BICYCLE INFRASTRUCTURE AND CYCLING IN SMALL TOWNS IN THE NETHERLANDS

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Abstract

The factors that affect why individuals may choose to cycle are vast. Evidence suggests infrastructure is a key factor affecting cycling levels. This thesis will investigate the correlation between cycling infrastructure and cycling levels within small towns in the Netherlands. A brief review of cycling in the Netherlands is presented to understand why cycling is remarkably popular across the country and extensive prior research is discussed regarding factors that affect cycling levels. The existing research is fundamental to the theoretical framework developed here. The framework included factors affecting cycling levels and determined how cycling infrastructure affects cycling levels. Through statistical analysis the relationship between the factors, focusing on factors of cycling infrastructure, was assessed. The data utilised in the analysis was inadequate to produce statistically significant results. Nonetheless, the correlation between bicycle infrastructure and cycling levels is significant, as has been examined by several authors, in existing cycling research. In summary, this analysis did not produce statistically significant results accounting for the relationship between all factors identified in the theoretical framework. While the research question could not be answered through the collected data it has been confirmed that there is a positive relationship between the existence of suitable cycling infrastructure and high cycling levels. Further research would be required to produce statistically significant results to determine the exact correlation between cycling infrastructure and cycling levels in small Dutch towns.

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1 Introduction

Bicycling, as a mode of transportation, is a complex phenomenon. Reasons for this complexity are attributed to a country or specific area's culture, history, infrastructure, socio-cultural factors, policies, politics, natural environment and climate. The bicycle is common nearly worldwide and the popularity of bicycling has been growing recently. Considerable debate and inquiry occurs amongst cycling researchers attempting to determine motivations for cycling. Motivations for cycling will be examined and are guided by the relationship between cycling and infrastructure. While all motivations relevant to understanding cycling levels will be discussed in this thesis, the focus will be on the influence cycling infrastructure has on cycling.

The relationship between cycling levels and cycling infrastructure has been studied extensively and it is well known that there is a significant correlation between the two. However, what is not well known is the relationship between cycling levels and infrastructure in small towns in the Netherlands. Thus, this study has identified this research gap.

The Netherlands has the world's highest cycling levels and an extensive history of using the bicycle as a primary mode of transportation (Ministry of Transport, Public Works and Water Management & Fietsberaad, 2009). Generally, research on cycling has mostly been restricted to large urban areas; this is especially true in the Netherlands. Thus, this research will focus only on small Dutch towns with populations under 50,000. The following chapter discusses the research question and objectives, presents the societal and scientific relevance of the research conducted and gives an overview of the thesis. The thesis seeks to fill the gap in the research on small towns in the Netherlands, and to examine the extent to which infrastructure influences cycling levels within these towns. The following chapter will expand on the aforementioned concepts to determine the relevance of the following research question:

Does better bicycle infrastructure correlate with higher cycling levels in small towns in the Netherlands?

1.1 Research Question and Objectives

Following a brief history of cycling in the Netherlands and a discussion of cycling culture and cycling levels that provides background and context to the research undertaken, the research question will be discussed. The research question addressed is:

Does better bicycle infrastructure correlate with higher cycling levels in small towns in the Netherlands?

Part of this question is not entirely new; researchers have been attempting to determine factors that affect cycling levels for many years. Substantial research has been conducted on the motivations of bike use (e.g. Harms, Bertolini, & Te Brömmelstroet, 2014; Heinen, van Wee, & Maat, 2010). What is not yet clear is which strategies are highly influential in increasing cycling rates and which have little effect (Handy, van Wee, & Kroesen, 2014). Although it is evident that infrastructure is a well-known motivation for bicycle use, the present analysis specifically of small towns will bridge the gap in knowledge on cycling levels and their relation to infrastructure in areas which are not predominately large and urban. In this research, three queries are important to take into consideration throughout the research. While they are not research questions themselves they will be utilised to guide the discussion on the relationship between cycling levels and infrastructure. The queries are: firstly, are people likely to cycle with increased support from infrastructure; secondly, will people cycle regardless; and thirdly, will cycling demand lead to more investments in infrastructure (Pucher, Dill & Handy, 2010). Answering the above research question will aid continued cycling research and will be answered by examining cycling data from the Netherlands.

The objectives of this thesis are as follows:

1. Create a theoretical model of factors that affect the cycling levels in small towns in the Netherlands.

2. Propose a method of isolating infrastructure from other cycling level influences to determine the impacts of infrastructure alone on cycling levels.

3. Discuss the benefits of, and the need for, studying cycling in small towns compared to large cities.

4. Contribute to the body of academic literature examining cycling usage by specifically focusing on the effects of infrastructure in small towns in the Netherlands using existing bikeability data.

1.2 Societal and Scientific Relevance

Academic literature on cycling as a mode of transportation is extensive. Significant knowledge and understanding of cycling exists, although predominantly only related to large cities and urban areas (e.g. Dufour, 2010; Forsyth & Krizek, 2011; Martens, 2004; Pucher & Buehler, 2007; van Goeverden & Godefrooij, 2011). Literature pertaining to cycling in small cities or towns is almost non-existent (Handy, Heinen & Krizek, 2012). Therefore, the scientific significance of this thesis exists in studying the gap in literature on cycling in small towns. To overcome this identified gap the thesis endeavors to broaden the availability of information, perceptions, and data on cycling in small towns. It is fundamental to recognize that although the relationship between small towns and cycling has not previously been explored as extensively as the relationship between cycling levels and cities, small towns are not irrelevant to cycling research. Planners and policy makers at the local and national level may utilize outcomes from this research in making decisions for cycling infrastructure in small towns. As the cycling culture and infrastructure in the Netherlands is considered by other countries to be highly desirable it is important for these countries to be able to understand how cycling can work in their own country, not only in large urban areas but also in smaller towns and communities. The results aim to show an overview of factors influencing cycling levels in small towns with a focus on infrastructure.

The societal relevance of this research is found in the societal benefits of cycling. In general, in the Netherlands, benefits of cycling are vast. Studies indicate that high cycling levels in the Netherlands benefit the health of residents; 6,500 deaths are avoided each year and residents' life expectancy is estimated to be six months longer due to improved health. The increased health of residents also benefits the economy by €19 billion annually which is more than 3% of the Netherland's Gross Domestic Product from 2010 and 2013 (Fishman, Schepers & Kamphuis, 2015; CBS, 2015). Other benefits include improved mobility for residents, decreased noise and air pollution, energy saving, decreased congestion and decreased strain on the environment (Pucher & Dijkstra, 2003).

This study provides an exciting opportunity to advance the knowledge of factors affecting cycling levels. With an increased interest in cycling worldwide, as well as higher bicycling levels, there is currently more demand for insight related to cycling levels: how can they be increased and what it is that encourages increased cycling (van Goeverden, Nielsen, Harder & van Nes, 2015). This is particularly important for the Netherlands as many countries look to the Netherlands as leaders in cycling as a mode of transportation and for expertise in methods for increasing cycling levels in countries around the world (van Goeverden., Nielsen, Harder & van Nes, 2015)

1.3 Thesis Overview

The overall structure of this thesis takes the form of five chapters, including this introductory chapter. This chapter introduced the context of the thesis by introducing cycling culture in Netherlands, presented the research question and provided the societal and scientific relevance of the research. Chapter two is concerned with the methodology and research strategy used in this study. The research areas, approaches, progress, and perceived limitations are demonstrated here. Chapter three provides a literature review of the current debates in the field of cycling levels and infrastructure. A theoretical framework is introduced exhibiting the theoretical dimensions of the research. Chapter four contains the empirical analysis portion of the thesis examining local contexts and discusses the analysis results for the factors discussed in the theoretical framework. A full discussion specifically on the relationship between cycling infrastructure and cycling levels is included. The final chapter contains the conclusion; a discussion of limitations, a reflection of the research and final discussion on the research question.

2 Literature Review and Theoretical Framework

The purpose of this chapter is to (1) review existing literature on cycling infrastructure, cycling levels and factors affecting bicycle use while exploring how they are relevant in small towns; and (2) formulate a theoretical framework that will inform the empirical research presented in the remainder of the thesis. This chapter begins with an overview of the history and culture of cycling in the Netherlands followed by a discussion of relevant literature on cycling levels and influencing factors. The work of a number of authors in the field of cycling and cycling infrastructure research is critically assessed. A framework from Rietveld and Daniel (2004) and one from Ververs and Ziegelaar (2006) are presented that discuss factors influencing cycling levels in municipalities and towns in the Netherlands. These frameworks assisted in establishing the theoretical framework that is introduced and discussed in this chapter. Criteria for the main requirements of bicycle infrastructure, as per CROW (a Dutch non-profit technology platform for transport, infrastructure and public space), are discussed at length leading into a discussion on the relationship between cycling infrastructure and cycling levels. To complement academic research, analysis of the Dutch *Fietsbalans*, or bikeability, is presented to provide an on-the-ground assessment of significant requirements of cycling infrastructure, based on research conducted across the Netherlands. The relevance of small towns for the research is introduced. The conclusions of the literature review are encapsulated and result in a theoretical framework identifying the key factors affecting cycling levels used in this research and a full explanation of these factors is included.

2.1 Cycling in the Netherlands

In order to comprehend the importance and uniqueness of cycling infrastructure in the Netherlands it is imperative to compare Dutch cycling history to other parts of the world. While there is not much knowledge on the emergence and advancement of cycling historically in European countries it was likely related to societal developments (Stoffers, 2012). Prior to the popularity of the automobile, cycling was a primary mode of transportation in many parts of the world. When cycling was introduced around the world it gave people mobility and enabled them in various ways; this new mode of mass transit was innovative and improved access for people across countries. With a newfound ability to travel greater distances in shorter amounts of time using less energy, the concept of distance was altered, with new perspectives leading to increased possibilities for development, especially in the Western world (Stoffers, 2012). Following both World Wars many European countries obliterated bicycle infrastructure in order to create more space for the increasing popularity of cars. However, the Netherlands was not among them and, unlike their neighboring countries, retained substantial levels of bicycle infrastructure. Reasons for this are vast and partially due to the popularity of cycling across the country (Stoffers, 2012). It was at this point that the Netherlands differentiated itself in terms of cycling from the majority of European countries. By investigating the reasons for this differentiation and examining the key developments in Dutch cycling infrastructure, present day cycling popularity can be better understood. In the 1960s there was little regard for the safety of cyclists in the Netherlands and consequently the development of cycling was prompted by a number of large social movements (Stoffers, 2012). These movements began following the too frequent deaths of cyclists, and called for the improvement of cycling conditions and more investment in cycling infrastructure (Stoffers, 2012). Recognizing the importance of creating change, the Dutch government was proactive in establishing new and improved cycling infrastructure, a considerable amount of which emphasizes the separation of different modes of transportation. This separation has since become intrinsic in urban planning throughout the Netherlands and was instrumental in positioning the Netherlands apart from the rest of Europe in regard to bicycle use patterns, cycling levels, planning and policy (Stoffers, 2012; Welleman, 1999; Peters, 2006). Through this brief historical overview of cycling in the Netherlands, it is clear that local governments have prioritized cyclists, at least in comparison to other countries, allowing this mode of transportation to become ever present in the lives of the Dutch.

Meanwhile, starting in the 1980s and predominately in the 2000s, many other Western countries have seen a restored interest in cycling. While varying from country to country, a common reason for re-found cycling enthusiasm is an increase in environmental awareness compelling people to see the bike as a sustainable and environmentally friendly mode of transportation. The bicycle promotes decreased automobile use that helps decrease pollution rates, strengthen the population’s fitness and health and alleviates the strain of urban congestion, although the latter seems to be more predominant in Europe (Oja, Vuori & Paronen, 1998; Stoffers, 2012). Thus, without a strong history of cycling and infrastructure it is likely cycling levels in the Netherlands would not be what they are today. The history of cycling in the Netherlands indicates there is a significant relationship between historical movements and high cycling levels in present day.

Today, cycling has a strong presence in almost every city, town and village in the Netherlands and bicycle use is generally high. Significant statistics highlighting the presence of cycling in the Netherlands are presented here:

- Approximately 50% of the population makes one return cycling trip per day (CBS, 2015)
- 27% of all journeys are made by bike (CBS, 2015)
- Over 80% of residents own at least one bicycle (Borgman, 2003)
- As of 2011, 31.2% of Dutch people of all ages use their bike as a main mode of transportation (Borgman, 2003)

Cycling is popular amongst all age groups, classes and genders. Even older people continue to bike and those that are 65 and older make over a quarter of their journeys by bicycle. This trend continues with the increased availability and popularity of the e-bike, allowing people to exercise and get around with a bit of pedal assistance and the ability to travel further distances (Fishman & Cherry, 2015). Figure 1 indicates the main mode of transportation for various trip distances with cycling being the highest for trips under 7.5 kilometres. The high cycling levels shown are a result of many factors including extensive cycling infrastructure, cycling policies, integration with public transportation, the natural environment of the country, ample traffic education for cyclists and motorists, and considerable emphasis on the right of way for cyclists. These factors contribute to the success of cycling through cultural support and the support of the general public (Pucher & Buehler, 2008b; Flash Eurobarometer, 2011). In fact, cycling is so common in the Netherlands that there is not much awareness of the significance it has on the Dutch land, cities and culture (van den Boomen & Venhoeven, 2012). The following phrases are commonly used by governments and native residents reflecting on the Dutch culture of cycling: “The Netherlands and cycling have been synonymous for years” (Ministry of Transport, Public Works and Water Management & Fietsberaad, 2009, p. 9), “Cycling is in our DNA” (van Der Kloof, 2013, p.78) and “You just take the bicycle. Everyone cycles. You would not know how to do it differently” (Kuipers, 2010, p. 8). Despite these phrases exploring cycling culture there is little comprehension, scientifically speaking, about the significance of a cycling culture. Elements behind the Dutch cycling culture, traffic education and events promoting cycling, have not been fully examined nor analyzed (van Der Kloof, 2013). Nevertheless, what is known is there is a strong cycling culture visible across the Netherlands. Cycling culture cannot be quantified, making it hard to assess, but it is nonetheless important to mention the complexity of cycling culture in the Netherlands in this thesis.

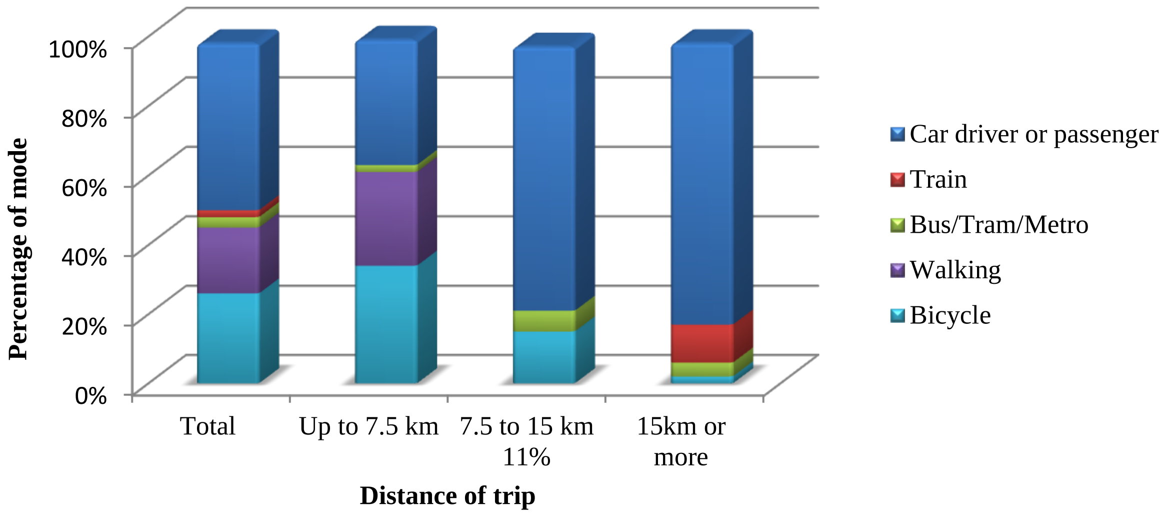

Figure 1. Main mode of transportation for trips in 2007 across the Netherlands (MON, 2007; Ministry of Transport, Public Works and Water Management & Fietsberaad, 2009)

2.2 Cycling Levels

Cycling level data is essential in this research and other academic research on cycling. Cycling levels can be presented in a variety of ways, such as the average distance cycled per person per day in a given area or as a percentage in the total mode share. In this research cycling levels are defined as the percentage of number of trips under 7.5 kilometres made by bicycle per day in comparison with walking, public transportation (bus, tram, metro, and train) and private transportation (cars and taxi). Cycle levels can be analysed at the town, provincial or national level. An example of cycling levels is shown in Figure 2 indicating the cycle rates for the Netherlands compared with the United Kington from 1952-2006. Cycling levels can be broken down further into understanding the purpose of the bicycle trips, the gender, age and income of cyclists and can then be utilized to assess various aspects of cycling (Pucher & Buehler, 2008b).

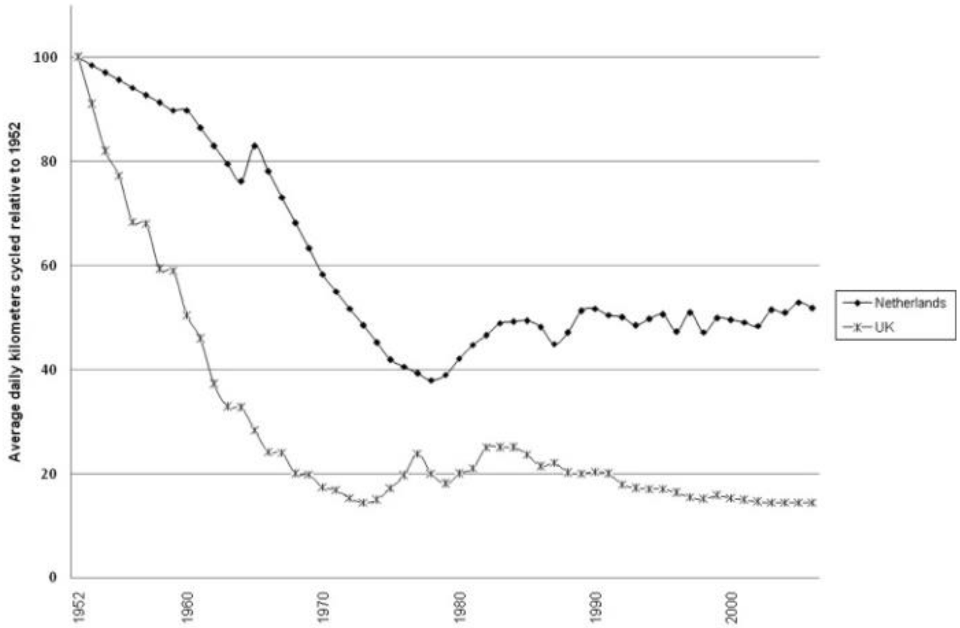

Figure 2. Trends in kilometres cycled per resident per year in the Netherlands and the UK from 1952-2006 (Department for Transport, 2007; Netherlands Ministry of Transport, 2007).

The factors that influence whether people will cycle or not cycle are complex and vast. Although this thesis focuses on the relevance of cycling infrastructure, it is crucial to discuss other factors affecting cycling levels. Some of these factors include a person's age, gender, cultural background, and household income. Another factor associated with cycling is cost, such as repairs and purchasing. The availability of other modes of transportation, such as bus, tram and metro, is also a factor, as is weather and topography. Many of these factors are interrelated and can strengthen or weaken each other. Table 1 presents a series of significant factors which affect cycling levels, as determined by two papers heavily examined in this thesis, Rietveld and Daniel (2004) and Ververs and Ziegelaar (2006). A further discussion on these factors follows.

Table 1

Significant Factors Affecting Cycling Levels and Cited Literature Comparison

Reference	**Factors**						
	Characteristics of the Population	Generalized Cost of Bicycling	Policy	Infrastructure	Physical Characteristics	Spatial and Spatial-economic features	Competing Modes of Transportation
Rietveld & Daniel, 2004	Individual features: income, gender, age, activity Socio-cultural factors: Image of the bicycle as a mode of transport, cultural background, ethnic origin, political preference	Monetary cost, travel time, physical needs-energy, risk of injury risk of theft, comfort, personal security	X	Quality and capacity of bicycle dedicated infrastructure, spatial design of the city	X	X	Parking costs, tax of fuels, tolls, supply of public transport services, pricing of private car use
Ververs & Ziegelaar, 2006	Characteristics of the native population: ethnicity, age distribution, political preference, religion, unemployment, household composition, health, income level	X	Traffic policy: competitive cycling, road safety, road infrastructure density, car ownership	Cycling policy: cycling infrastructure: directness, comfort, attraction, cyclist satisfaction, cycling policy on paper	Temperature, sunshine, wind speed, rainfall, degree of relief	Population density and growth, urban density, density of retail outlets and schools, number of universities and colleges, distance to a supermarket and share for recreation	X

2.2.1 Characteristics of the Population

An important aspect of this study is the characterization of the population under study. Characteristics of the population include: ethnicity, political preference, religion, unemployment, household composition, health, income level, gender, age and activities. A general overview of how these factors may affect cycling levels is presented here. Income is vital as it affects the possibility of an individual owning a private vehicle which may influence their decision to cycle or drive. In the model used here, age and individual physical fitness are relevant factors affecting an individual's ability to cycle or likelihood of cycling. Activities are the movements of people as they travel to work, school, social events or for errands. These movements, the distance required and the modes of transportation available could affect cycling levels, either negatively or positively. This section also includes socio-cultural factors, the individuals' perception of the bicycle as mode of transportation, their cultural background, their ethnic origin and their political preferences (Rietveld & Daniel, 2004). The personal history of individuals may affect their norms of experience influencing how willing individuals are to cycle based on their cultural, religious, ethnic or political background. This could positively or negatively influence cycling levels.

2.2.2 Generalized Cost of Bicycling

Within the category of generalised costs of bicycling are monetary cost, travel time, physical need, energy required, risk of injury, risk of theft, comfort and personal security. Travel time is influenced by the spatial structure of the area and effectiveness of cycling infrastructure including efficiency of a route. If travel time is faster, it is expected cycling levels would be higher as it is increasingly convenient for cyclists. Physical need in terms of comfort refers to the quality of available infrastructure, physical conditions, amount of personal energy required for cycling, weather and topography as well as pollution levels. Traffic safety indicates the risk of injury due to motorised vehicles while personal security refers to the ease of an individual's trip with no fear of travel. Risk of bicycle theft and vandalism denotes the hesitation to cycle given that bicycle theft or vandalism is a possibility. Monetary cost of bicycle use signifies the costs associated with bike parking, maintenance, repairs and purchasing (Rietveld & Daniel, 2004). With increased costs of cycling, the likelihood of people cycling decreased; however, relative to the car, monetary costs of cycling will always be lower but other factors will still come into consideration such as convenience. Personal security could play a role in women's comfort when traveling by bike at night or their perception of cycling being safe, negatively influencing cycling levels and activity patterns dictate where people need to go.

2.2.3 Policy

Bicycle policy is an integral component of cycling levels. However, in this research cycling policy will not be the central focus and is introduced here as it relates to infrastructure. In the Netherlands, national, state, and local policies are instrumental in the excellence and ability of cycling infrastructure and spatial design, as well as the regulation of competing modes of travel specifically private car use and public transportation (Hull & O'Holleran, 2014). The influence of cycling policy is not easy to quantify although it has been represented in the *Fietsbalans* reports as the number of policies on paper and plans existing in a town. In this research cycling policy has not been used as a measure of existing infrastructure across the research towns. In the Fietsersbond's reports substantial emphasis is put on the importance of cycling infrastructure to influence cycling policy across towns in the Netherlands. Cycling policy has not been especially focused on in this research however it does have significant impacts on cycling infrastructure and cycling levels. Cycling policy also can be influenced by the findings of the Fietsersbond's reports identifying areas for improvement. When looking at cycling levels as they relate to the current infrastructure it is imperative to include governmental spending per person on cycling. In the Netherlands, the government spent thirty-four Euros per person, per year on cycling (Cyclist Touring Club, 2013; Pedal on Parliament, 2014). Despite the success of cycling in the Netherlands there is little evidence indicating the understanding of how cycling policy works or does not work (Handy, van Wee, & Kroesen, 2014). Thus, the direction of causality is difficult to determine (Krizek, Handy, & Forsyth, 2009). Cycling policy has not been examined further in this research due to the difficulty in quantifying the impact.

Many studies seeking to determine the effectiveness of cycling public policy often employ a methodology that does not provide conclusive results due to the lack of before and after results (Handy et al., 2014). However, studies do conclude that public policy does play a key role in cycling levels and confirm the effectiveness of definitive projects related to cycling infrastructure such as the introduction of cycling lanes and bicycle parking (Harms, Bertolini and Te Brömmelstroet, 2016). Previous research has attempted to determine the relationship between cycling infrastructure and cycling levels but these analyses were unable to determine the direction of causation. In studies where regression analysis was used in relation to cycling levels, it is often cross-sectional, where the variable in question (cycling levels) is different across the study areas while all the other variables remain the same. This can be useful for describing the characteristics of the factors but cannot determine any type of relationship that might exist or the direction of this relationship. Faults with this methodology include being unable to account for the implications about changes that occur over time. To account for these changes a before and after analysis can be useful in some ways but other factors influencing cycling levels are not included (Buehler & Pucher, 2012). These individual studies, which are disaggregated, are able to alleviate problems caused by aggregate data analysis. However, in doing so comparisons between cities can be challenging as important differences may exist in policy and determining the effects of various factors is inconclusive (Buehler & Pucher, 2012).

2.2.4 Infrastructure

The most significant group of factors affecting cycling levels used in this thesis is infrastructure. Both towns and cities in the Netherlands are seen as “best practice examples” for cycling culture and infrastructure (van der Kloof, 2015, p. 78). This has led to the creation of vibrant cities and towns with high bikeability. This is evident in the Dutch government’s emphasis on cycling policy, cycling research and traditional high bicycle usage (van Goeverden & Godefrooij, 2011). As the research question for this thesis is focused on the infrastructure aspect of cycling it is crucial to define what cycling infrastructure means. The ideal bicycle infrastructure equips residents with the most efficient, enjoyable and safe route to get where they need to go (Borgman, 2003). The types of infrastructure include: bicycle lanes, paths, shared spaces, intersections, bridges, public bike parking, signage, roundabouts, traffic signals for bicycles, road surfaces, markings on paths, lighting and tunnels. In discussions on cycling infrastructure there are five key requirements for effective infrastructure: “coherence, directness, attractiveness, safety, and comfort” (van Goeverden & Godefrooij, 2011, p. 2). Without these factors bicycle use cannot be promoted as effective or efficient. According to a report published by the European Union’s Intelligent Energy-Europe programme the more each of these qualities is satisfied the more likely it is that people will cycle (Dufour, 2010). These factors are discussed here and examined in order of priority for utility cycle networks.

Safety: An important aspect of bicycle infrastructure is safety, as it is important for people to feel safe when using cycling infrastructure (Dufour, 2010). Due to the enormous differences between vehicles and cyclists in terms of speed and mass, cyclists are at risk. Cyclist safety can be enhanced in three different ways. Firstly, decreasing the intensity of traffic; secondly, enforcing low speed limits in mixed use areas; and thirdly, giving cyclists their own space, such as segregated bike lanes, away from vehicles and ensuring there are clearly marked areas for cyclists at intersections (van Goeverden & Godefrooij, 2011). The safety of cyclists can be measured by casualties, major and minor, and the risk of accidents occurring.

Directness: In terms of the directness of infrastructure, cyclists must be able to get where they need to go efficiently and effectively with minimal detours and delays. Cyclists' travel time is important in regard to cycling, helping to promote cycling as quick, and thus direct. Directness is increased in the following ways: giving cyclists the right of way at intersections, short delays and detours, and minimal traffic lights along a route which results in higher cycling speeds (Dufour, 2010).

Coherence: The coherence of infrastructure entails the ability of cyclists to travel from their origin to their destination without disruption. The route must be logical, distinguishable and comprehensible to all users. The routes must be laid out in a way that cyclists can see where they need to be and the routes must be where users want to go. Ideally the infrastructure should also be able to connect cyclists to larger cycling or transportation networks, including public transportation stops and hubs (Dufour, 2010).

Comfort: The way cyclists feel when using bicycle infrastructure is attributed to comfort. Cyclists want to experience an enjoyable and gentle ride requiring minimal effort. Comfort is viewed both physically and mentally and can be negatively influenced by having to stop often, rough road materials, unclear pathways, not having priority on the road or having to make too many turns (van Goeverden & Godefrooij, 2011; Borgman, 2003).

Attractiveness: The final requirement of effective cycling infrastructure is attractiveness. In order to encourage people to cycle, infrastructure must be attractive and incorporated appropriately into the setting. It must make people want to take advantage of the available infrastructure. Factors of attractiveness also include the amount of noise pollution, as determined by the Fietsersbond reports (Borgman, 2003). The design and people's perceptions of attractiveness are also taken into consideration (Dufour, 2010).

Cycling infrastructure in the Netherlands is an essential factor affecting cycling levels, yet to what extent it is essential is relatively unknown. The relative importance of the various factors affecting cycling levels, as discussed above, is also unknown. This research attempts to determine the significance of cycling infrastructure on cycling levels. Dutch bicycle infrastructure design is fundamentally based on a design manual for bicycle infrastructure created by CROW, a Dutch non-profit technology platform for transport, infrastructure and public space. The design manual was the first to introduce the five main requirements necessary in the creation of bicycle-friendly effective infrastructure: "coherence, directness, attractiveness, safety, and comfort" (van Goeverden & Godefrooij, 2011, p. 2; Ministry of Transport, Public Works and Water Management, 2009, p. 55). These requirements are to be implemented into cycling networks, including intersections across the Netherlands. Cycling networks are increasingly becoming important in the study of cycling and cycling infrastructure; not only should infrastructure links be assessed but also the entirety of the network. According to Buehler and Dill (2016) in terms of cycling routes the "effect of the network is greater than the sum of its parts" (Buehler & Dill, 2016, p. 15). A further explanation of the relevance of cycling infrastructure is provided by the following citations. The public interpretation of bicycle policy is that "for many people, constructing cycle paths is also synonymous with bicycle policy. But in a bicycle-friendly infrastructure, the issue is more than just cycle paths" (Ministry of Transport, Public Works and Water Management, 2009, p. 55). The core components of bicycle friendly infrastructure are critical. "The construction of good cycling networks and parking facilities are the main components…besides physical and spatial measures to stimulate bicycle use, education and information are vital" (Ministry of Transport, Public Works and Water Management, 2009, p. 26). These references and the requirements of cycling infrastructure make it clear that the emphasis in Dutch cycling policy has always been on improving cycling infrastructure and that infrastructure is considered the most important factor in high cycling levels.

A significant number of studies have indicated there is a clear correlation between developing and improving cycling infrastructure found in manmade surroundings, such as cycling networks and routes, and increased cycling levels (Buehler & Pucher, 2012; Forsyth & Krizek, 2010; Krizek & Johnson, 2006; Ogilvie, Bull, Powell, Cooper, Brand, Mutrie, Preston, & Rutter, 2011; Parkin, Ryley, & Jones, 2007; Pucher et al., 2010; Rietveld & Daniel, 2004;Vernez-Moudon, Lee, & Cheadle, 2005; Winters, Teschke, Davidson, & Kao, 2011). In order to understand the correlation between infrastructure and cycling levels, an examination of a number of these studies is necessary. Cycling levels are impacted by various factors, which are difficult to isolate making it challenging to determine those that have strong impacts, as has previously been discussed (Meyer & Miller, 2001). Graham-Rowe et al. (2011) and Harms et al. (2016) assert that supportive cycling infrastructure "increases attractiveness and opportunities for cycling" (Harms et al., 2016, p. 138).

Research conducted by Harms et al. who reviewed a significant number of academic papers discussing factors that determine cycling levels concluded the validity of these studies is not credible due to the challenge to control and isolate factors (Harms et al., 2016) (e.g. Meyer & Miller, 2001; Yang et al., 2010). The independent variable in the model is cycling levels that are influenced by a number of independent variables. The influences between the independent variables are mutual.

In one study conducted by Dill and Carr (2003) researchers sought to determine the relationship between bicycle infrastructure and cycling levels with the statement: "if you build them, commuters will use them"; focusing on commuters in major American cities. Results stated that higher levels of bicycle infrastructure were indeed significantly correlated with higher levels of cycling usage in this case, through commuting. Other variables were also studied including income, gas prices and public transit availability, but did not appear significant in regression models. Limitations of this study and opportunities for further research are based on the lack of existence or direction of a cause-effect relationship. This relationship is stated as: "People may be commuting by bicycle more because there are more lanes and paths. Alternatively, because people are commuting by bicycle, the city is building more bike lanes and paths. Both relationships may be occurring to varying degrees in each city" (Dill & Carr, 2003, p. 7). What is concluded through this research is that cycling levels will increase with more options for cycling, such as cycling lanes and paths, but infrastructure is not the only influential factor (Dill & Carr, 2003; Nelson & Allen, 1997; Buehler, 2012; Buehler & Pucher, 2012).

Based on the above review of relevant literature the relationship between infrastructure and cycling levels has become more defined. Evidently studying this relationship is challenging as there are many factors affecting cycling levels and isolating infrastructure may not produce reliable results. However, what can be concluded is that there is a clear correlation between developing and improving cycling infrastructure and increased cycling levels.

2.2.5 Physical Characteristics

A major factor in the success and popularity of cycling in the Netherlands is attributed to the natural environment. With a generally flat topography, cycling is relatively easy in the Netherlands compared to hillier or mountainous countries which may deter cyclists due to the increased effort required (Gatersleben & Appleton, 2007; van den Bulcke, Dujardin, Thomas, Geus, Degraeuwe, Meeusen, & Panis, 2011). The climate of the Netherlands is also highly suitable for cycling, with a moderate climate resulting in a small number of days below freezing, little annual snowfall and moderate summer temperatures. While a generally moderate climate is ideal for cycling, the Netherlands does face high levels of precipitation and thus low rates of sunshine; research has shown precipitation to be the least desirable weather factor (Heinen et al., 2010).

2.2.6 Spatial and Spatial-Economic Features

As shown in Table 1 and in the framework from Ververs and Ziegelaar (found in Figure 3) the following spatial and spatial-economic factors are relevant to cycling levels and may affect them positively or negatively: population density and growth, urban density, density of retail outlets and schools, number of universities and colleges and land share for recreation.

In a study completed in 2010 researchers used controlled comparisons to review 25 studies which examined factors which were determined to be effective in promoting cycling. The study concluded that promotional activities on a community level and infrastructure improvements for cycling do increase cycling levels a moderate amount (Yang, Sahlqvist, McMinn, Griffin &

Ogilvie, 2010). According to Harms et al. the conclusions from Yang et al. are not entirely reliable as the methodologies differ between studies. There are no evaluative studies that combine various factors and variables such as social and spatial factors (Harms, Bertolini & Brömmelstroet, 2016). However, a quantitative meta-study by Rietveld and Daniel related municipality variations in bicycle use to social and spatial features such as population, individual features, policies and physical features. The result of this study indicates "most of the inter-municipality variation in bicycle use is related to physical aspects such as altitude differences and city size, and features of the population (share of youngsters). Differences in ethnic composition also appear to matter. Important policy-related variables are: the number of stops cyclists have to make on their routes, hindrances in road use, and safety of cyclists. In addition the relative position of bicycles with respect to cars (speed, parking costs) also appears to matter" (Rietveld & Daniel, 2004, p. 531). This previous research is critical in guiding the research conducted in this paper.

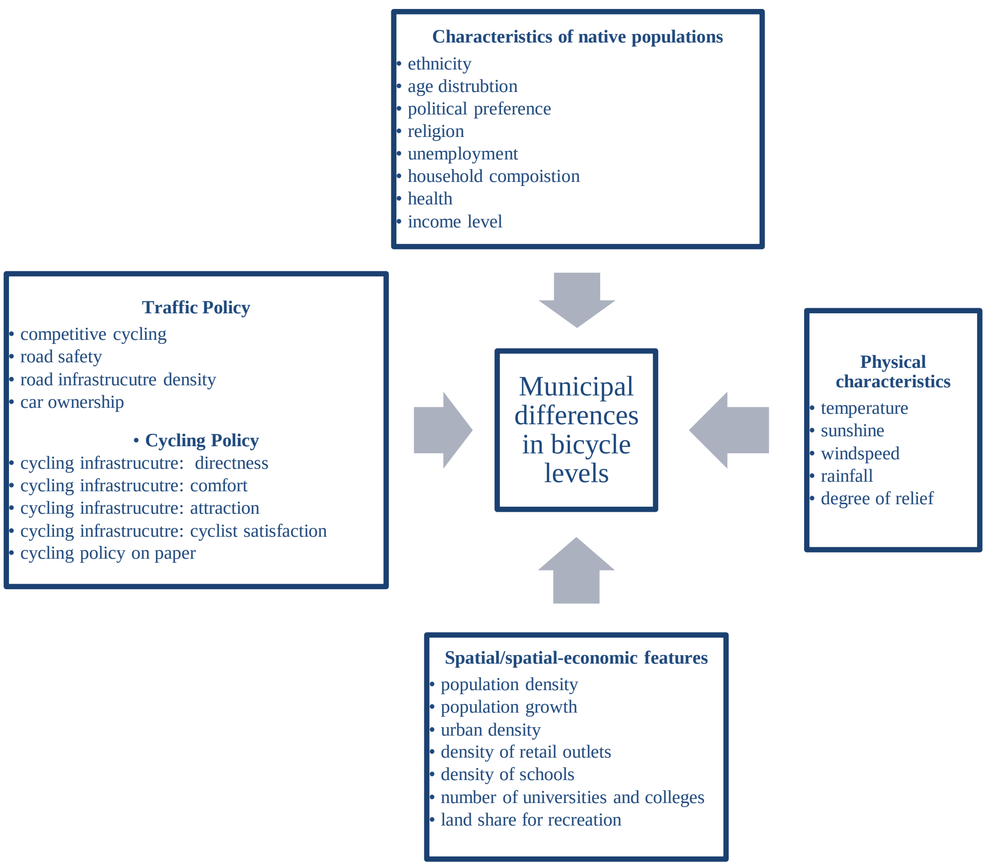

Figure 3. Factors influencing bicycle use (Ververs & Ziegelaar, 2006, p. 10).

2.2.7 Competing Modes of Transportation

A summary of the relationship between competing modes of transportation and cycling levels is now reviewed. The category of competing modes of transportation includes parking costs, tax on fuel, tolls, supply of public transport services and private car use. These factors and generalised costs of bicycling can be influenced by local authority initiatives, policy variables such as the quality and capacity of bicycle dedicated infrastructure, spatial design of the city, and pricing of private car use (Rietveld & Daniel, 2004). Residents can typically choose between multiple, and hence competing, modes of transportation. Researchers Rietveld and Daniel note that it is important to recognize the cycling referred to in this framework is a mode of transportation, not as a leisure activity, as it is in many countries (Rietveld & Daniel, 2004). All the factors discussed, and shown in Figure 4, may influence whether people will cycle or not. Some factors increase cycling levels while some decrease them. The relationship between the dependent variable in this framework, cycling level, and the independent variables is one directional. In high density urban areas within Netherlands driving a car is expensive; costs associated with car ownership are generally greater than countries outside of Europe, including parking rates, taxes, insurance and the price of gasoline. Public transportation is widely available in the Netherlands; an efficient national rail system serves a large portion of the country however it is not an alternative to cycling as it is used for distances which are less than ideal to cycle. To serve areas in between rail stations there are, in most areas, local buses. Within the Netherlands there are a few rapid transit systems and, while not widespread, tram systems and light rail systems are operational in some areas. In the Netherlands there are 5.5 million bus, tram, train and metro trips made per day (Ministry of Transport, Public Works and Water Management, 2010). These transportation systems can have comparatively low costs, compared to car ownership; thus they are an economical means of transportation for the user (Ministry of Transport, Public Works and Water Management, 2010). It is important to note this may not always be the case. If individuals already own a car, or are provided with a company vehicle, public transportation may be costlier. Many public transportation trips are part of a larger network of multi-modal movements whether by bike, car, foot or another type of public transportation. Compared to public transportation cycling has significant advantages, there is a high level of flexibility with regards to route, time and destination and it is more direct not having to make multiple stops contributing to making it often faster. Public transportation has its advantages over cycling in that it is more desirable for longer distances, in inclement weather and for those with mobility issues. Rietveld and Daniel's overarching conclusion indicates that are two fundamental ways of encouraging bicycle use. These push and pull policies indicate cycling levels can be encouraged either by (1) improving the attractiveness of a mode by reducing its generalised costs or (2) by increasing the cost of competing modes (Rietveld & Daniel, 2004).

2.2.8 Culture

The relevance of looking at Dutch cycling culture in the context of this thesis, specifically studying infrastructure, is that the culture is built upon the relationship between practice and context. Cycling in the Netherlands is a part of the culture; bicycles are used daily for transport and Dutch culture supports this lifestyle through societal and political norms (van Oijgen, Pelzer, & Graumans, 2011). Citizens are educated as cyclists and later as motorists, focusing on cycling having the right of way. The available infrastructure helps to create and sustain this cycling culture and vice versa. Therefore, the existence of a cycling culture enables and supports the provision of bicycle infrastructure.

In fact, cycling is so common in the Netherlands that there is not much awareness of the significance it has on the Dutch land, cities and culture (van den Boomen & Venhoeven, 2012). The following phrases are commonly used by the Dutch government and residents reflecting on the Dutch culture of cycling: "The Netherlands and cycling have been synonymous for years" (Ministry of Transport, Public Works and Water Management & Fietsberaad, 2009, p. 9), "Cycling is in our DNA" (van Der Kloof, 2013, p.78) and "You just take the bicycle. Everyone cycles. You would not know how to do it differently" (Kuipers, 2010, p. 8). Despite these phrases exploring cycling culture there is little comprehension, scientifically speaking, about the significance of a cycling culture. Elements behind the Dutch cycling culture, traffic education and events promoting cycling, have not been fully examined nor analyzed (van Der Kloof, 2013).

2.2.9 Frameworks

In Rietveld and Daniel's 2004 paper, *Determinants of bicycle use: do municipal policies matter?*, the authors investigate the factors influencing bicycle use within municipalities in the Netherlands. These factors are assembled into a framework which gives an overview of the influences affecting people's decision to cycle. The relationships between the factors are complex; there are many ways to represent these relationships. The framework in Figure 4 highlights four main categories: (1) individual features and socio-cultural features, (2) generalised costs of bicycling, (3) local authority initiatives and policy variables, and (4) generalised costs of other transport modes. The roles these factors play in cycling levels and a deeper exploration of the categories is presented below. Overall, findings from the study indicate that certain physical aspects of municipalities have significant influences in bicycle use as well as the characteristics of the population (Rietveld & Daniel, 2004).

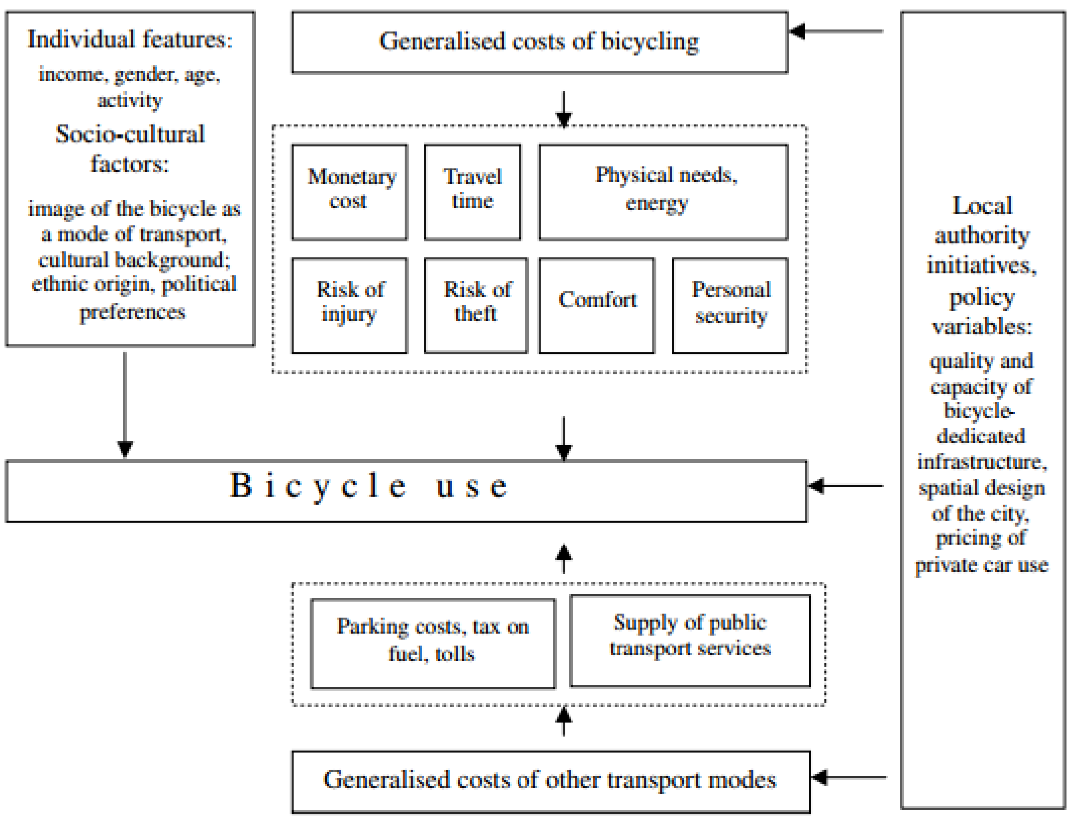

Figure 4. Factors influencing bicycle use (Rietveld & Daniel, 2004, p. 533).

Similar to Rietveld and Daniel's research and framework, researchers Ververs and Ziegelaar, (2006) have conducted research on factors influencing bicycling in the Netherlands. Their model is focused on differences in cycling levels between municipalities and the factors influencing these whereas Rietveld and Daniel focus on bicycle use more generally. Ververs and Ziegelaar tested various factors affecting cycling use to determine which explanatory factors are due to autonomous factors and which can be influenced by policy factors. In order to fulfill this research, the authors created a framework presenting possible factors influencing cycling levels which could be used as a tool to assist municipalities with traffic or bicycle policies (Ververs & Ziegelaar, 2006). In this framework, shown in Figure 3, factors that affect the differences in cycling levels at the municipal level are presented. These factors are divided into four categories: (1) characteristics of the population, (2) physical characteristics, (3) spatial and spatial-economic features, and (4) policy, both traffic and cycling. Cycling policy indicators can be explained as the measurable outcomes resulting from bicycle policy, as conducted by the Fietsersbond in their *Fietsbalans* research (Borgman, 2003).

Ververs and Ziegelaar establish in their research that in order to increase municipal bicycle use two types of factors must be distinguished. First, factors that affect bicycle use but which cannot be controlled by municipalities (i.e. weather, rainfall), and second those that can be influenced by factors the municipality can change (i.e. policies, infrastructure). Ververs and Ziegelaar's 2006 study was conducted in 117 Dutch municipalities with the central goal of determining the policy relevance of cycling levels in their model (see Figure 3). By using data from the Fietsersbond' s *Fietsbalans* reports, CBS StatLine (Central Bureau for Statistics [Centraal Bureau voor de Statistiek]) and KNMI (the Royal Netherlands Meteorological Institute [Koninklijk Nederlands Meteorologisch Instituut]), the researchers used statistical modeling to determine which factors affecting cycling levels had strong relevance to policies and which were independent of policies. The three most relevant autonomous factors which increase cycling levels were determined to be: (1) mode share of alternative modes of transportation, such as bus, tram and metro movements, measured in percent of total trips; (2) parking costs (euro cents per hour); and (3) the ratio of bicycle to car travel time (Ververs & Ziegelaar, 2006). Autonomous factors that have a negative effect on cycling levels were determined to be the percent of Muslims in an area (number of Muslims divided by the population, measured in percent), average rainfall, and degree of relief (Ververs & Ziegelaar, 2006). By creating several models to determine significant factors and eliminating factors that were not statistically significant, the authors were able to determine eleven significant factors giving a R^2 factor of 0.726. Thus, according to them, 73% of the differences between municipalities can be explained by these eleven factors, shown in Table 2. Overall, their research concluded that policy factors account for 40% of the variance of cycling levels between municipalities. Thus, 60% of the differences between municipalities were due to autonomous factors that cannot be influenced by policy or the municipality (Ververs & Ziegelaar, 2006).

Table 2

Key Policy Factors Influencing Cycling Levels in Dutch Municipalities (Ververs & Ziegelaar, 2006).

Weak Relevant Policy Factors (decrease cycling levels)	Muslims share (number of Muslims / population in percent)
	Share Protestants (number of Protestants / population in percent)
	Average rainfall (average annual rainfall from 1971 to 2000 three averages in mm)
	Degree of relief (ranging from 0 to 1)
Moderate Relevant Policy Factors	Proportion of single-person households (%)
	Share of unemployment benefit claimants (amount per 1000 inhabitants)
	Proportion of young people (amount of resident ages 10-20 years/ population in %)
	Amount of urban space (hectares)
Strong Relevant Policy Factors (increase cycling levels)	Share of bus, tram, metro movements (percent of total number of trips)
	Parking cost (cents/hour)
	Travel time ratio bike-car (cycle time/auto time x 100%)

2.3 Bikeability

In order to connect the discussed academic research, which has been undertaken and reviewed, with the goals and objectives of this thesis the term "bikeability" is introduced. Bikeability is a key term and index used in the transportation and mobility field. Bikeability is the degree to which an area, street, city, or country is bike friendly. The Netherlands is a leading country when it comes to creating cities and towns with high bikeability. This is evident in their emphasis on cycling policy, cycling research and traditionally high cycling levels (van Goeverden & Godefrooij, 2011). The Dutch cyclists' union, the Fietsersbond, has conducted extensive research on *Fietsbalans*, which directly translates to "cycle balance" and has a similar meaning to the English word bikeability. The *Fietsbalans* reports are the Fietsersbond's assessment of certain municipality's local conditions for cycling based on ten factors (Fietsersbond, 2009). These factors and a general overview of the results are shown in Table 3 and Figure 5. The ten dimensions in Table 3 are key factors in assessing bicycle infrastructure; each of these factors has an influence on how bike-able an area is. Figure 5 gives a general overview of the information collected through the *Fietsbalans* research; it also shows which factors were used in the research (Borgman, 2003; Fietsersbond, 2009). According to the Fietsersbond, and corresponding to the academic research of van Goeverden and Godefrooij, as well as the Ministry of Transport, Public Works and Water Management there is a need for cycling infrastructure that is coherent, direct, attractive, safe and comfortable (van Goeverden & Godefrooij, 2011, p. 2; Ministry of Transport, Public Works and Water Management, 2009, p. 55). In addition to the aforementioned five requirements, the Fietsersbond has added the five factors of competitiveness with the car, bicycle use, urban density, cyclist satisfaction and cycling policy on paper. The Fietsersbond eliminated cohesion and divided safety into two categories, obstruction and road surface. Of these ten factors identified by the Fietsersbond, those which affect infrastructure and cycling levels have been adapted into the theoretical framework for this thesis. Using bikeability as an index to identify how accessible and bike-able streets are is a good indicator of the conditions of cycling (van Goeverden & Godefrooij, 2011). The results from the *Fietsbalans* research, focused on the ten factors or dimensions, shown in Table 3, will be used in the data analysis chapter.

Table 3

Ten Dimensions of the Cycle Balance Assessment (Borgman, 2003)

1. Directness	6. Bicycle use
2. Comfort (obstruction)	7. Road safety of cyclists
3. Comfort (road surface)	8. Urban density
4. Attractiveness	9. Cyclist satisfaction
5. Competitiveness compared to the car	10. Cycling policy on paper

Assessed (sub)dimension	Standard	Interval	Overall Average	Average big towns*	Average medium size towns**	Average small towns***
Directness						
Detour factor (ratio)	1,25	0,1	mediocre	mediocre	very good	mediocre
Delay (sec/km)	16,5	10	good	mediocre	good	very good
Actual cycling speed (km/h)	15,5	1	mediocre	mediocre	mediocre	good
Overall judgement directness			**mediocre**	**mediocre**	**mediocre**	**mediocre**
Comfort (obstruction)						
Chance of stopping (N/km)	0,75	0,5	mediocre	bad	mediocre	good
Slow cycling and walking (% of time)	7,5	5	mediocre	mediocre	mediocre	mediocre
Traffic-obstruction (v-Fv)	1,75	1,5	mediocre	mediocre	mediocre	mediocre
Infrastructural impediment (v-Fi)	0,75	0,5	mediocre	mediocre	mediocre	bad
No right of way (N/km)	2,5	1	mediocre	mediocre	mediocre	bad
Turning off(N/km)	2	0,5	mediocre	mediocre	mediocre	bad
Overall judgement comfort (obstruction)			**mediocre**	**bad**	**mediocre**	**mediocre**
Comfort (road surface)						
Hindrance caused by vibrations (v-Ft)	100	40	**mediocre**	**mediocre**	**mediocre**	**bad**
Attractiveness						
Noise pollution (v-Fg)	130	40	**mediocre**	**bad**	**mediocre**	**good**
Competitiveness						
Journey time ratio (ratio)	1	0,1	good	good	mediocre	mediocre
Journey bikes faster (% of journeys)	70	20	mediocre	mediocre	bad	mediocre
Costs per journey (cents)	100	30	bad	good	bad	very bad
Overall judgement Competitiveness			**mediocre**	**good**	**mediocre**	**bad**
Bicycle use						
Share in trips to 7.5 km (%)	43	4	**mediocre**	**mediocre**	**bad**	**mediocre**
Road safety of cyclists						
Victims per 100 million cycle km (N)	14	4	**mediocre**	**mediocre**	**bad**	**mediocre**
Urban density						
Adresses per square kilometre (N)			**mediocre**	**good**	**good**	**mediocre**
Cyclists satisfaction						
Bicycle parking (% dissatisfied)	17,5	15	mediocre	mediocre	mediocre	bad
Comfort (% dissatisfied)	17,5	15	mediocre	mediocre	mediocre	mediocre
Road safety for cyclists (% dissatisfied)	17,5	15	mediocre	mediocre	mediocre	mediocre
Social safety (% dissatisfied)	17,5	15	good	good	good	good
Approach to bicycle theft (% dissatisfied)	17,5	15	very bad	very bad	very bad	very bad
Municipality's cycling ambitions (% dissatisfied)	17,5	15	good	good	good	good
Report mark	7,25	0,5	mediocre	mediocre	mediocre	mediocre
Overall judgement cyclists satisfaction			**mediocre**	**mediocre**	**mediocre**	**mediocre**
Cycling policy on paper						
Policy papers and plans (N)	16	4	mediocre	mediocre	mediocre	bad
Bicycle network (N)	13,5	4	mediocre	mediocre	mediocre	mediocre
Bicycle parking (N)	14	3	bad	mediocre	mediocre	bad
Budgets (N)	4	1	bad	mediocre	bad	bad
Council as employer (N)	5	1	mediocre	mediocre	good	mediocre
Overall judgement cycling policy on paper			**mediocre**	**mediocre**	**mediocre**	**bad**

* big towns = more then 100.000 inhabitants

** medium size towns = 50.000 - 100.000 inhabitants

*** small towns = 20.000 - 50.000 inhabitants

Figure 5. General overview of the *Fietsbalans* assessment results (Borgman, 2003; Fietsersbond, 2009).

2.4 Small Towns

Above, various factors influencing cycling levels and a full discussion on cycling infrastructure, as an influence on cycling levels, have been addressed. The following section will discuss the relevance of small towns to the research question. Throughout this thesis the term “small towns” is used to refer to a town in the Netherlands with a population of fewer than 50,000 residents. This classification of a small town has been identified by the Dutch cyclists’ union, the Fietsersbond, throughout their report on *Fietsbalans* (Borgman, 2003).

To date there has been no significant research conducted on small towns, and it is challenging to find information on cycling in smaller urban areas. One book, *City Cycling,* has a specific chapter on *Cycling in Small Cities*. In this book a small city is defined as less than 300,000 residents, unlike the definition used in this thesis, which is more applicable to the Netherlands (Handy et al., 2012). Other research on cycling, cycling levels and infrastructure mostly focuses on larger urban areas such as Amsterdam, London and Copenhagen. As discussed in the Netherlands cycling infrastructure section previously, extensive networks of a mixture of bike paths, and streets and lanes have been developed to serve people’s everyday routes. These routes occur not only in large urban areas but also in smaller rural areas (Pucher & Dijkstra, 2003).

Despite the lack of research conducted on small towns, they should not be overlooked in research and literature on cycling. A different set of benefits characterise cycling in small towns compared to larger ones. They are geographically smaller and there is generally less traffic, making it easier and safer to get around (Handy et al., 2012). As cycling can be used as an alternative to public transportation or as a connection to public transportation these two relationships, cycling as an accompaniment to public transit and cycling as a competitor for public transit, are imperative to small towns as they are often poorly served by public transit (Handy et al., 2012). In small towns cycling may be the only reasonable option for accessing larger transportation hubs, such as train stations. This type of active transportation is called “bike-and-ride”. Cycling makes up a relatively high percentage of commuter traffic across the Netherlands. At least 25 percent of all commuter traffic is cycling with 40 per cent of these trips being multi-modal, often in combination with the train (across all of the Netherlands) (MON, 2007). Studies have found that train stations in the Netherlands located in smaller towns observe higher levels of bike-and-ride use compared to larger cities (Nagele, Wilbers & De Bruin, 1992).

This is likely due to residents cycling to the train station in order to access larger cities for employment or educational purposes. Every day nearly forty percent of train passengers arrive to the station by bicycle, thus the relationship between the train and the bike is imperative and vital (Martens, 2004; Martens, 2007). However, the modes of available transportation which connect people to different types of public transportation, such as buses, metros and trams, are not as common in small towns as they are in larger cities (Martens, 2004). A further discussion of the effects of public transportation on cycling levels will be given in the explanation of the theoretical framework.

2.5 Theoretical Framework

Above, the relationship between cycling levels and infrastructure, as well as factors which influence cycling levels have been discussed thoroughly. Based on the above academic research the theoretical framework, Figure 6, has been developed to answer the research question: *Does better bicycle infrastructure correlate with higher cycling levels in small towns in the Netherlands?* In order to answer the question it is essential to have a model in which all factors, variables and determinants relevant to cycling in small towns in the Netherlands are linked together. Rietveld and Daniel's framework, shown in Figure 4, details the factors influencing bicycle use. Borgman's research with the Fietsersbond generated ten dimensions of assessment for bikeability, as detailed in Table 3 and Ververs and Ziegelaar, see Figure 3, similar to Rietveld and Daniel, examined factors influencing municipal differences in bicycle levels with an emphasis on policy use. Collectively these three studies and resulting frameworks and dimensions provide a thorough basis of both factors that (1) affect the bikeability of a location and (2) influence bicycle use. These three frameworks have been adapted to serve the needs of this thesis. Adapting the frameworks was a result of the focus of this thesis being on the effects of infrastructure on cycling levels. In order to incorporate the main source of data, the *Fietsbalans* reports from the Fietsersbond, the ten dimensions of bikeability, as described by Borgman and the Fietsersbond were incorporated into the framework. Ververs and Ziegelaar's framework was also focused on the effects of policy and thus had to be altered to fit the needs of this thesis. It is important here to note that this framework is specifically aimed at small towns in the Netherlands. Elsewhere in the world cycling levels may be affected by varied factors such as extreme elevation changes, high levels of pollution and extreme weather, both hot and cold (Harms et al., 2016).

The theoretical framework, shown in Figure 6, shows four main groupings of factors: bikeability and infrastructure, spatial and spatial-economic, characteristics of the population, and competing modes of transportation. Many of the factors affecting cycling levels are interlinked, and each framework discussed above is a simplified version of reality. It is impossible to include all factors and thus the most important factors based on the works of Rietveld and Daniel (2004), Borgman (2003) and Ververs and Ziegelaar (2006) have been incorporated into this research. In order to determine the effects infrastructure has on cycling levels this variable must be isolated. Isolating independent variables is challenging often leading to difficulty in understanding the impact various factors have on cycling levels. The direction of causality is thus relatively unknown for most factors; for example, does increased or better infrastructure lead to higher cycling levels or does increased cycling lead to more or better infrastructure. Based on the literature reviewed it is likely that both scenarios are possible. Either the theoretical model could show explicit relationships through bidirectional arrows suggesting that independent factors such as bikeability and infrastructure factors can influence cycling levels and also that cycling levels can influence bikeability and infrastructure factors. Or it is possible that the relationships between the dependent variable, cycling level and independent variables are one directional. In this research the data has been analysed as if the relationship is one directional, where cycling level is a dependent factor. All the independent variables influence bicycle use without bicycle use influencing the independent variables. This is done based on the lack of available data which would be required to analyse the data in the case of a bidirectional relationship between cycling levels and infrastructure. The author is aware this may skew the results.

The following section will demonstrate the implementation of the previously discussed three studies into the research (Borgman, 2003; Rietveld & Daniel, 2004; Ververs & Ziegelaar, 2006). As far as this research is concerned cycling levels are primarily influenced by four groupings of factors. For the purpose of this research only the following factors influencing cycling levels are considered: competitive modes of transportation, bikeability and infrastructure factors, characteristics of the population and spatial and spatial-economic factors. It is crucial to note here that while these factors have been identified in the theoretical framework they have not all been analyzed through statistical data. These factors are outlined in the theoretical framework shown in Figure 6. In the section that follows, these factors will be discussed in detail. It is important to clarify that there are other factors that influence cycling but are not shown in the framework.

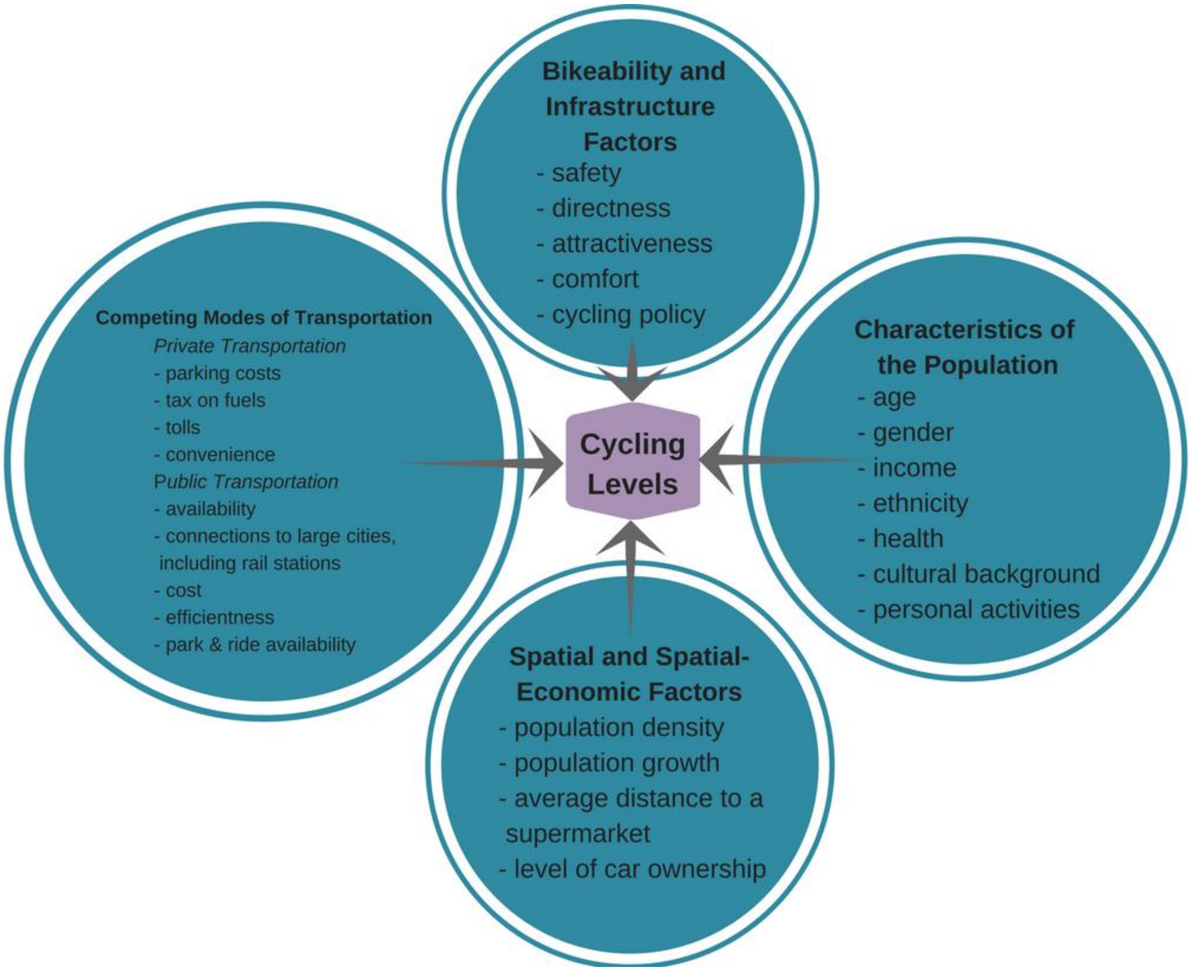

Figure 6. Theoretical framework of factors influencing cycling levels in small towns across the Netherlands (adapted from Borgman, 2003; Rietveld & Daniel, 2004; Ververs & Ziegelaar, 2006).

2.5.1 Bikeability and Infrastructure Factors

Bicycle infrastructure such as bicycle lanes, pathways and networks including segregated and shared cycling lanes are important factors affecting cycling levels. Data regarding different types, sizes and amounts of different types of infrastructure should be assessed. It is known that the width of the cycle lane is crucial in the way cyclists with different levels of confidence, ability and cycling speed can feel comfortable cycling (Buehler & Pucher, 2012). Factors included in the theoretical framework include: safety, directness, attractiveness, comfort and cycling policy. These factors have been discussed above in section 2.2.4.

The relationship between the independent variable, infrastructure, and the dependent variable, cycling levels, is complex. Cycling infrastructure includes a broad variety of physical and spatial requirements. Effective cycling infrastructure is not only presented by physical bicycle lanes but also includes the functionality of facilities. As previously discussed in the literature review cycling infrastructure must be coherent, direct, attractive, safe and comfortable (van Goeverden & Godefrooij, 2011). Cycling policy, education and information strongly encourages and promotes the implementation of effective cycling infrastructure and encourages its use. A strong relationship between infrastructure and cycling levels has been reported in the literature; most authors cited in this research would agree however, the extent to which the factors are related is unknown. A discussion on the factors influencing cycling infrastructure used in the research, as presented in Figure 6, follows.

2.5.2 Characteristics of the Population

The characteristics of a population, relating to bicycle use and including individual factors, socio-cultural factors and neighbourhood factors, are defined as: age, gender, income, ethnicity, religious background, cultural background, personal activities, car ownership levels and health.

Individual features such as age, gender, income and personal activities are essential to determining cycling usage. The age of residents is vital as they may not be old enough to drive or own a car or they may be physically unable to ride a bicycle due to immobility or illness. The percentage of the population between the ages of 10 and 25 was analysed to determine if there was a relation between younger populations who are more likely to cycle. Alongside age, an individual’s health will certainly affect capabilities to cycle. Gender is also important as, for example, it is possible women do not feel safe cycling in some areas at night. Income will affect the likelihood of households owning a car and being able to cover the costs associated with vehicle ownership such as fuel, taxes and parking and availability. With cycling used as a mode of transportation in the Netherlands, not only for leisure, it is important to look at the purpose of cyclists’ trips. Reasons for trips may be travelling for school and work or for social outings, shopping or running errands. There are many socio-cultural factors influencing cycling such as people’s perceptions of the bicycle as well as their cultural, religious and ethnic background. People from countries where cycling is not prominent may not feel as comfortable cycling and may choose an alternative mode of transportation to get around (Rietveld & Daniel, 2004).

2.5.3 Spatial and Spatial-Economic Factors

Cycling levels are highly dependent on spatial and spatial-economic factors of an area. These factors exist in many forms such as population density, population growth, demographics, the size of the town, urban density, average distance to a supermarket and level of car ownership. The following presents a brief summary of the spatial and spatial-economic factors which influence cycling levels, examining how they have an effect on cycling levels.

Where people live relative to the city centre is important to look at when examining how they use cycling to get around in comparison to other modes of transportation. Various densities are taken into consideration within a city or town, such as population density, urban density and density of retail outlets and supermarkets. These densities provide valuable information in understanding the town and distances that must be traveled as well as how many people live in one area.

By analysing factors related to spatial and spatial-economics the towns can be differentiated by various factors with the goal of determine how cycling levels are influenced. The population density of an area will affect cycling use. In areas of low-density, cycling levels are comparatively lower than areas of medium-density, which experience high levels of bicycle trips per person per day. In high-density areas, cycle rates decrease again as there is an increased availability of other modes of public transportation and the distances they are required to travel are shorter thus making less total movements (Rietveld & Daniel, 2004; Snellen, Hilbers &

Hendriks 2010). The number of businesses per resident is included to show the economy of the town, mostly used in comparison to other towns. Researchers have also studied the income, household size, and car ownership levels of highly urbanized areas and less urbanized areas and discovered there is a significant difference in the mobility of residents in the two areas (Bouwman & Voogd, 2005). Where people choose to live could also be influenced by cycling levels; if an area has high cycling levels it may be seen as more safe and thus more desirable to live in. This is called residential self-selection. It is also possible that population density could be influenced by cycling levels; increased cycling, aided by decreased auto-centric transportation, could contribute to higher levels of population density due to the desire of people to travel shorter distances to destinations and live close to amenities.

2.5.4 Competing Modes of Transportation

While researching, it is vital to examine other modes of transportation besides the bicycle in order to examine the relationship they have to each other, both as a competitor and collaborator. Figure 7 shows the mode share of the total population of the Netherlands based on trips per person per day. This indicates that the most common mode of transportation is the private car followed by bicycle. However, this graph shows the total number of trips, regardless of length. It is important to look at trips under 7.5 kilometres also. In Figure 8 the mode share of trips with a distance of less than 7.5 kilometres is shown, this chart shows a significant decrease in vehicle use for these trips and increase in cycling and walking as a mode of transportation.

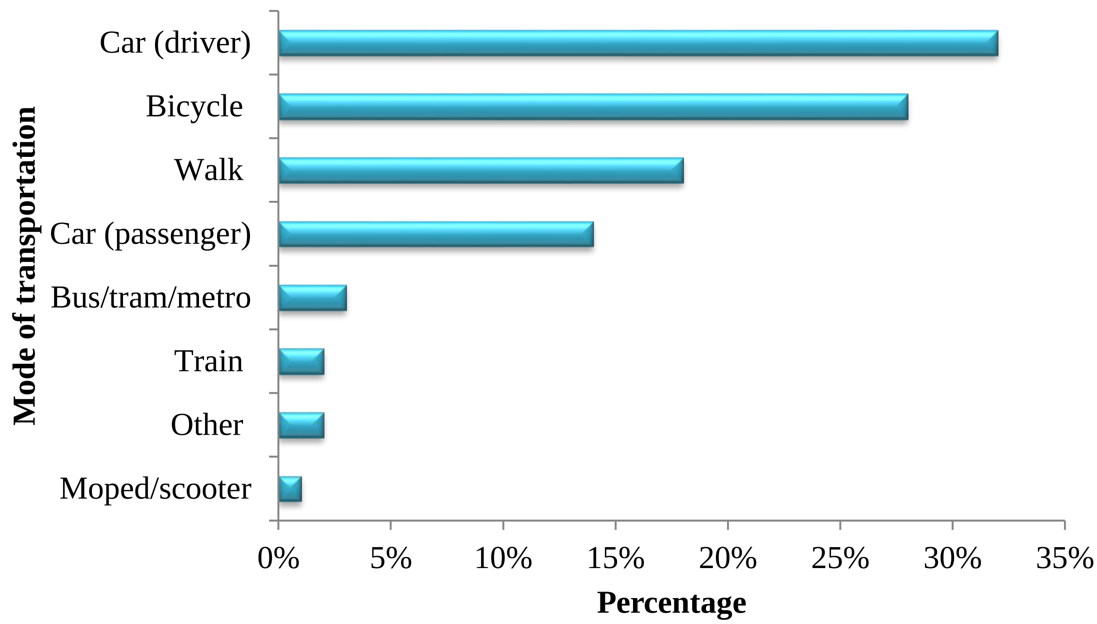

Figure 7. Mode share of all trips per person per day, Netherlands, 2014 (CBS, 2014).

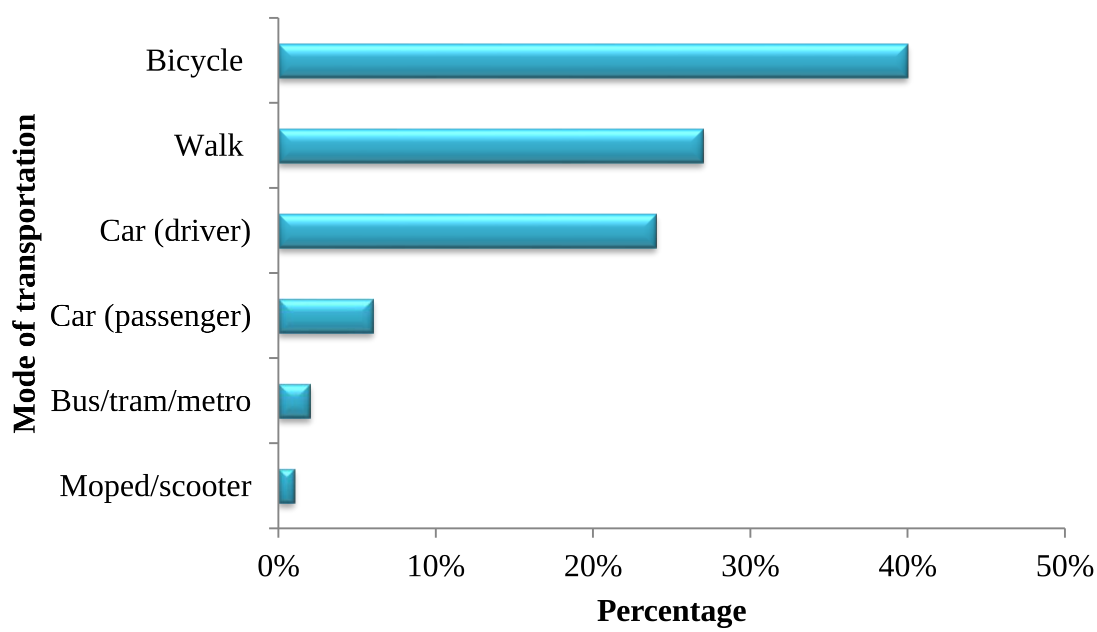

Figure 8. Mode share of trips under 7.5 kilometres per person per day, Netherlands, 2014 (CBS, 2014).

The availability of public transportation is a large factor affecting the competitiveness of transportation modes. The quality and availability of buses and trains dictates the choices residents have for mobility. Public transportation could impact the likeliness of residents to use a park-and-ride model of transportation to get where they need to go (Rietveld & Daniel, 2004). This relationship, shown in Figure 9, indicates 42% of all train trips in the Netherlands start with cycling. Studies have shown that having ample space for bicycle parking at train and metro stations is likely one of the most significant practices of multimodal coordination done by cities (Pucher & Buehler, 2007, 2008). Public transportation has a 38% mode share for people who reside within three kilometres of a train station (Givoni & Rietveld, 2007). High levels of public transportation use are a result of various factors, such as wide availability, and the unattractive aspects associated with private vehicle ownership in the Netherlands, such as high taxes on gas, lack of available parking, tolls and high gas prices.

The relation of the town to larger cities plays a key role in the accessibility of the city; towns with a train station are more likely to see higher levels of residents cycling to the station compared to driving. Public transportation can also be a competing mode of transportation for the bicycle for journeys under 7.5 kilometres. The cost of public transportation is likely to affect the likelihood of individuals cycling instead of using public transportation over shorter distances or with limited incomes or, in poor weather.

In the theoretical framework factors for competing modes of transportation are divided into two categories, public transportation and private transportation. Within the category of private transportation, the following factors are included: parking costs, tax on fuels, tolls, and convenience. Public transportation includes: availability, connections to large cities including rail stations, cost, efficiency and park and ride availability.

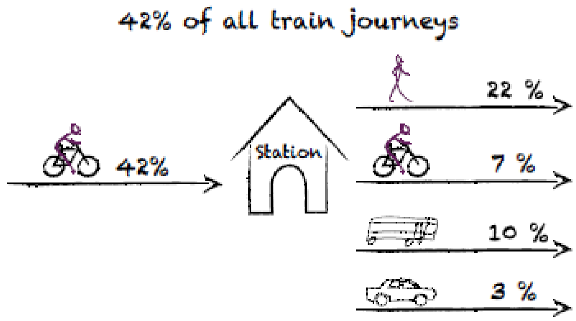

Figure 9. The importance of cycling and walking for train journeys in the Netherlands (Scheltema, 2012).

2.6 Conclusion

Chapter two has provided an extensive review of existing literature on cycling infrastructure, cycling levels and factors affecting bicycle use while exploring how they are relevant in small towns. An overview of factors that influence varying cycling levels in municipalities have been presented. Criteria outlining the main requirements of bicycle infrastructure from CROW were discussed at length leading to a discussion on the relationship between cycling infrastructure and cycling levels. The theoretical framework was introduced, adapted from the research of Rietveld and Daniel (2004) and Ververs and Ziegelaar (2006) and to integrate academic research with praxis the analysis of the Dutch *Fietsbalans* was presented to provide an on-the-ground assessment of significant requirements of cycling infrastructure based on research conducted across the Netherlands.

Based on the above findings it has been shown, based on existing research, that it is challenging to determine the impacts cycling infrastructure has on cycling levels while considering a wide range of other variables and attempting to regulate them (Buehler & Pucher, 2012). Thus, the direction and significance of causality between cycling levels and independent factors can be difficult or impossible to determine as has been established through a discussion of existing relevant research (Dill & Carr, 2003). With the complete theoretical framework now introduced, it will inform the empirical research presented in the remainder of the thesis. The following chapter will examine the research strategy and methodology of the research.

3 Research Strategy and Methodology

The research question for this thesis is: *Does better bicycle infrastructure correlate with higher cycling levels in small towns in the Netherlands?* This chapter will discuss the methodology that has been applied in order to answer this question. The chapter begins with an overview of the research strategy implemented followed by an extensive look at the data sources available for this research. The next section discusses the ways in which data will be analyzed, including methods and outcomes. The final section of the chapter considers the towns where the research has been conducted, providing a brief overview of key statistics of the towns.

3.1 Research Strategy

The research focuses on factors which affect cycling levels in small towns, as well as on whether infrastructure influences cycling levels. In order to answer the research question, small towns in the Netherlands were studied. In order to be considered a small town, the towns must have a population under 50,000 residents. Ideally, selected towns should be comparable in all ways except the dependent variable, cycling levels. The selected towns should be comparable for factors such as distances to larger cities, availability of shopping facilities, population density, access to public transportation, inclusion of a train station and various other key factors. However, due to a limited set of independent variables caused by lack of data it was not possible to use comparable towns, minus similar population size, in the research. These factors were previously discussed in chapter two.

The research strategy involves analysing various secondary data from the Fietsersbond and CBS Statline. Independent variables which have been determined to influence cycling levels, as shown in Table 5 and in the theoretical framework, were analysed against cycling levels in the eight research towns in an attempt to determine which factors correlate with high cycling levels.

As discussed in the previous chapter, cycling levels are influenced by a substantial number of factors that several academic studies have researched and reported on. In order to obtain relevant scientific data these factors must be considered when analysing the available data from small towns to answer the research question. While there are an extraordinary number of factors which affect cycling levels, it is not feasible to assess all the factors considering time and research constraints. Thus, factors determined by Ververs and Ziegelaar (2009), Rietveld and Daniel (2004) and the author to have significant influences on cycling levels, and discussed in the previous chapter, will be utilised in this research.

The study uses quantitative analysis of a set of numerical data from secondary sources in order to gain insights into the effects of cycling levels on cycling infrastructure. One method of analysing the data was using descriptive statistics. This strategy was chosen as a way to answer the research question, mostly focusing on observations from the data set. Using descriptive statistics can be beneficial in determining the status of variables, in this case cycling infrastructure and cycling levels where the variables are not controlled (Bernard, 2012). Correlational approaches are also used in this research to determine the relationships between variables, different factors affecting cycling levels, and cycling levels and the method is observational from data analysis. The research uses secondary data from CBS Statline and from the Dutch Cyclists' Union, the Fietsersbond. Descriptive analysis was used to provide general observational non-statistical analysis however it cannot determine any type of relationship that might exist or the direction of the relationship. The reason for using secondary data instead of primary data is due to the existence of exceptional data collected by the Fietsersbond. The level of research conducted by the Fietsersbond is detailed, complex and was a substantial undertaking which could not be completed by one individual alone for the purposes of a master's thesis.

3.2 Analysis

Quantitative methods are used in this research to analyse the relationships between the numerous variables obtained from the Fietsbalans reports and from the CBS. The secondary data available will help to understand the impact infrastructure has on cycling levels. These methods involve objective measurements and statistical analysis, in this case, collected by gathering pre-existing statistical data and manipulating it through calculation techniques. Quantitative research is relevant in this research as it allows the researcher to collect numerical data and then generalize it across a group of people or areas (Babbie, 2010; Muijs, 2010). Data management and analysis performed using statistical tools in Microsoft Excel will be used for descriptive analysis, bivariate analysis and regression analysis. As there are differences between the cycling levels in the eight different towns regression analysis was used to determine which factors increase cycling levels and thus attempt to explain the differences in cycling levels between the towns. By comparing the bikeability of different small towns the impact infrastructure has on cycling levels can be determined (Borgman, 2003).

Using qualitative methods to answer this research question did not seem feasible. The reliability and validity of results obtained using qualitative methods are not often credible. Creating a survey to ask people questions such as their age, income, gender, how often they cycle, why they cycle, how they use bicycle infrastructure and what kind of cycling infrastructure they use is not a valid method of answering the research question. Using surveys with qualitative methods often entails errors found in the way respondents answer and understand questions (Saunders, Lewis & Thornhill, 2009). There are often large biases when asking respondents questions through a survey, the data received frequently does not truly reflect the respondent's opinions and may be altered depending on the weather, time of day, and personal feelings (Saunders et al., 2009). The results sought in this thesis are concrete and cannot be captured in a qualitative investigation, qualitative approaches seek to answer the "who" and "how" of decision making while important to cycling levels does not impact the research. As the research focuses on infrastructure, which is measured quantitatively no qualitative methods will be used in this research.

Table 4

Methods of Analysis Used to Assess Dimensions of the Cycle Balance Assessment, as Indicated in Figure 5 (Borgman, 2003; Fietsersbond, 2009)

Method	Completed by	Uses/Application
Questionnaire for the municipality	Municipal civil servants	▪ assesses local cycling policy on paper ▪ addresses: policy papers and plans, the bicycle network, bicycle parking, budgets and the council as an employer ▪ a good policy is required for long-term decision making and practice
Questionnaire on cyclist satisfaction	Cyclists	▪ assess if cycling conditions are meeting the requirements of everyday cyclists ▪ questions on bicycle parking, cycling comfort, safety, bicycle theft and the municipality's cycling determination
Local cycling conditions data	National databases Central Bureau of Statistics (CBS) Institute for Road Safety Research (SWOV)	▪ data is used to show bicycle-use, road safety and urban density levels
Quick scan indicator for cycling infrastructure	Measuring bikes	▪ recording distances, speeds, sounds and vibrations on the bike ▪ video camera records: road profiles, road surface, manoeuvers and obstacles ▪ assesses directness, comfort and attractiveness

3.2.1 Descriptive Statistics

An important group of factors have been determined and identified in the literature review and theoretical framework. These groupings include competing modes of transportation, bikeability and infrastructure, characteristics of the population and spatial and spatial-economic factors. For each variable a summary of the observational relationship between the addressed variable and cycling levels is provided, based on literature. The second component of the analysis is describing the indicators used to analyze the relationship followed by a description of the variable using descriptive statistics to observe how the variable differs across the selected towns.

3.2.2 Bivariate Analysis

A correlation analysis was conducted between the variables used in the analysis, and cycling levels to determine their correlation. The variables with significant correlation to cycling levels were then assessed through quantitative analysis, a bivariate analysis. These factors were then graphed against cycling levels in an attempt to determine the empirical relationship between the independent variables and dependent variable, cycling levels. These graphs can be found in Appendix A. Bivariate analysis is then used as an explanatory analysis. Correlation analysis is also conducted between individual variables and cycling levels.

3.2.3 Multivariate Analysis

Following the analysis conducted using descriptive statistics, bivariate analysis and correlation analysis on the different identified variables; all the variables will be assessed using regression analysis. This analysis will be used to assess multiple variables. By using regression analysis, the relationship between the dependent variable cycling levels and independent variables: bikeability and infrastructure factors, characteristics of the population, spatial and spatial-economic factors and competing modes of transportation can be determined. This will help to assess the impact cycling infrastructure has on cycling levels.

3.3 Operationalization

The factors which have been utilized in the analysis are indicated in Table 5; these do not include all factors which have been addressed in theoretical framework. The following section will describe the factors used in the analysis. Unfortunately, information for each factor identified in the theoretical framework was not available for each town and thus only the available data was used in the analysis. All the data used here was from 2013, as it was the closest to the year cycling level data was collected. The dependent variable used in this research is cycling levels, cycling levels are defined in section 2.2, and this variable is often used in cycling research as a dependent variable. Variables which affect the dependent variable, cycling levels, are extensive. A number of independent factors that affect cycling levels and relate to the research conducted in this thesis are outlined in the theoretical framework in Figure 6.

Table 5

Independent Factors Affecting Cycling Levels used in Analysis

Category	**Factors**
Competing Modes of Transportation	Occurrences of Cycling being Faster than Driving
Bikeability and Infrastructure Factors	Stop Frequency
	Slow Cycling and Walking
	Traffic Obstruction
	Infrastructure Barrier
	No Priority Rights
	Number of Turns
	Vibrations on the Pavement
	Noise Pollution
	Casualties
	Detour Factor
	Delay
	Average Speed
Characteristics of the Population	Average Income
	Gender- Percentage of Females
	Percentage of Non-Western Immigrants
	Percentage of Population between 10 and 25 Years Old
Spatial and Spatial-Economic Factors	Population
	Population Density
	Population Growth
	Car Ownership per Household
	Average Distance to a Supermarket

3.3.1 Infrastructure

Safety is one of the most important requirements of cycling infrastructure; cyclists are not as well protected in the case of an accident as motorists. The differences in mass and speed between the two modes must be considered. The safety of cyclists is quantified in the Fietsbalans research by the number of serious accidents involving cyclists per 100 million kilometres (Fietsersbond, 2009B). “Safety in numbers” theory may be relevant in this research. This theory suggests that more cyclists on the street results in an increased perceived notion of safety thus increasing cycling levels while at the same time motorists are more cautious of cyclists when there are more on the streets (Jacobsen, 2003). Prior to extensive research there was significant concern that as cycling levels increased so to would the number of casualties, with more cyclists on the road there could be more risk of injury. However, this is not true and is instead the opposite and called ‘non-linearity of risk’ (Elvik, 2004).

Directness includes factors which affect the travel time and distance for cyclists; through the Fietsersbond’s research this was measured to include: (1) the detour factor (2) the delay of cyclists and (3) actual cycling speed. How much of a delay cyclists face due to stopping at traffic lights is measured in seconds per kilometre. The average speed cyclists travel in the town is recorded as kilometres per hour. The detour factor is the ratio between the length of the route on the road and the straight-line distance. The CROW design manual for bicycle traffic gives a standard for the detour factor of up to 1.2 for designated main routes and either 1.3 to 1.4 for other routes. In addition, the manual gives as an indicator of the quality of the bicycle network, with the guideline that approximately 70% of bicycle trips should be completed on these designated main routes (CROW, 2016). Based on this the Fietsersbond used 1.25 as a standard for the detour factor that means that the route of the road is 1.25 times the straight line distance at an interval of 0.1 (i.e. for each 0.1 lower or higher the score is either better or worse) (F. Borgman, personal communication, April 7, 2017; Fietsersbond, 2009B).

Comfort indicates the measure of obstructions whilst cycling. For the purposes of the Fietsbalans report the following factors were used: frequency of stopping, slow movements, amount of traffic, infrastructure barrier, number of no priority turns, number of turns and vibrations felt on a bicycle while on pavement, which is disruptive to cyclists and could cause damage to bikes. The vibrations are measured in m/s^2, vibrations can be caused by pavers and cobblestones and other uneven surfaces. Some of these factors are determined by a special method of the Fietsersbond. The measure for traffic is measured through, verkeershinder, or traffic obstruction, Fv. This measurement is the probability that cyclists will encounter and come into conflict with other road users. The CROW design manual for bicycle traffic indicates that traffic obstruction should be minimized by uniting busy cycle routes with busy road connections as little as possible, specifically in the longitudinal and the transverse direction (CROW, 2016). The operationalization for traffic obstruction chosen in the Fietsbalans research was 'the necessity to ride single file because of interference by other road users' and the percentage of distance this occurred (F. Borgman, personal communication, April 7, 2017). Author of the report Frank Borgman provided the following example of the variable of traffic obstruction, “given the vulnerability of cyclists it is undesirable for cyclists being forced to ride single file due to the presence of other road users. For example, to safely guide young children through traffic it is imperative that parents can remain next to their children on bikes, especially when there is close by moving motorized traffic” (F. Borgman, personal communication, April 7, 2017). Infrastructural impediment, Fi, is an indicator of the lack of space on the cycling infrastructure available for safe manoeuvring. The CROW manual discusses preventing loss of time caused by sharp corners and insufficient width of cycling infrastructure. The operationalization for the measure of infrastructure impediment chosen in the Fietsbalans was 'the necessity to ride single file due to narrow passages or narrow cycling infrastructure’. The Fi is calculated in a similar fashion as the Fv. It is the sum of frequencies per cause (bollards or narrow infrastructure) per kilometre plus 0.01 times the number of metres travelled in a kilometre (F. Borgman, personal communication, April 7, 2017, Fietsersbond, 2009B).

Slow cycling is a measurement based on the CROW design manual that specifies that in order to remain stable a cyclist must be travelling at a minimum of 12 kilometres per hour. Any time that this speed is not reached it is determined to be slow. This measurement is based on the percentage of time during a trip where a speed of less than 10 kilometres per hour was recorded. Experience would suggest that it is not logical that with a higher amount of “slow” time that cycling levels would increase, the opposite would be more reasonable. This factor may be present when a cyclist has to dismount, walk a bike and speeding up and slowing down. Thus, this measurement indicates the percentage of the trip time where the speed of movement was less than 10 kilometres an hour (Fietsersbond, 2009B). The factor of ‘no priority rights’ is directly related to the comfort of cyclists in their movements. The factor is measured as the number of occurrences in one kilometre where cyclists have to give priority to other modes of transportation, mostly vehicles (Fietsersbond, 2009B). The number of turns on a cycling route impacts a clear continuous connection (Fietsersbond, 2009B).

Attractiveness is defined as the environmental characteristics surrounding the cyclists. In the Fietsbalans study the amount of noise pollution was used as an indicator and quantifies noise levels. This factor is measured as the noise levels in the selected towns in decibels (dB) in various locations and then the sum of the various measurements around the town are weighted to produce the measurement Fg. The lack of noise caused by other traffic makes cycling more enjoyable (Fietsersbond, 2009B).

It is important to note here that some factors may be overlapping. Some independent factors are indeed influenced by other factors outlined in the theoretical framework, found in Figure 6. The research here is conducted as if the factors are entirely independent. An example is provided here: the traffic obstruction variable reflects other factors within the category of comfort including the number of stops or turns required and the priority of the bike.

3.3.2 Characteristics of the Population

Personal activities and health were not included in the analysis. The health of individuals is challenging to quantify; no data was available for the towns which would be useful in determining how health impacts cycling levels in small Dutch towns and therefore has not been included in this study but still mentioned as an important factor influencing cycling levels. Similarly, the activities of people cannot be quantified but will be discussed as a relative factor influencing cycling levels. It is likely that characteristics of the population do impact cycling levels. The degrees to which they have an impact are relatively unknown. Prior studies have noted the importance of the characteristics of the population on cycling levels and thus they were included in the theoretical framework.

The average income per capita of individuals was used; this is not the same as average income per person with an income. The percentage of females was used as a measure of gender. The only statistic related to ethnicity and cultural background available was the percentage of immigrants, this can be broken down into western immigrants and non-western immigrants. For research purposes, statistics of non-western immigrants were used as there is more likely to be a difference in cycling culture in non-western countries which may decrease the likelihood of immigrants cycling. The population between the age of 10 and 25 was used a measure of age which could be quantified, as was highly likely to correlate to high cycling levels based on existing research.

3.3.3 Spatial and Spatial-Economic Factors

The indicators of spatial and spatial-economic factors will be described. Select factors were available on CBS Statline and used in the research including population, population growth, population density, average distance to a supermarket, and average cars per household (CBS, 2008, 2013). The data available from CBS Statline is from 2008 and 2013, for consistency within the rest of the research (CBS, 2008, 2013). The indicators which are used here are not an entire representation of spatial and spatial-economic factors and do not necessarily align with the factors indicated in the theoretical framework. The population of the towns from 2008 was used as a standard for comparing spatial and spatial-economic factors. Similarly, the population density has been calculated based on the size of the population and the area of the town in square kilometres. This number dictates how many residents live in one square kilometre. Population growth is based on the percent change in population from 2000 to 2009 and relevant to cycling levels as with increased numbers of residents in a town there will be more cyclists and thus higher cycling levels. Population growth alone cannot account for an increase in cycling levels for example when there is an increase in population development patterns and areas of intensification are crucial to the increase or decrease in cycling. The number of cars owned per household was used to show how competitive the car is with the bicycle, the likelihood of cycling if residents already have a car and the ability of residents to be able to afford a vehicle. The average distance to the supermarket was used; this statistic is comparative to population density as it dictates how far residents will have to travel to access a supermarket. Overall, cycling levels may influenced by spatial and spatial-economic factors.

3.3.4 Competing Modes of Transportation

In light of the available data, only competition between the car and bicycle was taken into account in this study. Two measures of competitiveness were tested through the Fietsbalans research, travel time ratio and percent occurrences of cycling being faster, however only the second was used in the research. The first measurement is the travel time ratio between a bike and a car, identifying the percentage of occurrences where the time it takes to travel a certain distance by bike, was either faster or slower than by car. This was measured as a ratio, assuming a standard of 1, meaning the car and bicycle travel the same speed. The second measurement is the percentage of trips where cycling is faster this statistic is measured in percentage of occurrences in which journeys by bike are faster than by car (Fietsersbond, 2009). The standard for this calculation is 70%, where the bicycle is faster than or just as fast as the car. Travel time also includes searching for a parking space, both for bicycles and cars, and walking to your destination (Borgman, 2003).

3.4 Data Sources

Main data sources are obtained from extensive research conducted by the Fietsersbond. Data was collected by the Fietsersbond as part of the cycle balance report, *Fietsbalans*, or bikeability index, as discussed in the previous chapter. The Fietsersbond is a Dutch Cyclists' Union which has over 35,000 members serving the Netherlands' 13.5 million cyclists. Their main goal is to create more and better opportunities for cycling across the country (Fietsersbond, 2016). The data used in this thesis details the results of a cycle balance/bikeability assessment, *Fietsbalans*. This assessment was conducted between 2000-2004 and then again during *Fietsbalans 2* between 2008 and 2013. Only data from *Fietsbalans* 2 was used in this research. The data was collected in an effort to stimulate policies which encourage increased cycling in municipalities across the Netherlands (Fietsersbond, 2009). Table 4 gives an overview of the four methods of data collection used in the *Fietsbalans* research. There were two questionnaires, one for cyclists assessing if the cycling conditions desired by cyclists were being met and questions on bicycle parking, cycling comfort, safety, bicycle theft and the municipality's cycling dedication (Borgman, 2003). The second questionnaire was for municipal civil servants addressing local cycling policy papers and plans, cycling networks, parking and budgets. The third method of data collection involved assessing local cycling conditions based on data from the CBS and from the Institute for Road Safety Research (SWOV) relating to bicycle levels, road safety and urban density levels. The fourth method of data collection, and most important to this research, is the quick scan indicator for cycling infrastructure. This data was collected using specially designed bikes equipped with a laptop and camera gathering information on the state of the cycling infrastructure around various towns and cities. It recorded distances, speeds, sounds and vibrations of various trips within the area. The camera provided data on road profiles, road surfaces, manoeuvers and obstacles and collectively was able to determine the directness, comfort and attractiveness of cycling infrastructure (Borgman, 2003). An example of the data collected by the Fietsersbond is shown in chapter 2, Figure 5. This figure gives an overview of the dimensions which have been assessed based on the above data sources as well as the standard of measurement intervals and averages.

Portions of data used in the Fietsbalans analysis were obtained through the Central Bureau of Statistics (CBS), in the Netherlands. The CBS has extensive information on various statistics in the Netherlands relevant to this research. The most important statistic used in this research and obtained by the CBS is cycling levels. The available data from the CBS will optimally reveal a range of cycling levels across the different small towns.

3.5 Selected Towns

A small sample of Dutch towns was chosen due to the expected difficulty in obtaining data from the Fietsersbond. From the *Fietsbalans* research conducted by the Fietsersbond, eight towns fit the criteria required by this thesis. Table 6 shows the eight towns with details such as location (Dutch province), population, geographical size, population density, presence of a train station, and availability of other modes of public transportation. Five of the eight towns have a train station connecting to larger cities and all towns are served by bus routes. The data provided in this table is from 2008 and reflects the conditions that were present at the time of data collection.

Table 6

Key Statistics of Research Areas (CBS, 2008, 2013).

Town	Province	Population	Size (km^2)	Density (residents/$km^{2)}$	Train station (yes or no)	Other public transportation
Boxtel	Brabant	30,241	64.65	468	Yes	Bus
Gorinchem	South Holland	34,472	21.93	1,572	Yes	Bus
Hellevoetsluis	South Holland	39,620	46.27	856	No	Bus
Houten	Utrecht	46,475	58.99	788	Yes	Bus
Leiderdorp	South Holland	26,376	12.28	2,148	No	Bus
Soest	Utrecht	45,560	46.43	981	Yes	Bus
Wageningen	Gelderland	36,215	32.36	1,119	No	Bus
Weert	Limburg	48,305	105.52	458	Yes	Bus

3.6 Conclusion

This chapter has discussed the research strategy and methodology of this thesis. The research strategy was presented detailing how the research question will be answered. Data sources, from the CBS and the Fietsersbond, were introduced. Variables used in the research, both dependent and independent were mentioned, although they were extensively discussed in the previous literature review chapter. An overview of the data analysis process was presented including the methods of quantitative data analysis: descriptive statistics, bivariate analysis and regression analysis. The justification for using these types of analysis were determined to be useful in determining the status of variables, in this case cycling infrastructure and cycling levels, where the variables are not controlled. Correlational approaches are also used in this research to determine the relationships between variables, comparing different factors affecting cycling levels to cycling levels; in this case the method is observational from data analysis. The outcomes of the data analysis will result in a further understanding of the research question and provide insights into the relationship between cycling levels and cycling infrastructure. The final section of the chapter considered the towns where the research has been conducted, providing a brief overview of key statistics of the towns. Setting the context for the research areas helps understand and develop the relationship between the towns and the research undertaken.

4 Empirical Analysis

This part of the thesis discusses the findings of this research. This chapter is divided into five main sections each of which presents the results relating to the research question: *Does better bicycle infrastructure correlate with higher cycling levels in small towns in the Netherlands?* The first section will discuss local contexts, providing an overview of each of the eight selected towns. The second section provides a comprehensive analysis of data as it relates to the theoretical framework and factors affecting cycling levels. The third section discusses what the results and analysis indicate for small towns in the Netherlands. And the final section concludes the chapter and provides discussion on the answer to the research question.

4.1 Local Context

Eight towns were used in this research; each town was selected primarily based on population of less than 50,000 residents and available data. Ideally, these towns would share similar features allowing for a systematic comparison. The selected towns have different populations, geographies, demographics, densities among other differentiating factors. Each town will be discussed below to provide background and a further understanding of the cycling levels in that town. Varying amounts of information are available for the different municipalities; some municipalities promote cycling heavily, while others hardly mention cycling in any policy documents. This may play a role in the research outcomes as it is possible documents were not available to the public. Images of each municipality are provided; these topographical images show geographical features such as waterways and greenspace as well as urbanized areas.

4.1.1 Cycling in Boxtel

The town of Boxtel is located in the province of Brabant. The population at the time the research was conducted was 30,241. A topographical map of Boxtel is shown in Figure 10. Boxtel is situated between three major Dutch cities: Den Bosch, Tilburg and Eindhoven. There is a local bus and railway station. Boxtel is proud of its cycling policy, culture and bicycle usage and has an eight-page *Fietsvisie* (Cycle Vision) document for the municipality of Boxtel from 2010-2020 (Municipality of Boxtel, 2009). In 2009 Boxtel had a cycling level of 39% for trips under 7.5

kilometres; by 2020 they aim to increase this number to 43% (Municipality of Boxtel, 2017; Fietsersbond, 2009).

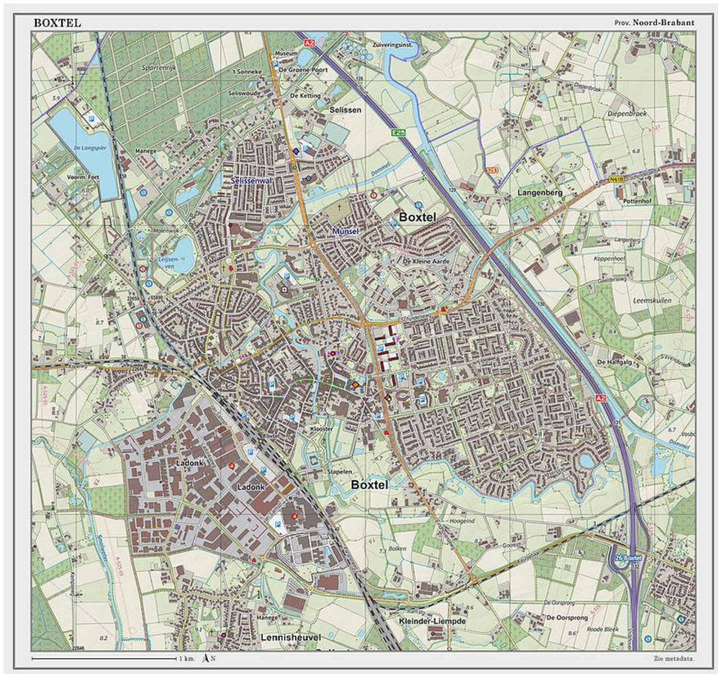

Figure 10. Topographical map of Boxtel (van Aalst, 2014)

4.1.2 Cycling in Gorinchem

Gorinchem is located in the province of South Holland and has 34,472 residents. It has a relatively high population density for a municipality of this size with a density of 1,572 residents per km^2. A topographical map of Gorinchem is shown in Figure 11. As of 2009 Gorinchem had a cycling level of 35% and aims to increase the cycling level to 45% by 2030, for trips under 7.5 kilometres (Municipality of Gorinchem, 2013). Gorinchem has significant goals to encourage and increase in cycling levels by:

- Encouraging more cycling exercise and healthy behaviors of our people;
- Reducing the amount of internal traffic, with fewer short car trips reducing local parking pressure

- Supporting cycling and discouraging car use which immediately contributes to an increased quality of life in the town (Municipality of Gorinchem, 2013; Fietsersbond, 2009).

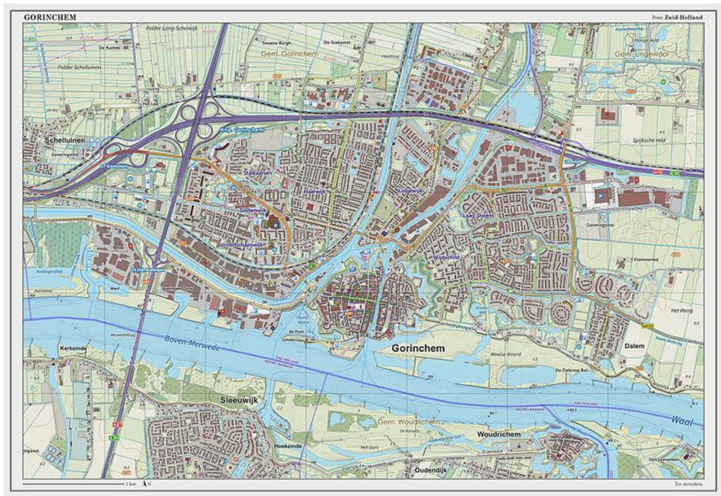

Figure 11. Topographical map of Gorinchem (van Aalst, 2014).

4.1.3 Cycling in Hellevoetsluis

Hellevoetsluis has 39,620 residents and is located in the province of South Holland. It is located on the Haringvliet near to the sea. For this reason it is a popular location for water sports and tourism. A topographical map of Hellevoetsluis is shown in Figure 12. It does not have a train station but is serviced by a local bus. Hellevoetsluis' population density is 856 residents per km^2 (Municipality of Hellevoetsluis, 2017; Fietsersbond, 2009).

Figure 12. Topographical map of Hellevoetsluis (van Aalst, 2014).

4.1.4 Cycling in Houten

Houten is one of the larger municipalities in the research with a population of 46,475. The main town of Houten is often referred to as a commuter town for the large nearby city, Utrecht. For this reason there are two operational railway stations as well as regional buses. A topographical map of Houten is found in Figure 13. In 2008 Houten was designated as the country’s best bicycle town for being safe and bicycle friendly. In part this award is a result of comprehensive urban design promoting sustainable modes of transportation. Houten has more than 130 kilometres of bicycle only paths and has the second highest cycling level of municipalities used in this research with a mode share for cycling at 40% for trips under 7.5 kilometres (Fietsersbond, 2008; Jaffe, 2015).

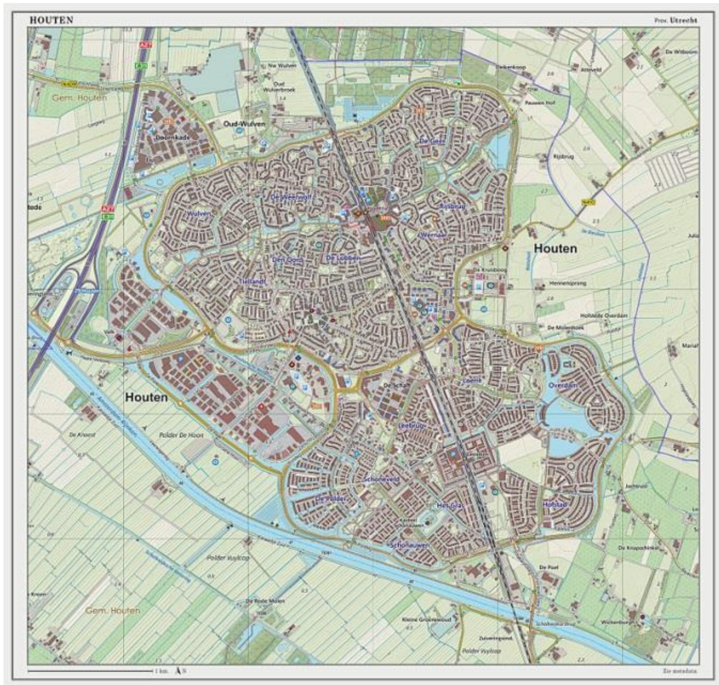

Figure 13. Topographical map of Houten (van Aalst, 2014).

4.1.5 Cycling in Leiderdorp

Leiderdorp is located in the province of South Holland and has a population of 26,786. It is a geographically small municipality of 12.38 km^2 with a resulting high population density of 2,148 residents per km^2. A topographical map of Leiderdorp is found in Figure 14. Leiderdorp is nearby to the large university town of Leiden and is now referred to as a commuter suburb of Leiden (Municipality of Leiderdorp, 2017; Fietsersbond, 2009).

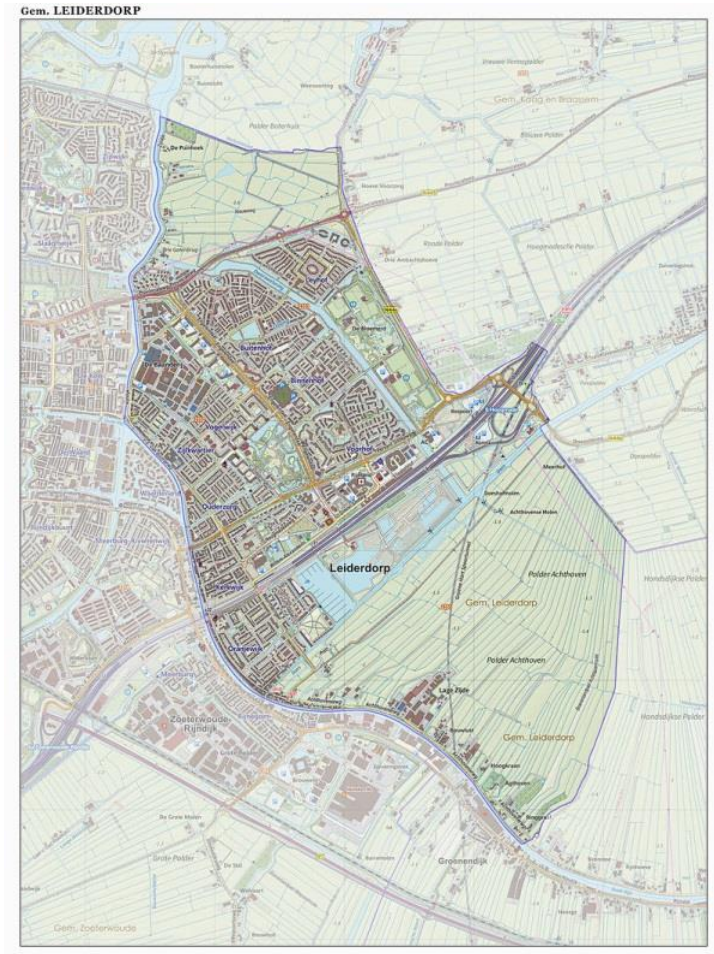

Figure 14. Topographical map of Leiderdorp (van Aalst, 2014).

4.1.6 Cycling in Soest

Soest is a relatively large small municipality with 45,560 residents and located in the province of Utrecht. Within Soest there are three railway stations and regional bus stations. A topographical map of Soest is found in Figure 15. Soest has the lowest cycling level of the surveyed municipalities with a cycling mode split of 28% for trips under 7.5 kilometres (Municipality of Soest, 2017; Fietsersbond, 2009).

Figure 15. Topographical map of Soest (van Aalst, 2014).

4.1.7 Cycling in Wageningen

Wageningen has the highest cycling level of municipalities used in this research with a bicycle mode share of 44% for trips under 7.5 kilometres. It does not have a train station within its jurisdiction but is served by a regional bus connecting to a train station. A topographical map of Wageningen is found in Figure 16. It is home to a large university, Wageningen University, which may account for its high cycling levels (Municipality of Wageningen, 2017; Fietsersbond, 2009).

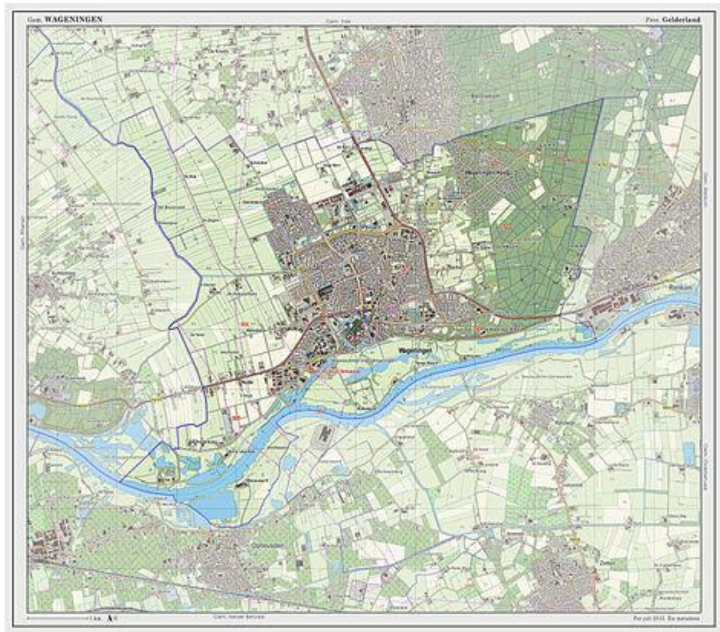

Figure 16. Topographical map of Wageningen (van Aalst, 2014).

4.1.8 Cycling in Weert

Weert is located in the province of Limburg, in the southeastern Netherlands. It has a population of 48,305 and the lowest population density of the towns used in this research at 458 residents per km^2. A topographical map of Weert is found in Figure 17. The town of Weert has a railway station and regional buses (Municipality of Weert, 2017; Fietsersbond, 2009).

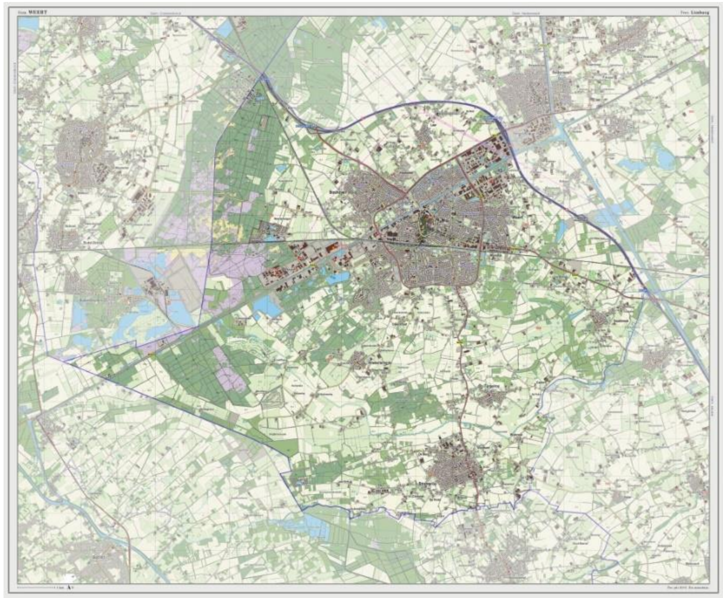

Figure 17. Topographical map of Weert (van Aalst, 2014).

4.2 Cycling Levels

One aim of this paper was to provide a conceptual theoretical framework based on the research of Borgman, (2003), Rietveld and Daniel, (2004), Ververs and Ziegelaar, (2006) of factors affecting cycling levels. While a major focus was put on the factor of infrastructure it was inconclusive to only write and research about this factor when there are many other contributing factors influencing cycling levels. Thus, the factors of competing modes of transportation, spatial and spatial-economic factors and characteristic of the population have also been included.

Here, the findings of the research and discussion of the analysis is presented. The results are presented in four groupings of factors which affect cycling levels. The first which will be presented is the most important for this research, bikeability and infrastructure factors. The second section discusses characteristics of the population, how these relate to cycling levels and how they were assessed to reflect the effects they have on cycling levels. In the third section spatial and spatial-economic factors are discussed. The fourth section presents the findings from modes of transportation competing with the bicycle. In each of the four groupings of factors which influence cycling levels a similar format for discussion is applied firstly, (1) the first section will discuss the relationship between the variable addressed and cycling levels, (2) a description of the indicators used to analyze the relationship is provided, (3) the variable is described and discusses how it varies across the selected towns, (4) and lastly a bivariate and correlation analysis is presented providing a description of the results.

In the final section in order to determine the significance of key factors, as identified through correlation analysis a regression analysis is presented. The evidence presented in this section presents a detailed analysis of the effects of factors influencing cycling on cycling levels.

4.2.1 Bikeability and Infrastructure Factors

This section will examine the factor of cycling infrastructure extensively. Significant research has been conducted by the Fietsersbond on *Fietsbalans* (bikeability), these results and other substantial data has been used in the research to determine the relationship between cycling infrastructure and cycling levels in small Dutch towns. Table 7 presents the most significant results from assessing infrastructure and bikeability across the research towns.

Table 7

Significant Findings in Assessing Infrastructure and Bikeability across Research Towns (Fietsersbond, 2009)

Towns	Cycling Levels (%)	Comfort	Stop Frequency (N/km)	Slow cycling (% of time)	Traffic obstruction (Fv)	Infrastructure barrier (Fi)	No priority rights (N/km)	Turns (N/km)	Vibrations (ft) of pavement	Attractiveness	Noise pollution) (Fg)	Safety	Casualties per 100 million km (N)	Directness	Detour Factor (ratio)	Delay (sec/km)	Average Speed (km/hr)
Boxtel	39		0.7	14	1.6	4.3	3.7	2.1	169		133		16.9		1.34	12	15.3
Gorinchem	36		0.3	14	4	1.6	4.2	2.5	194		186		38.8		1.51	4	15.9
Hellevoetsluis	34		0.5	14	2.4	2	4.9	2.9	207		124		19		1.45	3	15.6
Houten	40		0.2	15	1.4	2.4	6	3.6	126		106		15.4		1.34	2	15.7
Leiderdorp	33		0.6	18	6.7	5.4	5.9	2.9	139		150		38.2		1.39	13	14.3
Soest	28		0.4	11	3.1	1.4	3.8	2.8	174		149		30.4		1.34	9	15.6
Wageningen	44		0.5	16	1.2	1.3	3.9	2.8	138		114		18.8		1.37	9	14.5
Weert	36		0.6	16	4.1	2.4	4.2	2.5	83		142		29.8		1.41	13	14.8
Correlation[1]			-0.01	0.44	-0.57	-0.07	-0.30	0.05	-0.30		-0.50		-0.57		-0.11	-0.11	-0.23

[1] Between variable in top row and cycling levels

Based on the data collected in Table 7, this section will describe the variables in the table and how they differ across the research towns. Infrastructure includes a large set of factors with many variables and relationships within it, both spatial and physical characteristics and policy and perception factors. Some factors have significant differences between the investigated towns while others do not. This section will provide a brief description of how the variables differ across the towns. The next section will provide more detail and a bivariate analysis.

The number of stops within a kilometre ranges from 0.2 to 0.7 and while this difference seems small over a longer distance the number of stops could be significant. The percentage of time which is considered to be slow does not vary significantly over the eight towns and the average time the cycling is slow is 15%. The amount of traffic, indicated by the score of traffic expressed as the Fietsersbond traffic obstruction, Fv, varies across the towns from 1.2 to 6.7. Wageningen has the lowest score for traffic obstruction while Leiderdorp has the highest. The number of occurrences in one kilometre where cyclists do not have priority for movements is determined to be between 3.7 and 6 stops per kilometre across the research towns. This change is significant as the number of stops almost doubles between the town of Boxtel and the town of Houten. The number of turns required in one kilometre does not vary significantly across the towns and averages 2.8 turns per kilometre. The amount of noise pollution does not vary significantly across the towns, the average noise pollution is 138 Fg and the range between the towns is quite minimal. When safety is assessed the number of significant casualties per 100 million kilometres ranges significantly across the towns, Houten has 15.4 casualties while Gorinchem has more than double at 38.8 casualties per 100 million kilometres. The measurement of directness assessed by delay ranges from two seconds per kilometre, Houten, to over six times that delay at thirteen seconds per kilometre for Weert and Leiderdorp. The average speed per kilometre does not vary much across the towns, despite the differences in delay and detours; the average speed of cyclists across the towns is 15.2 kilometres per hour. According to the results of the *Fietsbalans* the Fietsersbond suggests this is due to minimal delay for cyclists in small towns compared to larger towns. The minimal delay is likely caused by the low number of traffic lights in small towns, in large towns traffic lights cause 80% of delays (Borgman, 2003).

As these factors are broad in their variations across towns it is hard to determine whether they have a significant impact on cycling levels. Each factor itself is influenced by various factors and thus can be challenging to comprehend and determine the significance of the data. The following section will use a bivariate analysis to further examine the results.

In this section the data which has been collected is analysed against the cycling levels. The data which is predicted to have the most significant effects on cycling levels has been put into graph form to display their relation to cycling levels, based on Table 7 and descriptive statistics. The data which is predicted to have significant effects was determined through descriptive statistics, based on the results of Table 7 which showed which variables appeared to vary significantly across the factors and the towns. The factors which are shown here are comfort: the number of stops per kilometre, the variable for traffic, the number of turns per kilometre, safety: the number of casualties per 100 million kilometres, directness: the delay of cyclists in seconds per kilometre and the average speed of cyclists in kilometres per hour. Through a correlation analysis between the factors and cycling levels none of the factors were statistically significant correlated to cycling levels, as shown in Table 7. Graphs displaying these analyses are shown in Appendix A.

Research sources suggest that with a decreased number of stops, less than 0.3 stops per kilometre, cycling levels increase (Rietveld & Daniel, 2004). This does not correlate with the data used in this research which does not show a significant relationship between cycling levels and stop frequency, as shown through the correlation analysis in Table 7. This relationship relates directly to the comfort of cyclists as well as the design of cycling networks. Interestingly the number of stops plays a key role in the physical effort required by cyclists as the stopping and starting to cycle again requires more strength than not stopping (Fajans & Curry, 2001). The starting and stopping also relates directly to how attractive the bicycle is compared to the car. The fewer stops cyclists are required to take the faster they can travel, increasing the competitiveness with the car.

The number of turns cyclists are required to make in one kilometre is proposed to have similar results to stop frequency and have the same overall impacts on the competitiveness of cycling. Looking at the data in Appendix A and the correlation analysis in Table 7 it is clear there is a slight correlation between the number of turns and cycling levels however it is not as predicted. While the relationship is weak it indicates that cycling levels will increase with an increased number of turns required for cyclists.

The relationship between traffic obstruction and cycling levels are significant as shown in Appendix A. The data suggests that with increased amounts of traffic cycling levels will decrease. This is not a surprising finding considering the traffic obstruction variable, which accounts for the probability that cyclists will encounter and come into contact with other road users, reflects other factors within the category of comfort including the number of stops or turns required and the priority of the bike. This relationship has been analysed as though the relationship does not overlap. Correlation analysis shows there is a negative correlation between the two factors of 0.57.

The relationship between casualties per 100 million kilometres and cycling levels is significant, as shown in Appendix A. Results indicate the lower the number of casualties the higher the cycling levels. This relationship may be explained by the strong existing safe infrastructure which decreases the likelihood of casualties while cycling. Or it could be explained by the perception of safety, if the safety risks of cycling are perceived to be high people may not cycle as often resulting in lower cycling levels. As was introduced in the literature review, and a key contemplation, cycling infrastructure may be improved when cycling levels increases or vice versa. Correlation analysis shows there is a negative correlation between the two factors of 0.57.

The average speed of cyclists was expected to have a significant relationship showing that higher average speed equals higher cycling levels. However, the data shown in Appendix A indicates almost the opposite. While the relationship is not significant it does indicate it is possible that the higher the average speed of cyclists the lower cycling levels will be. Similar to waiting time, delay time and the delay ratio factor, this factor relates strongly to the cycling network design in the research town which affects how direct and efficient cycling routes are.

In conclusion, this section provided mixed results. While it has been suggested by existing research that infrastructure has a significant impact on cycling levels the results of this research do not suggest a strong correlation, in most cases. Possibly the data used is not statistically significant enough as there is not a large sample size. It is possible that with more research towns more significant results could be found. What has been shown in the literature review is that there is a relationship between cycling levels and infrastructure. To what extent it is significant cannot be shown through this research. Bikeability was used in this thesis to determine the importance of bicycle infrastructure in the Netherlands. Bikeability connected existing academic research with the data collected and presented by the Fietsersbond. All factors of cycling infrastructure affect the bikeability of a town and thus are relevant and significant in the research.

4.2.2 Characteristics of Population

This section of the analysis contains relevant information regarding the characteristics of the population, how they relate to cycling levels and the data analysis on this factor.

As discussed extensively in the literature review, characteristics of the population can have significant effects on cycling levels. The characteristics of a population, relating to bicycle use, are defined as: age, gender, income, ethnicity, cultural background, personal activities, and health. Individual features such as age, gender, income and personal activities in many cases are correlated to cycling usage. The age of residents is vital as individuals may not be old enough to drive or they may be physically unable to ride a bicycle due to immobility or illness. Alongside age, an individual's fitness will certainly affect capabilities to cycle. Gender is also important as it is possible women do not feel safe cycling in some areas at night which can result in lower cycling levels for women. Income will affect the likelihood of households owning a car and being able to cover the costs associated with vehicle ownership such as fuel, taxes and parking and availability. With cycling used as a mode of transportation in the Netherlands, not only for leisure, it is important to look at the purpose of cyclists' trips as this relates to the characteristics of the population.

Many socio-cultural factors may influence cycling such as people's perceptions of the bicycle as well as their cultural, religious and ethnic background (Rietveld & Daniel, 2004; Ververs & Ziegelaar, 2006). People from countries where cycling is not prominent may not feel as comfortable cycling and may choose an alternative mode of transportation to get around (Rietveld & Daniel, 2004). Research conducted by Ververs and Ziegelaar determined that the percentage of Muslims in an area has a negative effect on cycling levels (Ververs & Ziegelaar, 2006). However religion alone cannot account for these factors and instead is likely related to cultural background. For this reason religious background has not been used as a factor affecting cycling levels. Instead ethnicity and cultural background were combined to be reflective in observing the percentage of non-western immigrants.

In this part of the investigation, the factors have been compared using descriptive statistics to determine how the variable differs across the selected towns. Across the eight towns considered here there is not a significant difference in the gender dispersal between the small towns. In 88% of the towns there were a higher percentage of females, although the difference is minimal, thus this is likely not a significant indicator in factors affecting cycling levels The average income per capita of all individuals varies somewhat but only by a maximum of 6,200 Euros. The percentage of non-western immigrants varies from between 6 and 15 percent and given the populations of these towns this number could be a difference of thousands of individuals. To show age differences, the average percentage of the population between 10 and 25 years of age for these towns is 19.6%. A summary of these results are shown in Table 8 and further analysis of these results compared to cycling levels follows.

Table 8

Indicators of Characteristics of the Population (CBS, 2008)

Town	**Cycling Levels (%)**	**Average income (x1000 Euros)**	**Gender (percentage of females)**	**Non-western immigrants (%)**	**Population between 10 and 25 (%)**	**Population (n)**
Boxtel	39	22.2	50.4	7	19.2	30,241
Gorinchem	36	22.5	50.8	15	18.5	34,472
Hellevoetsluis	34	24.9	50.3	8	19.0	39,620
Houten	40	26.2	50.7	6	20.7	46,475
Leiderdorp	33	26	51.7	10	17.6	26,376
Soest	28	25.6	51.2	11	17.6	45,560
Wageningen	44	20	52.0	12	24.6	36,215
Weert	36	22.1	50.0	9	17.9	48,305
Correlation[2]		-0.62	0.12	-0.13	0.81	-0.12

The results of this analysis did not detect any evidence suggesting that characteristics of the population have a significant impact on cycling levels. In conducting a bivariate analysis results did not show strong correlations. Through correlation analysis the population between the age of 10 and 25 does have a statistical significance of 0.81, as shown in Table 8. The town of Wageningen has the highest percent of individuals between the age of 10 and 25, due to a large student population and thus the highest cycling levels; this observation meets the expectation of the research.

When average income per capita of individuals was analysed against cycling levels an interesting observation was made regarding the town of Wageningen. Wageningen had the lowest average income. There are several possible explanations for this result, for example, having a lower income could result in the inability to purchase a car.

[2] Between variable in top row and cycling levels

However, if this was the case the town with the highest income levels would have the lowest cycling rates, which is not the case. Wageningen is a student town that accounts for both the low income levels and high cycling levels. On the contrary, the line of best fit indicates that the higher the average income in a town is, the lower the cycling levels will be. Some authors have stated that rates of cycling are comparable across all levels of income and across various countries (German Federal Ministry of Transport, 2003; U.S. Department of Transportation, 2003; Department for Transport, 2006; Danish Ministry of Transport, 2007; Statistics Netherlands, 2007). Other researchers have concluded that cycling levels are slightly higher amongst lower-income groups and that cycling is predominantly an equitable mode of transportation (Pucher & Buehler, 2008b). However, this particular study was conducted in the United States and may vary in other countries. This measure of income does not take into account factors affecting the presented income variable.

The number of non-western immigrants in a town does not appear to have a significant impact on cycling levels; the margin of which the percentage of immigrants differs is minimal and thus inconclusive as to the relationship between these two factors as shown in Appendix A and analyses in Table 8. As mentioned in the literature review cultural tradition and ethnicity are closely related and these results do not indicate a significant relationship there is likely a strong relationship between the cycling cultures in the countries immigrants come from and cycling levels in towns, however immigrants are only a small proportion of the population and may not provide a significant correlation.

In conclusion, based on the literature review when assessing characteristics of the population the factors which were determined to significantly affect cycling levels were: age, gender, income, ethnicity, cultural background, personal activities and health. While these factors were predicted to have significant effects on the cycling levels in the towns, the results did not show this to be the case. No significant relationship was determined between gender, income, ethnic and cultural background and cycling levels in the research towns. It is possible that the sample size was too small to indicate a strong correlation or that cycling levels are impacted by a large number of factors that make it challenging to see significant correlations between all factors. However, the strongest correlation between all variables in the research and cycling levels was determined to be the age of residents. The number of residents between the age of 10 and 25 correlates highly with cycling levels as shown in Table 8.

4.2.3 Spatial and Spatial-Economic Factors

In this section, spatial and spatial-economic factors will be analysed to determine if they are valuable in explaining the difference in cycling levels in the eight selected towns. The following factors are included: population, population density, population growth, average distance to a supermarket and level of car ownership.

Here, descriptive statistics were used to assess how the variables differ across the selected towns. The data for this analysis is found in Appendix A. Spatial and spatial-economic factors such as population density reveal substantial differences between the towns. The number of residents per km^2 affects the ability of residents to cycle, lower densities may present challenges for cycling as the distances required to travel are much greater. Medium densities are best for cycling as distances between destinations are not as wide spread. In areas of high density cycling levels are likely to decrease again as distances are so short that walking may be preferred or the access to public transportation is increased. The town with the highest population density is Leiderdorp with a density of 2,148 residents per km^2 and the town with the lowest population density is Weert at 458 residents per km^2. There are almost five times as many residents per km^2 in Leiderdorp as in Weert. Interestingly the town with the highest population, Weert, has the lowest population density and the town with the lowest population has the highest population density.

Population growth varies substantially across the towns; growth may influence cycling levels as with increased numbers of residents in a town there will be more cyclists and thus higher cycling levels. Population growth has been assessed against cycling levels. The town of Houten had significant growth at 36.9% increase while the town of Weert only increased 0.7%.

Car ownership across the towns varies only slightly with most towns averaging 1.1 vehicles per household. The average distance to the supermarket varies only slightly across the towns, with the average supermarket being between 0.7 km and 1.2 km away. The closer the supermarket, the less likely it is that individuals will cycle there as walking is more convenient. However, if the supermarket is too far individuals will be more likely to drive over cycle.

Table 9

Indicators of Spatial and Spatial-Economic Factors Affecting Cycling Levels (CBS, 2008, 2013)

Town	**Cycling Levels (%)**	**Population (n)**	**Population Density (residents/km^2)**	**Population Growth (percent increase)**	**Car ownership per household (n)**	**Average distance to a supermarket (km)**
Boxtel	39	30,241	468	3.5	0.6	0.9
Gorinchem	36	34,472	1,572	3.0	1	0.6
Hellevoetsluis	34	39,620	856	2.8	1.1	0.7
Houten	40	46,475	788	36.9	2.4	1.2
Leiderdorp	33	26,376	2,148	1.5	1.1	0.8
Soest	28	45,560	981	2.8	1.1	0.7
Wageningen	44	36,215	1,119	10.1	1.1	0.7
Weert	36	48,305	458	0.7	1.1	0.9
Correlation[3]		-0.12	-0.24	0.46	0.20	0.32

Following the descriptive statistical analysis a bivariate analysis was conducted. This analysis produced significant results for the factors that were predicted to have a strong relationship between the data set and cycling levels. A correlation analysis was conducted and is shown in the last row of Table 9.

When the average distance to a supermarket was compared to cycling levels the further the distance from a supermarket the higher the cycling levels, shown in Appendix A, figure A9. According to these results the cycling levels increase when the distance to the supermarket is further, this could be due to the increase in the need to cycle over walking to the grocery store for greater distances. The population density of towns analysis indicated that the greater the population density, the lower the cycling level. This result may be explained by the decreased need to travel far as amenities are nearby. Further data is shown in Appendix A. Using the population density variable is challenging as it does not incorporate the density of the built up

[3] Between variable in top row and cycling levels

area alone but the density for the entire municipality. It was predicted that areas with lower population densities would have lower cycling levels as the distances to amenities is further. This does not appear to be the case in this data set. Interestingly, the same two towns which were outliers in the distance from the supermarket are outliers in this subsection as well. The percent of population growth a town experiences will have impacts on cycling levels. With higher levels of population growth, cycling levels will also increase as shown in the town of Houten. Houten experienced significant population growth at 36.9% while is correlated with the second highest cycling levels across the towns. The number of cars per household does not have any significant correlation with cycling levels, as the linear trend line shows cycling levels increase with increased levels of car ownership. Thus, there is a relationship but it is not the relationship expected. The town of Houten is an outlier in this analysis with a significantly higher average number of cars per household. Reasons for this outlier may be related to income and/or demographic composition. Not including this outlier results in the remaining towns having almost the same average car ownership levels. Thus, as shown in the correlation analysis in Table 9 there is not a significant relationship between cycling levels and car ownership for the research towns.

4.2.4 Competing Modes of Transportation

The level of cycling in a town depends in part on the competing transport modes: walking, driving, and public transport. Walking is additionally more attractive if distances to destinations are short due to dispersion of services and efficient pedestrian routes.

The following section fully describes the indicators used to analyze the relationship between competing modes of transportation and cycling levels. Public transportation can influence cycling levels in towns in two ways, as discussed in chapter 2. First, public transport can be a competitor for cycling, in particular for distances above three kilometres (Handy et al., 2012). Second, the bicycle and public transport can be complementary means of transport, especially for longer distance trips (Martens, 2004; Martens 2007). Like public transport, the car is also a competitor, especially for longer distance trips. In contrast to public transport, the car is only an alternative for people who have a driving license and have access to a car.

In what follows, descriptive statistics are used to analyse the relationship between the selected towns followed by a discussion as to whether there is a relationship between competitiveness and cycling levels, while taking into account that cycling levels cannot be understood from one factor.

Table 10

Occurrences of cycling being faster than driving (Fietsersbond, 2009)

Town	**Cycling Levels (%)**	**Percent of occurrences of cycling being faster than driving**
Boxtel	39	63
Gorinchem	36	38
Hellevoetsluis	34	50
Houten	40	60
Leiderdorp	33	63
Soest	28	69
Wageningen	44	56
Weert	36	36
Correlation[4]		-0.18

Table 10 indicates the occurrences where cycling is faster than driving and descriptive statistics are used to analyse this data. The town where cycling was the most competitive with the car is Soest. In 69% of trips traveling by bicycle was faster than by car in Soest. These trips are determined by measuring the same movements door-to-door made by bicycle and by car. This method of measurement also contributes to the directness of infrastructure for cycling. When cycling routes are increasingly direct they are often faster than traveling by car. When the bicycle is faster than the car the likelihood of cycling is increased. This statistic does not account for exactly how much faster the bicycle or car was. In some cases the travel time difference was quite insignificant, for example, less than three minutes. However, in some cases this might make the bicycle not as attractive as the car to select individuals. Research from the Fietsersbond has determined that the competitiveness of the bicycle, compared to the car, is one of the most important factors in determining the difference in bicycle use between towns (Fietsersbond, 2009). The town with the least competitive rate is Weert at 36%. This is a significant difference

[4] Between variable in top row and cycling levels

and may account for lower cycling levels. The average occurrence of cycling being faster than driving difference between the eight towns is 54%.

Proximity to a train station was projected to have significant effects on cycling levels. The towns of Hellevoetsluis, Leiderdorp and Wageningen do not have train stations and experience a range of cycling levels. Wageningen has the highest cycling levels while Leiderdorp one of the lowest. Thus, no conclusions can be drawn on the relationship between cycling levels in proximity to train stations based on data from the eight selected cities.
The previous section has discussed the variable of the competitiveness of cycling compared to vehicles. The data was further analysed against the cycling levels in the research towns. By doing so it is expected that towns with highly competitive cycling rates compared to vehicles would have higher cycling levels. If it is faster to cycle than drive in these areas it would be expected more individuals would choose to cycle. The correlation analysis, shown in Table 10 indicates there is no significant correlation between the competitiveness with the car, measured as percent of occurrences of cycling being faster than driving and high cycling levels. Bivariate analysis was used to determine if there is a relationship between the two variables used, cycling levels and the level of competitiveness between the bicycle and the car. The dependent variable, cycling levels, was assessed against the available data from the Fietsersbond regarding competiveness with the car. The results of this analysis did not show any significant relationship between cycling levels and competing modes of transportation as was anticipated. It is somewhat surprising that there was not a significant relationship between the independent factor of competing modes of transportation and dependent factor of cycling level. In comparing these data sets there are many factors which are not taken into account. As has previously been discussed, cycling levels are influenced by a large number of factors and thus the inconclusive relationship between competitiveness with a car and cycling levels is not significant. Key findings are presented here:

- In the town of Soest the cycling level in 2009 was the lowest of all the towns in this research, at 28%, but had the highest percentage of occurrences when cycling was faster than vehicle where 69% of bicycle trips were faster than car trips.
- Similarly, looking at the percentage occurrences where cycling is faster than driving the town with the lowest cycling level, in the Fietsbalans report, has the highest percentage of occurrences where cycling is faster, Soest.

In conclusion, within competing modes of transportation the only data available was related to the competition between the bicycle and vehicles. The data does show there is certainly a competitive edge to cycling across the eight research towns. When compared against cycling levels there does not seem to be a strong correlation between the percent of occurrences where cycling is faster than the car and cycling levels in the towns. With more substantial data relating to other competing modes of transportation the relationship between all competing modes and cycling levels could be evaluated. In the theoretical framework significant factors under the heading competing modes of transportation include private transportation: parking costs, taxes on fuels, tolls, amount of use, and public transportation: availability, connections to large cities, cost, efficiency, park and ride availability. Unfortunately for many of these factors the data was not available for the selected small towns which results in an inconclusive exhibit of competing modes of transportation as a factor influencing cycling levels.

4.3 Regression Analysis

Each of the factors discussed in the above analysis have some significance in affecting cycling levels across small towns in the Netherlands. Correlation analysis provides significant insights into the relationship between the independent variables and dependent variable, cycling levels. Because of the correlation analysis the factors shown in Table 11 were determined to either be positively correlated to cycling levels, increasing cycling levels, or negatively correlated to cycling levels, causing cycling levels to decrease. For this research the degree of correlation was determined to be significant if it was above 0.45 or below -0.45. All other factors used in the research were determined, through correlation analysis, to have an insignificant relationship with cycling levels. However, cycling levels are not affected by one independent variable alone and are likely to be influenced by a number of variables interacting which also includes variables which are challenging to quantify and thus have not been included in the data analysis, such as cycling culture in the Netherlands.

The most significant factor positively affecting cycling levels was determined to be the percent of the town's population between the age of 10 and 25. This is in line with the expectations of the research. Earlier in the research Wageningen was identified as having the highest cycling levels; reasons for this correlate with the high number of students who live and study in Wageningen. Students and young people either cannot drive due to lack of having a driver's license or not being able to afford a vehicle or do not have a desire to drive as they can get around by bicycle.

The correlation between population growth and cycling levels is 0.46, while this is not as significant as the correlation between the percentages of town's population between the age of 10 and 25 and cycling levels it is considerably higher than any other variables used in this research. The relationship between the growth in a town and cycling levels may be explained by the increased number of people in the town which equates to more cyclists and thus higher cycling levels.

Average income had a high negative correlation with cycling levels at -0.62 meaning the higher people's average income is the lower cycling levels will be. Reasons for this are unknown. It is possible those with higher income may more often be able to afford a car, but this is not always the case. The factor of average income does not differ significantly between the towns that may also cause a discrepancy in the results.

The number of casualties per 100 million kilometres also had a negative correlation with cycling levels. This indicates the higher the number of casualties the lower cycling levels will be. This result is significant. With increased casualties in the town people may be apprehensive to cycle or it may mean the infrastructure is not safe. These conclusions cannot be drawn from the data analysis but are possible explanations. It is possible the opposite could also be the case, where the higher the cycling level is the higher the number of casualties will be due to a proportionally higher number of cyclists however, this research does not show this to be the case.

Traffic obstruction correlated against cycling levels results in a -0.57 correlation. The measurement of traffic obstruction is the probability that cyclists will encounter and come into conflict with other road users. This measurement should be minimal and thus beneficial to cycling and logically increases cycling levels as cyclists feel more comfortable cycling when there is minimal risk of encountering conflict with other cyclists, motorists or pedestrians.

Comparing noise pollution against cycling levels results in a correlation of -0.50. The assessment of the relationship between these two factors presents expected results. The louder the environment is for cyclists the less attractive it is thus it is expected that cycling levels would be lower in noisy areas.

Table 11

Independent Factors Which Have a Significant Correlation to Cycling Levels

Correlation Relationship	**Factors**	**Correlation**
Positive	Percent of the population between the age of 10 and 25 years old	0.81
	Population growth	0.46
Negative	Average income	-0.62
	Casualties	-0.57
	Traffic obstruction	-0.57
	Noise pollution	-0.50

The above discussion presented the most significant factors affecting cycling levels, according to a correlation analysis. The factors were outlined and how they affect cycling levels and whether the result was expected. Despite these results and what they may mean for factors influencing cycling level it is imperative to recognize that correlation does not equal causation.

While the data was not able to show statistically significant data results it is certain that each factor plays some sort of role in determining whether people will cycle or not. A regression analysis for variables which had a strong (higher than ±0.45) positive or negative correlation to cycling levels as shown in Table 11 can be found in Appendix C. A regression analysis was conducted with the six variables from Table 11. The results of this analysis give an R^2 statistic of 0.92; this indicates the dependent variable, cycling levels, can be explained by the independent variables from Table 11. However, significance F results in a value of 0.36. To be statistically significant significance F should be less than 0.05. P-values were also all over 0.05, which is not desirable. A regression line for the factors found in Table 11 is presented below.

Regression line:

$$\begin{aligned} Cycling\ levels = {} & 0.18 + 2.51 * (\text{Traffic obstruction}) + 0.15 * (\text{Noise pollution}) - 0.76 * (\text{Casualities}) \\ & - 0.44 * (\text{Average income}) + 195.71 * (\text{Percent of population between age 10 and 25}) \end{aligned}$$

In conclusion, the empirical analysis chapter was expected to show a significant correlation between the dependent variables and the independent variable, cycling levels. However, no statistically significant results were produced given that only eight observations were used. Factors which had the highest correlation coefficient are presented in Table 11.

A method of isolating infrastructure from influences on cycling levels was done using regression analysis; this did not produce statistically significant results (shown in Appendix C) and thus has not been extensively discussed. Despite this lack of conclusions from the data it is still accurate to determine, based on the research of a multitude of authors discussed in the literature review, the factors used in the research and others which were not found to have significant impacts on determining the cycling levels of towns across the Netherlands. Although significant results were not published here, further insight into cycling levels and influences in non-major Dutch towns has been discovered.

5 Conclusion and Discussion

The aim of this thesis was to determine if better bicycle infrastructure correlates with high cycling levels in selected small towns across the Netherlands. Based on the analysis a clear answer to the research question was not found. While the literature review, through the work of Rietveld and Daniel (2004) and Ververs and Ziegelaar (2006), did reveal there is a significant relationship between cycling levels and cycling infrastructure neither these authors nor this research has been able to determine the direction of the relationship between the two variables. As the analysis for this research, both bivariate and regression, did not produce statistically significant results the research question cannot be answered. Cycling levels are dependent on a significant number of factors, both by factors that can be controlled by policy and government, and those that cannot be influenced. This research extends the knowledge of factors influencing cycling levels and further underscores the complexity of the relationship between the dependent variable, cycling levels, and the various independent variables, factors affecting cycling levels.

In the introduction to this thesis four objectives were identified, these objectives have been achieved. A theoretical model of factors that affect cycling levels in small towns in the Netherlands was introduced. This model classified the factors that affect cycling levels into four categories: bikeability and infrastructure factors, characteristics of the population, spatial and spatial-economic factors and competing modes of transportation. Each of these categories was extensively examined with material from existing literature, research data and scientific analysis. A method of isolating infrastructure from influences on cycling levels was done using regression analysis; this did not produce statistically significant results (shown in Appendix C). Secondly, data collected of factors indicated in the theoretical framework and shown in Table 5 was used in the analysis of the results. This data was analysed through descriptive statistics, bivariate analysis and correlation analysis with the goal of determining factors which were statistically significant in affecting cycling levels. Through the correlation analysis six factors were determined to be statistically significant. These factors were then used in a regression analysis, as shown in Appendix C and discussed in chapter 4.

The significance of conducting this research on small towns was to aid in eliminating the gap in research on cycling in small towns. While the significance of the town being small does not have an impact on this study, as small towns were not compared to larger ones, it is nonetheless insightful to present a comprehensive understanding of factors affecting cycling levels across the Netherlands. Other cities and towns in the Netherlands with populations over 50,000 are likely to be affected by similar, if not the same, set of factors. However, in small towns there is generally less traffic affecting the use of infrastructure for both vehicles and bicycles. Outside of the Netherlands factors may change significantly and could be affected by major elevation changes, high pollution levels and extreme variance in weather conditions. In conclusion, the data did not provide conclusive information regarding the effects of bicycle infrastructure on cycling levels that were specific to small towns. This was not a research question and thus should not be taken into consideration towards inconclusive results of the thesis. Small towns provide a significant understanding of cycling on smaller scale with less traffic and easier and shorter distances to travel. They also can provide significant understanding of cycling to cities around the world that may not be as large as Amsterdam and want to be able to understand influences of cycling on smaller cities. Lastly, the final objective of the thesis was to contribute to the body of academic literature focused on factors which affect cycling usage, specifically focused on the effects of infrastructure by analyzing existing data on bikeability in a number of small towns in the Netherlands. The overall body of the thesis contributes to an understanding of the factors which affect cycling levels. While no significant results were presented through bivariate analysis or regression analysis the literature review does offer an overview of key factors affecting cycling levels. It is known that there is a clear correlation between developing and improving cycling infrastructure found in manmade surroundings, such as cycling networks and routes and increased cycling levels Each of the four objectives outlined in the introduction of the thesis have been acknowledged and explained to the best of the author’s ability. At times the objectives were not met with the projected responses nonetheless; the research has significant findings for factors affecting cycling levels.

5.1 Limitations

The findings in this thesis are subject to a number of limitations. The study was firstly limited by the lack of data available. Useful data was only found for eight towns which fit the criteria for the research towns. The criteria consisted of a population of less than 50,000 residents where *Fietsbalans* research had been conducted and reports written. Eight towns is not a statistically significant sample size. Secondly, data was not found to include all factors which were originally included in the theoretical framework. Other data, which came from CBS Statline, was limited in that most available statistics were for the entire province, not specific for towns. Additionally all the data, research reports and available statistics were in Dutch and the researcher has a low comprehension of the language. This presented an additional challenge in comprehending the data. The main weakness of the data was not being able to access the original and raw data used in the *Fietsbalans* reports for each town due to the loss of data at the Fietsersbond. Had this been available the sample size would have been significantly larger and the data could have been manipulated more extensively. This could have resulted in more significant research results. For specific variables found in the theoretical framework some of the data available was not precisely what was needed for the research. An example of this being that the available data on population density did not incorporate the density of the built up area alone but the density for the entire municipality which can skew the results especially in areas that are less built up and more rural. Additionally, a lack of data for variables addressed in the theoretical framework and literature review as key factors affecting cycling levels was limited. With more substantial data relating to other competing modes of transportation the relationship between all competing modes and cycling levels could be evaluated. In the theoretical framework significant factors under the heading competing modes of transportation include, private transportation: parking costs, taxes on fuels, tolls, amount of use, and public transportation: availability, connections to large cities, cost, efficiency, park and ride availability. Unfortunately for many of these factors the data was not available for the selected small towns which results in an inconclusive exhibit of competing modes of transportation as a factor influencing cycling levels.

Each of the eight small towns has been analysed only with data provided by the Fietsersbond or by CBS Statline. Given more resources this research could provide a more in depth examination of factors affecting cycling levels, specifically in small towns. The research question: *Does better bicycle infrastructure lead to higher cycling levels in small towns in the Netherlands*? results in an inconclusive answer. Through the literature review we know that infrastructure has a significant impact on cycling levels but it was not possible to determine exactly what the extent of this relationship is.

5.2 Reflection and Future Research

The research presented in this thesis has changed significantly since the conception of this thesis. The biggest weakness of this thesis was related to the collection of secondary data. Originally, I had hoped and planned on the Fietsersbond being able to provide me with raw data from all the small towns where the *Fietsbalans* research was conducted. Unfortunately this data was completely lost during the Fietsersbond's office relocation and after months of waiting for the data to be recovered I was forced to change direction. This loss of this data negatively impacted the quality of my work significantly as I was only able to find the *Fietsbalans* reports for eight towns. The data available in these reports was quite limited and could not be extensively analysed as previously planned. This research does have significant strengths through providing a different and new perspective on cycling in small towns, which have not previously been studied. The literature review has also reviewed a large number of academic sources that discuss cycling levels and how they are impacted. The results of this thesis did not produce statistically significant results regarding the correlation between cycling infrastructure and cycling levels in small Dutch towns; this was a disappointing conclusion. This thesis would have been more significant to cycling research if it were able to produce significant results which were able to determine the relationship between cycling levels and cycling infrastructure. My personal reflections of this thesis are summarized in my amazement in the existing culture and infrastructure of cycling in the Netherlands. Through this research my understanding of factors which influence cycling levels has been fully established and I hope to bring this understanding and knowledge to cycling in North America.

Opportunities for future research should include data from small towns within the Netherlands. Significant research is conducted in Amsterdam, which is indisputably important. However, smaller towns provide insights into factors affecting cycling levels that are not in major cities. The research could include the levels and motives of cycling where there is little access to public transportation. Further research might explore the data from the Fietsbalans reports more extensively, if it was available for research purposes. Further research may also explore, in greater detail, all the factors that affect cycling levels. More scientific research should be conducted to better understand the culture of cycling in the Netherlands. Many factors affecting cycling levels are able to be understood and quantified, as have been identified in this thesis. However, health and activities of persons were unable to be quantified. Developing a method to quantify these factors could provide further insights into the motives of cyclists. Developing a method to quantify significant benefits of cycling including health and economic benefits would also be beneficial to cycling research. Recommendations for practice include further investigation into cycling in small towns worldwide examining independent variables. Further longitudinal research seeking to determine the causal links between bike networks and cycling levels would be useful in determining the direction of causality. Research on smaller towns may help cities around the world develop cycling infrastructure and policy as in the Netherlands. The theoretical framework produced in this thesis could be utilised in further research, given more significant data or could be used by the research towns to develop further cycling policies based on the factors which were determined to be strongly correlated to cycling levels. Further research into the effect that culture has on cycling levels could also help understand this culture and provide guidance to countries seeking to increase their cycling levels.

Bibliography

Babbie, E. R. (2010). *The practice of social research*. 12th ed. Belmont, CA: Wadsworth Cengage.

Bernard, H. R. (2012). *Social research methods: Qualitative and quantitative approaches.* London: Sage.

Borgman, F. (2003). The cycle balance: Benchmarking local cycling conditions. In: Tolley, R. (ed.) *Sustaining Sustainable Transport: Planning for Walking and Cycling Urban Environments.* Cambridge, UK: Woodhead Publishing Limited, 511-25.

Bouwman, M.E., Voogd, H., (2005). Mobility and the urban-rural continuum. *GBER, 4* (3) 60-69.

Buehler, R., & Pucher, J. (2012). Cycling to work in 90 large American cities: New evidence on the role of bike paths and lanes. *Transportation, 39*(2), 409 – 432.

Buehler, R., & Dill, J. (2016). Bikeway networks: A review of effects on cycling. *Transport Reviews, 36* (1), 9-27.

Bryman, A. (2012). *Social research methods*. 4th ed. London: Oxford University Press.

CBS. (2008). Population dynamics: population on 1 January. CBS Statline. Retrieved 24 May 2016 from http://statline.cbs.nl/Statweb/

CBS. (2013).Key figures for neighbourhoods. CBS Statline. Retrieved 24 July 2016 from http://statline.cbs.nl/Statweb/

CBS. (2014). Mode share of trips per person per day. Retrieved 24 July 2016 from http://statline.cbs.nl/Statweb/

CBS. (2015).Cycling levels. CBS Statline. Retrieved 24 October 2016 from http://statline.cbs.nl/Statweb/

Chatterjee, K., Sherwin, H., & Jain, J. (2013). Triggers for changes in cycling: The role of life events and modifications to the external environment. *Journal of Transport Geography, 30*,183–193.

CROW. (2016). Design manual for bicycle traffic. 2016 edition. National information and technology platform for transportation, infrastructure and public space. Ede, the Netherlands: CROW

Cyclist Touring Club. (2013).CTC welcomes Government progress on cycling but far more is needed. Retrieved March 13, 2016, from http://www.ctc.org.uk/news/ctc-welcomes-government-progress-on-cycling-but-far-more-still-needed

Danish Ministry of Transport. (2007). *Danish national travel surveys.* Copenhagen: Danish Institute of Transport Research.

Department for Transport. (2006). *National travel survey 2005.* London: Department for Transport. Retrieved July 3, 2016 from http://www.dft.gov.uk/

Department for Transport. (2007). *National travel statistics.* London: Department for Transport. Retrieved July 3, 2016 from http://www.dft.gov.uk/

Dill, J., & Carr, T. (2003). Bicycle commuting and facilities in major US cities: if you build them, commuters will use them. *Transportation Research Record: Journal of the Transportation Research Board, (1828),* 116-123.

Dufour, D. (2010). *Promoting cycling for everyone as a daily transport mode (PRESTO); Cycling policy guide, cycling infrastructure.* Amsterdam: Intelligent Energy Europe.

Elvik, R. (2009). The non-linearity of risk and the promotion of environmentally sustainable transport. *Accid Anal Prev, 41,* 849–855.

Fajans, J., Curry, M., (2001). Why bicyclists hate stop signs. *Access, 9* (18), 28–31.

Fietsberaad. (2012). Holland is still the foremost cycling country. Retrieved July 24 2016 from http://www.fietsberaad.nl/index.cfm?lang=en&section=nieuws&mode=newsArticle&repository=Holland+is+still+the+foremost+cycling+country

Fietsersbond. (2009). Fietsbalans Report Boxtel. Part 1 Analysis and Advice. Utrecht: Fietsersbond

Fietsersbond. (2009B). Fietsbalans 2 Research Report, Chapter 3: From measurement to assessment. Utrecht: Fietsersbond

Fietsersbond. (2008). Fietsstad [Cycling City] 2008. Retried January 13, 2017 from http://www.fietsstad2008.nl/houten_thema_verkeersveilighei.php

Fietsersbond. (2016). Wat doet de Fietsersbond? [What does the Fietsersbond do?]. Retrieved March 18, 2016, from http://www.fietsersbond.nl/de-fietsersbond/wat-we-doen#.VvVcpRFVhBd

Fishman, E., & Cherry, C. (2015). E-bikes in the Mainstream: Reviewing a Decade of Research. *Transport Reviews, 36(*1), 72-91.

Fishman, E., Schepers, P., Kamphuis, C.B.M. (2015). Dutch cycling: Quantifying the health and related economic benefits, *Am J Public Health, 105*(8), 13-15.

Fishman, E. (2016) Cycling as transport, *Transport Reviews, 36*, (1), 1-8,

Flash Eurobarometer. (2011). Future of transport: Analytical report. *PLoS One, 312,* 1-67.

Forsyth, A & Krizek, K. (2011). Urban design: Is there a distinctive view from the bicycle? *Journal of Urban Design, 16*, 531-549.

Forsyth, A., & Krizek, K. (2010). Promoting walking and bicycling: Assessing the evidence to assist planners. *Built Environment, 36*(4), 429 – 446.

Gatersleben, B., & Appleton, K. M. (2007). Contemplating cycling to work: attitudes and perceptions in different stages of change. *Transportation Research Part A*, 41(4), 302–312.

German Federal Ministry of Transport. (2003). *German Federal Travel Survey 2002 (MiD).* Berlin: German Federal Ministry of Transport.

Graham-Rowe, E., Skippon, S., Gardner, B., & Abraham, C. (2011). Can we reduce car use and, if so, how? A review of available evidence. *Transportation Research Part A, 45*, 401 – 418.

Givoni, M., & Rietveld, P. (2007). The access journey to the railway station and its role in passengers' satisfaction with rail travel. *Transport Policy, 14*(5), 357-365.

Handy, S.L., Heinen, E. & Krizek, K.J. (2012). Cycling in Small Cities, in J. Pucher and R. Buehler, eds., *City Cycling.* Cambridge, MA: MIT Press, pp. 257-286.

Handy, S., van Wee, B., & Kroesen, M. (2014). Promoting cycling for transport: Research needs and challenges. *Transport Reviews: A Transnational Transdisciplinary Journal, 34*(1), 4–24.

Harms, L., Bertolini, L., & Te Brömmelstroet, M. (2014). Spatial and social variations in cycling patterns in a mature cycling country; exploring differences and trends. *Journal of Transport & Health, 1*(4), 232–242.

Harms, L., Bertolini, L., & Te Brömmelstroet, M. (2016). Performance of municipal cycling policies in medium-sized cities in the Netherlands since 2000, *Transport Reviews, 36*(1), 134-162.

Heinen, E., van Wee, B., Maat, K. (2010). Commuting by bicycle: An overview of the literature. *Transport Rev.*, *30*(1), 59-96.

Herlihy, D. V. (2004). *Bicycle: The history*. London: Yale University Press.

Hull, A., O'Holleran, C. (2014). Bicycle infrastructure: can good design encourage cycling? *Urban, Planning and Transport Research, 2* (1), 369-406.

Jacobsen P.L. (2003). Safety in numbers: More walkers and bicyclists, safer walking and bicycling. *Inj Prev, 9*, 205–9.

Jaffe, E. (2015). A case study in bike-friendly suburban planning. City Lab. Retrieved January 13, 2017 from www.citylab.com/cityfixer/2015/06/a-case-study-in-bike-friendly-suburban-planning/396107/

Krizek, K. J., & Johnson, P. J. (2006). Proximity to trails and retail: Effects on urban cycling and walking. *Journal of American Planning Association, 71*, 33–42.

Krizek, K., Handy, S., & Forsyth, A. (2009). Explaining changes in walking and bicycling behavior: Challenges for transportation research. *Environment and Planning B: Planning and Design, 36*(4), 725 – 740.

Kuipers, G. (2010). *De Fiets van Hare Majesteit* [Her Majesty's Bicycle]. Retrieved October 15, 2016 from www.eur.nl/nieuws/detail/article/19958/

La Paix Puello, L. C., & Geurs, K. T. (2015). Modelling observed and unobserved factors in cycling to railway stations: application to transit-oriented-developments in the Netherlands. *European Journal of Transport and Infrastructure Research, 15*(1), 27-50.

Ligtermoet, D. (2014). Overheidsbestedingen aan fietsverkeer [Governmental spending on bicycle traffic]. Gouda: Ligtermoet & Partners.

Martens, K. (2004). The bicycle as a feedering mode: experiences from three European countries. *Transportation Research Part D: Transport and Environment 9* (4), 281-294.

Martens, K. (2007). Promoting bike-and-ride: the Dutch experience. *Transportation Research Part A: Policy and Practice 41*(4), 326-338.

Meyer, M., & Miller, E. (2001). *Urban transportation planning: A decision-oriented approach* (2nd ed.). New York: McGraw-Hill.

Ministry of Transport, Public Works and Water Management & Fietsberaad. (2009). *Cycling in the Netherlands.* The Hague, the Netherlands: Ministry of Transport, Public Works and Water Management.

Ministry of Transport, Public Works and Water Management. (2010). *Public transport in the Netherlands.* The Hague, the Netherlands: Ministry of Transport, Public Works and Water Management.

MON. (2007). *Mobiliteitsonderzoek Nederland 2007 [*Mobility Research Netherlands].Den Haag: Ministry of Infrastructure and Environment

Muijs, D. (2010). *Doing quantitative research in education with SPSS*. 2nd edition. London: SAGE Publications.

Municipality of Boxtel. (2017). Fietsen in Boxtel. Retrieved February 23, 2017, from https://www.boxtel.nl/leven-en-wonen/verkeer-vervoer/fietsen.html

Municipality of Boxtel. (2009). Fietsvisie. Retrieved November 10, 2016, from https://www.boxtel.nl/zoeken.html?q=fietsvisie&id=38

Municipality of Gorinchem. (2013). Bicycle Gorinchem 2013-1065. Retrieved January 13, 2017 from https://www.gorinchem.nl/bestuur-organisatie/raadsbesluiten_41135/item/2013-1065-fietsplan-gorinchem-beleidsdeel-en-uitvoeringsdeel_26745.html

Municipality of Hellevoetsluis. (2017). Inhabitants. Retrieved January 12, 2017 from https://www.hellevoetsluis.nl/Inwoners

Municipality of Leiderdorp. (2017). Inwoners [Inhabitants]. Retrieved January 12, 2017 from https://www.leiderdorp.nl/

Municipality of Soest. (2017). Wonen & Leven [Residents]. Retrieved January 12, 2017 from https://www.soest.nl/wonen-leven/

Municipality of Wageningen. (2017). Inwoners [Inhabitants]. Retrieved January 12, 2017 from http://www.wageningen.nl/

Municipality of Weert. (2017). Wonen & Leven [Residents]. Retrieved January 12, 2017 from http://www.weert.nl/

Nagele, R.C., Wilbers, P.T. & De Bruin, R.A. (1992). Integratie Fiets—Openbaar Vervoer. [Integration of the Bicycle-Public Transport].Traffic Test, Veenendaal in Martens, K. (2004). The bicycle as a feedering mode: experiences from three European countries. *Transportation Research Part D 9*, 281-294.

Nelson, A.C., & Allen, D. (1997). If you build them, commuters will use them: Association between bicycle facilities and bicycle commuting. *Transportation Research Record, 1578*, 79-83.

Netherlands Ministry of Transport. (2007). *Passenger Kilometres of Cycling and Fatality Rates*. Rotterdam: Ministry of Transport, Public Works, and Water Management.

Ogilvie, D., Bull, F., Powell, J., Cooper, A., Brand, C., Mutrie, N., Preston, J., & Rutter, H. (2011). An applied ecological framework for evaluating infrastructure to promote walking and cycling: The iConnect study. *American Journal of Public Health, 101,* 473–481.

Oijen, J., van & Pelzer, P. & Graumans, E. (2011). Fietscultuur behouden? Zet in op marketing en communicatie! [Keep cycling culture? Focus on marketing and communication!] Retrieved June 2 2016 from www.verkeerskunde.nl/Uploads/2011/10/Bijdrage53.pdf

Oja, P., Vuori, I. & Paronen, O., (1998). Daily walking and cycling to work: their utility as health-enhancing physical activity. *Patient Education and Counseling, 33*, 87–94.

Oldenziel, R., & Albert de la Bruhèze, A. (2011). Contested spaces: Bicycle lanes in urban Europe, 1900–1995. *Transfers, 1*(2), 29-49.

Parkin, J., Ryley, T., & Jones, T. (2007). Barriers to cycling: An exploration of quantitative analyses. In D. Horton, P. Rosen, & P. Cox (Eds.), *Cycling and society* (pp. 67–82). Aldershot: Ashgate.

Pedal on parliament. (2014).Why £10 per head is not enough. Retrieved March 13, 2016, from http://pedalonparliament.org/why-10-per-head-is-not-enough/

Peters, P. F. (2006). *Time, innovation and mobilities: Travel in technological cultures*. London: Rutledge.

Pucher, J., & Buehler, R. (2007). At the frontiers of cycling: Policy innovations in the Netherlands, Denmark, and Germany. *World Transport Policy and Practice*, *13*(3), 8-57.

Pucher, J., & Buehler, R. (2008a). Cycling for everyone: Lessons from Europe. Transportation Research Record: *Journal of the Transportation Research Board, (2074*), 58-65.

Pucher, J., & Buehler, R. (2008b). Making cycling irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews, 28* (4), 496-528.

Pucher, J., & Dijkstra, L. (2003). Promoting safe walking and cycling to improve public health: Lessons from the Netherlands and Germany. *American Journal of Public Health, 93*(9), 1509-1516.

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine, 50,* 106-125.

Rietveld, P., & Daniel, V. (2004). Determinants of bicycle use: Do municipal policies matter? *Transportation Research A,* 38, 531–550.

Saunders, M.N.K., Lewis, P., & Thornhill, A. (2009). *Research methods for business students.* Essex: Pearson Education Limited.

Scheltema, E. B. (2012). ReCYCLE City: Strengthening the bikeability from home to the Dutch railway station (Doctoral dissertation, TU Delft, Delft University of Technology).

Schmidt, S., Buehler, R., (2007). The planning process in the US and Germany: A comparative analysis. Int. *Plan. Stud. 12*, 55–75.

Silverman, D. (Ed.) (2016). *Qualitative research.* London: Sage.

Statistics Netherlands. (2007). *Transportation Statistics*. Amsterdam: Statistics Netherlands.

Stoffers, M. (2012). Cycling as heritage: Representing the history of cycling in the Netherlands. *The Journal of Transport History, 33*(1), 92-114.

SWOV. Institute for Road Safety Research [Stichting Wetenschappelijk Onderzoek Verkeersveiligheid]. (2004). *Fact sheet for bicycle facilities on roadways and intersections of distributor roads.* Den Haag: SWOV

U.S. Department of Transportation. (2003). National household travel survey, 2001. Washington, DC: Federal Highway Administration.

van Aalst, J. (2014). Topographic maps. Open Topo. https://commons.wikimedia.org/wiki/File%3ABoxtel-plaats-OpenTopo.jpg

van den Boomen, T. & Venhoeven, T. (2012). De mobiele stad - Over de wisselwerking van stad, spoor en snelweg [The mobile city- about the interaction of city, rail and highways]. NAi Publishers: Rotterdam.

van den Bulcke, G., Dujardin, C., Thomas, I., Geus, B. D., Degraeuwe, B., Meeusen, R., & Panis, L. I. (2011). Cycle commuting in Belgium: Spatial determinants and ‘re-cycling’ strategies. *Transportation research part A: policy and practice, 45*(2), 118-137.

van der Kloof, A. (2013). Lessons learned through training immigrant women in the Netherlands to cycle. In Cox, P. (ed.) (2015). *Cycling Cultures.* Chester: University of Chester Press.

van Goeverden, K., Godefrooij, T. (2011). The Dutch reference study: Cases of interventions in bicycle infrastructure reviewed in the framework of Bikeability. Delft: University of Technology, Department of Transport & Planning.

van Goeverden, K., Nielsen, T. S., Harder, H., & van Nes, R. (2015). Interventions in bicycle infrastructure lessons from Dutch and Danish cases. *Transportation Research Procedia, 10*, 403-412.

Venhoeven, T. (2010). *Duurzame Stad 2040; Vijf ontwerpen, vijf gesprekken* [Sustainable City 2040: Five Designs, Five Discussions]. The Hague: Planning agency for the living environment.

Vernez-Moudon, A., Lee, C., & Cheadle, A. (2005). Cycling and the built environment, a US perspective. *Transportation Research Part D: Transport and Environment, 10*, 245 – 261.

Ververs, R., Ziegelaar, A. (2006). Explanatory model for bicycle use in municipalities. Leiden: Institute for Policy Research.

Welleman, T. (1999). *The Dutch Bicycle Master Plan: description and evaluation in a historical context*. Amsterdam: Min. of Transport, Public Works and Water Management.

Winters, M., Teschke, K., Davidson, G., & Kao, D. (2011). Motivators and deterrents of bicycling: Comparing influences on decisions to ride. *Transportation, 38*(1), 153 – 168.

Yang, L., Sahlqvist, S., McMinn, A., Griffin, S., & Ogilvie, D. (2010). Interventions to promote cycling: Systematic review. *British Medical Journal*, *341*(7778), 870.

Appendix A

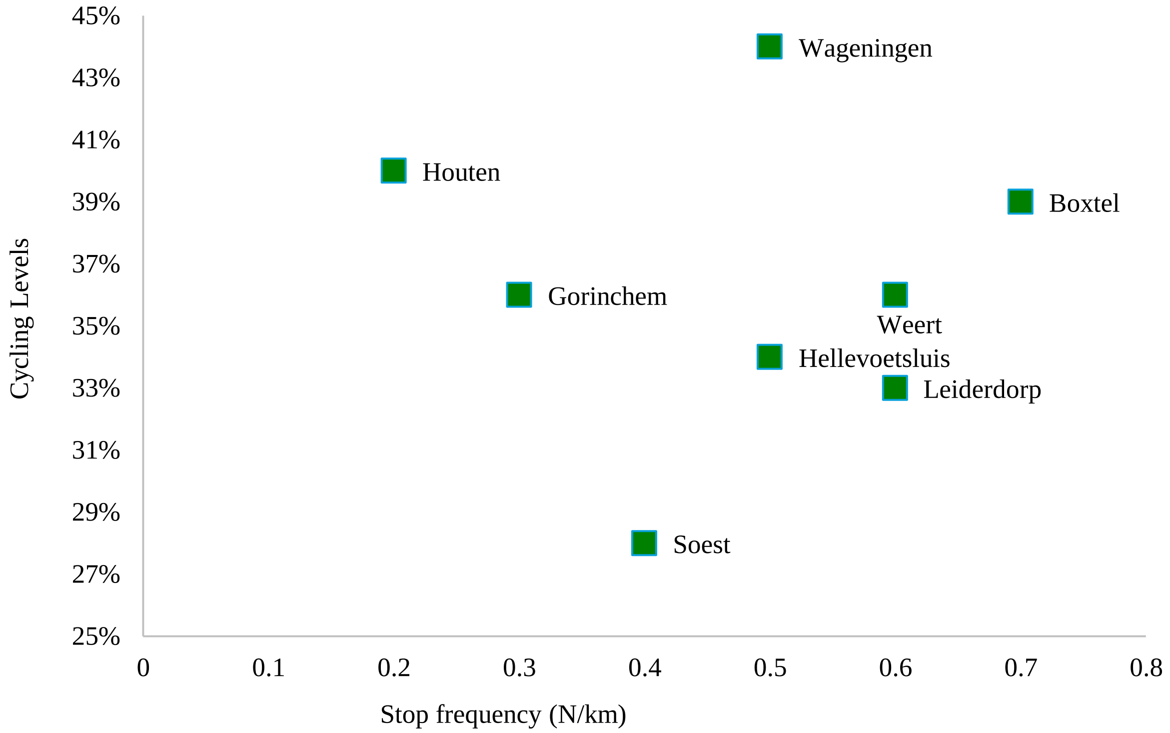

Figure A 1. Stop frequency compared to cycling levels (Fietsersbond, 2009; Statline, 2009).

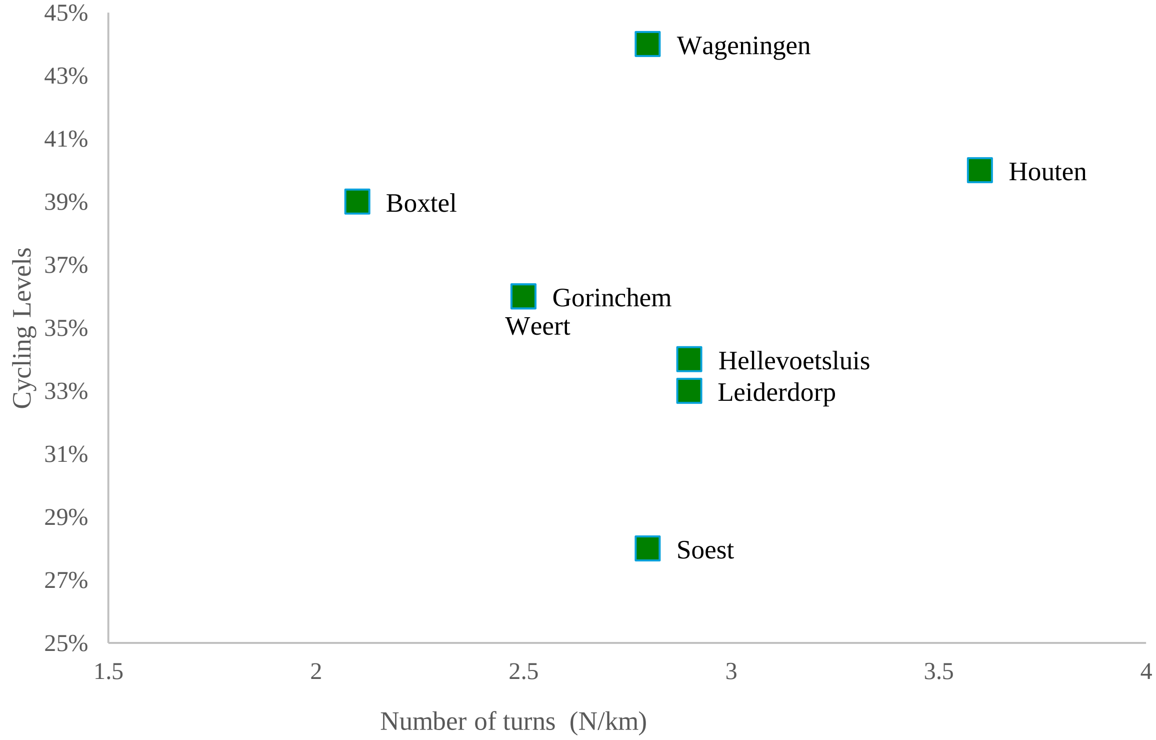

Figure A 2. Number of turns for cyclists in a kilometre compared to cycling levels (Fietsersbond, 2009; Statline 2009)

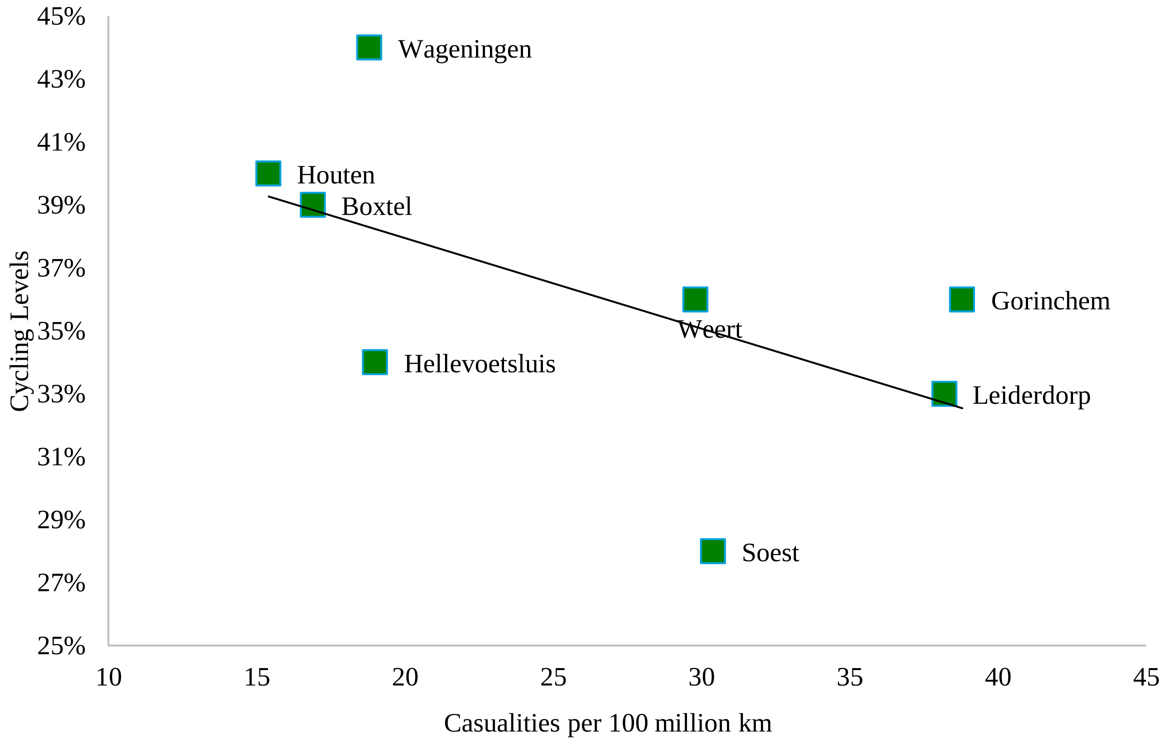

Figure A 3. Casualties per 100 million kilometres compared to cycling levels (Fietsersbond, 2009; Statline 2009)

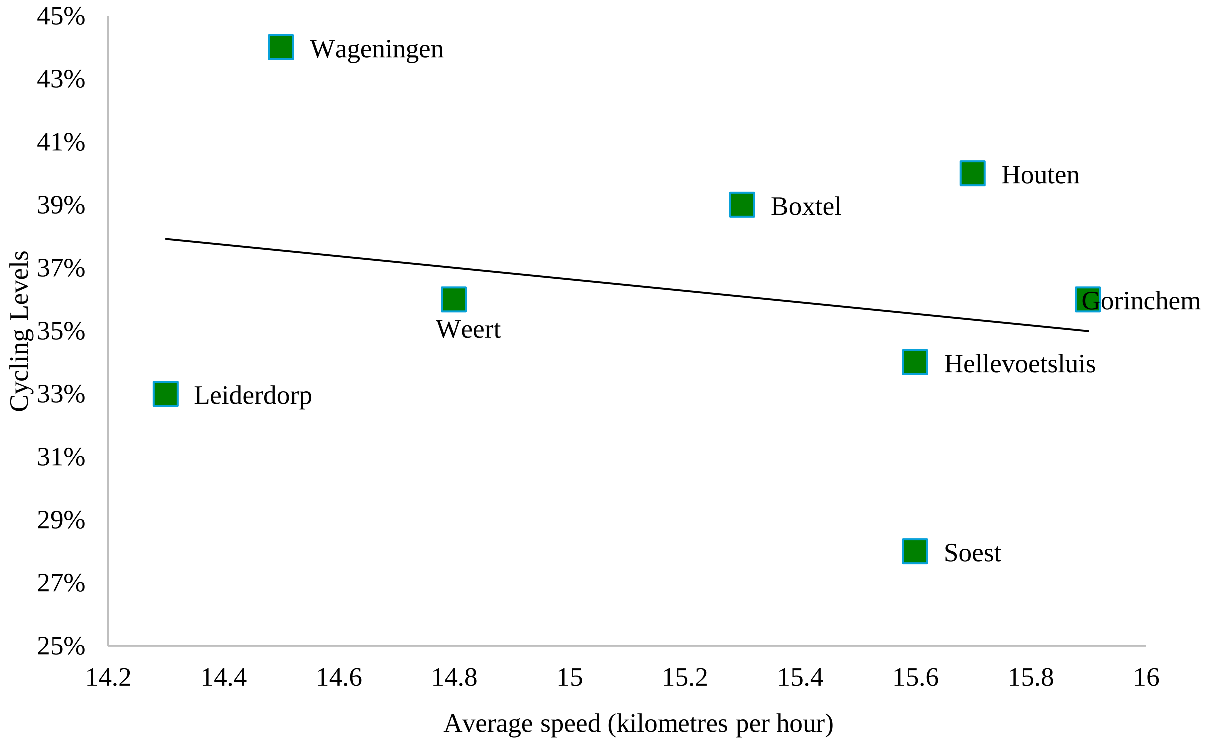

Figure A 4. Average speed of cyclists compared to cycling levels (Fietsersbond, 2009; Statline 2009)

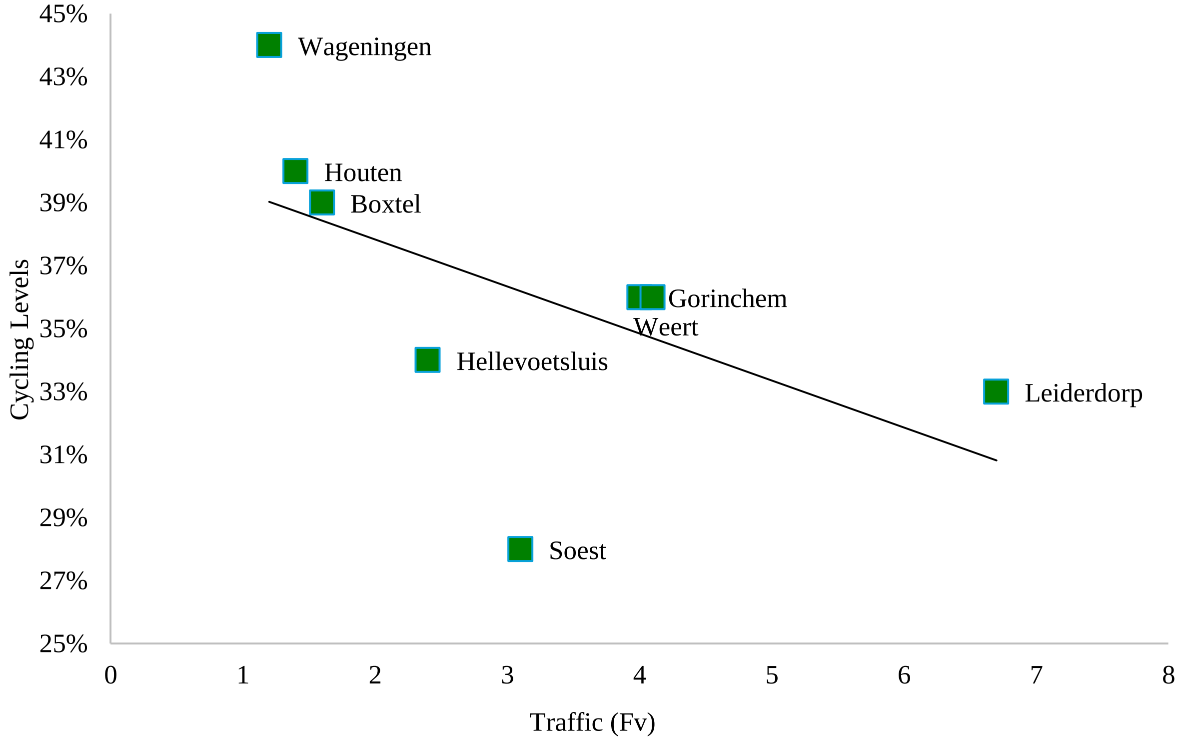

Figure A 5. Traffic obstruction (Fv) compared to cycling levels (Fietsersbond, 2009; Statline 2009)

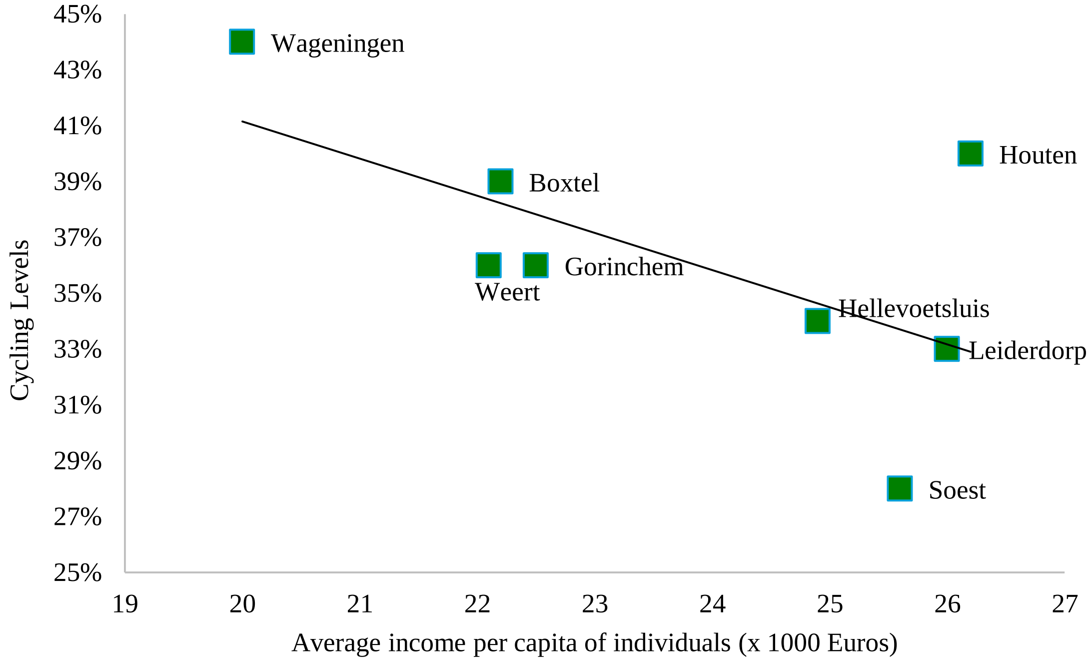

Figure A 6. Average income per capita of individuals compared to cycling levels (Statline, 2008)

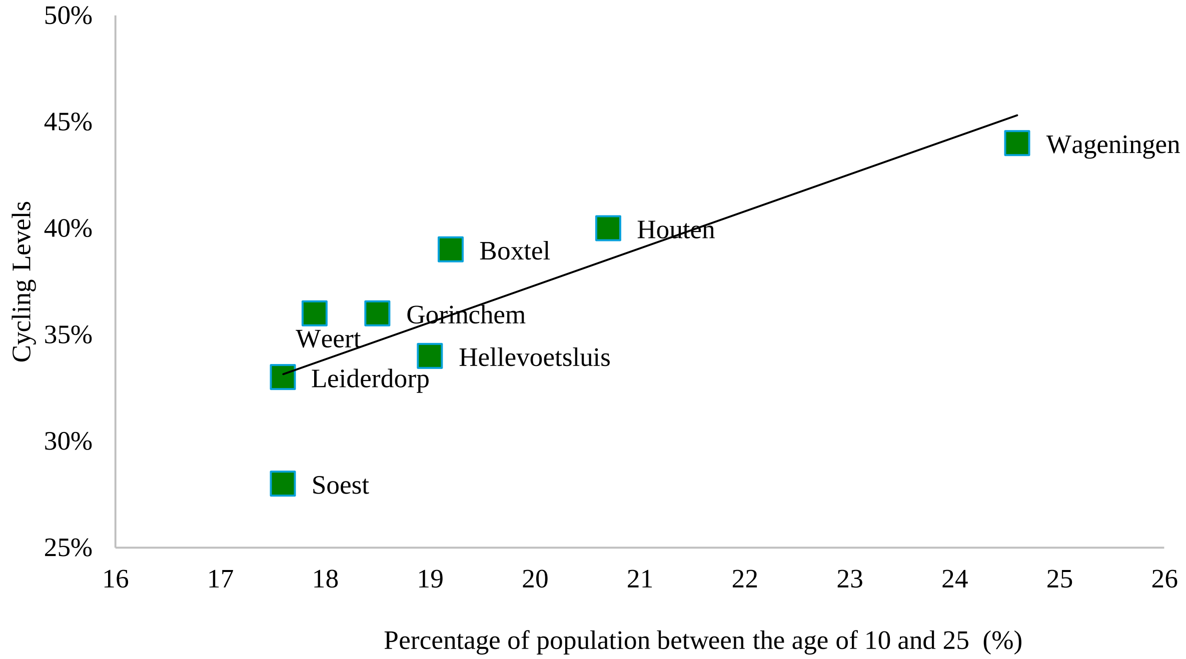

Figure A 7. Population between age 10 and 25 years of age compared to cycling levels (Statline, 2008)

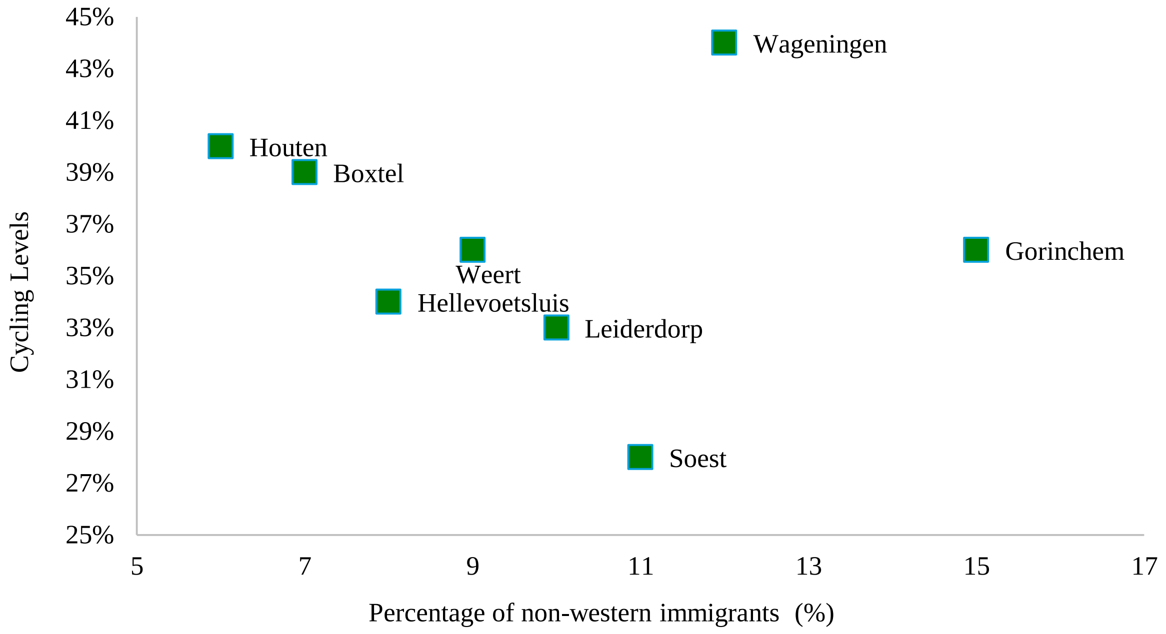

Figure A 8. Percentage of non-western immigrants compared to cycling levels (Statline, 2008)

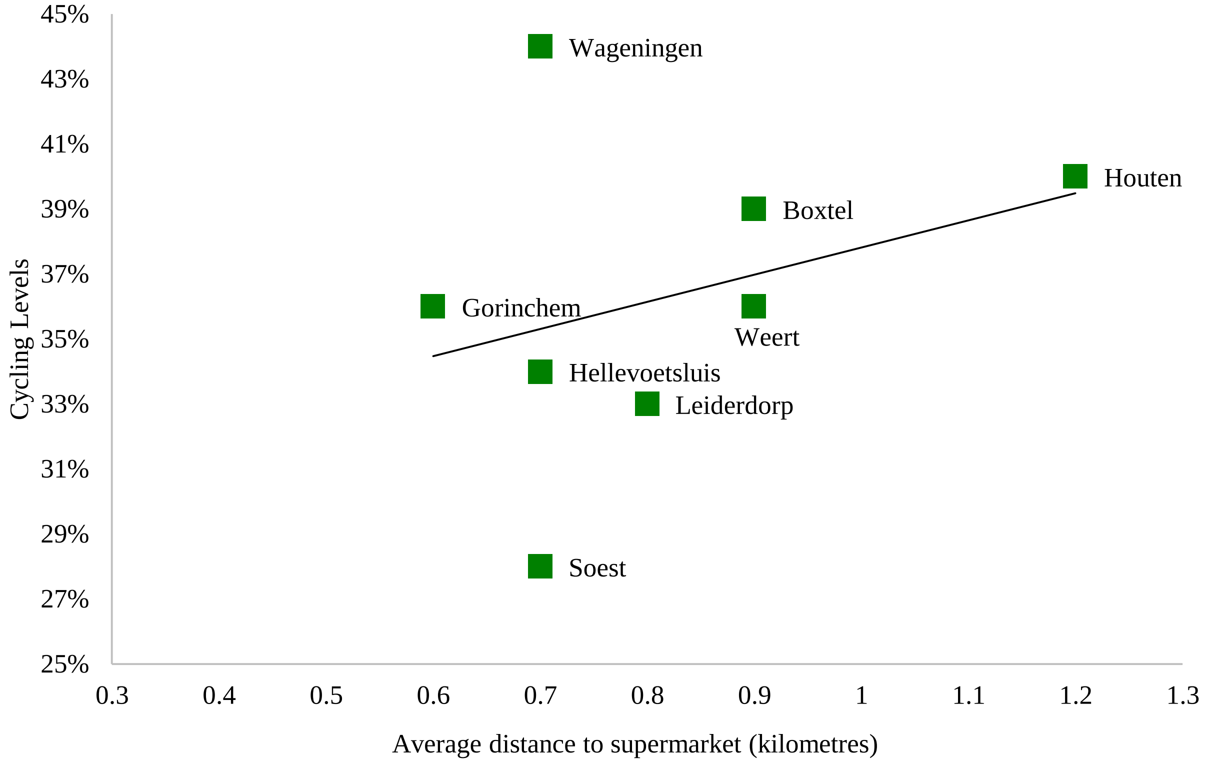

Figure A 9. Average distance to a supermarket compared to cycling levels (Statline, 2009, 2013)

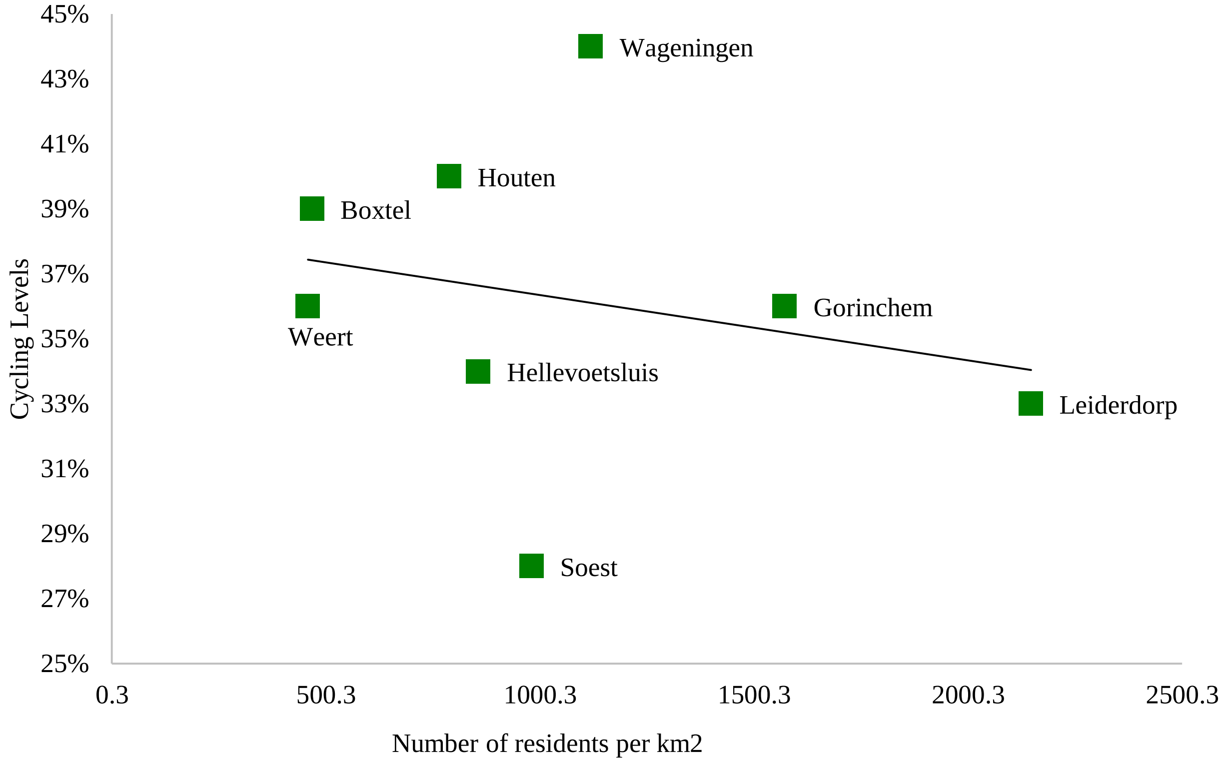

Figure A 10. Population density compared to cycling levels (Statline 2008, 2009)

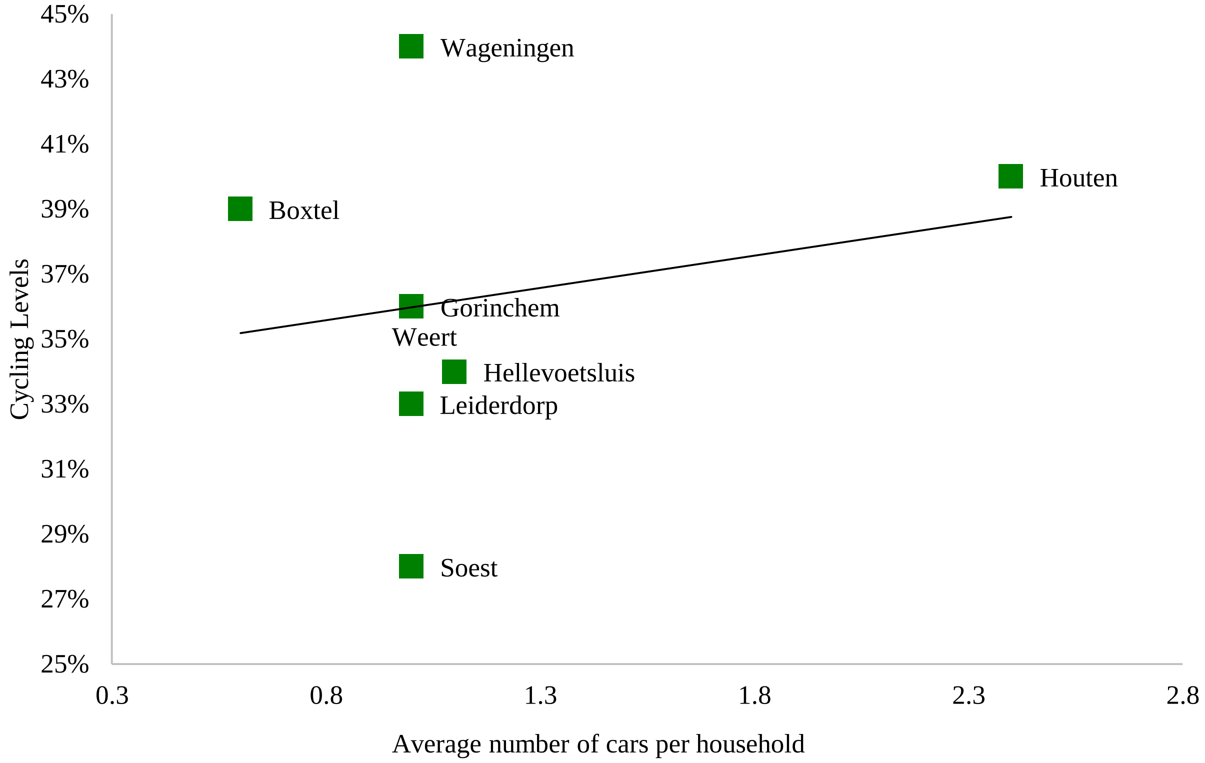

Figure A 11. Average number of cars per household compared to cycling levels (Statline, 2009, 2013)

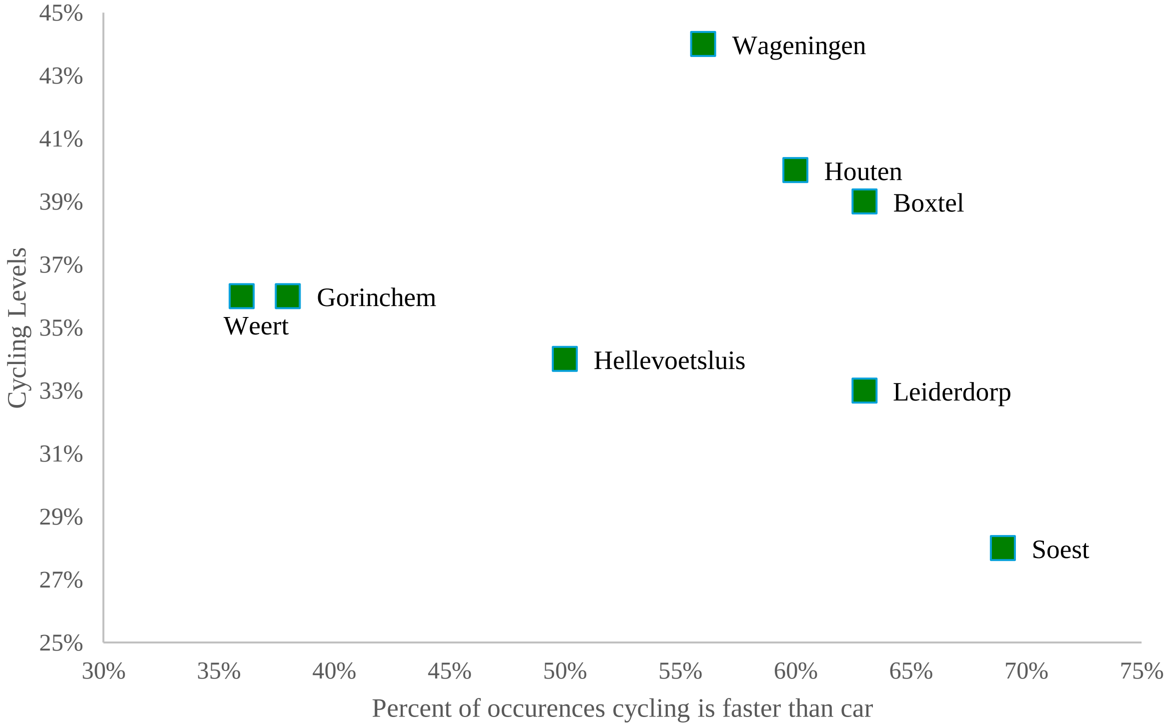

Figure A 12. Occurrence of cycling being faster than vehicles compared to cycling levels (Fietsersbond, 2009)

Appendix B

Table B 1

Data from Boxtel

Factor	**Measure**
Cycling Level (%)	39
Stop Frequency (N/km)	0.7
Slow cycling and walking (% of time)	14
Traffic obstruction (Fv)	1.6
Infrastructure barrier (Fi)	4.3
No priority rights (N/km)	3.7
Turns (N/km)	2.1
Vibrations (ft) of pavement	169
Noise (pollution) (Fg)	133
Casualties per 100 million km (N)	16.9
Detour Factor (ratio)	1.34
Delay (sec/km)	12
Average Speed (km/hr)	15.3
Average income (x1000 Euros)	22.2
Gender- percentage of females	50.4
Percentage of non-western immigrants	7
Percentage of population over 65	14.3
Population (N)	30,241
Population Density (residents/km^2)	468
Population Growth (% increase from 2000-2009)	3.5
Population Growth (% increase from 2009-2015)	0.3
Car ownership per household (N)	0.6
Average distance to supermarket (km)	0.9
Degree of Urbanization	3
Percent of occurrences of cycling being faster than driving	63
Percent of the population age 10-25	19.2

Table B 2

Data from Gorinchem

Factor	**Measure**
Cycling Level (%)	36
Stop Frequency (N/km)	0.3
Slow cycling and walking (% of time)	14
Traffic obstruction (Fv)	4
Infrastructure barrier (Fi)	1.6
No priority rights (N/km)	4.2
Turns (N/km)	2.5
Vibrations (ft) of pavement	194
Noise (pollution) (Fg)	186
Casualties per 100 million km (N)	38.8
Detour Factor (ratio)	1.51
Delay (sec/km)	4
Average Speed (km/hr)	15.9
Average income (x1000 Euros)	22.5
Gender- percentage of females	50.8
Percentage of non-western immigrants	15
Percentage of population over 65	14.8
Population (N)	34,472
Population Density (residents/km^2)	1,572
Population Growth (% increase from 2000-2009)	3.0
Population Growth (% increase from 2009-2015)	1.4
Car ownership per household (N)	1
Average distance to supermarket (km)	0.6
Degree of Urbanization	2
Percent of occurrences of cycling being faster than driving	38
Percent of the population age 10-25	18.5

Table B 3

Data from Hellevoetsluis

Factor	**Measure**
Cycling Level (%)	34
Stop Frequency (N/km)	0.5
Slow cycling and walking (% of time)	14
Traffic obstruction (Fv)	2.4
Infrastructure barrier (Fi)	2
No priority rights (N/km)	4.9
Turns (N/km)	2.9
Vibrations (ft) of pavement	207
Noise (pollution) (Fg)	124
Casualties per 100 million km (N)	19
Detour Factor (ratio)	1.45
Delay (sec/km)	3
Average Speed (km/hr)	15.6
Average income (x1000 Euros)	24.9
Gender- percentage of females	50.3
Percentage of non-western immigrants	8
Percentage of population over 65	12.4
Population (N)	39,620
Population Density (residents/km^2)	856
Population Growth (% increase from 2000-2009)	2.8
Population Growth (% increase from 2009-2015)	-2.4
Car ownership per household (N)	1.1
Average distance to supermarket (km)	0.7
Degree of Urbanization	2
Percent of occurrences of cycling being faster than driving	50
Percent of the population age 10-25	19

Table B 4

Data from Houten

Factor	**Measure**
Cycling Level (%)	40
Stop Frequency (N/km)	0.2
Slow cycling and walking (% of time)	15
Traffic obstruction (Fv)	1.4
Infrastructure barrier (Fi)	2.4
No priority rights (N/km)	6
Turns (N/km)	3.6
Vibrations (ft) of pavement	126
Noise (pollution) (Fg)	106
Casualties per 100 million km (N)	15.4
Detour Factor (ratio)	1.34
Delay (sec/km)	2
Average Speed (km/hr)	15.7
Average income (x1000 Euros)	26.2
Gender- percentage of females	50.7
Percentage of non-western immigrants	6
Percentage of population over 65	8.9
Population (N)	46,475
Population Density (residents/km^2)	788
Population Growth (% increase from 2000-2009)	36.9
Population Growth (% increase from 2009-2015)	2.7
Car ownership per household (N)	2.4
Average distance to supermarket (km)	1.2
Degree of Urbanization	3
Percent of occurrences of cycling being faster than driving	60
Percent of the population age 10-25	20.7

Table B 5

Data from Leiderdorp

Factor	**Measure**
Cycling Level (%)	33
Stop Frequency (N/km)	0.6
Slow cycling and walking (% of time)	18
Traffic obstruction (Fv)	6.7
Infrastructure barrier (Fi)	5.4
No priority rights (N/km)	5.9
Turns (N/km)	2.9
Vibrations (ft) of pavement	139
Noise (pollution) (Fg)	150
Casualties per 100 million km (N)	38.2
Detour Factor (ratio)	1.39
Delay (sec/km)	13
Average Speed (km/hr)	14.3
Average income (x1000 Euros)	26
Gender- percentage of females	51.7
Percentage of non-western immigrants	10
Percentage of population over 65	15.9
Population (N)	26,376
Population Density (residents/km^2)	2,148
Population Growth (% increase from 2000-2009)	1.5
Population Growth (% increase from 2009-2015)	0.3
Car ownership per household (N)	1.1
Average distance to supermarket (km)	0.8
Degree of Urbanization	2
Percent of occurrences of cycling being faster than driving	63
Percent of the population age 10-25	17.6

Table B 6

Data from Soest

Factor	Measure
Cycling Level (%)	28
Stop Frequency (N/km)	0.4
Slow cycling and walking (% of time)	11
Traffic obstruction (Fv)	3.1
Infrastructure barrier (Fi)	1.4
No priority rights (N/km)	3.8
Turns (N/km)	2.8
Vibrations (ft) of pavement	174
Noise (pollution) (Fg)	149
Casualties per 100 million km (N)	30.4
Detour Factor (ratio)	1.34
Delay (sec/km)	9
Average Speed (km/hr)	15.6
Average income (x1000 Euros)	25.6
Gender- percentage of females	51.2
Percentage of non-western immigrants	11
Percentage of population over 65	16.6
Population (N)	45,560
Population Density (residents/km^2)	981
Population Growth (% increase from 2000-2009)	2.8
Population Growth (% increase from 2009-2015)	-0.5
Car ownership per household (N)	1.1
Average distance to supermarket (km)	0.7
Degree of Urbanization	3
Percent of occurrence of cycling being faster than driving	69
Percent of the population age 10-25	17.6

Table B 7

Data from Wageningen

Factor	**Measure**
Cycling Level (%)	44
Stop Frequency (N/km)	0.5
Slow cycling and walking (% of time)	16
Traffic obstruction (Fv)	1.2
Infrastructure barrier (Fi)	1.3
No priority rights (N/km)	3.9
Turns (N/km)	2.8
Vibrations (ft) of pavement	138
Noise (pollution) (Fg)	114
Casualties per 100 million km (N)	18.8
Detour Factor (ratio)	1.37
Delay (sec/km)	9
Average Speed (km/hr)	14.5
Average income (x1000 Euros)	20
Gender- percentage of females	52
Percentage of non-western immigrants	12
Percentage of population over 65	13
Population (N)	36,215
Population Density (residents/km^2)	1,119
Population Growth (% increase from 2000-2009)	10.1
Population Growth (% increase from 2009-2015)	2.1
Car ownership per household (N)	1.1
Average distance to supermarket (km)	0.7
Degree of Urbanization	2
Percent of occurrences of cycling being faster than driving	56
Percent of the population age 10-25	24.6

Table B 8

Data from Weert

Factor	Measure
Cycling Level (%)	36
Stop Frequency (N/km)	0.6
Slow cycling and walking (% of time)	16
Traffic obstruction (Fv)	4.1
Infrastructure barrier (Fi)	2.4
No priority rights (N/km)	4.2
Turns (N/km)	2.5
Vibrations (ft) of pavement	83
Noise (pollution) (Fg)	142
Casualties per 100 million km (N)	29.8
Detour Factor (ratio)	1.41
Delay (sec/km)	13
Average Speed (km/hr)	14.8
Average income (x1000 Euros)	22.1
Gender- percentage of females	50
Percentage of non-western immigrants	9
Percentage of population over 65	17
Population (N)	48,305
Population Density (residents/km^2)	458
Population Growth (% increase from 2000-2009)	0.7
Population Growth (% increase from 2009-2015)	1.3
Car ownership per household (N)	1.1
Average distance to supermarket (km)	0.9
Degree of Urbanization	3
Percent of occurrences of cycling being faster than driving	36
Percent of the population age 10-25	17.9

Appendix C

Table C 1.

Regression Analysis for Significantly Correlated Factors, as found in Table 11

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.92							
R Square	0.84							
Adjusted R Square	0.43							
Standard Error	3.67							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	5	138.59	27.72	2.06	0.36			
Residual	2	26.91	13.46					
Total	7	165.50						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.18	60.83	0.00	1.00	-261.57	261.93	-261.57	261.93
Traffic obstruction (Fv)	2.51	2.73	0.92	0.46	-9.24	14.26	-9.24	14.26
Noise (pollution) (Fg)	0.15	0.22	0.67	0.57	-0.80	1.10	-0.80	1.10
Causalities per 100 million km (N)	-0.76	0.80	-0.95	0.44	-4.21	2.69	-4.21	2.69
Average income (x1000 Euros)	-0.44	0.94	-0.46	0.69	-4.50	3.63	-4.50	3.63
Percent of population age 10-25	195.71	137.41	1.42	0.29	-395.53	786.96	-395.53	786.96

Table C 2

Residual Output for Significantly Correlated Factors, as found in Table 11

RESIDUAL OUTPUT		
Observation	*Predicted Cycling Level*	*Residuals*
1	*38.93*	*0.07*
2	*34.74*	*1.26*
3	*36.46*	*-2.46*
4	*36.83*	*3.17*
5	*33.37*	*-0.37*
6	*30.19*	*-2.19*
7	*45.19*	*-1.19*
8	*34.29*	*1.71*

Table C 3

Regression Analysis for Infrastructure Factors

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	1							
R Square	1							
Adjusted R Square	65535							
Standard Error	0							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	12	165.5	13.79167	#NUM!	#NUM!			
Residual	0	0	65535					
Total	12	165.5						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1.590007967	0	65535	#NUM!	-1.590008	-1.59001	-1.59001	-1.59001
Stop Frequency (N/km)	0	0	65535	#NUM!	0	0	0	0
Slow cycling and walking (%of time)	2.469159413	0	65535	#NUM!	2.46915941	2.469159	2.469159	2.469159
Traffic obstruction (Fv)	-4.862561682	0	65535	#NUM!	-4.8625617	-4.86256	-4.86256	-4.86256
Infrastructure barrier (Fi)	0.611664941	0	65535	#NUM!	0.61166494	0.611665	0.611665	0.611665
No priority rights (N/km)	0	0	65535	#NUM!	0	0	0	0
Turns (N/km)	0	0	65535	#NUM!	0	0	0	0
Casualties per 100 million km (N)	0.33680033	0	65535	#NUM!	0.33680033	0.3368	0.3368	0.3368
Detour Factor (ratio)	0	0	65535	#NUM!	0	0	0	0
Delay (sec/km)	-0.036782398	0	65535	#NUM!	-0.0367824	-0.03678	-0.03678	-0.03678
Average Speed (km/hr)	0	0	65535	#NUM!	0	0	0	0
Vibrations (ft) of pavement	-0.006892986	0	65535	#NUM!	-0.006893	-0.00689	-0.00689	-0.00689
Noise (pollution) (Fg)	0.053278899	0	65535	#NUM!	0.0532789	0.053279	0.053279	0.053279