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Tracing the Level of Cycling among Women in Rotterdam, The Netherlands

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Summary

The gender gap in cycling signifies the manifestation of a higher prevalence of men in cycling activities, encompassing both recreational and transportation purposes, within urban areas. However, according to Goel et al. (2021), the Netherlands has a share of females in cycling trips at 54.4, highlighting the country's gender equality in cycling and the balance in accessibility of cycling as transport. This phenomenon is only prominent in a handful of countries, including the Netherlands, Japan, Germany and Finland (Goel et al., 2021). Therefore, it is clear that the Netherlands is a country with lower levels of gender inequality in a pro-cycling environment (Prati, 2018), making it an important case study to understand gender equality, and explain factors that can contribute to closing the gap.

The research focus of this study was analysed based on literature review findings that safety, built environment, culture and socio-demographic background are key determinants of cycling, especially for women. The findings of the literature review required analysis of not only cycling, but cycling from the female perspective. Further, the conceptual frameworks presented from literature that were relevant to this paper identify some of the factors explaining the level of cycling in cities. This is taken a step further by explaining these factors from a gender perspective to provide an additional level of analysis.

The objective of this research was to explain the factors of gender equality in cycling in Rotterdam. The strategy adopted web-based surveys and interviews with bicycle users to inform the factors in the adoption of bikes. Web-based surveys and interviews helped inform the perceptions of women around cycling to gain insight into the experiences of women, an identified focus area for future research (Prati, 2018). This study asserts that understanding the factors influencing cycling among women is essential for promoting gender equality and informing planning efforts aimed at enhancing sustainable transportation in cities. This study identified income level, personal health reasons, urban road safety, infrastructure, trip costs, personal costs and weather conditions as main determinants explaining the level of cycling among women in Rotterdam. This was supported by statistical evidence whereby characteristics of both the person and place interact to encourage female participation in cycling.

Keywords

cycling, gender equality, sustainable mobility, planner's perspective

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Abbreviations

IHS	Institute for Housing and Urban Development Studies
CO_2	Carbon Dioxide
GTHA	Greater Toronto and Hamilton Area
EUR	Erasmus University Rotterdam
GDPR	General Data Protection Regulation
MCA	Multi-criteria Analysis
VIF	Variance Inflation Factor

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Chapter 1: Introduction

In many countries worldwide, a prevalent disparity between men and women in terms of cycling participation exists, highlighting unequal opportunities for cycling participation across genders (Goel et al., 2021). However, a few countries, including Japan, Germany, Finland, and the Netherlands, stand out as having a higher proportion of women participating in cycling trips. These countries exhibit a more equitable distribution of cycling across genders and demonstrate a greater level of gender equality within a bike-friendly environment that supports cycling. While existing literature explores the barriers and deterrent factors faced by women in cycling, there remains a research gap concerning the specific level of cycling experienced by women who actively participate in cycling (Prati, 2018). Additionally, there is a need for further research that focuses on gender equality rather than solely on gender gaps, within the Dutch context.

This chapter aims to provide contextual background information relevant to the problem outlined in the problem statement. It will subsequently justify the research objective and research focus, aligning with the research question formulated in the introduction. Furthermore, this chapter will explain the significance of this study and its academic relevance. Additionally, it will acknowledge and address the various limitations associated with the study.

Background

The global population is experiencing rapid urbanisation, and the urban population percentage is expected to increase to 68% (Amin et al., 2020). This trend towards urban living brings forth significant challenges related to sustainability and urban mobility. The urbanisation and growth of cities leads to increased energy consumption which affects the environment and contributes to the increase of CO_2 emissions (Amin et al., 2020). Due to the rising energy consumption and other consequences of urban population growth, the sustainability of cities is at stake. These consequences include environmental impacts such as air pollution, CO2 emissions, and a growing carbon footprint. Additionally, societal challenges arise, including traffic congestion and a decreasing quality of life and convenience (Amin et al., 2020). The current and future problems of environmental pollution and global warming necessitates a sustainable transportation system as a way of addressing these emerging issues.

Cycling holds a prominent position in the hierarchy of sustainable transportation modes. Its contribution to efficient urban transport is significant, as it reduces traffic congestion, lowers noise pollution, and, in certain cases, enables faster travel compared to cars or public transport due to its manoeuvrability. Furthermore, cycling promotes liveable cities, offers health benefits to users, and provides environmental advantages, including cleaner air and reduced fossil fuel consumption (Garrard, 2003).

The Netherlands has gained international recognition for its sustainable mobility practices, particularly its emphasis on cycling. With a bicycle density of 1.3 bicycles per inhabitant, the Netherlands boasts the highest bicycle ownership rate in the world (Netherlands: bicycle fleet | Statista, 2023). As early as 2004, the Netherlands ranked first among EU countries in terms of both bicycle share and ownership, followed by Denmark and Germany. In light of the Netherlands' reputation as a global leader in sustainable mobility and cycling, this research aims to delve into the phenomenon of cycling in Rotterdam (Figure 1). By studying the travel behaviour of individuals and analysing the factors influencing cycling, this research seeks to

contribute to the understanding of sustainable urban mobility and provide valuable insights for policymakers and urban planners in developing effective strategies to promote cycling and enhance urban sustainability.

Figure 1: Woman Cycling in Rotterdam (Source: Author)

Problem Statement

Through a growing awareness of livability concerns, cycling is becoming recognised as a functional vehicle for city travel (Fishman, 2016). Within the concept of cycling as a mode of transportation, there is a clear gender gap that is identified in many countries. This is particularly evident in the USA where the share of females in cycling trips is 30.2, and Brazil with a share of 13.2 (Goel et al., 2021, Table 1). The gender gap in cycling is impacting the use of cycling as an important main mode of commuting for everyone in a city. For example, females account for only 29% of current cyclists in the Greater Toronto and Hamilton Area (GTHA) in Canada, whereas men account for 71% (Mitri & Nash, 2019). Therefore, men tend to cycle more than women, creating an unequal distribution in a prominent mode of transport.

Table 1: Cycling behaviour and characteristics of cyclists for urbanised areas nationwide (Goel et al., 2021)

Country	Region	Mode share of cycling (%)					Share of females in cycle trips
		All trips	Non-work trips	Work trips	All trips Males	All trips Females	
Netherlands	Europe	26.8	27.1	25.3	25.4	28.2	54.4
Japan	Asia	11.5	11.9	10.1	10.2	12.7	56.4
Germany	Europe	9.3	9.2	9.4	9.5	9.1	49.2
Finland	Europe	7.8	7.8	8.4	8	7.6	50.4
Switzerland	Europe	6.7	6.3	8.1	7.2	6.3	46.6
Argentina	Latin America	3.6	3.3	5	4.9	2.4	33.6
Chile	Latin America	2.7	2.3	3.7	3.9	1.6	30.8
England	Europe	2.1	1.6	3.9	3.2	1.1	26.5
Australia	Australia	1.8	1.8	1.2	2.4	1.2	35.5
USA	North America	1.1	1	1.3	1.6	0.6	30.2
Brazil	Latin America	0.8	0.4	1.3	1.4	0.2	13.2

Many countries experience a gender gap in cycling, therefore only a few locations that have gender equality in cycling can be evaluated. Japan (56.4), Germany (49.2) and Finland (50.4) are among the countries with the highest share of females in cycling trips (Goel et al., 2021), highlighting the possibility for cities and countries to have a balanced distribution of cycling for all genders.

The Netherlands is one of few countries with a lower level of gender inequality in cycling, having a high share of females in cycling trips (54.4) (Goel et al., 2021). Particularly, the Netherlands has gained international recognition for its extensive cycling culture and infrastructure, and its relatively higher level of gender equality in cycling participation (Rietveld, 2000). The Dutch context offers a unique setting to investigate the factors that contribute to gender equality in cycling. The Netherlands has a long-standing tradition of investing in cycling infrastructure, including dedicated cycling lanes, traffic-calming measures, and bicycle-friendly urban design (Pucher et al., 2010). Additionally, social norms and cultural attitudes toward cycling in the Netherlands have fostered a more inclusive cycling culture, encouraging women's participation in cycling (Pucher et al., 2010; Rietveld, 2000). The role of gender is therefore important and contributes to the sense of equality in a city among other benefits economically, socially, and environmentally.

Gender equality in cycling is a desired trait for this mode of transport. Not only does gender equality promote equal opportunities and social justice, it also leads to improved overall health and fitness. For women in particular, gender equality in cycling allows women to have a sense of independence and freedom of movement. There have also been clear efforts from other countries to encourage women to cycle more. This can be seen through UK’s 2025 cycling targets including a world class cycling network that has yet to be seen (Geffen, 2021), and New York City’s commitment to the use of bicycles for commuting, but the government has failed to deliver on improvements (Kuntzman, 2021). Therefore, there has been little success in increasing the number of cyclists, female or otherwise (Shaw et al., 2020).

Rotterdam, a city located in the province of South Holland, the Netherlands, does have suitable bicycle infrastructure, however it differs in that it has a lower bicycle use (18%) than the country average (26%) (OBI, 2015). This can be observed through the statistics showing that bicycle use only makes up 24% of trips under 5 km, whereas this is 41% in Utrecht (Chart 1). Given Rotterdam's status as one of the major cities in a country known for its commendable cycling culture, there is room to enhance the transportation system's sustainability through the promotion of bicycle use. There is a need for a deeper understanding of the motivating factors that influence women's decisions to adopt bicycles. Therefore, the primary objective of this study is to examine the factors that have an influence on the selection of bicycles as a mode of transportation, specifically focusing on their relevance to the context of Rotterdam.

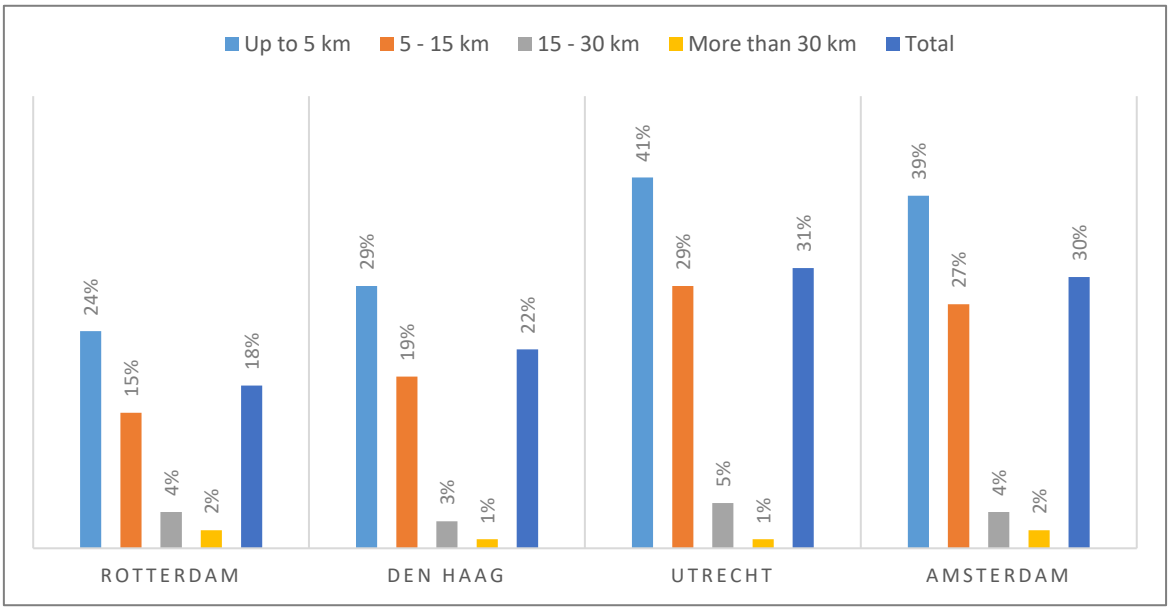


Chart 1: Bicycle Trips by Trip Distance in the Netherlands (OBI, 2015)

While the deterring factors are clearer, such as poor infrastructure and comfort concerns (Manaugh et al., 2017), little research considers the factors contributing to a high level of cycling. Particularly among women in the Netherlands where the share of women in cycling trips is higher than most countries, contributing towards gender equality in cycling. Clarification on the factors explaining the level of cycling among women in the Netherlands can help to describe gender equality in cycling. Although literature highlights factors that limit and deter women's participation in cycling (Prati, 2018; Garrard, 2003), specific factors that encourage women to cycle based on perceptions and experience are not as detailed. Therefore, it is difficult to set up the conditions for women to adopt cycling as the main mode of commuting (Krizek et al., 2004; Prati, 2018).

Research Gaps and Objective

Current literature on the gender gap in cycling is extensive, and provides insight on the key deterrents of cycling in cities for women. Mogaji & Uzondu (2022) and Battiston et al. (2022) have published articles outlining key factors contributing to the level of cycling among women in different contexts. An article entitled *Gender equality and women's participation in transport cycling* by Prati (2018) is the main piece of literature related to gender equality. Evidently, there is a lack of literature on gender equality in cycling and the important factors

encouraging cycling instead of factors deterring cycling. There is little literature pertaining to gender equality in cycling and specifically, the experience and perception of women who cycle, as opposed to the focus on the gender gap.

The research gap this study seeks to address is related to the level of cycling particular to the experiences of women who cycle (Prati, 2018) and the need to provide further research on gender equality, as opposed to gender gaps. Literature suggests looking at the participation of women in cycling for different types of activities in order to understand how women get around (Singleton & Goddard, 2016). Another way this thesis addresses a relevant gap in research is by evaluating the level of cycling in the Rotterdam context because much of the current literature looks at specific contexts, but not the female Dutch experience. Therefore, the objective of this research is to explain the factors of gender equality in cycling, specifically among women in Rotterdam. By focusing on the Dutch context, this study aims to unravel the factors that contribute to women's active involvement in cycling and explore the experiences unique to women who engage in cycling. The findings of this research will enhance our understanding of the complex dynamics shaping gender equality in cycling and provide evidence-based insights for policymakers and urban planners to develop effective strategies and interventions that foster gender equality and promote women's cycling participation in Rotterdam and beyond.

While the gender gap in cycling has been extensively examined, there is a research gap regarding the level of cycling specific to women who actively engage in cycling and the promotion of gender equality in the Dutch context (Prati, 2018). This research intends to address this research gap by investigating the determinants of gender equality in cycling and shedding light on the factors that influence the level of cycling among women in Rotterdam. By exploring these factors, the study seeks to provide valuable insights that can inform planning efforts aimed at promoting equitable cycling participation and enhancing gender equality in cycling.

Research Focus

The research focus of this study requires analysis of not only cycling, but cycling from the female perspective. This is based on literature review findings that safety, built environment, culture and socio-demographic background are key determinants of cycling, especially for women. The purpose is to examine the impact of personal motivations and attitudes towards cycling on the level of cycling among women in Rotterdam. The focus on the level of cycling, considering the female perspective, allows the investigation of the experiences of women who actively engage in cycling, with a specific focus on gender equality in the Dutch context. By focusing on the factors that influence women's cycling behaviour in Rotterdam, this research contributes to the broader goal of achieving gender equality in cycling and provides valuable insights for policymakers and practitioners in designing inclusive and sustainable transportation systems.

Research Question

In light of the different perspectives on the role of gender in cycling, this paper seeks to explain the level of cycling by women in Rotterdam, the Netherlands in the context of gender equality. Ultimately, the main research question and sub questions this paper seeks to answer, based on the problem statement and research gap that has been identified, is as follows:

Which factors explain the level of cycling of women in Rotterdam, the Netherlands?

- To what extent does safety determine the level of cycling by women?
- To what extent does socio-demographic background determine the level of cycling by women?

Within the process of finalising the research question, different urban mobility issues were considered such as the adoption of e-bikes and bakfietsen. However, this was broadened to cycling in general in order to be inclusive of a larger population that may use other forms of cycling (e-bikes or bakfietsen). This was further narrowed down by looking at just female participation to explore the gender perspective. After conducting the literature review, the sub questions were formulated based on the most prominent factors of the literature review, including safety and socio-demographic background. Data was collected on the experiences and perspectives of women who cycle in Rotterdam to answer the research question. This is supported by an evaluation of gender equality in cycling in the Netherlands, and the need to evaluate the impacts of gender as well as the experiences of women to better understand the role of gender in cycling.

Significance of the Study

The research regarding the gender gap in cycling is assessed by identifying the factors of use for women that influence the level of cycling. This makes the problem of gender inequality in cycling relevant because it is essential for policy-making, solving issues of environmental concerns, and can add value to academic literature. The purpose is to understand which factors are most crucial to Dutch women, and which have the biggest influence on increasing the level of cycling. These may include topics such as safety, infrastructure, and culture based on the current literature. This is further described in the following section. Since the Netherlands has significant gender equality in cycling, the research utilises that aspect as a basis for exploring the role of gender in cycling and how it can inform the gender gap in cycling in other countries, and increasing the participation of women. Therefore, the academic relevance of this research not only provides a unique planner perspective to evaluate factors, but it also addresses an area of research that requires further investigation.

This research analyses the role of gender in cycling to gain a better understanding of the gender role in different cycling methods to ensure a spread of results. It can be useful for other countries to gather information on gender equality in cycling, such as in Rotterdam, and gain insights and lessons from this, thereby reducing the gender gap in their countries. The research is also useful for Rotterdam considering the cycling levels are relatively low compared to the rest of the Netherlands (Chart 1).

Extent and Limitations

The scope of this study included evaluation of the female population who cycle in order to target the correct population and create an appropriate sample size to ensure the results are specific to women. The study was limited to the legal geographical boundaries of Rotterdam (Figure 2) with a time frame of 3 months to begin and complete the research. However, a limitation of this was the little statistical information available that made the sample size slightly unreliable. Therefore, the population used was the female population of Rotterdam, and not specifically those who cycle. It was not representative of the population, making it a

main limitation of the research. Another limitation was the time restriction and low response rate during the data collection period, which highlighted the low validity of the research.

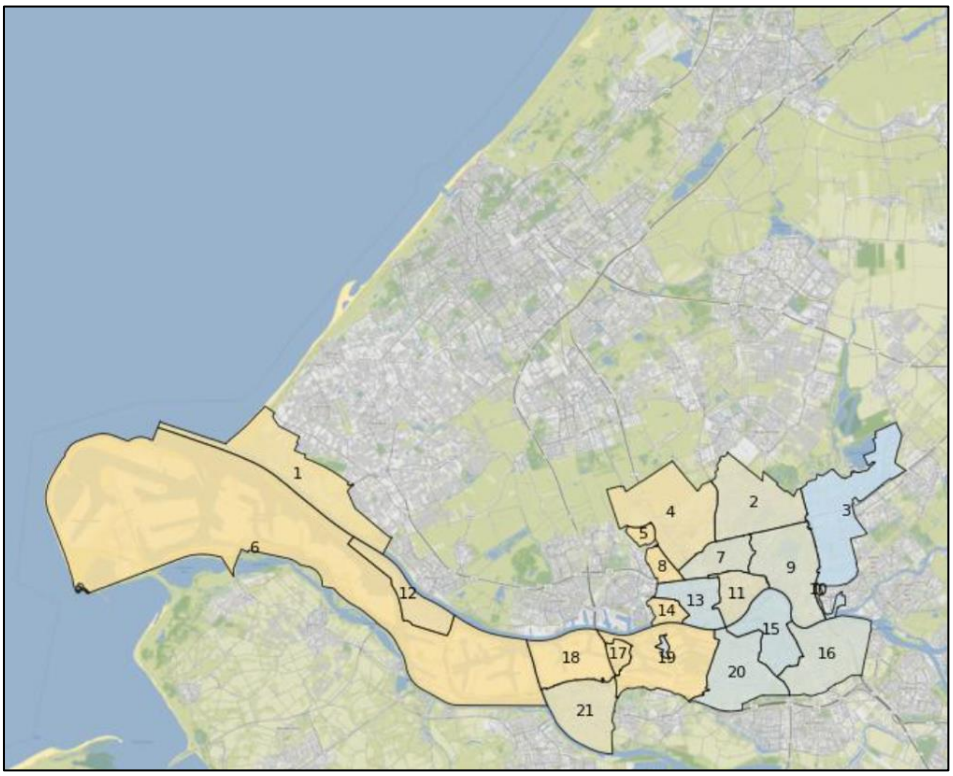


Figure 2: Map of Geographical Boundaries of Rotterdam (Information about the municipality of Rotterdam, 2023)

While the research explores the experiences of women who cycle and the need to provide further research on gender equality gaps, the focus on the Dutch context narrows the focus and create a unique study. In order to help explain the level of cycling among women in Rotterdam, the main research question this study sought to answer is: Which factors explain the level of cycling of women in Rotterdam, the Netherlands? Through the use of surveys, the research highlighted key findings that can inform the level of cycling where gender equality is more evident than in other countries. Research findings of this study show infrastructure, trip cost and personal costs as important to women who completed the survey. Specifically, personal health reasons, weather conditions, urban road safety and income level are other factors that illustrate statistical significance and are therefore important factors in explaining cycling among women. This study asserts that understanding the factors of cycling among women in Rotterdam is essential for promoting gender equality in cycling and informing policy and planning efforts aimed at enhancing sustainable transportation in cities.

Chapter 2: Literature Review

This chapter seeks to understand arguments from existing research and theoretical studies put forth to create a cohesive and well-informed conceptual framework that can be used to guide the current study. The main arguments from current literature, that can be applied to the Dutch female context, are centred around behaviours, perceptions and attitudes that influence individual, social and physical factors. Safety, infrastructure, sociodemographic, and household structure/responsibilities are some of the common factors that can be identified among a range of studies. Many scholars discussed the gender gap in mobility being dependent on female experiences that informs the different theoretical frameworks presented in literature. The findings from existing research were a good starting point to determine the impacts in terms of the Dutch female context.

The hypothesis specific to this research was that the level of cycling among women is influenced by a combination of person and place factors, specifically inclusive of urban road safety and socio-demographic background being key factors in explaining the level of cycling.

Arguments on Participation in Cycling

Current literature considers different types of determinants contributing to women's participation in cycling. Certain scholars have identified various gender differences in cycling behaviour to examine cycling and travel patterns, all of which have social, economic, and environmental impacts (Krizek et al., 2005; Emond et al., 2009; Nobis & Lenz, 2005). The studies from literature outlined how individual, social and physical factors all play an important part in determining bicycle use, but that these factors differ for men and women (Emond et al., 2009). Therefore, cycling behaviour greatly depends on the environment and attitudes towards cycling and cycling infrastructure. The behaviour of a cyclist is strongly related to safety perceptions and household responsibility, as put forth by Emond et al., 2009. They argued the importance of the social and physical environment, and the key difference in safety perception that further contributes to a gender gap (Emond et al., 2009). Travel patterns, which are considerably influenced by gender, have been examined extensively to clarify cycling behaviours and perceptions, most of which are related to safety, household structure, employment status, and individual, social and physical factors. Findings from literature have suggested gender differences and the need for gender sensitivity in the bicycle planning process.

Other arguments from existing literature on participation in cycling supported findings of safety, infrastructure, sociodemographic, and household structure/responsibilities as some of the common factors among a range of studies in the United States, New Zealand, Nigeria, UK and Canada (Edmond et al., 2009; Russell et al., 2021; Mogaji & Uzondu, 2022; Mitra & Nash, 2019). Specific to the European context, scholars Prati et al. (2019) highlighted how women have distinctive attitudes towards cycling compared to men, such as higher risk perceptions, but ultimately, different factors help in explaining gender differences in cycling behaviour. Fong et al. (2020) are scholars that also identified the lack of women in cycling communities, based on different barriers to cycling. Similarly, several articles focused on research that help to explain the barriers and deterrents that limit women's participation in cycling (Fong et al., 2020; Jahanshahi et al., 2021). The argument that women's attitudes and behaviours significantly differ to men's, in terms of cycling, is therefore a well-supported and proven argument by different pieces of academic literature.

As a whole, current literature mainly focused on the gender gap in mobility and the difficulties women face surrounding it. Prati et al. (2019) discuss these difficulties, specifically for women, based on evidence from a survey of cyclists across Europe. The findings highlighted the linkage of cycling and socio-economic factors (Prati et al., 2019). This publication is one example of research pertaining to cycling behaviours, perceptions and attitudes of both male and female cyclists. These are the underlying aspects of the gender gap in mobility that is dependent on the experiences of women from a particular geographic context. The European and North American context is widely researched in current literature (Prati et al., 2019; Mitra & Nash, 2019), however the Dutch context requires detailed investigation.

Sustainable Mobility in the Netherlands

According to Hildermeier & Villareal (2014), urban transport is responsible for approximately one quarter of CO_2 emissions in Europe, mostly resulting from growing urbanisation leading to congestion and pollution in Europe's largest cities. City planners, enterprises and consumers need to search for joint solutions that aim to reduce emissions and congestion to create 'sustainable mobility' (Hildermeier & Villareal, 2014). Sustainable mobility can provide an alternative paradigm to complexity that can strengthen the relationship between land use and transport (Banister, 2008).

The transition towards sustainable mobility requires equitable transport to guide effective sustainable mobility (Miralles-Guasch et al. 2016). The recent mobilisation of sustainable mobility and transport shows the desires and importance of living in a cleaner and greener world. Although progress has been made through the promotion of non-oil based fuels and the push towards electric-powered vehicles (Ackrill & Zhang, 2020), there is a mind shift required and a need to address challenges of climate change.

Gender Equality in Cycling

The level of gender equality evident in cycling differs greatly from city to city in Europe. In an article by Prati (2018), the need to consider gender equality was highlighted when compared to women's participation in cycling in Europe. Findings have shown women's participation in cycling was higher in EU countries that scored higher on the Gender Equality Index (Prati, 2018), a measurement of gender gaps put forth by the European Institute for Gender Equality. The measure accounts for work, money, knowledge, time, power, and health. Based on these indicators, female cyclists can be understood as a minority within a minority for which the indicators have varied effects. It is clear that gender inequality in cycling is more evident globally. However, it can be insightful to observe the level of cycling and its relationship with gender equality for improving cycling opportunities for all genders.

Gender equality in cycling should seek a combination of tools from different stakeholders to promote equality in cycling. This includes willingness from community stakeholders, encouragement and improvement of the place from the government, and support from external stakeholders to finance the required changes. Cities should encourage cycling with all genders in mind, and take into account the perspectives and behaviours of women towards cycling.

Key Determinants of Cycling

In light of the need for cities to transition towards sustainable mobility, and the need to break the cycle of inequality in cycling to achieve its full potential, the following factors from relevant

literature have been identified as some of the key determinants for the level of cycling by women. These include, but are not limited to, urban road safety, the quality and capacity of infrastructure, one's socio-demographic background, and the education level and household size. These factors helped to define a criterion for the research and provided an academically supported basis for explaining the level of cycling, with concepts taken from existing literature. The factors also helped to formulate the conceptual framework from which this research is analysed.

1. *Urban Road Safety*

According to articles by Garrard (2003) and Battiston et al. (2022), urban road safety has been a significant concern that deters women from cycling. Urban road safety refers to the perception of safety in regards to the methods and measures used in a city that might prevent road injuries and deaths. Garrard highlighted safety concerns as main deterrents to cycling for women, taken from results of a pilot study in Sydney, Australia (Garrard, 2003). These road safety concerns refer to the role of safe cycleways, road safety and secure bicycle parking. Evidently, from a study of cycling in Australia, urban road safety was found to be a significant reason for gender difference, which makes it important for this case study.

Similarly, Battiston et al. (2022) found a positive correlation between female cycling rates and urban road safety. This shows the importance of safety for eliminating the gender gap in cycling and building towards more sustainable mobility. Their research supported the hypothesis that low levels of women's engagement with cycling may be explained by a greater concern for safety compared to men (Battiston et al., 2022). Therefore, gender specific preferences on road safety was further explored in this study to gain insight into the female perception.

2. *Quality and Capacity of Infrastructure*

Another key determinant of cycling, for women specifically, was the preference for cycling infrastructure that is separated from motorised traffic (Battiston et al., 2022). The quality of infrastructure was identified in the Battiston et al. (2022) and Rietveld & Daniel (2004) articles as a factor associated with a more balanced gender ratio, where safety is dependent on the infrastructure conditions. This may include dedicated cycling infrastructure and ensuring the presence of physical separation to make urban environments more accessible for women (Battiston et al., 2022).

The availability of this infrastructure was also clearly correlated to safety perceptions and overall cycling rates (Rietveld & Daniel, 2004) as women have a higher preference related to infrastructure compared to men. The infrastructure a city has, and the amount of cycling infrastructure available to the public, can have a major impact on the gender equality in cycling within that city. Therefore, the infrastructure of a city is another key factor of the level of cycling, and specifically cycling among women.

3. *Socio-demographic Background*

Gender equality in cycling is further influenced by one's socio-demographic background as it was found as a factor explaining the gender gap (Mechakra-Tahiri, 2012). This refers to a range of demographic characteristics including age and gender. Since this study only considered survey responses from women, gender is not a factor that was considered as men are ruled out of the study and there is no comparison between genders. This is enhanced by the inclusion of socio-economic attributes such as occupation and income level that are identified in the conceptual framework for a cycling decision taken from Zhang et al. (2020). Socio-demographic background can provide insight into the influence of individual and personal

attributes and how they interact with other factors to inform decision-making specific to cycling.

4. *Education Level and Household Size*

The final key determinant explaining the level of cycling was the combination of education level and household size, based on literature defining them as factors describing the different mobility patterns in men and women (Olabarria et al., 2013). Education level has been found to be a factor associated with greater time spent travelling for work-related reasons and household size being a factor associated with greater time spent travelling for home-related reasons among women (Olabarria et al., 2013). Evidently, mobility is heavily influenced by education level and household structure which makes these factors important for analysis of gender equality in cycling.

Theoretical Review of Frameworks from Literature

In order to understand the factors explaining the level of cycling among women, we first analysed the existing literature in terms of the theories offered, and the factors considered. The factors considered are outlined above, including urban road safety, quality and capacity of infrastructure, education level and household size, and socio-demographic background. However, this study also required review of the conceptual frameworks provided in literature to gain knowledge on existing research and how the frameworks can be applied to the Dutch female context. The conceptual frameworks outlined in literature are rooted in the arguments from existing research surrounding individual, social and physical factors. Although literature identified key factors in bicycle use, and that among women, the conceptual frameworks visualise the thought process and categorisation of factors. By analysing the current conceptual frameworks in academia, the framework specific to this study was developed through creative output and was made slightly different from the structure of current frameworks to account for only the female perspective.

Framework 1: Zhang et al., 2020

The first conceptual framework that was presented in current literature pertaining to a cycling decision and willingness to cycle, and used as a reference for this study, was taken from Zhang et al. (2020). The authors identified five groups of factors; personal attributes, personal psychological attributes, built environment, socio-economic attributes, and the nature of trips (Zhang et al., 2020) (Figure 3). One of the groups that can be highlighted for this study was the built environment which entails urban form, infrastructure, weather and topography. This showed the importance of considering weather and topography. Weather was identified as one of many factors affecting cycling behaviours (Krizek et al., 2005). Similarly, topography was another factor that was mentioned in other articles as a barrier in cycling and therefore something that can impact women's participation in cycling (Fong et al., 2020).

The emphasis on the nature of trips as an important attribute of individuals was highlighted in this framework and other literature, showing the importance of this factor. Trip nature, and more specifically the trip purpose, cost and distance, can heavily influence travel patterns and does differ for women compared to men which shows travel patterns are highly linked with nature of trips and family obligations (Nobis & Lenz, 2005). The most common trip purposes, which were included in this study, were found to be influential in the travel of women that is shaped by social processes (Shaw et al., 2020). Another key finding was that the distance of trips is also important as people reach different destinations (Larson et al., 2010). Lastly, the

cost of trips was a key consideration for people as a basic measurement of travel behaviours and in research put forth by Nobis & Lenz (2005), they found that men tend to have higher travel costs than women. Therefore, this study considered the addition of trip nature to identify if it is an important factor for women considering the difference with men and the need to explore this further. The trip purposes used for this study are taken from Shaw et al. (2020) and Larson et al. (2010) which highlighted the following purposes; shopping, leisure/recreation, (going to) work/school, social visits. The study also included transporting children and gym/fitness as other potential purposes to account for the trip purposes of mothers and breaking down recreation.

This framework includes some of the common factors outlined above and provides insight into the details of each factor that can be applied to the gender specific context. Essentially, it is about looking at more than just the built environment, but also the infrastructure, weather and topography as individual factors. This framework was adjusted and applied to the Dutch female context in terms of how these factors contribute to the willingness of women to cycle based on the factors identified within each of the five groups.

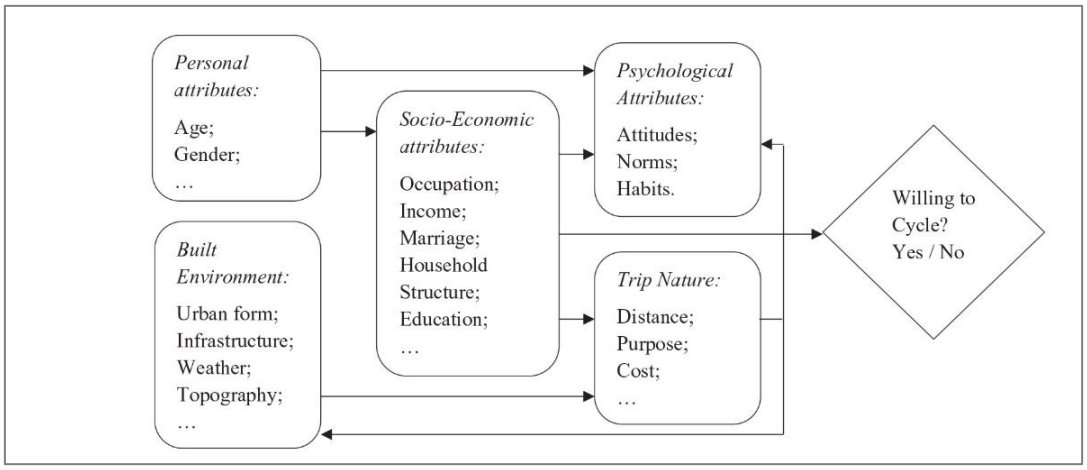


Figure 3: Conceptual Framework for a Cycling Decision (Zhang et al., 2020)

Framework 2: Rietveld & Daniel, 2004

Another framework related to the factors explaining bicycle use was presented by Rietveld & Daniel (2004) which highlighted individual features and socio-cultural factors in combination with the generalised costs of bicycling to explain bicycle use (Figure 4). In this context, costs refer to literal monetary costs and the social costs associated with cycling. This framework was important for breaking down the costs of bicycling (monetary, time, physical, comfort, risk, and security) to understand how the cost of bicycling can explain and impact the use of bicycles. The framework was also useful to visualise the different costs of cycling, compared to the costs of other transport modes, and reflection of this in terms of women's participation in cycling. Although Figure 4 mostly focuses on associated costs, it was useful for identifying types and aspects of costs that can be presented to participants within the general factor of 'costs' and what that can mean.

While this framework outlined the importance of considering the generalised costs of bicycling, another important factor that can be applied to this study is the ethnic origin and cultural background of individuals. Ethnic origin and cultural background do refer to different aspects of a person's individual attributes. Ethnic origin refers to the origins of the person's ancestors,

whereas cultural background refers to their sense of belonging to a specific society, regardless of their origins. By considering these factors, the study could determine if women consider these two factors differently, and if they are influential in explaining the level of cycling.

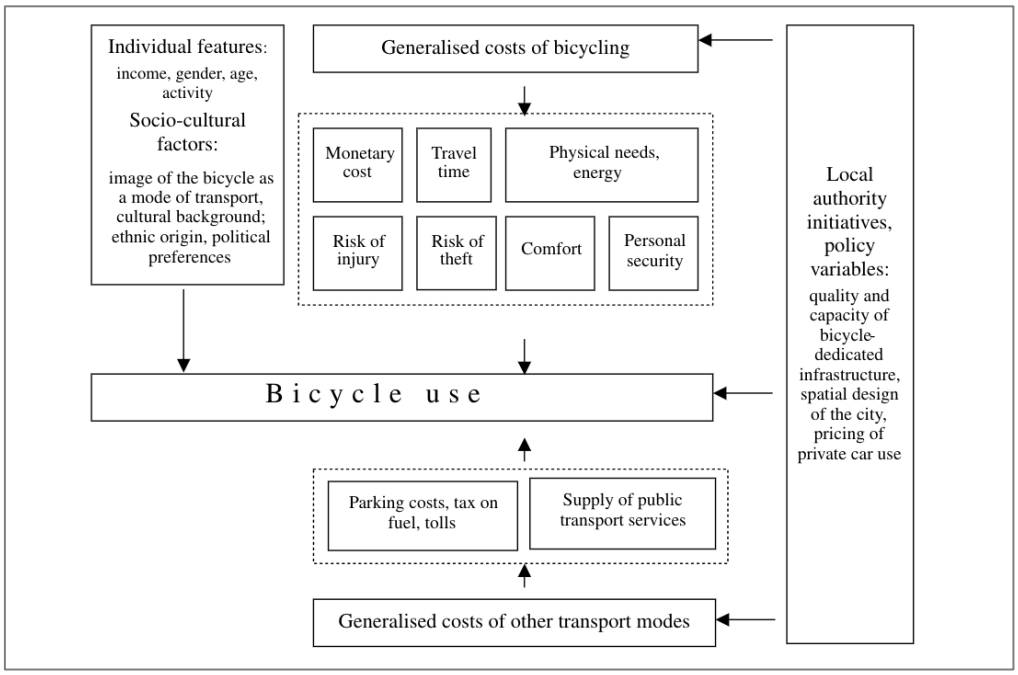


Figure 4: General Framework of Factors Explaining Bicycle Use (Rietveld & Daniel, 2004)

Framework 3: Krizek et al., 2009

The third conceptual framework applicable to this study, outlined in a paper by Krizek et al. (2009), identified the causal factors, primary effects and secondary effects, on both the individual and community level. The authors considered individual, interpersonal, and environmental factors that impact levels of walking and cycling and make up the 'causal factors' (Figure 5). The framework outlined factors as well as primary and secondary effects from the causal factors, which allowed for a more robust framework that shows how the factors impact the individual and the community. The focus on environmental factors is another key finding because of the growing concerns of environmental impact and climate change as researchers have acknowledged the importance of the quality of the environment as a determinant of behaviour (Krizek et al., 2009). Therefore, climate change and environmental concerns were another potential factor that was included in this research to ensure different aspects of the physical environment were considered; both built environment and environmental impact.

However, the effects would be presumptuous and only based on current literature which mostly pertains to factors explaining the level of cycling among both men and women. Therefore, it did not seem relevant to include effects in the conceptual framework for this study. Although the framework refers to levels of walking and cycling, it was adjusted to account for only the level of cycling among women.

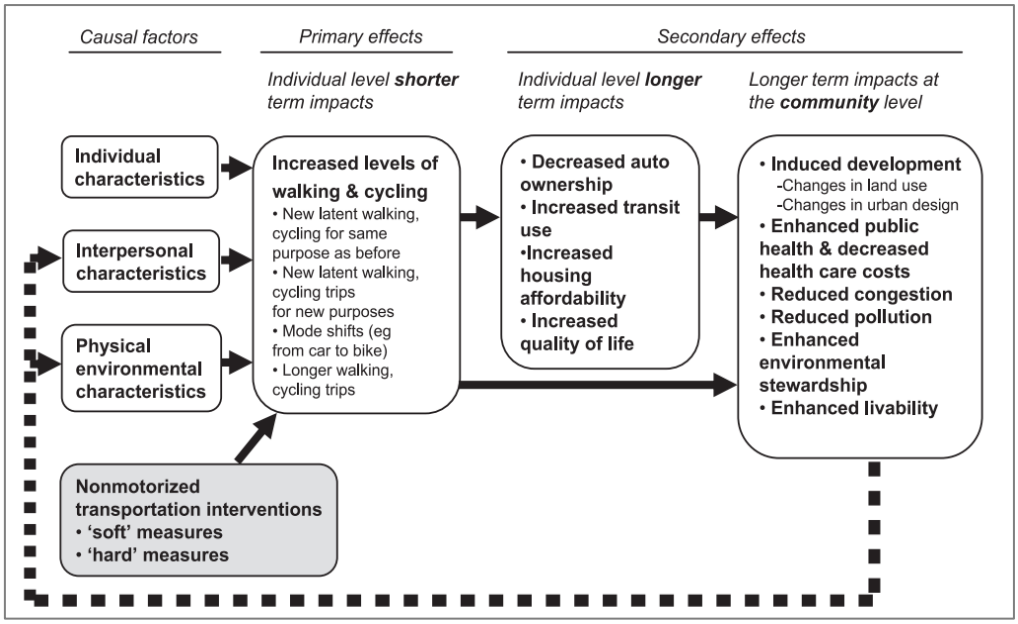


Figure 5: Conceptual Framework (Krizek et al., 2009)

Another key factor considered in this study that was not explicitly included in the frameworks presented was the factor of health. According to Le et al. (2019), health is one of the most important factors for women to cycle for transport or recreation. Scholars highlighted the cycling motivations of women being highly linked to personal health compared to men, and the importance of it especially for non-utilitarian cycling (Malchrowicz-Mośko et al., 2019; Le et al., 2019). Based on the conceptual frameworks defined in academic literature and a review of literature identifying key determinants of cycling, socio-demographic background, safety, culture and built environment were the general factors identified as key factors of the level of cycling among women. Each factor entails more detailed aspects, such as safety referring to road safety, cycleways, and safe bicycle parking. The chosen determinants informing the conceptual framework for this research was based on the common factors found in various academic articles that make up the conceptual framework for the gender context.

Conceptual Framework

The conceptual framework illustrated below (Figure 6) outlines the key determinants that help to explain the level of cycling among women. This was developed using the findings from literature that identified different factors. Concepts of built environment and trip nature were applied to the framework based on Zhang et al. (2020), specifically weather and topography as well as trip distance, cost and purpose. This was applied because it is mentioned by other scholars and shows the importance of considering built environment and trip nature (Krizek et al., 2005; Nobis & Lenz, 2005). The developed framework also employed the socio-cultural factors, presented by Rietveld & Daniel (2004), to frame the indicator of cultural background, especially given the multiculturalism present in Rotterdam. Both frameworks outlined personal attributes as a factor, including age and income, as important factors for explaining level of cycling. Therefore, considering personal attributes was crucial in explaining women's cycling participation. Lastly, environmental characteristics are drawn from the framework presented by Krizek et al. (2009). Therefore, the elements chosen in constructing the conceptual framework are theoretically well-established in literature. However, the framework developed

was unique in that it is divided into both personal and place characteristics to create a distinctive approach to factors of cycling for women.

This unique approach employs a 'planner's perspective'. A planner's perspective refers to the analysis of a city based on people-place connections to design with culture and incorporate place-identity into decision-making (Stephenson, 2010). This unique view allows readers to better understand the level of cycling among women in another way in which decision-making considers change for the people. The framework combines the previous frameworks presented by different scholars to confirm current literature and highlight which aspect is most influential, personal or place characteristics.

In this context, personal characteristics were one of two categories of factors. This included personal attributes such as age, income, education, household structure, cultural and ethnic background, personal health, and social costs of cycling for the person (monetary, time, physical, comfort, risk, security). Therefore, this category refers to any factors impacting the person and specific to their personal experience of cycling. The second category looked at place characteristics related to the location itself. This included place factors such as safety, quality and capacity of infrastructure, weather, topography, and the role of environmental impacts in that particular city. This two-fold framework helped to consider how the interaction between the personal and place factors played a role in explaining the level of cycling among women, and which of the two categories was more influential or important to women.

This conceptual framework was key in answering the research question because it considered specific and detailed characteristics of the indicators discussed by scholars. It shows a more detailed version of frameworks presented, using the planner's perspective as a lens for evaluation. The strengths of the framework are that it is supported by literature, considers more than just common factors but broken down factors, and it presents a cohesive and understandable structure.

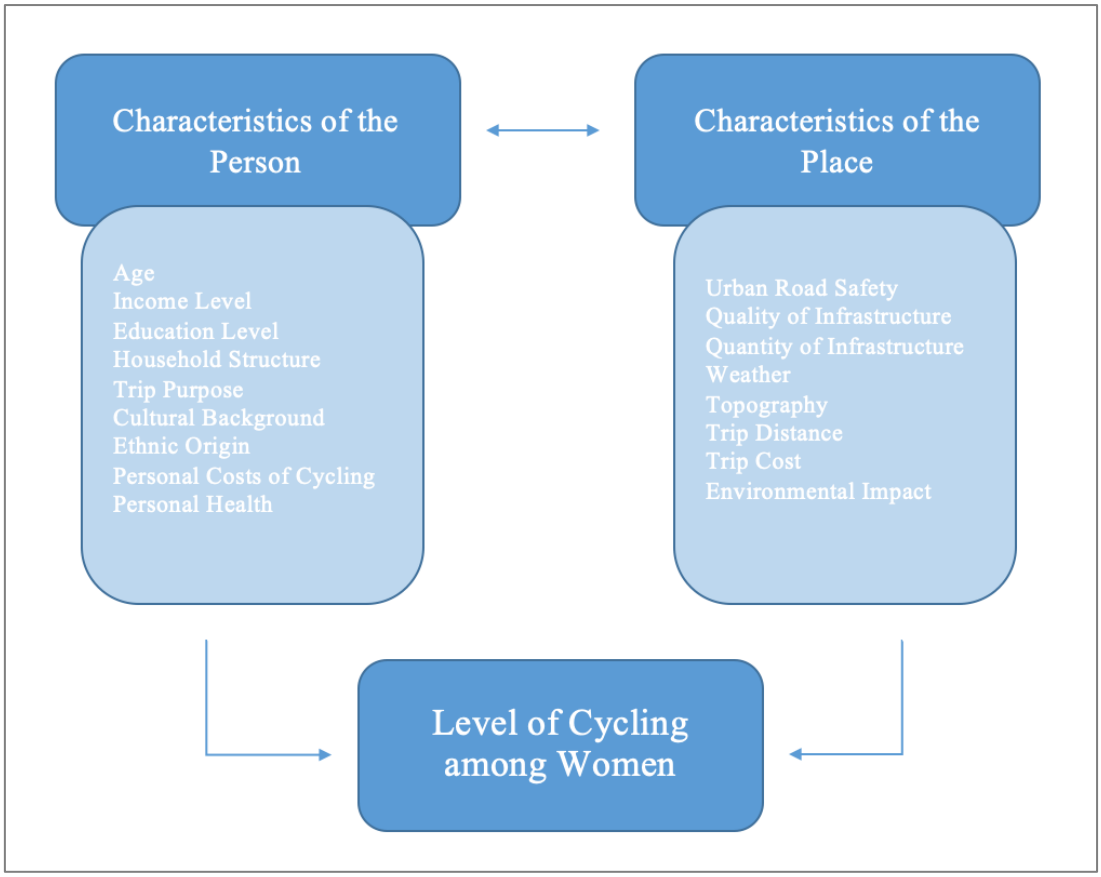


Figure 6: Conceptual Framework (Source: Author)

The current findings provided an initial point to explore the factors explaining the level of cycling among women. However, considering the 'planner's perspective' to create a unique approach gives a new take on the topic. Planning theory focuses on the interconnection of people and place, which has a wide implication on the planning practice (Stephenson, 2010). The factors, which are those that show commonalities in existing research and have been identified by scholars, are split into personal and place characteristics (Figure 6). This approach uses the 'planner's perspective' to analyse the level of cycling among women and how people and places interact, in terms of cycling among women, to understand the implication on the planning practice.

Chapter 3: Methodology

The research methodology employed a quantitative analysis approach to guide the data collection process. This included the utilisation of online surveys targeting a specific sample of women residing in Rotterdam and actively participating in cycling. The chapter provides an explanation of the sample selection, which is based on population statistics. Subsequently, a comprehensive description and analysis of the research methods employed are presented. The operationalisation of the research is also outlined, accompanied by an operationalisation table that explains the factors, indicators, and measurement methods utilised for each aspect of the study. Additionally, this chapter delves into a detailed description of the data collected and explores the potential implications of the study. Emphasis is placed on the data collection methods employed and the operationalisation of the research to ensure the validity and reliability of the findings.

Sample Selection

The survey sample for this research comprised women residing in Rotterdam who engage in cycling within the age range of 18-64 years. The specific data on the number of female cyclists was not publicly available, and despite efforts to obtain it from the municipality of Rotterdam, it could not be obtained within the limited timeframe. Therefore, targeting the age group of 18-64 years was deemed most suitable, considering it represents an active age range with higher probability of engaging in cycling. The population size in this age group is substantial, estimated to be approximately 214,907 women (Region ROTTERDAM: Population by Age 2020, n.d). Utilising an equation for sample size calculation (Figure 7), the target sample size for the online surveys was set at 384 respondents, aiming for a 95% confidence interval with a margin of error of +/- 5%. However, due to feasibility considerations, a more realistic goal of obtaining a minimum of 90 responses was established, ensuring a 95% confidence interval with a margin of error of +/- 10%.

$$n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

Figure 7: Equation for Calculating Sample Size. (Sample Size Calculator, n.d)

The combination of purposive and stratified sampling methods yielded valuable outcomes. Purposive sampling was utilised to select individuals who met specific criteria relevant to the research objectives, such as being female residents of Rotterdam who engage in cycling. This approach targeted individuals who were active on social media platforms or frequently visited the stores where the flyers were distributed. Stratified sampling involved dividing the population into subgroups based on age and cultural background, ensuring proportional representation from each subgroup. By employing these methods, the sample obtained for analysis was diverse and representative, enabling robust quantitative analysis and yielding meaningful insights. Purposive sampling facilitated a focused examination of participants likely to provide valuable insights related to the research questions, while stratified sampling ensured the inclusion of participants from various backgrounds, mitigating bias and enhancing the generalizability of the findings. Although the collected responses were fewer than the target sample of 384 due to time constraints and the specific focus on women in Rotterdam, a dataset of 98 responses was deemed sufficient for statistical analysis.

Research Methods

The research methods applied online surveys to gather comprehensive data. Online surveys were chosen for their advantages in maintaining participant anonymity and facilitating access to a larger number of respondents. Despite some potential drawbacks, web-based surveys offer direct data processing and the utilisation of supportive technology for construction and analysis (Van Selm & Jankowski, 2006). The primary objective was to gather quantitative data through empirical investigation, and the survey strategy allowed for a broad scope of data collection and the generation of generally applicable findings. However, given the complexity of the topic of gender equality in cycling among women, a deeper understanding of perceptions and opinions was sought. To address this, complementary semi-structured interviews were conducted, incorporating original survey questions as a basis for in-depth conversations with the participants. Guest et al. (2006) suggest that a sufficient number of interviews, in this case, 12 interviews with women who cycle in Rotterdam, can provide valuable insights into common perceptions and experiences within this stakeholder group.

While online surveys may present certain challenges such as lower response rates and sampling errors, they offer advantages in terms of efficiency, cost-effectiveness, and flexibility (Granello & Wheaton, 2004). The data collection process resulted in 98 survey respondents, supplemented by 12 interviews. Interviews were recognized as a valuable method for collecting primary data, and with adequate skills and resources, they can be a credible option for research (Mannan & AFNI, 2020). Both the surveys and interviews were conducted within the framework of multi-criteria analysis (MCA) to enhance and validate the findings by examining their consistency with existing literature. The MCA approach involved soliciting respondents' importance weights and judgments on the contribution of each factor to overall performance, thus applying a comprehensive MCA methodology.

Operationalisation: Variables, Indicators

The survey predominantly consisted of closed-ended questions for quantitative analysis, supplemented by optional open-ended questions to facilitate qualitative analysis. The survey encompassed sixteen questions covering personal information, level of cycling, ranking of personal factors influencing the decision to cycle, ranking of surroundings/place factors influencing the decision to cycle, and the identification of the most important factor and reasons behind it, along with additional comments. The survey instrument and interview guide can be found in Appendix 2. A total of 98 responses were obtained from the online surveys, indicating statistical significance but limited generalizability to the larger population. Nonetheless, the survey data remained interpretable, and statistical analysis was conducted.

In parallel, interviews were conducted with 12 women, providing an opportunity for participants to ask questions, elaborate on their responses, and discuss their experiences in a more open-ended format. The interview sessions allowed for in-depth discussions and further exploration of the research topic. Based on the allocated 30-day fieldwork period, a maximum of 15 interviews were planned, with one interview per day, leaving the remaining 15 days for transcription. The interview duration ranged from 15 to 30 minutes, with responses becoming repetitive in relation to the most important factors after the 10th interview. Therefore, only two additional interviews were conducted to ensure validity and conclude the data collection strategy.

Various communication channels, including social media posts, emails, and in-person flyers distributed at stores, libraries, and cafes, were utilised to approach survey respondents. However, operationalising the research encountered challenges due to limited connections in Rotterdam, hindering data collection efforts. Additionally, participation was restricted to individuals residing in Rotterdam, leading to a smaller pool of potential respondents. To address this limitation, flyers were posted across the city at different locations to compensate for the exclusion of participants from other cities.

To ensure data quality, several measures were implemented. The survey instrument underwent validation to assess clarity, relevance, and appropriateness, ensuring the effective capture of the intended variables. Pilot testing of the survey was conducted in two rounds with a small sample of women to identify any issues, misunderstandings, or ambiguities in the questionnaire. Additionally, rigorous monitoring of the data collection process was carried out to ensure data integrity and minimise errors. This involved regular reviews of the collected data for completeness and accuracy, identification of any missing or inconsistent responses, and resolution of any discrepancies or anomalies encountered during data collection.

The operationalisation process ensured the collection of reliable, valid, and objective data, enabling rigorous analysis and meaningful conclusions. It established a strong connection between theoretical concepts and empirical observations, providing a solid foundation for the research findings.

Operationalisation Table

Table 2 presents the operationalisation table, which outlines the various indicators associated with the person and place factors and aids in describing and defining the variables. The assignment of indicators to each factor group is based on the findings of the literature review. It is important to note that the categorisation of factors into specific groups is contingent upon the perspective adopted in this study, aiming to align with the ‘planner’s perspective’. The operationalisation of these indicators is accompanied by a description of the measurement methods employed to assess these indicators within the framework of the online survey and in the complimentary interviews.

In this research, the dependent variable is the level of cycling which is measured by kilometres cycled per week. The independent variables are the factors, split into people and place factors, including 16 variables; 9 pertaining to personal characteristics and 7 pertaining to place characteristics.

Table 2: Operationalisation Table (Source: Author)

Factor	Definition	Indicator/Variable	Measurement Method	Reference
Characteristics of the person	This refers to personal attributes, including socio-economic background of the person, to help understand the impact of these characteristics in women's participation in cycling and the decision to cycle. This group of factors also refers to the individual costs of cycling that are personal, and considers the position of personal health in explaining one's cycling. The nature of individual trips, specifically the trip purpose is an established factor. Other factors related to the trip nature are within the 'place' category as they change depending on the place, but the purpose changes more so based on individual circumstances.	Age	● 18 – 24 ● 25 – 34 ● 25 – 44 ● 45 – 54 ● 55 – 64 ● 65 years or older	● Zhang et al. (2020) ● Rietveld & Daniel (2004)
		Income Level	● Less than €25,000 ● €25,000 - €50,000 ● €50,000 - €100,000 ● €100,000 - €200,000 ● More than €200,000	● Zhang et al. (2020) ● Rietveld & Daniel (2004)
		Education Level	● (Some) high school ● MBO ● HBO ● Bachelor's Degree ● Master's Degree ● PhD or higher	● Zhang et al. (2020)
		Household Structure	● None ● 1 ● 2-4 ● More than 4	● Zhang et al. (2020)
		Trip Purpose	● Work/school ● Shopping/groceries ● Recreation ● Gym/fitness ● Transporting kids	● Zhang et al. (2020) ● Nobis & Lenz (2005)

			• Competitive • Social visits	
		Cultural/ethnic background (separate factors)	• European • Sub Saharan African • Middle Eastern/North African • Hispanic/Latino • South Asian • East Asian • Other • How long have you lived in Rotterdam? • Were you born in NL?	• Rietveld & Daniel (2004)
		Personal Costs	• Monetary • Physical/comfort • Time • Risk of injury/theft • Security	• Rietveld & Daniel (2004)
		Personal Health	Likert scale (10pt)	• Malchrowicz-Mośko et al. (2019) • Le et al. (2019)
Characteristics of the place	Characteristics of the place include details on the	Urban Road Safety	Likert scale (10pt)	• Zhang et al. (2020) • Krizek et al. (2009)

	perceptions and experiences of women of the trip itself, in terms of how the place contributes to the level of cycling. It also refers to other built environment factors including weather and topography. Lastly, overall environmental impact/climate change concern is considered and the nature of individual trips (distance and purpose).	(Quality and Capacity of) Infrastructure	Likert scale (10pt)	• Zhang et al. (2020) • Krizek et al. (2009)
		Weather	Likert scale (10pt)	• Zhang et al. (2020)
		Topography	Likert scale (10pt)	• Zhang et al. (2020)
		Environmental Impact/ Climate Change Concerns	Likert scale (10pt)	• Krizek et al. (2009)
		Trip Distance	Likert scale (10pt)	• Zhang et al. (2020) • Nobis & Lenz (2005)
		Trip Cost	Likert scale (10pt)	• Zhang et al. (2020) • Nobis & Lenz (2005)
Questions on the survey/interview guide pertaining to income level and education level had options of 'prefer not to say' to ensure respondents felt comfortable in completing the survey.				

Data Description and Implications

The data collected contains information from women of different age groups, ranging between 18 and 64 years old. The research only targets women because of the focus on gender equality in cycling and the feasibility of analysing data from one gender as opposed to two in the short timeframe. The survey was closed at 98 responses, and although it is below the sample size target, it is triangulated with data from 12 interviews and kept within the timeframe. The data was collected using the Qualtrics platform to create, distribute, complete and analyse the survey responses. Qualtrics is a research survey software that has been officially approved by Erasmus University Rotterdam (EUR) and complies to General Data Protection Regulation (GDPR) standards. The data collection was conducted by the researcher, both the survey distribution and conducting the semi-structured interviews. STATA was also used in combination with Qualtrics to obtain summary statistics and correlation coefficients, and conduct regression analysis.

The implications of this research method vary for both the surveys and interviews that make up the data collection. In terms of the surveys, the data's integrity did rely heavily on the honesty of respondents, which was difficult to ensure especially with online surveys. Therefore, there is potential for unreliable data. Another issue is that surveys are inflexible and there is no room to elaborate on answers and ask follow-up questions. Online surveys also only reach those with internet access, which means it was limiting the responses by disregarding the population without internet access. Lastly, because the questions were quantitative and closed-ended, it was difficult to interpret the sentiments behind the answers given. In terms of the semi-structured interviews, although they allowed for some issues to be resolved such as inflexibility, they posed other implications. Interviews were time-consuming and the ability to select participants, and 'ideal participants', created a level of bias in the sample.

Validity and Reliability

By employing a combination of surveys and interviews for the use of multiple perspectives, one can gain a comprehensive understanding of the factors explaining the level of cycling among women in Rotterdam. This use of multiple sources and methods helped achieve data triangulation to enhance the reliability and validity of the findings that were otherwise hindered by a low response rate. The responses collected were less than the target sample of 384 responses, mostly because of the time limitation and the restriction of women living in Rotterdam only. However, an adequately large dataset was still collected, allowing for statistical analysis. Further, by combining the stratified and purposive sampling method, the validity and reliability of the quantitative analysis conducted was enhanced.

To increase validity and reinforce findings, the in-depth interviews with female cyclists were supported by a MCA approach. A MCA approach helps to estimate importance weights and judge the contribution of each factor in overall performance (Dodgson et al., 2009). The surveys and interviews were guided by an underlying MCA to reinforce and reconfirm if the findings are corroborating literature or not.

Chapter 4: Results, Analysis and Discussion

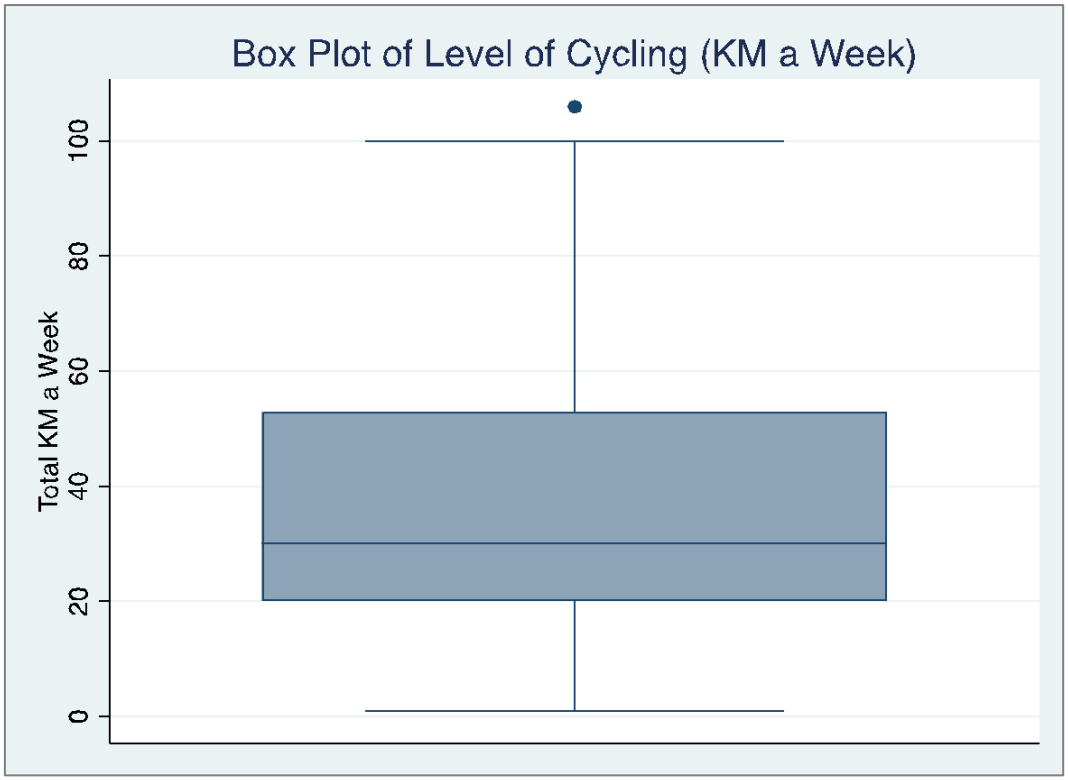
This chapter assumes a critical role within this research by presenting and interpreting the findings pertaining to the factors explaining women's cycling levels in Rotterdam. The primary objective was to comprehensively examine the collected data, conduct statistical analyses, and engage in a thorough discussion of the results. Through an exploration of the relationships between various variables and women's cycling behaviour, this chapter contributes to the existing body of knowledge concerning the factors influencing cycling patterns. The insights derived from this analysis hold significant implications for policymakers, urban planners, and other stakeholders invested in promoting sustainable transportation in Rotterdam and other cities worldwide.

To ensure a clear understanding of the analysis context, the chapter begins with a summary of findings from the descriptive analysis, followed by an overview of data quality. Next, inferential analysis is presented followed by an analysis of the key factors explaining the level of cycling among women using the data collected, and an interpretation of the results. By synthesising the findings, this chapter contributes to a deeper understanding of the complex dynamics that can explain women's cycling conduct in Rotterdam, ultimately informing the development of strategies and interventions to promote cycling as a sustainable mode of transportation for women in any city.

Summary of Findings from Descriptive Analysis

The survey data was exported from Qualtrics and imported to STATA, converting string variables to numeric where needed. After cleaning and importing the data, different functions were conducted in STATA to understand the statistical influence of each variable in the dataset.

The dependent variable in this research study was the level of cycling which is represented by the kilometres cycled per week. According to descriptive analysis, the average km cycled per week by women in Rotterdam, specifically participants of the survey, showed an average of 39.23 km/week. A visual breakdown of this dependent variable is provided in Graph 1. The maximum amount of cycling a female does in a week, from the sample of survey respondents, was 106 km/week which included cycling for leisure purposes. The trip purposes with the most amount of km assigned to them included ‘commuting to work/school’ which has an average value of 9.43km, followed by ‘social visits’ (7.39km) and ‘leisure’ (6.84km). A median of 30km for the variable ‘level of cycling’ indicated that half of the participants reported cycling less than or equal to 30 km per week, while the other half reported cycling more than 30 km per week. Therefore, a median of 30 km per week suggests that it represents an average level of cycling among the study participants. The range of the data was 105km, suggesting that the participants in the study reported a range of cycling distances, with the maximum value being 105 km more than the minimum value (1km). The range provides a simple measure of the spread in the data, highlighting the variability among the study participants.



Graph 1: Box Plot of Level of Cycling (KM a Week) (Source: Author using STATA)

To examine the extent of cycling participation among women in Rotterdam, a descriptive analysis was conducted. The dataset encompassed information regarding the frequency or duration of cycling activities for a representative sample of women in the city. The analysis revealed that the mean ($\bar{x}$) level of cycling among these women was 39.23 km/week. With a standard deviation of 28, the data demonstrated a moderate level of variability in cycling levels among the women. This suggests that the data points were dispersed around the mean value ($\bar{x}$), indicating that some women engaged in cycling activities at levels higher or lower than the average. These findings underscore the presence of heterogeneity in the level of cycling among women in Rotterdam, indicating a notable range of values. Further analysis, considering factors such as age, socioeconomic status, and infrastructure, may be necessary to gain deeper insights into the factors influencing the variation in cycling levels among women in the city.

A noteworthy group of observations in the dataset pertained to the postcodes representing the geographical locations of the respondents across different neighbourhoods of Rotterdam. To visualise this distribution, a map was generated using QGIS (Figure 8). The map highlights the principal neighbourhoods where the participants reside, mainly inclusive of Kralingen, Stadsdriehoek and Blijdorp. A key finding of this map was that the majority of participants lived in the upper-class area of Kralingen, where the highest income groups are concentrated (Karsten, 2007). This means the findings may be biased to those with higher incomes and better facilities/infrastructure available. From the map it was evident that there were no participants from the south of Rotterdam, which indicates a limitation of the data in not encompassing women residing in significantly diverse neighbourhoods in the city. The research does not address the cycling behaviours of the south which might differ because of a lack of infrastructure or it being a lower-class area (Karsten, 2007).

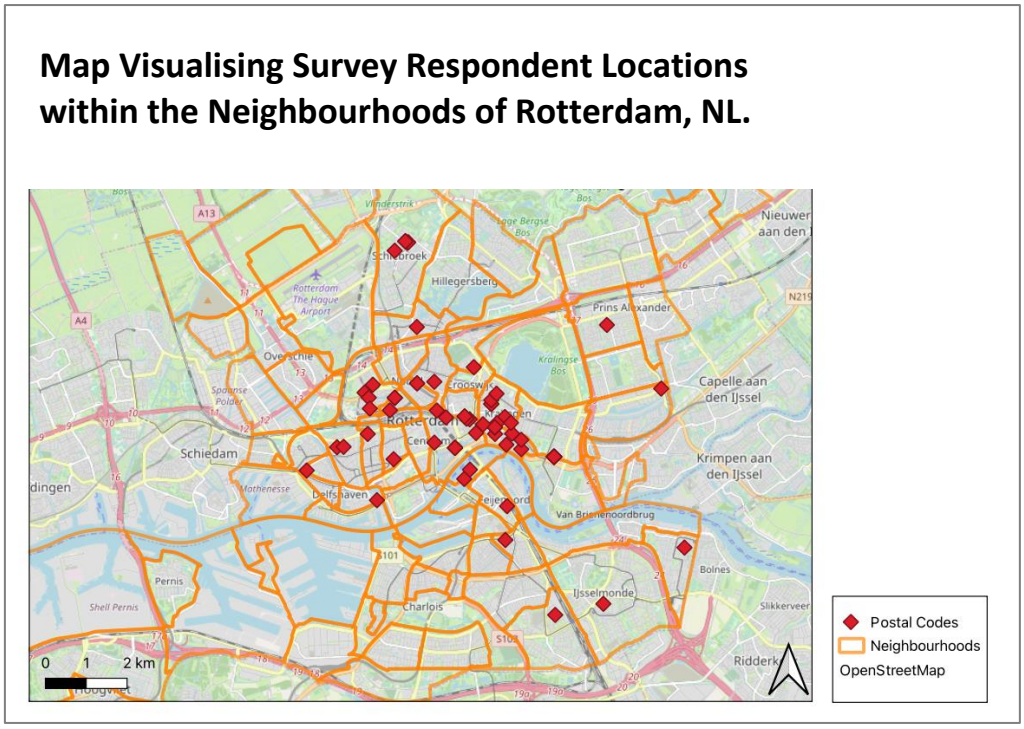


Figure 8: Map visualising Survey Respondent Locations within the Neighbourhoods of Rotterdam (Source: Author using QGIS)

Summary statistics were generated for the independent variables to understand which have the highest means. According to the statistical analysis, urban road safety has a mean ($\bar{x}$) of 7.15, infrastructure has a mean ($\bar{x}$) of 7.46, trip cost has a mean ($\bar{x}$) of 6.56, personal costs has a mean ($\bar{x}$) of 5.31 and personal health reasons has a mean ($\bar{x}$) of 5.15. These factors have the highest mean values among all the variables and the means help to represent the average values of those variables. This highlights where the bulk of the data points are located, wherein in this case most data points are under the safety, infrastructure, trip and personal costs, and personal health reasons to explain the level of cycling among women in Rotterdam. These factors are the highest ranked among all variables and are therefore important to women in Rotterdam in explaining their level of cycling. This is supported by data from interviews which discuss urban road safety as a "concern" and "very important". Furthermore, one respondent actually finds that personal health reasons are key and "I cycle because it keeps me healthy, I do it for health".

The results of the descriptive analysis indicated that the largest age group among the participants was the 25-34-year-old category, comprising 45% of the sample with 44 observations. The 18-24-year-old age group accounted for 34% of the sample with 33 observations. In contrast, both the 35-44-year-old and 45-54-year-old age groups each represented 7% of the sample, with 7 observations for each category. The 55-64-year-old age group had the fewest respondents, comprising only 6% of the sample (6 observations) (Chart 2). It is important to note that due to the limited generalizability of the data, it cannot be assumed that the majority of female cyclists in Rotterdam belong to the 25-34-year-old age group. Nevertheless, it is worth highlighting that as the age group increased (35-44, 45-54, and 55-64-year-old), the importance of the personal health factor became more prominent, resulting in a higher ranking of personal health among the participants. This suggests that personal health considerations gain significance as women's age increases within these age groups, influencing their cycling preferences.

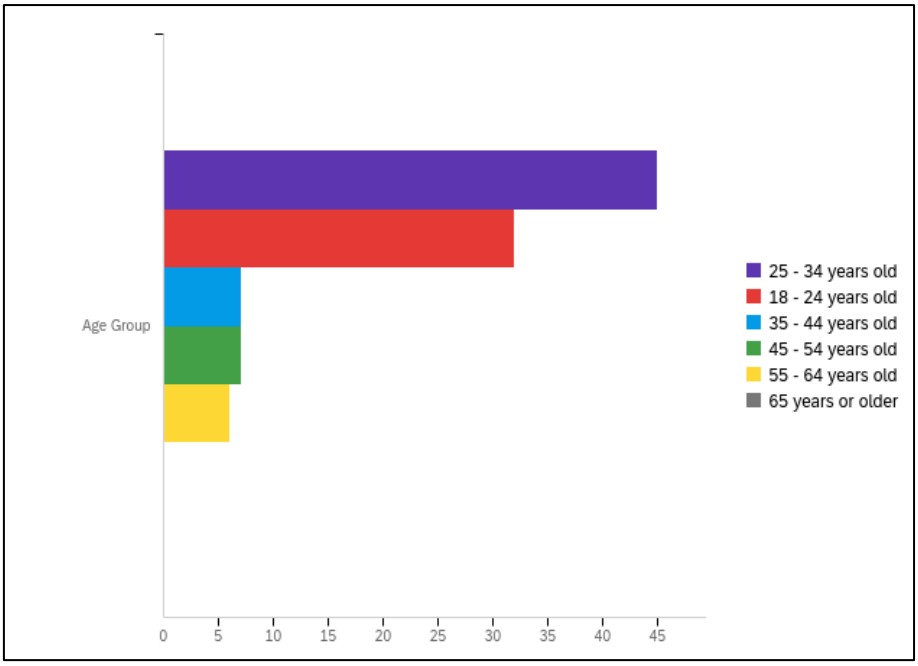


Chart 2: Bar Chart depicting Age Groups of Survey Respondents (Source: Author using Qualtrics)

The dataset included information on variables including ethnicity, place of birth, and whether women had children. The largest ethnic group in the sample was European (56%), comprising a significant proportion of the participants. This demographic composition suggests that the study population is diverse, allowing for potential variations in cycling behaviour across different ethnic backgrounds (Chart 3).

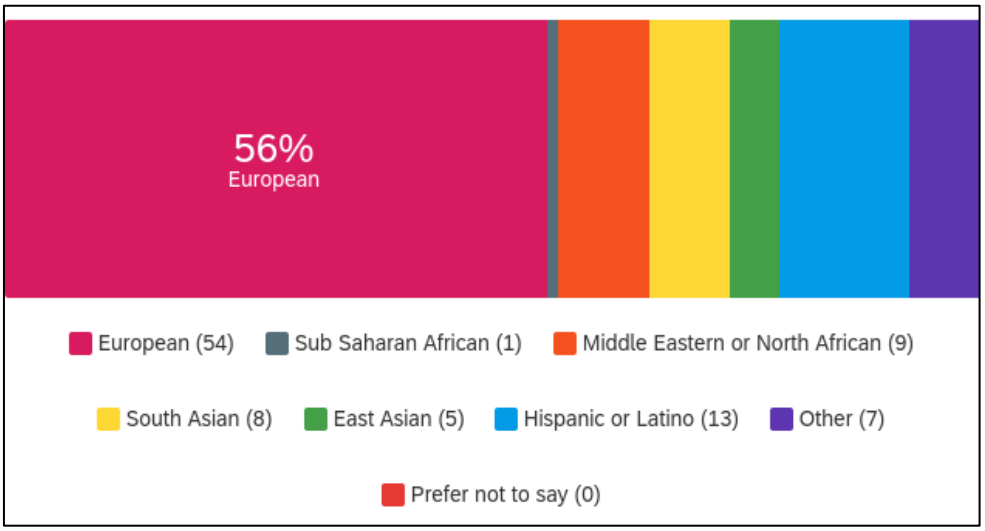


Chart 3: Chart depicting the Ethnicities of Survey Respondents (Source: Author using Qualtrics)

Furthermore, the data revealed that a substantial majority, 71% of the participants, were not born in the Netherlands (Chart 4). This finding suggests the presence of an international population in Rotterdam, which may influence cycling patterns due to cultural and contextual factors specific to each individual's country of origin. This was further shown through the complimentary interviews in which respondents from countries such as India and Brazil

discussed the cultural influence in Rotterdam. For instance, interviewee 11 stated that “The environment pushes it more than the cycling itself so I think one of the main reasons why women are not biking as much in Brazil is because of the urban safety”. Similarly, interviewee 9 said that “In India, biking is more of a recreation thing and women at large may not wear clothing that's very comfortable for bikes, it's also just a cultural thing. There's lots of hills so that makes it harder. Plus, the fact that it's a hot country, you basically get really sweaty. You do bike, but I think the biggest reason not doing it is the safety concern”. Therefore, safety is a big factor and the place or country is a big determinant of that.

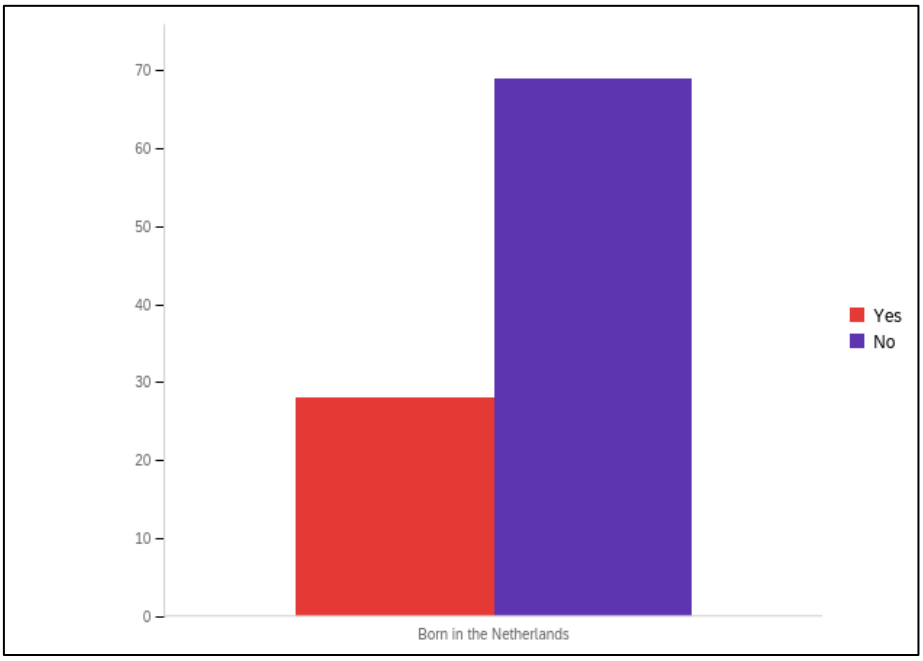


Chart 4: Bar Chart of Survey Respondents Born in the Netherlands (Source: Author using Qualtrics)

It is noteworthy that among the 97 observations, only 17 women reported having children. This indicates a relatively small proportion of women with children in the sample, which could have implications for their level of cycling. Understanding the reasons behind this low representation of women with children in the dataset could provide insights into potential barriers or facilitators to cycling among this specific subgroup. However, among those who do have children, they reported that their level of cycling was not impacted by having children and that it remains as convenient as before. Respondents of the survey expressed that "it’s very easy” and “still very convenient”. Respondents wrote in the survey that “we use it a lot so it has a big impact” showing the positive influence of cycling with children. Some respondents wrote that they are now “more aware” and “more aware of the rules”, however it was the commonality of cycling with children that was important to women. Respondents wrote that “by taking to school by bike, you want to show them that that way in common, not by car”. Interviewee 5 supported the claim of cycling with children as not an issue when saying that “you get used to it”. Therefore, cycling with children was not seen as a negative issue or decreasing levels of cycling among women. If anything, it was seen as an act of independence. As interviewee 12 stated, “for me, a bike is also really related to your sense of freedom and independence, and not having to depend on other people”.

This was further influenced by it being “normalised and accepted”, wherein the word “freedom” was used by 4 different interviewees. Clearly, the sense of freedom from cycling

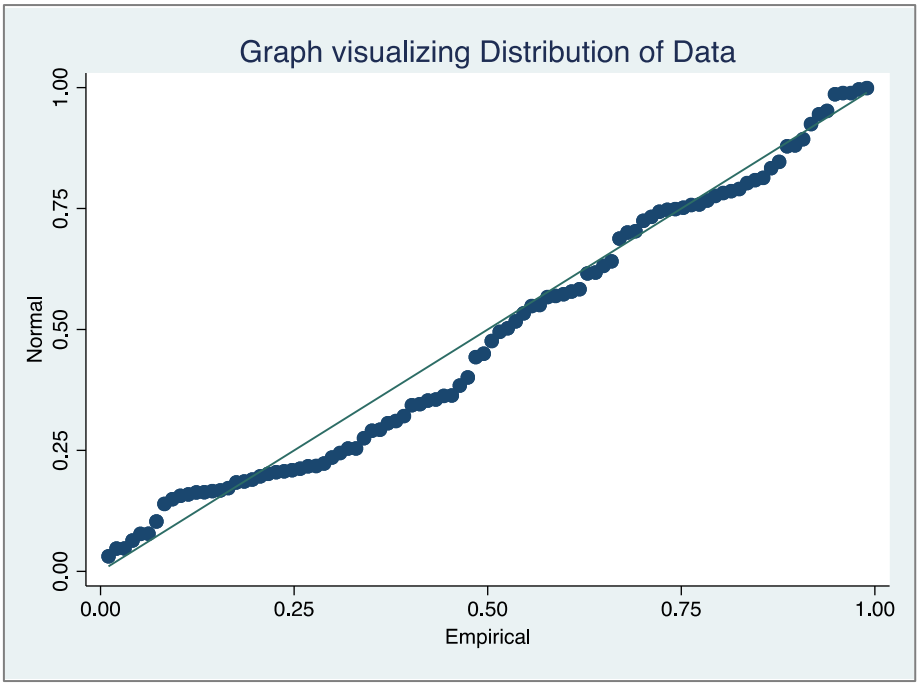
and the associated convenience and independence makes a great difference for women. When asked whether this could be replicated in other countries, most respondents believe it can be but that it depends on the physical environment followed by the personal attributes. However, cities can learn from Rotterdam and the Netherlands in general in terms of infrastructure and safety, which are such big concerns for women. By learning about safety in the Netherlands, gender equality in cycling can slowly be achieved because "it is definitely the future, especially considering climate change" (Interviewee 12).

Given these unique characteristics of the population, further analysis is needed to explore the factors that explain the level of cycling among women in Rotterdam. Potential variables of interest may include personal characteristics (e.g., age, income, education), and place factors (e.g., infrastructure, safety, weather). By investigating these factors, it will be possible to gain a deeper understanding of the determinants of cycling behaviour among women in Rotterdam, considering the diverse ethnic composition, international background, and the relatively small representation of women with children in the dataset.

Quality of Data

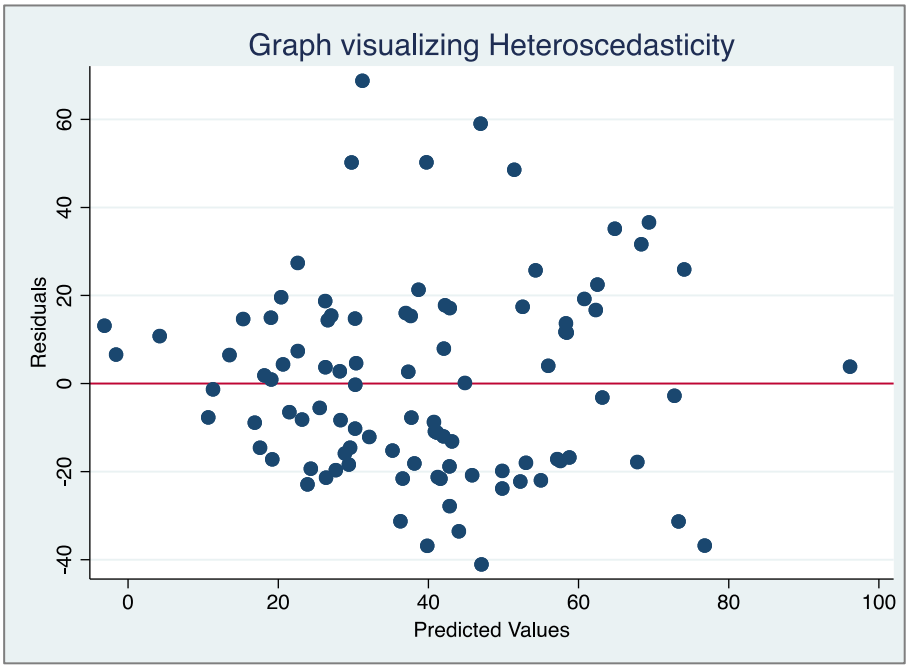
Ensuring the accuracy and reliability of results in regression analysis heavily relies on the quality of the collected data. Meeting the basic regression assumptions is essential in this regard, as these assumptions help guarantee that the inferences and predictions drawn from the analysis are valid. By adhering to these assumptions, researchers can effectively enhance the data quality and bolster the robustness of their findings. The three regression assumptions (normality, homoscedasticity and absence of multicollinearity) analysed in the context of this research were presented by Irfan (2023).

By ensuring that these basic regression assumptions are met, researchers can enhance the quality and reliability of their data analysis. Adhering to these assumptions helps to ensure that the results and conclusions drawn from the regression model are valid, enabling accurate inferences and reliable predictions. The first assumption states that residuals must be normally distributed. This is tested by creating a new variable with the regression residuals, which uses the 'predict' command in STATA followed by 'summarise' to determine the distribution. The skewness value is 0.69 which is sufficiently close to 0, suggesting that the residuals are indeed normally distributed. This is contradicted by the kurtosis value of 3.38 which is above 3 and could mean an abnormal distribution. However, as it is sufficiently close to 3, the variable can be considered as somewhat normally distributed. Based on the standardised normal probability plot (Graph 2), the plotted points are close to the straight line which means it is more likely for the variable to be normally distributed.



Graph 2: Graph visualising the Distribution of Data (Source: Author using STATA)

Secondly, examining heteroscedasticity is another regression test assuming violation of constant variance. This means that the variability in our outcome variable changes as the independent variable increases to show a violation, or not, of the homoscedasticity (constant variance) assumption. For this test, the null hypothesis presumes homoscedasticity/constant variance. Since the p-value for heteroscedasticity is more than 0.05 (0.45), the null is not rejected and therefore, heteroscedasticity is not present. This is further visualised by plotting the residuals and predicted outcome variable on a graph. Graph 3 highlights that residuals of the regression with higher fitted values do not adopt a greater variance, which means heteroscedasticity is not a problem in this regression.



Graph 3: Graph visualising Heteroscedasticity (Source: Author using STATA)

Testing for multicollinearity is the final regression assumption that contributes to the quality of the data by assuming that multicollinearity is not present. This means understanding if the independent variables in a regression are correlated. After running correlation and determining the VIF, the mean VIF is equal to 1.73 which is greater than 1, showing there is evidence of multicollinearity. Therefore, multicollinearity is present in the dataset and can lead to large standard errors and mislead a coefficient as statistically insignificant when it is significant in reality.

Ultimately, the data does not show violation of constant variance and is normally distributed, meaning the data is suitable for multiple regression. The probability plot supports this by showing plotted points close to a straight line (Graph 1). The p-value for heteroscedasticity is more than 0.05, meaning it is not present in the dataset. However, the independent variables in the regression are somewhat correlated to one another, meaning that multicollinearity is present and it is a problem. This issue could be mitigated by dropping certain independent variables from the regression to reduce the VIF values for the other variables, however this is not done to keep the validity of the data. Generally, the regression assumptions are mostly satisfied and the data can be held to a medium standard of quality. However, certain variables can and should be dropped to solve the issue of multicollinearity in the dataset.

Inferential Analysis

A rigorous regression analysis was conducted to explore the relationships between the independent variables and the dependent variable of kilometres cycled per week. The results of this analysis, including coefficients and p-values, provide crucial insights into the magnitude and significance of these relationships. According to data analysis, the factors most important to women include the urban road safety, the quality and quantity of infrastructure, trip costs, personal costs and personal health reasons. This shows a combination between place and person characteristics and how the interaction of both can make up the positive cycling of a city. Although these factors are highly ranked among participants, the regression analysis (Table 3) showed that weather conditions and income level are other factors of statistical significance with the level of cycling.

Key Factors Explaining the Level of Cycling among Women

Summary statistics were calculated because it clearly shows means ($\bar{x}$) and other descriptive statistics. After running summary statistic functions on all variables, the following factors were found to have the highest averages of all variables in which the mean shows the average value of the variable and represents the central tendencies. This shows that they were ranked higher than others, making them the key factors in explaining the level of cycling. Three factors were taken from the ‘place’ category’, and two from the ‘person’ category. The level of cycling among women in Rotterdam can be influenced by various factors, as indicated by the regression analysis conducted on kilometres cycled per week (Table 3). Key factors that were examined include income level, personal health reasons, personal costs, urban road safety, infrastructure, trip cost, and weather.

Table 3: Regression Analysis (Source: Author using STATA)

Source	SS	df	MS		
				Number of obs	= 96
				F(16, 79)	= 3.46
Model	32275.1586	16	2017.19741	Prob > F	= 0.0001
Residual	46024.7476	79	582.591742	R-squared	= 0.4122
				Adj R-squared	= 0.2932
Total	78299.9063	95	824.209539	Root MSE	= 24.137

KMaweek	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
IncomeLevel	2.435527	.9725965	2.50	0.014	.4996218	4.371432
EducationLevel	-.0921848	1.076143	-0.09	0.932	-2.234193	2.049823
HouseholdStruc	-.6335572	.9270609	-0.68	0.496	-2.478826	1.211711
CulturalInfluences	-1.072627	.8052642	-1.33	0.187	-2.675465	.5302116
EthnicOrigin	-.1768757	1.022639	-0.17	0.863	-2.212387	1.858636
PersonalCosts	1.019194	.9043998	1.13	0.263	-.780969	2.819356
Age	.467291	.943367	0.50	0.622	-1.410434	2.345016
TripPurpose	-.1381199	.7795783	-0.18	0.860	-1.689832	1.413592
PersonalHealth	1.488783	.9427389	1.58	0.118	-.3876922	3.365257
UrbanRoadSafety	2.965955	1.518347	1.95	0.054	-.0562395	5.98815
Infrastructure	-.9123927	1.617099	-0.56	0.574	-4.131149	2.306363
Weather	-4.568432	.9849655	-4.64	0.000	-6.528957	-2.607907
Topography	-.6415395	1.046804	-0.61	0.542	-2.72515	1.442071
EnvImpacts	.7432286	.9027065	0.82	0.413	-1.053564	2.540021
TripCost	-1.465293	1.06712	-1.37	0.174	-3.589342	.6587569
TripDistance	-.1812971	1.105114	-0.16	0.870	-2.380972	2.018377
_cons	47.6955	10.49728	4.54	0.000	26.80119	68.58981

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_i X_i$$

Y_i = KMaweek (level of cycling: dependent variable)
β_0 = Intercept
β_1 = Slope for X_i
X_i = Independent variable (IncomeLevel, PersonalHealth, etc.)

$$Z = \frac{\underline{X} - \mu}{\sigma}$$

Z = Z-score
$\underline{X}$ = Sample mean
μ = Population mean
σ = Standard deviation

The multiple linear regression analysis used the equation listed above to calculate coefficients. The p-values listed were calculated using the other equation provided above. The analysis revealed that even though income level did not have a high mean in terms of the ranking by respondents, the variable has a significant positive effect on the level of cycling, as indicated by a coefficient of 2.435527 and a p-value of 0.014. This suggests that higher income levels are associated with increased kilometres cycled per week among women in Rotterdam. Similarly, personal health reasons were also found to have a positive effect with a coefficient of 1.488783, although not statistically significant since the p-value is above 0.05 at 0.118. While the p-value does not reach conventional levels of significance, the coefficient suggests

that personal health reasons play a role in promoting cycling among women, although further research may be needed to establish a stronger relationship.

While personal costs had a high ranking among respondents in terms of importance for their level of cycling, this factor was not found to have a significant effect on the level of cycling, as indicated by a coefficient of 1.019194 and a p-value of 0.263. This suggests that the costs associated with cycling, including monetary, time, risk of injury/theft and personal security, do not have a substantial impact on women's cycling behaviour in Rotterdam. Further, infrastructure and trip cost did not show significant effects on the level of cycling among women in Rotterdam. The infrastructure p-value of 0.574 suggests that the relationship between infrastructure and level of cycling is not statistically significant. Similarly, trip cost did have a negative coefficient of -1.465293, but its p-value of 0.174 indicates that it is not statistically significant. Although, correlation coefficients show it has a strong correlation with income level (0.54). Another somewhat strong correlation is between trip distance and weather (0.42) showing a somewhat strong relationship (refer to Appendix 3 for STATA outputs including a correlation table). The coefficient for weather of -4.568432 signifies that unfavourable weather conditions are associated with lower levels of cycling, and the p-value of 0.000 suggests a strong statistical significance. Therefore, even though weather was not ranked highly, it does have strong statistical significance and can be seen as an indirect factor.

Lastly, urban road safety was found to have a positive effect on the level of cycling. While not statistically significant, with a p-value of 0.054, the coefficient of 2.965955 implies that better urban road safety conditions tend to be associated with higher levels of cycling among women, although the statistical significance is marginal. Overall, income level, personal health reasons, weather and urban road safety emerge as significant factors explaining the level of cycling among women in Rotterdam. These findings suggest that policies and interventions aimed at improving income levels, promoting personal health benefits, enhancing urban road safety and education on cycling in unfavourable weather could potentially increase cycling participation among women in the city. However, further research is needed to explore the influence of other factors and to establish stronger causal relationships between these variables and cycling behaviour.

Additional Regression Model Measure

$$RSME = \sqrt{\sum_{i=1}^{n} \frac{\left(\hat{Y}\imath - Yi\right)^2}{n}}$$

$$R^2 = 1 - \frac{RSS}{TSS}$$

$$Adjusted\ R^2 = 1 - \frac{(1 - R^2)(N - 1)}{N - \rho - 1}$$

In addition to the coefficient estimates and p-values, several ‘goodness-of-fit’ measures were calculated to assess the overall performance of the regression model explaining the level of cycling among women in Rotterdam. The calculations used the above equations to determine the values. The root mean squared error (RMSE), R-squared (r^2), and adjusted R-squared (r^2-

adj) were calculated. The RMSE of the regression model was found to be 24.137. This value signifies the average difference between the observed values and the predicted values from the regression model. A lower RMSE suggests a better fit of the model to the data, indicating that the model's predictions are closer to the actual observed values. The R-squared value, also known as the coefficient of determination, was calculated to be 0.4122. This value represents the proportion of the variance in the dependent variable (kilometres cycled per week) that can be explained by the independent variables included in the regression model. In this case, approximately 41.22% of the variation in the level of cycling among women in Rotterdam can be explained by the variables included in the model.

Finally, the r^2-adj value was calculated at 0.2932. The r^2-adj takes into account the number of variables in the model and adjusts the R-squared value accordingly. It provides a more conservative estimate of the model's explanatory power by penalising the inclusion of additional variables. In this analysis, the r^2-adj of 0.2932 suggests that around 29.32% of the variation in the level of cycling among women in Rotterdam can be attributed to the independent variables in the model, after accounting for the number of variables included.

These 'goodness-of-fit' measures provide an assessment of how well the regression model fits the data and explains the variability in the level of cycling among women in Rotterdam. While the r^2 value of 0.4122 suggests a moderate level of explanatory power, the r^2-adj of 0.2932 indicates that there may be other factors beyond the variables included in the model that contribute to women's level of cycling. The RMSE of 24.137 indicates the average prediction error of the model. Further research and exploration of additional variables may be needed to improve the model's performance and capture a greater proportion of the variability in women's cycling behaviour in Rotterdam.

Interpretation of the Results

The survey data, consistent with the interview findings, revealed that a combination of place and person characteristics best explains the level of cycling among women in Rotterdam. This conclusion is supported by the results of the regression analysis conducted on the dataset. The analysis highlights the significance of income level, personal health reasons, urban road safety, and weather conditions as factors influencing the kilometres cycled per week by women in the city.

The statistically significant coefficient of 2.435527 for income level suggests that higher income was associated with increased cycling levels. This indicated that women with higher incomes tend to engage in more cycling activities per week compared to those with lower incomes, underscoring the role of economic factors in promoting cycling among women in Rotterdam. While not statistically significant in this study, personal health reasons exhibited a positive coefficient of 1.488783, indicating that women who prioritise personal health are more likely to engage in cycling. Although further research is needed to establish statistical significance, this coefficient suggests a potential relationship worthy of exploration.

Urban road safety also demonstrated a positive coefficient of 2.965955, although without statistical significance at conventional levels. This implies that better urban road safety conditions are generally associated with higher levels of cycling among women. The lack of statistical significance suggested the possibility of other unaccounted factors influencing the relationship between road safety and cycling levels among women. Lastly, the coefficient for weather of -4.568432 signified that unfavourable weather conditions were associated with

lower levels of cycling. The strong statistical significance indicated by the p-value of 0.000 highlights the robustness of this finding. Factors such as personal costs, infrastructure, and trip cost did not demonstrate statistical significance for the level of cycling among women in Rotterdam. This suggests that these factors may have limited influence on women's decision to engage in cycling activities.

In answering the research question of which factors explain the level of cycling of women in Rotterdam, the findings identified several key factors. The analysis revealed that income level, personal health reasons, urban road safety, and weather conditions significantly influence the kilometres cycled per week by women in the city. These determinants shed light on the factors that promote or hinder women's engagement in cycling. In terms of safety specifically, the results indicated that urban road safety played a significant role in influencing the level of cycling among women in Rotterdam. While the statistical significance of the relationship between road safety and level of cycling was not achieved, the positive coefficient suggests that better road safety conditions tend to be associated with higher levels of cycling. Thus implying that creating safer cycling environments, including dedicated cycling lanes, traffic calming measures, and awareness campaigns, can contribute to increasing women's participation in cycling and promoting gender equality in cycling.

Similarly, in terms of if socio-demographic background determines the level of cycling, research revealed that income level significantly influences the level of cycling among women in Rotterdam. Women with higher incomes tend to engage in more cycling activities per week compared to those with lower incomes. This highlights the importance of considering socio-demographic factors, such as income level, in understanding and addressing gender inequalities in cycling. However, other socio-demographic factors such as ethnicity, education, and age were not specifically addressed in the provided information and require further investigation.

The literature review mentioned the importance of safety, infrastructure and socio-demographic background. While the regression analysis does confirm that safety is a statistically significant factor, it does not support the claims of infrastructure and socio-demographics being crucial in explaining women's cycling. However, infrastructure is highly ranked among survey respondents which shows that it may have some influence. The socio-demographic characteristic of income level does have statistical significance and further investigation is required to understand the importance of socio-demographic background. Therefore, the frameworks discussed in the literature review (Zhang et al, 2020; Rietveld & Daniel, 2004; Krizek et al., 2009) are significant and supportive of the findings. This is shown through the frameworks highlighting safety and physical environment, which is a key finding of this statistical analysis. The emphasis on socio-demographic background is also highlighted in this research by the statistical significance of income levels. Therefore, the frameworks from literature do support the findings. The conceptual framework developed specific to this research (Figure 6) is also helpful in describing the factors explaining level of cycling and highlights the different factors that can interact to lead to an increased level of cycling among women.

The hypothesis specific to this research is that the level of cycling among women is influenced by a combination of person and place factors, specifically inclusive of urban road safety and socio-demographic background being key factors in explaining the level of cycling. This hypothesis is tested through statistical analyses and it was found that urban road safety, income level, personal health reasons and weather are key factors in explaining gender equality in cycling participation. Therefore, it is not just the person or place that influences women's

participation in cycling, but rather a mix of person and place factors that contribute to gender equality in cycling (Figure 9).

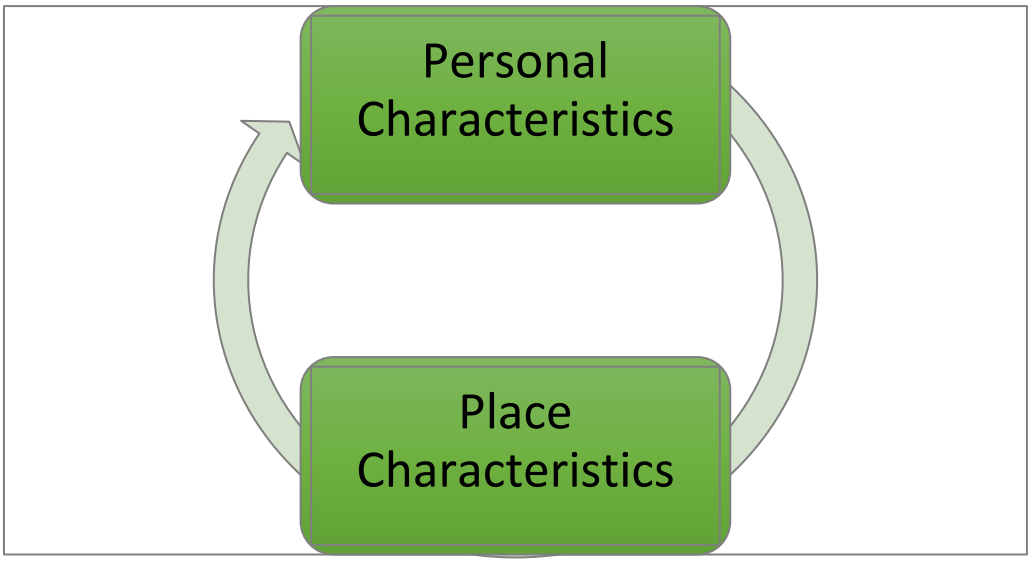


Figure 9: The Factors Contributing to Women's Participation in Cycling (Source: Author)

Overall, the results of the regression analysis provide insights into the factors explaining the level of cycling among women in Rotterdam. Income level, personal health reasons, and urban road safety and weather emerged as significant factors, highlighting the importance of economic factors, health motivations, and safe cycling environments in promoting cycling among women. The findings contribute to the understanding of the complex dynamics that shape women's cycling behaviour and can inform policymakers and urban planners in designing interventions to encourage and support cycling among women in Rotterdam and other similar cities.

Chapter 5: Conclusions

The factors explaining the level of cycling among women in Rotterdam are divided into two categories: characteristics of the person and characteristics of the place. This unique framework employs a 'planner's perspective' that uses urban planning theories to explore gender equality in cycling in the Netherlands through the people versus place lens. The results from the research showed the importance of both perspectives and how the interaction between person and place characteristics work together to improve the level of cycling among women in a city. The significance of one's income level, personal health reasons combined with safety, weather conditions and the importance of infrastructure, trip costs and personal costs highlighted the combination of factors and the need to encourage cycling through both the place/physical environments as well as the personal attributes.

Research regarding the factors explaining the level of cycling among women is crucial in explaining cycling among women in the Dutch context, who actively engage in cycling for the promotion of gender equality. The uniqueness of a planner's perspective allowed us to analyse the factors in combination and not as individual aspects. It is the combination and interplay between characteristics of both the place and the person that contributes to the level of cycling among women in a city. However, the low response rate did not allow the findings to be very generalizable, which means further research is required in order to ensure representation of all women who cycle in Rotterdam. By exploring different reasons that explain levels of cycling, the study showed the factors that can influence and make a difference for women in promoting equitable cycling participation and enhancing gender equality in cycling. Cycling should be available and accessible to all people in a city, similar to the availability in Rotterdam for all genders.

Societal and Scientific Contributions

This research study has several societal and scientific contributions that can positively impact various stakeholders, sustainability goals, and betterment for the community as a whole. The study also makes numerous scientific contributions that advance existing knowledge in the field of sustainable mobility and gender equality in cycling and explain cycling among women. First, societal contributions are outlined followed by explanations of the scientific contributions. Next, limitations of the study are presented. Lastly, recommendations are provided and suggestions for future research.

The findings can inform the development of targeted interventions and policies aimed at increasing women's participation in cycling, thereby reducing reliance on motorised vehicles and contributing to a more sustainable urban environment. This could be targeted cycling infrastructure improvements that are well-maintained and well-connected to encourage female cyclists. The research also sheds light on the specific barriers and facilitators that influence women's cycling patterns. By understanding these factors, urban planners can design infrastructure, programs, and initiatives that address the unique needs and concerns of women cyclists. This promotes gender equality and inclusivity in transportation planning, ensuring that cycling infrastructure and policies are accessible and accommodating for all members of society. This can be done by encouraging cycling among women and explaining the significant health benefits. By promoting active transportation options like cycling, this research supports public health initiatives by providing evidence of the positive impact of cycling on physical fitness, cardiovascular health, and mental well-being. These initiatives can include educational campaigns that raise awareness about the health benefits of active transportation. They can also

provide resources and support for individuals to incorporate walking and cycling into their daily routines, such as offering cycling maps and organising community events like biking challenges.

Overall, this research contributes to the broader societal goals of promoting sustainable transportation, gender equality, public health, environmental conservation, and improved urban planning. By addressing the specific challenges and opportunities related to women's cycling, this research has the potential to drive positive changes in transportation policies, infrastructure development, and societal attitudes towards cycling, ultimately benefiting the entire community through the income levels, personal health reasons/concerns, safety concerns, weather and the possible factors of infrastructure, trip cost and personal costs.

The research also has many scientific contributions. By conducting a rigorous analysis, the study contributes to scientific literature by providing quantitative insights into the factors explaining women's level of cycling. This research focuses specifically on women's cycling, filling a gap in the literature that often lacks gender-specific analyses. By examining the factors influencing women's cycling patterns, the study offers insights into the unique challenges and opportunities faced by women in engaging in cycling as a mode of transportation. The research also contributes to the methodological approaches used in studying cycling behaviour. By employing a quantitative analysis, specifically regression analysis, the study demonstrates the utility of statistical techniques in understanding the complex relationships between variables.

Overall, the scientific contributions of this research lie in the empirical evidence, gender-specific insights, identification of key factors, methodological approach, and generalizability of findings. These contributions advance the scientific understanding of factors explaining the level of cycling among women and provide a foundation for further research and development of evidence-based interventions and policies aimed at promoting sustainable and gender-inclusive transportation systems.

Limitations and Suggestions for Future Research

The main limitation was the less than ideal number of respondents. Although the target sample size of 384 was calculated to account for a generalizable population of women who cycle in Rotterdam, because of the limited time frame the target number was not met. Further, the population used to calculate the sample size was taken from the entire population of women who live in Rotterdam. This limitation could have been improved with specific numbers on the population of women who cycle in Rotterdam. Another limitation of the study is the restriction of research to just women. This meant that data collection was restricted and made it harder to find participants. Due to the focus on only women, the research had a one-angled focus that could have been very interesting if compared to the other perspective, in this case the perspective of men living and cycling in Rotterdam.

To build upon this research, future studies could expand the scope by incorporating a larger and more diverse sample. It could explore additional factors such as social norms, and employ more qualitative research methods to gain insights into the experiences and perceptions faced by women in relation to cycling. By employing a quantitative analysis, particularly regression analysis, the study demonstrated the utility of statistical techniques in understanding the complex relationships between variables. The methodology employed can serve as a foundation for future studies investigating factors influencing women's cycling behaviour and can guide researchers in designing appropriate data collection and analysis strategies.

Future research could delve deeper into the relationship between cycling among women and personal health reasons, exploring specific health benefits that resonate with women, potentially providing insights for targeted promotional campaigns and initiatives. Another key finding is the statistical significance of the income level. This finding emphasises the need for policies and interventions that address income disparities and promote affordability and accessibility to bicycles and cycling infrastructure for all socioeconomic groups.

Future research should also consider repeating this study but specifically with ethnicity in mind and how ethnicity explains the level of cycling. Considering the diversity of Rotterdam, it would be interesting to investigate the ethnicity factor further by targeting only those with a different cultural background/ethnicity. Many women in Rotterdam did not cycle in their home country, but cycle here. Future research could look at why that is the case and provide a unique aspect on the gender equality in cycling that is present in the Netherlands. This can also be the case with a target population of mainly mothers and/or parents by exploring their duties, role and how that is influenced by cycling. This can explain the impacts of having kids on one's level of cycling to improve rates among mothers and children. Cycling from a young age is common in the Netherlands, positively influencing freedom from a young age. This encourages independence regardless of legal driving age or monetary costs of public transport.

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Appendix 2: Survey/Interview Guide

Information sheet and consent form

Information sheet

Introduction
My name is Samha and I'm a master's student at IHS, Erasmus University Rotterdam. The Netherlands is one of few countries without the typical gender gap in cycling where men cycle more than women. In fact, it is more balanced here! The purpose of my study to understand why this is the case and what factors encourage women to cycle here to inform the participation of women in other countries. If you'd like to contact me, you can email me at samha.alam@gmail.com.

Data collection
The survey is made up of open and closed questions including information about your level of cycling and purposes of your bike trips, and then questions about personal factors that influence your decision to cycle followed by questions about your surroundings that influence your decision to cycle. The interviews will be recorded and transcribed, and I will also collect survey responses.

Potential inconvenience & risks
There are no physical, legal or economic risks associated with your participation in this study. It is not mandatory to answer all questions. Your participation is voluntary and you can stop at any time.

Confidentiality & data protection
The collected data will be used for an aggregated analysis and the only confidential information or personal data that will be included in the research outcome, should participants share that information which is completely voluntary, is the postal code. The data will be kept completely anonymous. The data is stored in a secure location and will be kept for 1 year.

Data sharing
I will share the data with Somesh Sharma for the purpose researching and writing my master thesis mandatory for completion of my studies at the Institute of Housing and Urban Development Studies at Erasmus University Rotterdam.

Voluntary participation & individual rights
Your participation is voluntary and you can stop at any time. When you participate in the research, you have the rights to request more information about the data collection, analysis or withdraw the consent and ask data erasure before the dataset is anonymized or manuscript submitted for publishing. You can exercise your rights by contacting Samha Alam.

If you have any complaints regarding the processing of personal data in this research, please contact Samha Alam.

Consent form *Tracing Cycling among Women*

Upon signing of this consent form, I confirm that:

- I've been informed about the purpose of the research, data collection and storage as explained in the information sheet;
- I've read the information sheet, or it has been read to me;
- I've had an opportunity to ask questions about the study; the questions have been answered sufficiently;
- I voluntarily agree to participate in this research;
- I understand that the information will be treated confidentially;
- I understand that I can stop participation any time or refuse to answer any questions without any consequences;
- I understand that I can withdraw my consent before the dataset is submitted for approval.

	Yes	No
I give permission to audio record the interview		
I give permission to use quotes from my interview		

Date: _____

Cycling Study among Women in Rotterdam

Do you enjoy cycling? Why?

When you think about factors that explain cycling or reasons for cycling, what comes to mind?

The next group of questions are closed-ended personal information questions. So it might be a bit easier if you can see them so I'll show/share my screen.

What is your age?

- ○ 18 - 24 years old
- ○ 25 - 34 years old
- ○ 35 - 44 years old
- ○ 45 - 54 years old
- ○ 55 - 64 years old
- ○ 65 years or older

Please specify your ethnicity.

- ○ European
- ○ Sub Saharan African
- ○ Middle Eastern or North African
- ○ South Asian
- ○ East Asian
- ○ Hispanic or Latino
- ○ Other

What culture do you identify with most? (ie. Dutch, North American, Latin American, British, Mediterranean, etc.)

_____

What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.

- ○ Some High School
- ○ High School
- ○ MBO
- ○ HBO
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ PhD or Higher
- ○ Prefer not to say

What is your annual household income?

- ○ Less than €25,000
- ○ €25,000 - €50,000
- ○ €50,000 - €100,000
- ○ €100,000 - €200,000
- ○ More than €200,000
- ○ Prefer not to say

Were you born in The Netherlands?

- ○ Yes
- ○ No

How long have you lived in Rotterdam?

- ○ Less than 6 months
- ○ 6 months - 1 year
- ○ 1 - 5 years
- ○ 6 - 10 years
- ○ 11 - 15 years
- ○ 16 - 20 years
- ○ 20 years or more

Please fill out the below by estimating how many km a week you assign to each trip purpose.

- ○ Going to work/school _____
- ○ Shopping/groceries _____
- ○ Recreation _____
- ○ Gym/Fitness _____
- ○ Transporting children _____
- ○ Competitive _____
- ○ Social visits _____

End of Block: Level of Cycling

Start of Block: Personal Characteristics

How many children do you have?

- ○ None
- ○ 1
- ○ 2 - 4
- ○ More than 4

(If you have children, how do your children impact (impacted) your level of cycling? Why?)

(Could you tell me more about your experience of cycling with kids?)

What is your post code?

_____

End of Block: Introduction Block

Start of Block: Level of Cycling

The following questions are asked to understand one's level of cycling and the purposes of bike trips made.

On average, how many kilometres do you cycle a week?

_____

The following question is related to the characteristics of the person that influences their level of cycling based on attributes that are specific to the person, regardless of the city.

Please rate the following factors in terms of importance in explaining your level of cycling and decision to cycle.

	Not important										Very important
NA	0	1	2	3	4	5	6	7	8	9	10
Personal income level											
Personal education level											
Household structure (size and responsibilities)											
Cultural influences											
Personal ethnic origin											
Personal costs (monetary, time, physical/comfort, risk of injury/theft, personal security)											
Age											
Personal health reasons											

End of Block: Personal Characteristics

Start of Block: Place Characteristics

The following question is related to the characteristics of the place that influences their level of cycling based on attributes that are specific to the city itself.

Please rate the following factors in terms of importance in explaining your level of cycling and decision to cycle.

	Not important 0 1 2 3 4 5 6 7 8 9 10 Very important	NA
Urban road safety (sense of safety)		
Infrastructure (quality and capacity of bike infrastructure)		
Weather (impact of sun, rain, snow, etc.)		
Topography (flatness of roads)		
Environmental impacts/climate change concerns		
Trip cost (cost of bicycle use compared to alternative modes)		
Trip distance (average travel distance by bike)		

Of all the factors discussed, which factors explain your cycling? Why?

Do you think this way of life of cycling, especially among so many women, can be a potential future for other cities in the world?

(How do you think other cities could achieve this gender balance?)

Is there anything you wish to add or any factors not mentioned?

(Follow up:
- Could you please tell me more about…?
- What are some of your reasons for liking it?
- Please expand on…
- Why?)

Appendix 3: STATA Outputs

Regression table:

KMaweek	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
IncomeLevel	2.435527	.9725965	2.50	0.014	.4996218	4.371432
EducationLevel	-.0921848	1.076143	-0.09	0.932	-2.234193	2.049823
HouseholdStruc	-.6335572	.9270609	-0.68	0.496	-2.478826	1.211711
CulturalInfluences	-1.072627	.8052642	-1.33	0.187	-2.675465	.5302116
EthnicOrigin	-.1768757	1.022639	-0.17	0.863	-2.212387	1.858636
PersonalCosts	1.019194	.9043998	1.13	0.263	-.780969	2.819356
Age	.467291	.943367	0.50	0.622	-1.410434	2.345016
TripPurpose	-.1381199	.7795783	-0.18	0.860	-1.689832	1.413592
PersonalHealth	1.488783	.9427389	1.58	0.118	-.3876922	3.365257
UrbanRoadSafety	2.965955	1.518347	1.95	0.054	-.0562395	5.98815
Infrastructure	-.9123927	1.617099	-0.56	0.574	-4.131149	2.306363
Weather	-4.568432	.9849655	-4.64	0.000	-6.528957	-2.607907
Topography	-.6415395	1.046804	-0.61	0.542	-2.72515	1.442071
EnvImpacts	.7432286	.9027065	0.82	0.413	-1.053564	2.540021
TripCost	-1.465293	1.06712	-1.37	0.174	-3.589342	.6587569
TripDistance	-.1812971	1.105114	-0.16	0.870	-2.380972	2.018377
_cons	47.6955	10.49728	4.54	0.000	26.80119	68.58981

Correlation table:

	Income~l	Educat~l	Househ~c	Cultur~s	Ethnic~n	Person~s	Age	TripPu~e	Person~h	UrbanR~y	Infras~e
IncomeLevel	1.0000										
EducationL~l	0.2395	1.0000									
HouseholdS~c	0.0879	0.1809	1.0000								
CulturalIn~s	-0.0559	0.1444	0.2332	1.0000							
EthnicOrigin	0.1490	0.2045	0.0299	0.3093	1.0000						
PersonalCo~s	0.4195	0.1231	0.2158	0.1863	0.0651	1.0000					
Age	0.3145	0.2527	0.3030	0.2703	0.2255	0.3635	1.0000				
TripPurpose	0.0735	0.2335	0.0528	0.1491	0.0841	0.0749	0.2599	1.0000			
PersonalHe~h	-0.0327	-0.0245	0.1729	0.2574	0.2164	0.1044	-0.0182	0.1763	1.0000		
UrbanRoadS~y	0.2652	0.2188	0.2574	0.2539	0.0564	0.2960	0.3159	0.2104	0.1732	1.0000	
Infrastruc~e	0.2187	0.2357	0.1922	0.3409	0.0348	0.3046	0.2727	0.2220	0.0255	0.7531	1.0000
Weather	0.1279	0.0050	-0.0223	-0.0068	0.1442	0.1253	0.1655	0.3378	-0.0309	0.1934	0.1001
Topography	0.2628	0.1116	0.1175	0.1132	0.0717	0.2404	0.3832	0.2565	0.0336	0.4877	0.4904
EnvImpacts	0.2188	0.3501	0.0388	0.2192	0.2937	0.1820	0.3315	0.1448	0.1052	0.3350	0.3193
TripCost	0.5499	0.2157	0.1051	0.0706	0.0847	0.4882	0.2823	0.2103	0.0575	0.1949	0.2780
TripDistance	-0.0139	0.1267	0.1105	0.0818	0.1841	0.1536	0.2735	0.3091	0.1475	0.1539	0.0154

	Weather	Topogr~y	EnvImp~s	TripCost	TripDi~e
Weather	1.0000				
Topography	0.3177	1.0000			
EnvImpacts	0.0589	0.2245	1.0000		
TripCost	0.1158	0.3429	0.2346	1.0000	
TripDistance	0.4208	0.2354	0.1921	0.2215	1.0000

Detailed Summary Statistics of Level of Cycling Variable:

```
. sum KMaweek, d
```

KM a week

	Percentiles	Smallest		
1%	1	1		
5%	3	2		
10%	6	3	Obs	97
25%	20	3	Sum of wgt.	97
50%	30		Mean	39.2268
		Largest	Std. dev.	28.55924
75%	53	100		
90%	85	100	Variance	815.6303
95%	100	106	Skewness	.8244235
99%	106	106	Kurtosis	2.75497

IHS
Making cities work

Institute for Housing and
Urban Development Studies of
Erasmus University Rotterdam