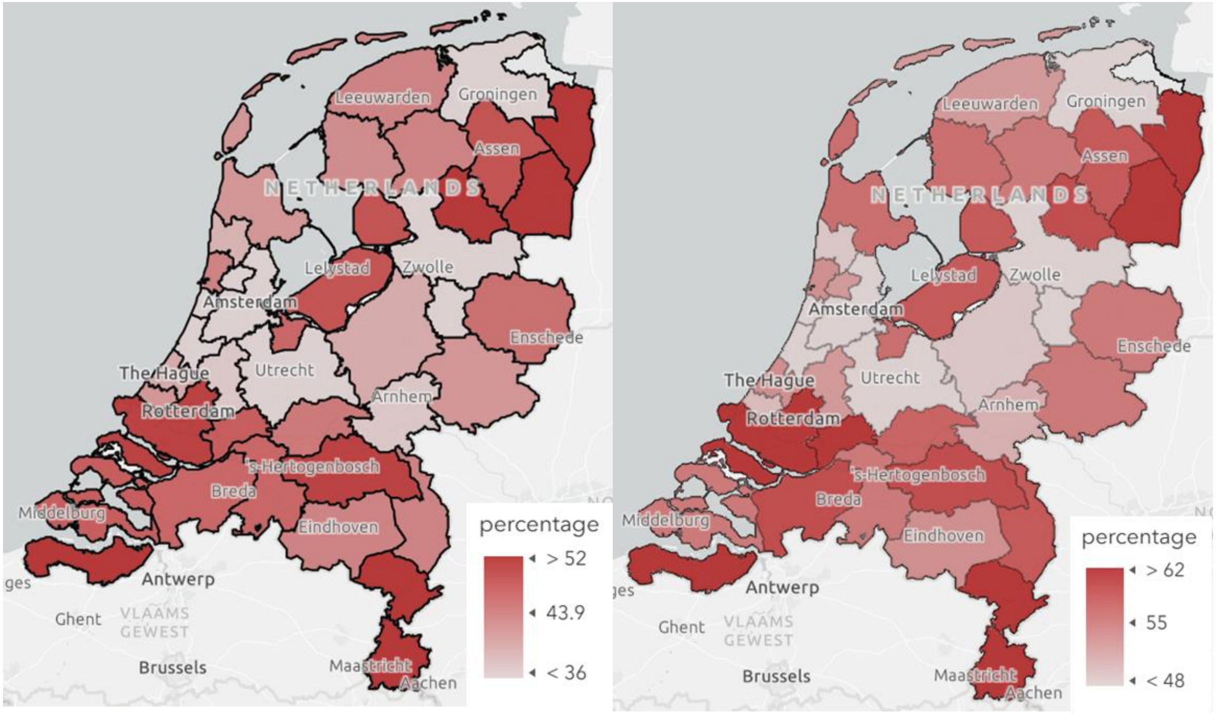


*Figure 3: Cycling dissonance in COROP areas*

The lighter areas have a lower cycling dissonance, meaning that within these areas, more people commute shorter distances by bicycle. The highest cycling dissonance is in the South-Limburg area, where the cycling dissonance is 61%. The lowest cycling dissonance is in the 'overig Groningen' area, where the cycling dissonance is only 26%. A big part of the inhabitants of this area live in the city of Groningen (~60%). A full table with the cycling dissonance in every COROP area is presented in the Appendix. The only COROP area that did not have enough respondents to be representative for the population is the Delfzijl area (top-right).

The 'Randstad' area seems to have a generally low cycling dissonance. The 'Randstad' is an urban configuration in the western part of the Netherlands (Van der Werff et al., 2013). Almost half of the Dutch population lives in this area. The area encompasses many urban cities and is more densely populated than the rest of the Netherlands. The part of the Randstad area that does have a high cycling dissonance, is the 'Rijnmond' area, in which the city of Rotterdam is located.

The south and north-east of the Netherlands have a higher cycling dissonance. Here, the 'Groningen' area is an exception. In this area more than half of the people live in the city Groningen.

The data can also be checked on a municipal level. However, due to the large number of municipalities in the Netherlands. This data is only representative of about half of the municipalities. In Table 7 the cycling dissonance is visualized for the ten most populous municipalities in the Netherlands

| Municipality | Cycling dissonance (<7.5km) | Dissonant population (<7.5km) | Cycling dissonance e-bike (<15km) | Dissonant population (<15km) |
|---|---|---|---|---|
| *Amsterdam* | 26% | 43,733 | 41% | 93,399 |
| *Rotterdam* | 46% | 40,682 | 57% | 72,980 |
| *The Hague* | 39% | 34,317 | 52% | 59,715 |
| *Utrecht* | 23% | 13,114 | 38% | 28,231 |
| *Eindhoven* | 34% | 15,826 | 44% | 29,104 |
| *Groningen* | 20% | 11,846 | 28% | 19,353 |
| *Tilburg* | 42% | 13,813 | 51% | 21,958 |
| *Almere* | 58% | 9,198 | 69% | 21,508 |
| *Breda* | 39% | 9,425 | 52% | 17,891 |
| *Nijmegen* | 24% | 8,473 | 38% | 15,085 |
| **National Average** | 48.4% | - | 57.8% | - |

*Table 7: Cycling dissonance in municipalities*

The major municipalities are all below the national average cycling dissonance, except for the municipalities of Almere and Rotterdam. This is not surprising as Rotterdam and Almere are known for being car cities (Van Eijck, 2020; De Bois, 2012).

## Multivariate model

In Table 9 the first multivariate model has been estimated. In this model, the dependent variable is the cycling dissonance. The spatial & infrastructure factors, employer policies, and social demographic variables have been entered.

As mentioned in Chapter 2, the dependent variable in the model is not a binary variable because it has been aggregated to the individual level. This causes the regression to estimate the effects of the predictors on *the average level of cycling dissonance per individual*.

In Table 8 a model summary of the model is shown.

**Model Summary**

| *R* | *R Square* | *Adjusted R Square* | *Std. Error of the Estimate* |
|---|---|---|---|
| .197[a] | .039 | .038 | .47967 |

*Table 8: Model summary*

In the model summary, the R value and R Square value of the model are given. The values of these variables indicate how well the regression model fits the data. In the model summary, the R value represents the multiple correlation coefficient. It indicates the overall strength of the linear relationship between the actual observed values of the dependent variable (cycling dissonance) and the values predicted by the regression model. For multiple regression, the R value is always positive and does not reflect the direction of the relationship, as individual predictors can have both positive and negative effects. In this model, the R value is 0.197, which suggests a weak linear relationship between the predicted and observed values.

The R square indicates the proportion of variance of the dependent variable explained by the independent variables. The model summary shows that the R square has a value of 0.039. This means that 3.9% of the variance of the dependent variable, cycling dissonance, is explained by the model. This indicates that the explanatory power of the model is limited. Most of the variation of cycling dissonance is not accounted for by the model.

This suggests that there are important factors that explain cycling dissonance, which are not included in the model. It could also be the case that commuting by bicycle is affected by complex, not linear, factors. These aspects are not accurately represented by a linear regression analysis. This is expected as the choice to commute to work by bicycle is very personal and cannot be accurately be captured by solely the variables included in the model.

**Regression Model (dependent variable: cycling dissonance)**

| | *Unstandardized Coefficients* | | *Standardized Coefficients* | | |
|---|---|---|---|---|---|
| | *B* | *Std. Error* | *Beta* | *t* | *Sig.* |
| (Constant)* | .651 | .040 | | 16.237 | .000 |
| Lease car* | .124 | .009 | .125 | 13.433 | .000 |
| Fixed travel reimbursement* | .071 | .013 | .049 | 5.386 | .000 |
| Variable travel reimbursement* | .099 | .013 | .069 | 7.551 | .000 |
| Urbanity* (1-5) | -.032 | .004 | -.081 | -7.684 | .000 |
| Detour factor (1-5) | -.009 | .007 | -.012 | -1.333 | **.183** |
| 50 km/h* (1-5) | -.027 | .009 | -.032 | -3.034 | .002 |
| Roundabouts* (1-5) | -.014 | .004 | -.030 | -3.264 | .001 |
| Education | .002 | .004 | .005 | .495 | **.621** |
| Gender* (male=1, female=2) | -.050 | .009 | -.051 | -5.658 | .000 |
| Income level household* | -.004 | .002 | -.019 | -1.991 | .046 |
| Age* | .002 | .000 | .057 | 6.239 | .000 |

**significant for p<0,05*

*Table 9: Model results*

## Coefficients

The 'B' value is the raw coefficient of the independent variables. This indicates how much the dependent variable changes if the independent variable changes by one unit. For example, the age variable has an unstandardized coefficient of 0.002. This means that if a person is 50, the model estimates that due to his age, the cycling dissonance increases by 50 * 0.002.

The constant term of the model is statistically significant (B = 0.651, $p < 0.001$), indicating the baseline level of cycling dissonance when all predictor variables are held at zero.

The employer policies all have a significant impact on cycling dissonance. Owning a lease car is the most important predictor for cycling dissonance of all the variables in the model as it has the biggest standardized coefficient. Individuals owning a lease car , on average, score 0.124 higher than those who do not own a leased car. Owning a lease car increases the cycling dissonance of a person with 12.4%. Both of the other employer policy variables were also positively and significantly related to cycling dissonance. People receiving a variable travel reimbursement based on the kilometres they have to commute, are more likely to have a higher cycling dissonance. The fixed travel reimbursement has the same effect, but smaller.

The urbanity score had a significant negative association (B = –0.032, $p < 0.001$), indicating that as urbanity increases, cycling dissonance tends to decrease. After the lease car, this was the most important variable in the model. Similarly, the presence of separate cycling lanes along 50 km/h roads and roundabouts that give way to cyclists in the municipality of residence were both negatively associated with cycling dissonance (B = –0.027 and B = –0.014, respectively, both $p < 0.01$). A higher score for these variables leads to lower cycling dissonance. If a municipality increases its score by one for one of these two variables by increasing the number of roundabouts that give way to cyclists or separate cycling lanes, the average cycling dissonance level of individuals in that municipality will drop by 2.7 percentage points and 1.4 percentage points.

In contrast, the detour variable was not statistically significant (B = -0.009, $p = 0.183$). This suggests that this variable did not have a meaningful linear relationship with cycling dissonance in this model.

For the social demographic variables, gender had a significant association (B = -0.050, $p < 0.001$) with cycling dissonance. This indicates a difference in cycling dissonance between males and females. Females have a cycling dissonance of, on average, 5% lower than males. The household income level showed a small but significant impact (B = -0.004, $p < 0.05$). Higher income level leads to slightly less cycling dissonance.

Age also has a small, but significant effect on the cycling dissonance (B =0.002, $p < 0.001$). However, when comparing the standardized coefficients, it becomes clear that age has a big impact. Because age spans a larger numerical range, each one-unit increase represents a relatively small proportion of its total variation, which leads to a smaller unstandardized effect size. Every year a person gets older, the average level of cycling dissonance increases by 0.2 percentage points. A 60-year-old has, on average, a 4% higher cycling dissonance than a 40-year-old.

Finally, the last socio-demographic variable, education, does not have a statistically significant impact (B = 0.002, $p = 0.621$). This indicates that there is no clear linear effect on cycling dissonance in this model.

Next to the unstandardized coefficients, the standardized coefficients are also shown. These coefficients indicate the relative importance of the independent variables, regardless of their scale. This allows for comparing the importance of age with that of gender, even though gender has the value 0 or 1 and age can range from 6 to 99.

The variable with the highest standardized coefficient is the lease car variable. This variable is thus the most important predictor for cycling dissonance as the standardized coefficient (Beta = 0.125) is the highest of the whole model. After the lease car variable the biggest standardized coefficients are urbanity (Beta = -0.081), variable travel reimbursement (Beta = 0.069), and age (Beta = 0.057). The difference between the unstandardized and standardized coefficient is especially great for age as this variable has the biggest range (6-99).

The least important variables in the model, with exception of the insignificant variables, are income level household (Beta = -0.019), roundabouts (Beta = -0.030), and 50 km/h (Beta = -0.032). These variables have the lowest standardized coefficients and the least impact on the average level of cycling dissonance per individual.

## Health benefits

Using the HEAT model of the World Health Organisation health benefits of a reduction of the current cycling dissonance have been calculated. These health benefits are only restricted to calculating prevented mortalities, and these have been quantified into a monetary value. This has been done using the value of a statistical life for the Netherlands and using a discount rate set by the government. This monetary value is calculated for a period of 10 years.

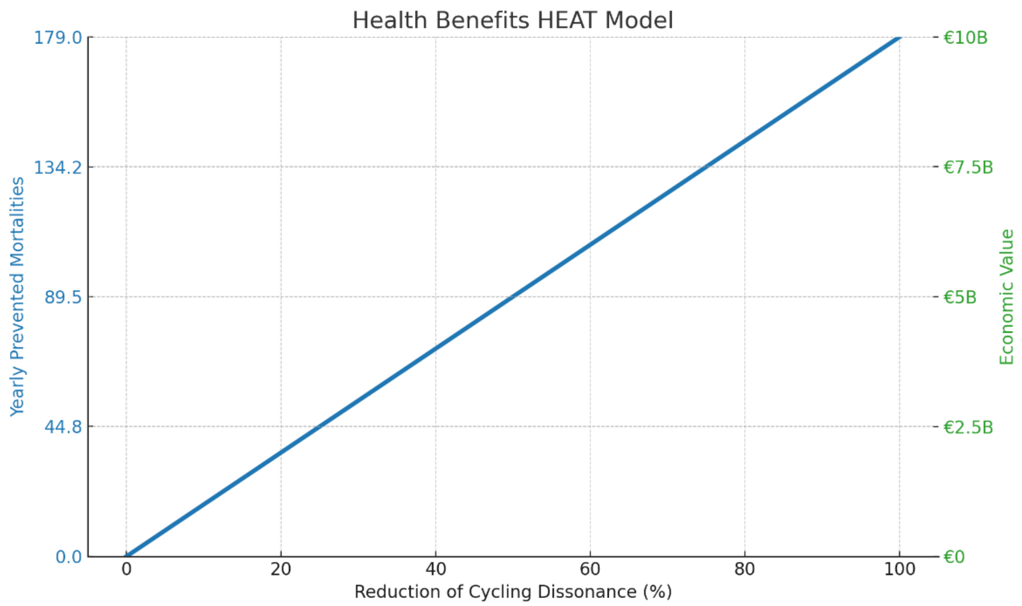


*Figure 4: Potential health benefits of the reduction of cycling dissonance*

As shown in Figure 4, reducing the cycling dissonance could save many lives per year due to the positive health effects of the increased physical activity. If cycling dissonance in the Netherlands were to cease to exist due to everybody living within a cyclable distance of their job choosing to cycle, this would lead to 179 prevented mortalities per year. While eliminating cycling dissonance in the Netherlands is not realistic, this number does highlight the positive effects of reducing cycling dissonance. If the cycling dissonance were reduced by only 50%, this would already prevent more than 89 deaths per year. If this were translated into an economic value, this would have a total economic impact of around €5 billion in an assessment window of 10 years.

With the assessment of the HEAT model, only prevented mortalities are calculated and presented. It is important to note that there are several other health effects of commuting by bicycle that are not included in these numbers. The literature review showed that mental health increases (Mytton et al., 2016; Singleton, 2018), the number of sick days reduces (Kalliolahti et al., 2024; Hendriksen et al., 2010; Mytton et al., 2016), and people live a generally healthier life due to commuting by bicycle (Neumeier et al., 2020. These effects were not quantified in this research, but are present when reducing cycling dissonance.

# Chapter 5: Discussion

In this chapter, the results will be further discussed and compared with existing literature findings. This will be done in order of the sub-questions, first discussing the results related to the cycling dissonant population in the Netherlands, then the factors impacting cycling dissonance, and finally the health benefits of reducing cycling dissonance in the Netherlands.

## Cycling dissonance

A 2022 report by MuConsult found that for commuting distances up to 7.5 km and between 7.5 and 15 km, 60% and 75% of commuters, respectively, did not travel by bicycle in the Netherlands. These findings are comparable to the results of this study, which calculated cycling dissonance. In this study, cycling dissonance was calculated at 48% for trips up to 7.5 km, and 75% for trips between 7.5 and 15 km. It should be noted that commuters who travelled on foot were excluded from these calculations. In this study, the cycling dissonance was further specified for different regions.

This study also calculated the absolute number of average daily cycling dissonant commuters. This gives greater insight into how many people could switch to commuting by bicycle.

Although regional differences in overall bicycle usage in the Netherlands were already documented (RIVM, 2022), this study examines regional patterns in cycling dissonance specifically. The results show that, consistent with general cycling trends, southern regions of the Netherlands have higher levels of cycling dissonance. Among the largest Dutch municipalities, cycling dissonance is generally lower than the national average, with the exceptions of Rotterdam and Almere. When looking at general cycling usage, fewer large municipalities exceed the national average, with only Amsterdam, Utrecht, Groningen, and Nijmegen scoring above average. The cycling dissonance in big municipalities thus does not match up with cycling in general. For short-distance commutes, the big municipalities are better for cycling than cycling in general.

While the regional spread of cycling dissonance showed that the 'Randstad' area had lower cycling dissonance, the urbanity variable also illustrated that densely populated areas have lower cycling dissonance. This is expected, as earlier research by Scheepers et al. (2013) found that, in the Netherlands in 2004-2009, people living in more urban areas had a higher modal share of active transport modes. This study found that people living in urban areas are more likely to commute by bicycle for short distances.

## Employer policies

The existing literature suggests that employer policies impact mode choice, thus affecting cycling dissonance. The results of the multivariate model support these findings. In particular, owning a company car or a leased car significantly affects cycling dissonance in the Netherlands. The influence of travel reimbursement on cycling dissonance is consistent with findings from Bueno et al. (2017). Their research also revealed that fewer people commute by bicycle due to mileage reimbursement from employers. It is interesting that the travel reimbursements still impact the cycling dissonance while not being specifically tied to a transport mode. An explanation for this could be that the relative costs of commuting by car decreases when an employee receives compensation. This makes the car a more competitive mode choice. Another reason could be that some employees only receive reimbursement for travelling by car. This also increases the competitiveness of this transport mode.

The great impact of a lease car on cycling dissonance was to be expected, as having a car available creates a low barrier to commuting by car. While this result is not surprising, no earlier literature had investigated the impact of lease cars on short-distance commutes. As the effect of a lease car was very large, especially considering that the commutes were of a cyclable distance, it should give insight to employers that offering a company car or lease car directly affects cycling dissonance. Employers should reconsider offering lease cars and company cars to their employees, especially if they live within a cyclable distance of the workplace, as it has a big impact on cycling dissonance.

## Spatial & infrastructure variables

The literature discussed in Chapter 2 showed that various infrastructure changes that are cyclist-friendly positively impact the number of cyclists. However, no studies were found about the effects of roundabouts that give way to cyclists. This study shows that in the Netherlands, roundabouts that are designed to give way to cyclists lead to lower cycling dissonance. The same was found for separated cycling lanes along 50 km/h roads. This also led to lower cycling dissonance. This aligns with the findings of a study in Montreal, Canada (Tanguay et al., 2024). Here, separated cycling lanes stimulated the number of cyclists in general.

Of the spatial & infrastructure variables, 3 out of the 4 had a significant impact on cycling dissonance. The more urban the municipality of residence of a person, the lower the cycling dissonance. Combined with the literature from the literature review, a couple of explanations for the relationship can be given.

First of all, urban cities are generally built more densely and are better suited for cyclists compared to car users. The travel time by car is relatively longer in urban areas due to crossings, traffic lights, and congestion (Kennisinstituut voor Mobiliteit, 2022). There could also be a link with more cycling infrastructure in urban areas. However, this relation is already (partly) covered by the inclusion of the two infrastructure variables. Finally, the direction of the relationship is also unclear. Scheepers et al. (2013) found a link between urban density and commuting by bicycle. However, they noted that this could also be because people who have a more positive attitude toward cycling tend to choose to live in more urban areas. In this case, a person's attitude toward commuting by bicycle reflects the true relationship, leading them to choose an urban environment in which to live.

The findings indicating that both of these variables contribute to a reduction in cycling dissonance demonstrate the impact of cycling infrastructure on the number of commuters choosing to cycle in the Netherlands, even for shorter distances. The variables of cyclist-friendly roundabouts and separate cycling lanes next to 50 km/h roads both lead to lower cycling dissonance. The first variable entails that the roundabouts in the municipality are designed in a way that gives priority to cyclists. The second variable concerns the number of cycling lanes that are separated from roads with a speed limit of 50 km/h. The findings that both of these variables lead to a decrease in cycling dissonance illustrate how cycling infrastructure can affect the number of commuters who go by bicycle in the Netherlands, even for short distances. Existing literature supports this. Shahriari et al. (2024) found that cycling infrastructure improvements in Lyon and Paris have led to a significant increase in cycling usage. Dill and Larsen & El-Geneidy (2009; 2010) also found that improvements to cycling infrastructure increase the number of cyclists. However, the findings of this study specifically show that better cycling infrastructure in the municipality of residence has a linear relationship with the average cycling dissonance score of an individual. Municipalities that have higher scores for these variables, and thus have more cyclist-friendly roundabouts and separated cycling lanes, have significantly more commuters who live close to their work commuting by bicycle. Investment in good infrastructure for cyclists and systematically prioritizing cyclists over car users thus leads to more people choosing to commute short distances with their bicycles.

The last variable in this group, detour, did not show a significant effect. This variable measures the additional distance a person needs to travel to reach a point exactly 1 kilometre from the municipality centre, serving as an indicator of how well the cycling network is integrated into that area. One possible explanation for its insignificance is that cycling dissonance already considers only trips within a feasible cycling distance, specifically under 7.5 kilometres. While a denser cycling network could theoretically encourage cycling for shorter trips, all trips in the analysis already fall within this manageable range. Therefore, an additional detour may not substantially influence the decision to cycle. Literature suggests that distance negatively affects cycling uptake (Ji et al., 2022), which could imply that a shorter detour should lead to higher cycling rates. However, because cycling dissonance focuses exclusively on trips within a cyclable distance, both distance and detour may have little influence on the mode choice in this context.

## Social demographic variables

The final group of variables included in the model are the social demographic variables. Firstly, there seems to be no relationship between the highest education completed by a person and cycling dissonance. The gender of a person is related to cycling dissonance. Women commute more often by bicycle than men. There is no clear explanation for this. Existing literature suggests that in other countries, men commute more often by bicycle than women (Sahlqvist et al., 2012; MacBride-Stewart et al., 2020; Nash et al., 2019). However, these results, focusing on cycling dissonance, show women having a lower cycling dissonance. Women, in the Netherlands, are more inclined to commute by bicycle when the distance is cyclable than men.

The income level of a household also impacts cycling dissonance. The higher the income of a household, the less likely a person is to have cycling dissonance. This is unexpected, as cycling is the cheapest travel mode in the Netherlands (Van der Heijden, 2021). However, the effect of income level on cycling dissonance is only small and barely significant. When analysing the mean cycling dissonance for every income group, there are no apparent differences. However, the lowest income group does have a significantly lower cycling dissonance than the average (33%). Possibly, only this income group is affected by the costs of travel for short commutes. A survey by the ANWB showed that in the Netherlands, owning and using a car is becoming increasingly expensive (Coevorden, 2025). More people are worried about the increasing costs of cars. The Nibud, the Dutch national institute for family finance information, also stated that cars are becoming too expensive for people with a median income. They say the same for the costs of public transit (Steffers, 2024). The fact that this is not visible in the coefficient of household income can have two reasons. Firstly, the relationship between income and cycling dissonance may not be linear. Only the lowest income group has a significantly lower cycling dissonance. Secondly, the higher income groups are overrepresented, while the lower income groups are underrepresented. This will be further discussed in the limitations.

A result that is not consistent with earlier scientific findings is the insignificant impact of education on cycling dissonance. In a study of the educational bias of commuter patterns in the Netherlands (Groot et al., 2012), the authors found that higher-educated individuals in the Netherlands are more likely to commute by bicycle. This does not align with the results of the multivariate model, which does not indicate a significant impact of education on cycling dissonance. This is, of course, not the same finding, as cycling dissonance is restricted to a certain distance. However, it was not expected that the results would differ from earlier scientific findings. What could explain the difference between these findings is the different coding of education. In the ODiN dataset, these education levels are divided into 5 groups, while the study by Groot et al. (2012) divided education levels into 7 groups. There is a significant impact of education on commuting by bicycle in Model 2. However, the direction of the coefficient is different from what was expected. The positive value suggests that more highly educated people commute less by bicycle. This is exactly the opposite of what has been found by Groot et al. Another possible reason could be the overrepresentation of highly educated individuals in the dataset. This could have skewed the results.

The final social demographic variable included in the model is a person's age. The older a person is, the more likely they are to express cycling dissonance. This relationship was expected, as cycling is a physical activity, and older people are generally less fit. Aging is related to the loss of muscle mass, muscle strength (Trouwborst et al., 2017; Phillips et al., 2019), and physical endurance (Mendonca et al., 2017). Cycling is a physical activity (De Hartog et al., 2010) and it is thus logical that older people are less inclined to cycle. E-bikes could be a good solution to get older people to commute by bicycle. They could compensate for the reduced physical strength of older people by assisting the rider. Van Cauwenberg et al. (2018) found that the primary reason older people use e-bikes is to be able to cycle longer distances. The E-bike is already most popular in the Netherlands among the older age groups (KiM, 2015).

## Health benefits

The results have shown that reducing cycling dissonance in the Netherlands can prevent 179 yearly mortalities. This number was calculated using the HEAT model from the WHO. Another study conducted in the Netherlands that used the HEAT model to estimate the health benefits of cycling was conducted by Fisherman et al. (2015). In this study, the authors calculated the prevented mortalities related to all the cycling that happened in the Netherlands. Their reference case was no cycling at all. The authors found that cycling in the Netherlands prevents 6,500 mortalities every year. When looking at the reduction of cycling dissonance and the related prevented mortalities, it is logical that this number is a lot smaller, as it encapsulates a lot less cycling. However, the number of 179 yearly prevented mortalities related to no cycling dissonance at all is still substantial. That more cycling leads to fewer mortalities complies with the findings of Tainio et al. (2016), who have found that even modest levels of cycling contribute to mortality reduction in urban settings, as the benefits of physical activity outweigh the negatives of exposure to air pollution. Another study that underlines the health benefits of commuting by bicycle was conducted by Friel et al. (2024). They found that active commuting, by bicycle, leads to a lower risk of all-cause mortality, any hospital admission, cardiovascular disease hospitalisation and medication, cancer incidence, mortality, and medication for poor mental health. These results were found based on a large representative sample, which provided robust evidence of the health benefits of commuting by bicycle. Pucher & Dijkstra (2003) found that risks related to cycling differ a lot between countries. They compared the likeliness of being injured or killed while cycling in the Netherlands, Germany, and the USA. The risks related to cycling were a lot higher in the USA than in the Netherlands and Germany. This causes the net benefits of commuting by bicycle to be lower in the USA than in the Netherlands. This means the findings of this study are specific to the Netherlands.

Next to the prevented mortalities, a reduction in cycling dissonance would also present other health benefits. These benefits were not calculated in this study but are important to mention, as they are also an important incentive for governments and employers to promote commuting by bicycle. For example, switching from commuting by car to commuting by bicycle leads, on average, to a weight loss of 0.75 kg (Dons et al., 2018). There is a clear relationship between commuting by bicycle and having a lower BMI (Makkonen et al., 2024). While BMI is, on an individual level, not a perfect indicator of health, Stenholm et al. (2017) found that for the general population, an excessive BMI is associated with substantially shorter life and more chronic illnesses. Commuting by bicycle is also associated with higher mental well-being scores (Mytton et al., 2016; Singleton, 2018). This even leads to bicycle commuters having 16% fewer mental health prescriptions (Berrie et al., 2022).

Importantly for employers, healthier employees are associated with better work productivity (Robroek et al., 2010). A more direct impact of healthier employees on employers is fewer sick days. In the Netherlands, the average sick leave is around 5.4% (Centraal Bureau voor de Statistiek, n.d.-d). This translates to around 13.8 days of sick leave per year per employee. Henriksen et al. (2010) found that commuters who go by bicycle in the Netherlands report, on average, one less sick day per year. Kalliolahti et al. (2024) also found this relationship in Finland. Active commuting reduced the number of sick days by around 8% - 12%.

# Chapter 6: Conclusions & Reflection

This thesis can be concluded by answering the main research question stated in the introduction:

*To what extent can cycling dissonance in the Netherlands be explained by employer policies, spatial factors, and demographics, and what are the potential health gains from reducing it?*

To give a concise and structured answer to this question, the four sub-questions will be answered first. For every sub-question, conclusions are presented. Finally, by combining the conclusions, an answer to the main research question will be given.

## Sub-question 1: What is the estimated cycling dissonance in the Netherlands, and how does it vary across different regions?

The cycling dissonance in the Netherlands is 48.4%. This means that of all the commutes in the Netherlands that are within 7.5 kilometres, almost half are not taken by bicycle. The average daily group of cycling dissonant people in the Netherlands is around 480,694 people. This number is the average for every day of the week. Most of the working population in the Netherlands has regular working hours. This means that they work from Monday to Friday from 9 to 5 (Putman, 2020). The cycling dissonant population is thus likely higher on weekdays and lower on weekends.

While cycling dissonance is prevalent throughout the Netherlands, significant regional differences exist. Most big municipalities score lower than the national average, and areas within the 'Randstad' region seem to score lower as well. The only region in the Randstad that scores higher for cycling dissonance is the 'Rijnmond' area. In this area, the city of Rotterdam is located. The city of Rotterdam and Almere both have a higher-than-average cycling dissonance. The other 8 biggest municipalities are below the average cycling dissonance. This could partly be due to the high level of urbanity of these big municipalities. While Rotterdam and Almere are known for being cities that have been designed for cars (Van Eijck, 2020; De Bois, 2012). This suggests that not only being a big urban city leads to a lower cycling dissonance, but designing the city for bikes is also necessary. Urbanity is included in the model used for answering sub-question 3 and will be further discussed there.

Even though the Netherlands is known for being a cycling country, the group of cycling dissonant people is still large. There is much potential for reducing emissions, congestion and capacity problems in public transport by reducing the number of cycling dissonant people.

A lot of people in the Netherlands do not commute by bicycle, while the distance to their workplace is not far. However, there are big differences between regions. The third sub-question will help explain the cycling dissonance and provide ways to decrease the cycling dissonance.

## Sub-question 2: How many people in the Netherlands, if given access to an e-bike, would be able to commute by bicycle?

In the previous sub-question, it was estimated that approximately 480,694 people in the Netherlands cycle daily for distances up to 7.5 kilometres, a distance suited for conventional bicycles. However, with the use of e-bikes, commuting distances can be extended up to 15 kilometres (KiM, 2016; Plazier et al., 2023). This means that e-bikes can potentially serve those traveling between 7.5 and 15 kilometres.

Within this distance range, approximately 409,621 people currently do not commute by bicycle, whether conventional, e-bike, or speed pedelec. In fact, 74.9% of commuter trips within this distance category (7.5–15 km) are not made by bicycle. This group is almost as large as the daily cycling dissonant population for short (7.5 km) distance trips. The potential for increasing commuting by bicycle with e-bikes is great.

According to Plazier et al. (2023), e-bikes have significant potential to substitute car travel, particularly for medium-distance commutes. Improving accessibility and adoption of e-bikes could lead to a substantial modal shift among the 409,621 people currently not cycling. This shift could play a meaningful role in reducing road congestion, particularly during peak travel times on highways. The share of e-bikes in the Netherlands is still growing (BOVAG, 2023). This highlights the potential for commuting by bicycle for this group of more than 400,000 people. This would have a great impact on emissions, congestion, and capacity problems in public transport. However, e-bikes are expensive as the average e-bike in the Netherlands costs more than €2700 (De Volkskrant, 2025). For many people in the Netherlands, this is a lot of money. Currently, in the Netherlands, most e-bikes are privately owned (96%) (BOVAG, 2023). For people with lower income levels, this high cost of e-bikes is likely a barrier to buying one. This prevents a big group of people in the Netherlands from commuting by e-bike for distances up to 15 kilometres due to the costs.

With an increasing number of people in the Netherlands starting to own an e-bike, more people who live 7.5 – 15 kilometres from their workplace can start commuting by e-bike. The e-bike could thus potentially have a big impact on commuting patterns in the Netherlands.

The regional spread of cycling dissonance for distances up to 15 kilometres does not differ much from the cycling dissonance for distances up to 7.5 kilometres.

## Sub-question 3: What is the impact of mobility policies of employers and spatial & infrastructure factors, controlled for social demographic variables?

The model presented in Chapter 4 shows that most variables that were included had a significant impact on the cycling dissonance. There were three classes of variables included in the model: employer policies, spatial & infrastructure, and social demographic variables. These will be discussed in this order.

### Employer policies

First, the mobility policies that were included in the model all had a significant effect on the cycling dissonance. If a person receives either a fixed or variable travel reimbursement, this person is more likely to show cycling dissonance. The variable travel reimbursement has the biggest impact of the two. This result can be explained rationally. If you are to be compensated for your commute, the car as a travel mode becomes a more attractive mode choice. Commuting by car is a relatively expensive travel mode compared to cycling (Van der Heijden, 2021). However, after receiving reimbursement, these costs can be covered. Bueno et al. (2017) showed that employees are sensitive to financial incentives when choosing their mode of transport. This corresponds with the finding that the variables about travel reimbursement have a relatively big impact on cycling dissonance.

The third employer policy included in the model was ownership of a lease car or company car within the household. This variable had a big impact on the cycling dissonance. The standardized effect of the lease car variable was the highest of all the variables included in the model. Once the employee has a car provided by the employer, many commutes will occur by car. Even though the trips for cycling dissonance are only restricted to distances up to 7.5 km. If an employer provides a leased car or company car to its employees, they are highly likely to use it for commuting even if it is less than 7.5 kilometres. Employers providing a lease or company car increases the cycling dissonance in the Netherlands. This employer policy is detrimental for reducing commuter-related emissions and congestion. Providing lease cars when employees live close by (<7.5 km) leads to an average increase of cycling dissonance level of 12.4%. This effect is big and unnecessary, as most people who live this close by should be able to commute by bicycle.

### Spatial & infrastructure variables

The analysis showed that three of the four spatial and infrastructure variables significantly influence cycling dissonance. Higher urbanity levels were associated with lower cycling dissonance, suggesting that densely populated areas provide conditions more suited to cycling for short commutes. In terms of infrastructure, the presence of separated cycling lanes along 50 km/h roads and roundabouts that give way to cyclists both had significant negative effects on cycling dissonance. This shows that investing in infrastructure for cyclists leads to more people commuting short trips by bicycle. Conversely, the detour factor did not show a significant effect. This variable is a measure of the directness of the cycling network. A likely explanation is that the definition of cycling dissonance already restricts trips to distances considered feasible for cycling. These findings underline the importance of targeted infrastructure improvements in reducing cycling dissonance, particularly in less urbanized areas.

### Social demographic variables

Several socio-demographic factors were found to significantly influence cycling dissonance. Gender had a big impact on cycling dissonance, with women less likely to exhibit cycling dissonance than men. Age was also significant, showing that older individuals are less inclined to cycle for short commutes. Household income had a small but significant negative association, suggesting that higher-income households are slightly less likely to commute by bicycle within cyclable distances. Education, however, did not show a significant effect in the model. This contrasts with earlier studies indicating that higher education levels are linked to greater bicycle use. This discrepancy may be related to differences in coding of the variable or the overrepresentation of highly educated individuals in the dataset. Overall, these results highlight the importance of considering demographic characteristics when developing targeted interventions to reduce cycling dissonance.

## Sub-question 4: **Given the previously calculated cycling dissonance, what potential health effects could result from its reduction in the Netherlands?**

To answer this question, the HEAT model of the World Health Organisation has been used. With this model, it was possible to calculate the effect of a group of people cycling more. More detail about the HEAT model was discussed in Chapter 3. The results show that yearly, 179 mortalities can be prevented due to the health benefits of increased physical activity. While it is unlikely that there will be no cycling dissonance at all, even a 50% reduction of cycling dissonance would prevent 89.5 yearly mortalities. These effects have also been quantified using the value of a statistical life for the Netherlands. This would represent an economic value of €5 billion to the Dutch government for a period of 10 years.

The findings of this study specifically showed that there is potential for preventing mortalities due to an increase in commuting by bicycle. This is an indicator for other health benefits that have not been specifically researched but are related to commuting by bicycle. The literature supports this and shows what effects this can have for employers. In the discussion it was mentioned that the results show serious incentives for the government and employers to promote cycling as a commuter mode as it is healthy. The health benefits are not only restricted to prevented mortalities, but also fewer sick days, better mental health and other health benefits are related to commuting by bicycle.

To conclude, the reduction of cycling dissonance has a big economic value due to the yearly mortalities it prevents, and it leads to people living healthier and happier lives. These health benefits should be a great incentive for employers and governments to try and reduce cycling dissonance.

## Main research question: **To what extent can cycling dissonance in the Netherlands be explained by employer policies, spatial factors, and demographics, and what are the potential health gains from reducing it?**

After answering the sub-questions, a clear and structured answer to the main research question can be given. This thesis shows that while the Netherlands is a cycling country, there is still a lot of potential for commuting by bicycle. The cycling dissonance (<7.5km) in the Netherlands is 48.4%, but there are some regional differences. One way the cycling dissonance can be reduced is through the construction and presence of cycling-friendly infrastructure. Both roundabouts that give way to cyclists and separate cycling lanes along 50 km/h roads lead to more people commuting by bicycle, and thus reducing cycling dissonance. This is in line with the findings of other literature. Investment in infrastructure that is safe and convenient for cyclists yields results; more people will commute by bicycle. Even in the Netherlands, where it is assumed that the cycling infrastructure for cyclists is very good in most places, differences in cycling infrastructure can still make an impact. Just the monetary value of the prevented mortalities due to a reduction of cycling dissonance could be up to €5 billion in 10 years. This excludes other positive (health) effects that commuting by bicycle has for society. There are enough incentives for the government(s) to increase the number of people who commute by bicycle, and they can do this through urban planning.

What also impacts cycling dissonance are employer policies. Employer policies can greatly impact the mode choice that employees make for commuting. Having a leased car available makes the choice to go by bicycle less likely. Even if it is just a short distance. Next to the lease car, variable - and fixed travel reimbursements also impact the cycling dissonance negatively. This illustrates that even when a person lives within a cyclable distance of their workplace, they may choose to go by car due to the reimbursements of their employer. Other literature also shows that the impact of employer policies on the mode choice for commuting is big. The government could help employers create stimulating policies by making it fiscally interesting to create these employer policies. There are already possibilities for employers to use a ‘fietsplan’ which are fiscally interesting (Belastingdienst, 2025). Employers should use these possibilities to incentivize their employees to cycle without having to make too many costs themselves.

To summarize, addressing cycling dissonance in the Netherlands can be achieved through investments in high-quality cycling infrastructure and the implementation of employer policies that discourage car commuting while actively promoting cycling as a viable alternative. Reducing cycling dissonance offers substantial health benefits, even preventing mortalities due to the physical activity related to commuting by bicycle. Even in the Netherlands, there is still much to win regarding commuting by bicycle. With more than 480,000 people in the Netherlands being cycling dissonant on a day to day basis. Employers and governments can help reduce this number through employer policies and infrastructure design.

## Policy implications

Two actors can use the findings of this study for policies. First of all, government bodies should use these findings for the improvement of infrastructure and regulations. The municipalities are mainly responsible for cycling infrastructure in the Netherlands, as these are mostly local roads. However, there are exceptions when the cycling lanes are the responsibility of provinces. Examples of this are 'cycling highways' which connect multiple municipalities (CROW, 2016). The central government mainly plays a supporting role. They can change regulations, commission research, conduct experiments, and in some special cases even co-fund projects. These projects are mostly bicycle parking near railway stations (Ministerie van Infrastructuur en Waterstaat, n.d.). The central government also creates regulations that can impact bicycle usage; determining tax-free travel reimbursement per mode, giving tax benefits for buying bicycles, etc. The different government bodies are thus responsible for cycling infrastructure and regulations.

The second group that can steer cycling dissonance are the employers. They create policies that can incentivize or discourage employees to commute by bicycle. By providing certain policies, employees are incentivized to pick certain modes of transport. Employers and governments are also reliant on each other for effective policies. The government has to create regulations that make it possible for employers to offer their employees policies that will lead to more cyclists. If the government creates these regulations, they are only effective if the employers utilize them. For both of these actors, policy recommendations will be given. Some policy recommendations are related to both actors.

### Governments

For the government, the findings of this study should be a great incentive to invest in reducing the cycling dissonance in the Netherlands. A reduction in cycling dissonance would make cities more liveable, reduce congestion and emissions, and helps solve capacity problems in public transport. But most importantly, the population in the Netherlands becomes healthier. This is something that the government is legally obliged to facilitate. Article 22 of the Dutch law states that: "The government takes measures to promote public health" (Vlemminx & Passchier, n.d.). Although the final decision to commute by bicycle is an individual's choice, the government can help steer this decision in a direction that promotes health. The following policy recommendations are relevant for the government in order to reduce cycling dissonance.

Municipalities are, for a large part, responsible for cycling lanes in the Netherlands. This study has shown that separated cycling lanes along 50 km/h roads can lead to decreased cycling dissonance. In Figure 5 a separated cycling lane is illustrated. For municipalities, a reduction of cycling dissonance should be an incentive to make changes. Cyclists make cities more liveable (Rijksdienst voor Ondernemend Nederland, 2024). Investing in cycling lanes that are separated, as shown in Figure 5, is a way for municipalities to decrease cycling dissonance. While these cycling lanes take up more space and are often more expensive (Rijkswaterstaat, 2025), they do reduce cycling dissonance, which has several desirable benefits for municipalities. Healthier inhabitants and a more liveable city are in many cases worth the costs.

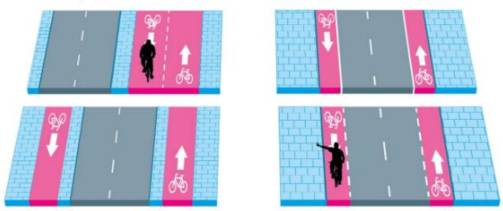

*Figure 5: Seperated cycling lanes (Left) vs normal cycling lanes (right) (Hendrich & Loumeau, 2025)*

Next to separated cycling lanes, roundabouts that prioritize cyclists have also been shown to reduce cycling dissonance. A roundabout that gives way to cyclists decreases travel times and increases comfort for bicycle commuters. These effects do have a significant impact on the cycling dissonance. Municipalities should make roundabouts where cyclists get right of way the standard.

The model also showed that there was no significant impact of the detour factor on cycling dissonance. The Netherlands already has a dense cycling network. Apparently, for short distances (7.5 km), it does not impact the cycling dissonance when people have to take small detours. The extra model estimated in the appendix did show that for commutes of all distances, the detour factor did affect bicycle commuters. If municipalities want to focus on short-distance cycling dissonance, it is not worthwhile to increase the density of the cycling network. However, if municipalities or provinces want to increase the number of commuter cyclists for longer distances, it does have a significant effect to invest in a denser cycling network where less detours are necessary. For longer distance commutes, there are often multiple municipalities involved. Here lies a role for the province to coordinate and invest in cycling lanes to increase the density of the cycling network.

The effects of good roundabouts and separated cycling lanes on cycling dissonance were significant, and policies stimulating these kinds of infrastructure should be prioritized by the municipalities.

Finally, the government has regulatory powers that can impact the cycling dissonance. By offering favourable tax exemptions, they can allow employers to provide incentives for their employees to commute by bicycle. The results show that individuals are impacted by travel reimbursements. Currently, the tax-free variable travel reimbursement is set at €0.23/km. The government could consider making this tax-free variable travel reimbursement mode specific. Making the reimbursement for commuting by bicycle higher, while making the reimbursement lower for other modes. This will make it more attractive for employers to offer differentiated travel reimbursement per mode, which will hopefully reduce cycling dissonance.

### Employers

The results clearly illustrated that providing lease cars has a big impact on cycling dissonance. Employers should rethink whether lease car policies are necessary and desirable. An alternative for providing lease cars, especially for employees who live nearby, is providing the option to lease a(n) (e-)bicycle. Only 4% of e-bikes in the Netherlands are currently leased. While e-bikes are rising in popularity (BOVAG, 2023), not many employees can lease an e-bike through their employer. The literature suggests that e-bikes could be an excellent substitute for commuting by car (up to 15 km) (Plazier et al., 2023). The same study showed that those with lower socioeconomic status and a household with children showed more willingness to use an e-bike in the future. This group would be helped especially by opportunities to lease an e-bike through their employer, as e-bikes are expensive. The mean price paid for an e-bike in the Netherlands was €2700 last year (De Volkskrant, 2025).

The results showed that older people are more likely to be cycling dissonant. This is likely due to the decrease of physical strength and endurance. Providing opportunities to lease e-bikes would be beneficial for this group as well. The reduced physical activity required by using an e-bike could help keep older people commuting by bicycle. Currently, only 20% of employers offer the opportunity to lease an e-bike (Ministerie van Infrastructuur en Waterstaat, 2025b). This is a big increase from 9% in 2021. However, still 80% of employers do not offer the possibility to lease an e-bike. Since January

2020, it has been possible for employers in the Netherlands to easily provide a bicycle for their employees (Ministerie van Algemene Zaken, n.d.). This highlights how the government provides the regulations and fiscal advantages, but employers are the ones who have to use this to incentivize their employees to commute by bicycle and reduce cycling dissonance. Employees of the central government can lease an e-bicycle since January 2025 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, n.d.)

Providing opportunities for employees to lease e-bikes will make e-bikes more attractive. Especially for people who live longer distances from their workplace (7.5 – 15 km) or older people, these e-bikes could be a great solution. While this study mainly researched and pointed out health benefits of commuting by a 'conventional' bicycle, Anderson et al. (2022) have shown that commuting by e-bike still provides a level of physical activity that leads to health benefits. They find that commuting by e-bike, compared to public transport or car, improves mental and physical health, happiness and overall sense of well-being.

The results also showed that variable travel reimbursement has a big impact on cycling dissonance. This illustrates the opportunities to influence the cycling dissonance with policies about travel reimbursement. Research from the Dutch Ministry for Infrastructure has shown that the mean travel reimbursement in the Netherlands for bicycles was €0.18 per kilometre (Ministerie van Infrastructuur en Waterstaat, 2025b). Employers in the Netherlands are allowed to provide a travel reimbursement of €0.23 per kilometre tax-free. It is allowed to provide an even higher travel reimbursement; however, then the reimbursement will be subject to tax. The gap between the allowed tax-free travel reimbursement and the mean travel reimbursement for bicycles highlights that there is still more potential for this policy to incentivize employees to commute by bicycle. Employers should make use of this tax-free policy and reduce cycling dissonance by increasing the travel reimbursement. Especially making sure that the travel reimbursement for cycling is higher than commuting by car or public transport will provide a financial incentive that will reduce cycling dissonance.

Finally, the employer can make use of the 'Werkkostenregeling' (WKR) to provide employees with good (e-)bicycles. Around half of the employers in the Netherlands use regulations to provide policies to employers for cycling (MuConsult, 2019). With the WKR, employers can provide a range of benefits and policies to their employees. Firstly, the 'bruto-netto voordeel'. With this regulation, an employee can buy a bicycle through the employer and deduct the costs from their gross salary. This uses a fiscal advantage as it saves taxes for the employee and does not cost the employer anything. However, only 29% of employers provide the opportunity to use this policy. For e-bikes this is just 21%. Employers can also use the WKR to (partly) sponsor a bicycle for their employees.

Employers should be aware of these policies and actively promote them to their employees. Having a good bicycle will reduce the cycling dissonance of employees. This provides benefits to the employers as they will get healthier employees in return.

## Limitations

In Chapter 3, the descriptive analysis of the model indicated that it does not perfectly reflect the population. The mean standardized income level of households revealed that the average income level of the respondents' household in the dataset was approximately 6.4, whereas a perfect representation would yield a mean of 5.5. After examining the distribution of respondents across different income levels, it became clear that the lower five income levels all fall below the 10%

representation threshold in the dataset. Meanwhile, the top four income levels are all represented at more than 10%, indicating an overrepresentation of wealthier households.

Additionally, the dataset also shows an overrepresentation of individuals with higher education levels. There are more highly educated respondents in the data than are present in the broader population. However, when assessing other socio-demographic variables, the dataset appears to accurately represent those groups. This skew in representation, particularly among income levels and education, should be taken into consideration when interpreting the results of the study. The findings are thus more representative of highly educated and high-income individuals. While both the variables of income level and education did not seem to have a big direct linear impact on cycling dissonance, possible underlying relationships could be impacted by this misrepresentation.

While the overrepresentation of some groups in the dataset can be compensated when calculating the cycling dissonance for regions or in total for the Netherlands by using the weight factors included in the dataset. These weight factors are created to compensate for the underrepresentation of certain groups in the dataset. However, these weight factors are not used for the regression model. The slight misrepresentation of certain groups could possibly lead to some skewed results.

The findings in this study are not necessarily true for other countries. The Netherlands is commonly known as a cycling country where cycling is embedded in its culture. The effects of employer policies and cycling infrastructure on cycling dissonance in the Netherlands are not necessarily the same as in other countries. Next to the geographical scope of the study, it is also important to note the study's time frame. The ODiN data that has been used is from 2023 and 2022 to reduce the impact of the COVID-19 pandemic on the findings. However, it could be possible that the pandemic still has an impact on the mobility of commuters. Working from home has doubled due to the COVID-19 pandemic (Jongen et al., 2021). However, employers are becoming more critical of working from home (CNV, 2025). The findings of this thesis may change slightly due to changing commuter patterns.

It should also be mentioned that people who currently walk to work have been excluded from the analysis. This group should technically be labelled as cycling dissonant, but there are no clear reasons to get them to start commuting by bicycle. It is not more sustainable or healthier if this group starts cycling. The exclusion of this group from the analysis does not have a big impact as this group is only 4.4% of the commutes within 7.5 kilometres.

As mentioned earlier, the prevented mortalities are an indicator of the health effects of a reduction of cycling dissonance. This study is limited to only calculating these health effects. More health effects of commuting by bicycle are mentioned in the literature and conclusions, but have not been quantified.

Lastly, it is assumed that every person who commutes less than 7.5 kilometres should be able to do so by bicycle. However, there are individual reasons that could prevent a person from commuting by bicycle, even if the distance is not too long. This is not included in the research as this most likely is not a big group and the reasons can differ and be specific for each individual. For example, people with physical limitations are not always able to use a bicycle.

## Recommendations for future research

The model in this study contained three different employer policy variables. These three were: fixed travel reimbursement, variable travel reimbursement, and lease car. The impact of these variables on cycling dissonance illustrates that employer policies can impact cycling dissonance and that having a leased car has by far the biggest impact. However, there exist more employer policies than just these three. Even in the ODiN dataset, there were 7 other employer policies included. However, these could not be included in the model. In the ODiN survey, respondents were only asked about employer policies related to the transport mode they reported using most frequently for commuting. For example, individuals who mainly travelled by car were only asked about car-related employer policies, while those who primarily used public transport were only asked about public transport-related policies. As a result, the data does not include information on the availability of employer policies for alternative modes of transport that a respondent did not use. This design made it impossible to accurately assess whether the presence or absence of certain employer policies influences the choice of commuting mode.

However, to effectively bring down cycling dissonance, it is important to know the effects of different employer policies. It is suggested that future research further investigate the relationships between multiple employer policies on cycling dissonance. This research has shown that employer policies can have a big impact on cycling dissonance. Now the question arises, what specific employer policies are most effective in reducing cycling and promoting commuting by bicycle. A specific study on the impact of different employer policies on cycling dissonance in the Netherlands is thus recommended. This study should not limit questions about employer policies to those who already commute most often with the related transport mode. This will present a clearer picture of the effectiveness and impact of different employer policies and will allow companies to carefully pick the best employer policies for reducing cycling dissonance. The relationship of the WKR policies and leasing e-bikes through the employer should be investigated, as these policies are not yet used by many employers and employees (MuConsult, 2019; BOVAG, 2023). There may be a lot of potential in these policies to reduce cycling dissonance.

This study mainly investigates the potential health benefits related to increased cycling due to a reduction of cycling dissonance. However, it has also become clear that, for longer distances, e-bikes could also be a great sustainable mode for commuting. However, the effects of e-bikes are less clear. While one would assume that commuting by e-bike, compared to commuting by car, would offer health benefits, this is not as clear. An overview of potential health benefits related to commuting by e-bike would help policy-makers decide if this is also a good commuter mode to promote for distances deemed too long for ‘conventional’ bicycles.

As mentioned in the conclusions, the prevented mortalities are not the only health effects of reduced cycling dissonance. Other health effects, such as better mental health, lower morbidity and lower BMI are also present. These effects have not yet been quantified. Further research should try and make these effect insightful by calculating them. Quantifying the reduced number of sick days could present a great incentive for employers to promote commuting by bicycle.

Lastly, this study focused on the health benefits of commuting by bicycle, as this offers a direct incentive for employers. However, reducing cycling dissonance can have additional benefits beyond health. Two important effects that could motivate not only the government but also employers are lower emissions and reduced congestion.

Research shows that cycling has the lowest $CO_2$ emissions of all transport modes, except for walking (Thomas & Serrenho, 2023). A reduction in cycling dissonance could therefore lead to lower emissions and help the Netherlands reach its climate goals of becoming carbon neutral by 2050 (Rijksoverheid, n.d.). These environmental effects were not calculated in this study, but future research could apply a similar method to estimate the cycling dissonance and use this to calculate the impact of reducing cycling dissonance on emissions.

In addition, future studies could explore how reducing cycling dissonance might ease road congestion and reduce pressure on public transport. Currently, both traffic jams and overcrowding in public transport are common during rush hours (Ministerie van Infrastructuur en Waterstaat, 2025a; RADAR, 2024). If the potential impact of cycling dissonance reduction on these issues can be estimated, it could offer a useful strategy for policymakers looking to address these challenges.

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# Appendix

## COROP dissonant people

In **Table x.x** the number of cycling dissonant people per COROP area is shown. These were calculated using the weight factors of CBS. CBS used the area of residence when creating these weight factors. The COROP area 'Delfzijl en omgeving' had less than 30 respondent and its data is thus not representative.

| COROP Area | Number of dissonant people (<7.5km) | Dissonant percentage (<7.5km) | Number of dissonant people (<15km) | Dissonant percentage (<15km) |
|---|---|---|---|---|
| Oost-Groningen | 5.355 | 55% | 9.770 | 65% |
| Delfzijl en omgeving | - | - | - | - |
| Overig Groningen | 20.750 | 26% | 37.025 | 36% |
| Noord-Friesland | 16.243 | 44% | 27.027 | 53% |
| Zuidwest-Friesland | 9.883 | 43% | 17.503 | 57% |
| Zuidoost-Friesland | 9.885 | 44% | 16.076 | 56% |
| Noord-Drenthe | 11.002 | 49% | 20.244 | 59% |
| Zuidoost-Drenthe | 8.959 | 56% | 16.265 | 67% |
| Zuidwest-Drenthe | 9.361 | 53% | 14.294 | 60% |
| Noord-Overijssel | 17.504 | 34% | 30.771 | 44% |
| Zuidwest_overijssel | 9.094 | 35% | 15.485 | 44% |
| Twente | 40.438 | 46% | 70.543 | 56% |
| Veluwe | 36.464 | 40% | 60.624 | 49% |
| Achterhoek | 21.749 | 42% | 45.029 | 56% |
| Arnhem/Nijmegen | 33.324 | 37% | 67.151 | 51% |
| Zuidwest-Gelderland | 12.954 | 45% | 24.019 | 58% |
| Utrecht | 56.759 | 35% | 113.665 | 47% |
| Kop van Noord-Holland | 18.929 | 42% | 41.296 | 57% |
| Alkmaar en Omgeving | 12.364 | 39% | 21.880 | 49% |
| Ijmond | 12.395 | 44% | 20.172 | 54% |
| Agglomeratie Haarlem | 8.253 | 30% | 17.456 | 44% |
| Zaanstreek | 6.582 | 34% | 17.113 | 53% |
| Groot Amsterdam | 73.018 | 33% | 148.034 | 47% |
| Het Gooi en Vechtstreek | 11.054 | 47% | 19.302 | 57% |
| Agglomeratie Leiden en Bollenstreek | 25.622 | 33% | 47.262 | 45% |
| Agglomeratie 's-Gravenhage | 50.605 | 40% | 97.534 | 54% |
| Delft en Westland | 15.434 | 42% | 26.486 | 50% |
| Oost-Zuid-Holland | 11.976 | 37% | 28.223 | 53% |
| Groot-Rijnmond | 88.662 | 51% | 164.949 | 62% |
| Zuidoost-Zuid-Holland | 20.867 | 48% | 40.186 | 62% |
| Zeeuwsch-Vlaanderen | 7.070 | 60% | 12.446 | 66% |
| Overig Zeeland | 18.965 | 48% | 30.221 | 56% |

| | | | | |
|---|---|---|---|---|
| West-Noord-Brabant | 33.607 | 47% | 63.892 | 60% |
| Midden-Noord-Brabant | 28.455 | 47% | 50.387 | 56% |
| Noordoost-Noord-Brabant | 42.638 | 51% | 77.053 | 60% |
| Zuidoost-Noord-Brabant | 54.617 | 44% | 101.794 | 54% |
| Noord-Limburg | 17.756 | 44% | 35.436 | 59% |
| Midden-Limburg | 17.727 | 60% | 25.758 | 66% |
| Zuid-Limburg | 40.726 | 61% | 63.520 | 68% |
| Flevoland | 22.234 | 49% | 41.349 | 59% |