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Commuting by bicycle in Rotterdam: encouraging and discouraging factors

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Summary

With the worldwide increasing demand for urban mobility and urban kilometres travelled, the cities are facing new ecological, social and environmental challenges in transportation system. To cope with these challenges, addressing the root – behaviour of users – and prioritizing sustainable modes of transport would be essential. Bicycle is one of such transportation modes – it is efficient, environmentally friendly and physically beneficial for its user. The Netherlands is world renown for cycling both in terms of existing bicycle culture and in the quality of infrastructure provided. However, one of its largest cities, Rotterdam is lacking behind with a bicycle share lower than the country average, especially for work trips. For this reason, travel behaviour and bicycle use of commuters in Rotterdam was thoroughly investigated in this study.

The main objective of this research was to explain the determinants of the current level of bicycle use in Rotterdam, specifically focusing on commuting. To achieve this objective, several groups of factors influencing user's decision to (not) cycle were examined. The study included not only hard factors, such as factors of built and natural environment, socio-economic and demographic factors, trip characteristics, but it also covered often neglected soft factors – psychological.

Survey was used as the main strategy of the research collecting user perspective. It was complemented by interviews with the experts in the field of urban mobility. As a result, both quantitative and qualitative primary data was generated. Quantitative data was analysed using descriptive statistics, cross-tabulation and multiple linear regression in SPSS and Excel in order to explain the relationship between the level of bicycle use and a number of travel behaviour factors: built and natural environment, socio-economic and demographic factors, psychological factors and trip characteristics.

Based on the concepts of travel behaviour factors, the analysis revealed a number of statistically significant determinants of bicycle use in Rotterdam. The two encouraging factors were bicycle ownership and convenience of cycling to work, while the discouraging factors were the following: long trip distance, positive attitude towards use of other modes of transport for commuting (in particular, car and public transport use), subjective norm (friends and family expectations) towards car use, public transport use and walking to work location.

Research findings also indicate the significant share of commuters traveling by train from other cities. It is important to ensure that cycling facilities are well connected with the public transport and commuters-targeted rental programs are available. Additionally, considering the strong influence of subjective norm (especially of friends and family), promotion of cycling among potential target groups could contribute to increasing its share.

Keywords

Travel behaviour, cycling, sustainable mobility, commuting to work, urban mobility.

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Abbreviations

CBS	Centraal Bureau voor de Statistiek, or Statistics Netherlands
CO_2	Carbon Dioxide
EU	European Union
IHS	Institute for Housing and Urban Development
KiM	Kennisinstituut voor Mobiliteitsbeleid, or Netherlands Institute for Transport Policy Analysis
NAT	Norm activation theory
SPSS	Statistical Package for Social Sciences
TIB	Theory of interpersonal behaviour
TPB	Theory of planned behaviour
TRA	Theory of reasoned action
WWII	World War II

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Chapter 1: Introduction

1.1 Background

The world is becoming increasingly urbanized: it is expected that 67% of the population will live in cities by 2050. By that time the total number of urban kilometres travelled is expected to triple, which means increasing demand for urban mobility and facing new challenges (Arthur D. Little, 2014). Considering such pace of development, sustainability of a city might be threatened with the following consequences:

- Environment: air pollution, CO_2 emissions, noise pollution, increasing ecological footprint
- Society: traffic congestion, traffic security, decreasing quality of life and convenience (the forecast is that by 2050 traffic jams will cost us 106 hours per year on average, which is twice more time than now)
- Economy: overloaded infrastructures, insufficient public transport capabilities and limited parking places as a result of increasing motorization

To cope with these challenges, it could be helpful to address the root – behaviour of users – and consider people's travel needs and habits, analyse what impacts them and how travel behaviour can be changed. For this reason, travel behaviour was chosen as the main focus of this research, in particular, focusing on the phenomenon of cycling in Rotterdam, the Netherlands.

Cycling deservedly occupies an important place in the hierarchy of modes of transport in terms of sustainability. The contribution of bicycle use to the efficiency of urban transport is high: it decreases traffic congestion, reduces traffic noise and in particular cases allows to reach the final destination faster than by car or public transport thanks to its manoeuvrability. Bicycle use contributes to liveable cities and brings health benefits to its user and a number of environmental benefits (clean air, saving fossil fuels). The economic importance of cycling is often neglected – it has been found that it improves the quality of life in central districts, thus, more activities and people attracted would ensue, resulting in consumers spending more (Habitat Platform Foundation, 2010).

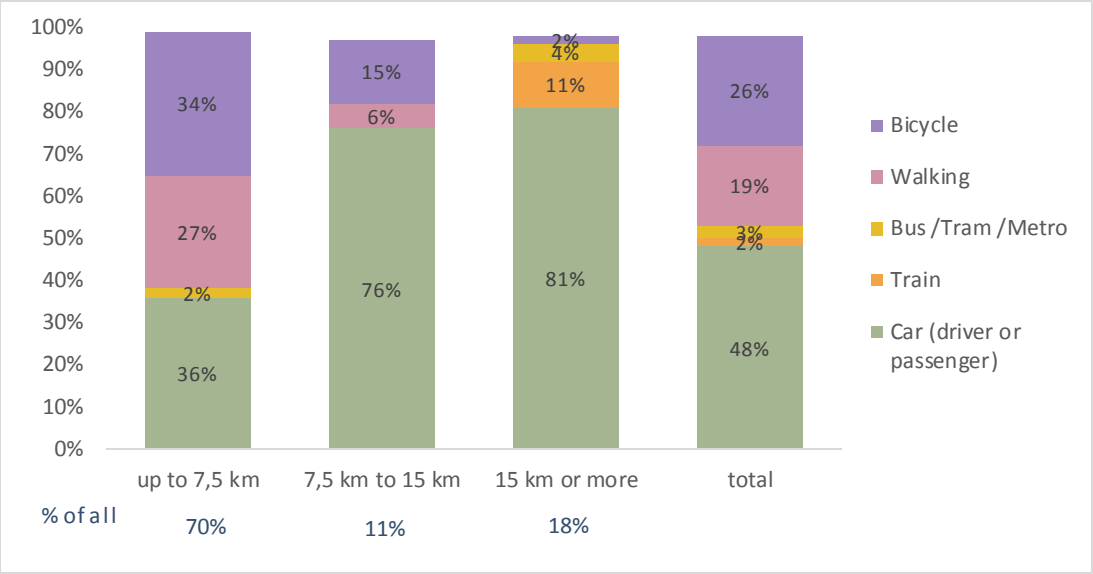
The Netherlands is world renown for sustainable mobility and especially cycling. With 1.1 bicycles per inhabitant, the Netherlands has the highest bicycle density in the world. Already a decade ago, in 2004, the Netherlands was ranked number one both in bicycle share and in bicycle ownership among EU countries, followed by Denmark and Germany.

Amsterdam, the capital city of the Netherlands, is often referred to as 'bicycle capital of the world'. In a city of 800 000 people, there are 880 000 bicycles, which is four times the number of cars. The modal share of bicycles in the city is growing, and now it composes about 38% of all trips within the city, compared with 22% of trips by car (Ministry of Transport Public Works and Water Management, 2009). After vast motorization trend in the Netherlands in the 1960s, current status is a good evidence of embracing the concept of sustainable mobility and developing towards it.

Bicycle infrastructure in the Netherlands is exemplary and is highly supported by policies. This includes an elaborate network of 35.000 km of designated cycle paths and a system of bicycle parking facilities. Railway stations in the country accommodate up to 330 000 bicycles (den Broeder et al., 2015). Cycling in the Netherlands is also safe, with the country listed among top 5 EU member states in the ranking on safety.

In total 26% of all trips in the country are made by bicycle. For the short distances up to 7,5 km (which makes 70% of all journeys) the modal share of bicycle is 34%, as figure 1 shows. Furthermore, the bicycle use keeps growing. According to the KiM Netherlands Institute for Transport Policy Analysis, bicycle use increased by nearly 11% in the last 10 years (since 2005 to 2015).

Figure 1: Modal split by distance in the Netherlands, 2007



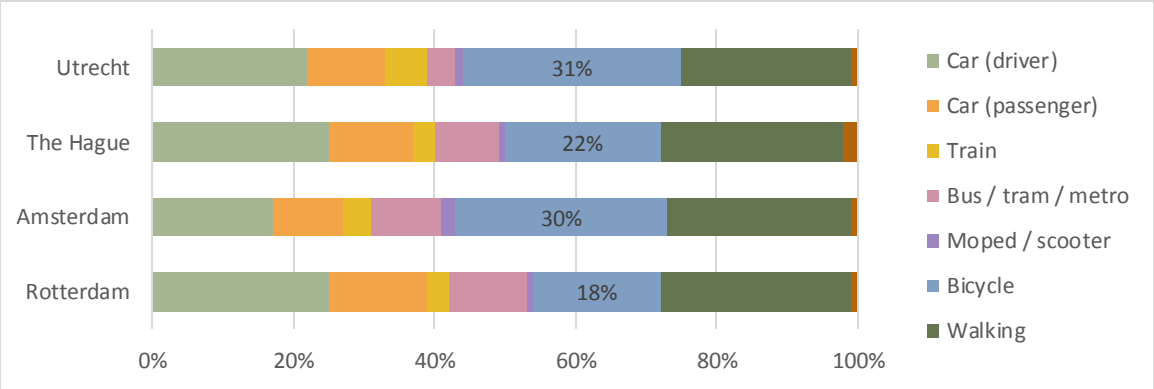
Source: (Ministerie van Verkeer en Watertstaat and Rijkswaterstaat, 2008).

According to Statistics Netherlands (CBS), the considerable number of bicycle paths and flat landscape make cycling a convenient means of transport in the Netherlands, suitable both for students and for commuting employees (2015).

1.2 Problem statement

Rotterdam, a city located in South Holland province, while offering a very good bicycle infrastructure, still demonstrates a slightly different travel behaviour with a lower bicycle use. Here bicycle share is 18%, which is not only lower than the country average but also lower than in three other largest Dutch cities: 31% in Utrecht, 22% in the Hague and 30% in Amsterdam (figure 2).

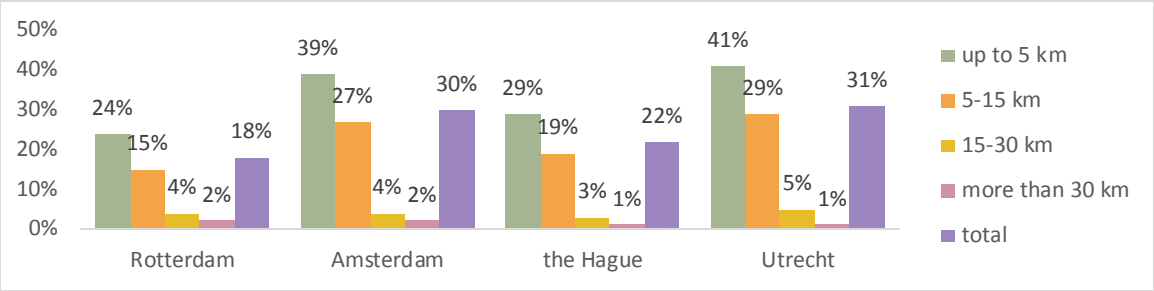
Figure 2: Modal split in four largest cities in the Netherlands, 2013



Source: (Onderzoek en Business Intelligence (OBI), 2015).

While the bicycle is a very common mode of transport for short distances (up to 5 km) and in Utrecht its share reaches 41%, in Rotterdam it is only 24% (figure 3).

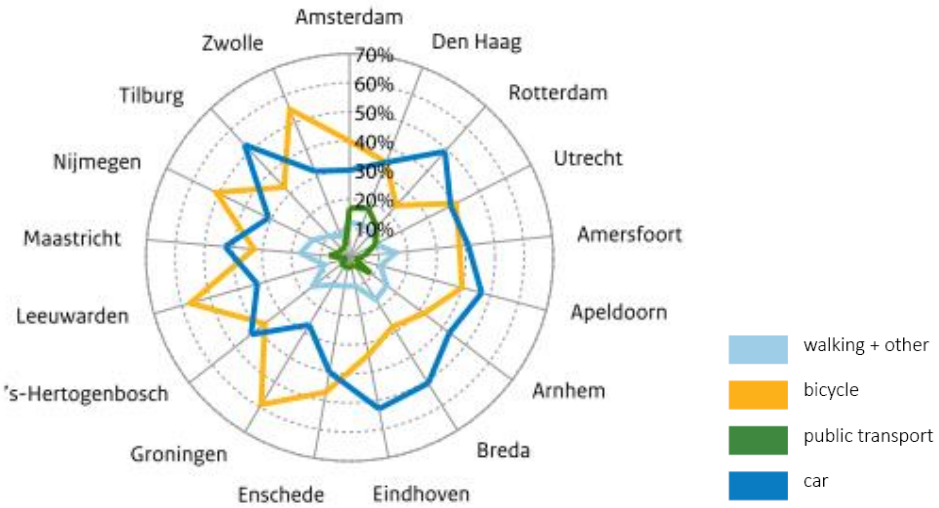
Figure 3: Bicycle use by trip distance in four largest cities in the Netherlands



Source: (Onderzoek en Business Intelligence (OBI), 2015).

Regarding trip purpose, according to the report of KiM Netherlands Institute for Transport Policy Analysis, the lowest bicycle use among 17 major cities was observed in Rotterdam (figure 4).

Figure 4: Modal split in 17 largest cities



Source: (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2014).

Thus, being one of the four largest cities in a country with exemplary bicycle culture, Rotterdam seem to have space for increasing sustainability of its transportation system by encouraging bicycle use, especially for work trips which compose a considerable share of total trips. For this reason, more insights on what motivates and demotivates users to use a bicycle for commuting are needed.

There haven't been many studies examining which factors are causing this modal share in Rotterdam. It is often called a city designed for cars. During the World War II, it was almost completely destroyed and rebuilt again afterwards with a car-oriented policy. On the other hand, it is also the most multicultural city in the Netherlands, hosting more than 160 nationalities. It is common that other nationalities don't have such a developed bicycle culture as the Dutch do and they tend to cycle less. Therefore, it might be one of the possible factors contributing to this phenomenon. This study aims to investigate which factors influence the choice of a bicycle as a mode of transport and which of them are valid for Rotterdam case.

1.3 Research objective

The main objective of this research is to explain the determinants of the current level of bicycle use for commuting in Rotterdam by examining different groups of factors and the nature of their influence on the user behaviour (encouraging or discouraging bicycle use).

1.4 Provisional research question

Provisional main research question:
Which factors explain that cycling is a less preferred mode of commuting in Rotterdam as compared to other cities in the Netherlands?
Provisional research sub-questions:

1. *Which factors encourage the choice of bicycle for commuting in Rotterdam?*
2. *Which factors discourage the choice of bicycle for commuting in Rotterdam?*

The main research question and sub-questions were revised on a later stage. Final research question and sub-questions can be found in paragraph 3.1 of chapter 3.

1.5 Significance of the study

The existing literature provides extensive general knowledge on travel behaviour in cities worldwide. However, each city characteristics vary significantly in terms of urban design, local culture and norms, weather conditions, the hilliness of the landscape and other factors, which make each city unique. Thus, urban complexity requires comprehensive research of the city. Since the little research was conducted in Rotterdam on this particular bicycle use for commuting, the outcome of this research is expected to add value to the academic literature.

A clear understanding of factors affecting modal choice of bicycle is also essential for policy-making. Choosing the mode of transport is a decision made by people, therefore addressing the core – the behavioural component – might result in helpful conclusions and that is why it is given a lot of attention in this research. Behavioural approach has become increasingly recognized, and in the Netherlands a Behavioural Insights Team was set up as a part of the Netherlands Ministry of Infrastructure and the Environment. A thoroughly conducted research would be helpful in developing policies on sustainable mobility.

This topic could also be of use for tackling traffic congestion issue in Rotterdam. According to INRIX Urban Mobility Scorecard Annual Report, the Netherlands is the second most congested country in Europe with an average driver spending 41 hours in traffic annually and costing around € 3 billion to the Dutch economy annually (2014). The implication is that a certain potential in solving the issue of congestion lies in influencing demand and shifting from private to public and non-motorized modes of transport, e.g. bicycle.

1.6 Scope and limitations

The scale of the study implied covering a full variety of industries of Rotterdam in order to address the commuting population. However, due to time limitations and lower response rate of commuters during data collection period in summer, an insufficient variety of industries and especially private sector participated in the research. For the reason that mainly public sector organizations took part in the research, the sample is unlikely to be representative of the population, which is the main limitation of the study.
Another limitation of this research is dictated by the complexity of human nature in the process of decision-making. Commuter is the central figure of this study, and a variety of factors influences his or her travel decisions. Commonly there is a gap between subjective perceptions and real factors, which is important to consider when addressing this topic. For this purpose, the study design included collecting both user perspective and expert opinions. Besides, the variety of possible determinants in constantly changing urban environment adds complexity to this research. However, theoretical review was of support to partially overcome this limitation.

Chapter 2: Literature Review

2.1 Introduction

The aim of this research is to identify which factors explain current level of bicycle use for commuting in Rotterdam, which of them encourage and discourage users to choose bicycle as a mode of transport. The purpose of the literature review is, therefore, to analyse theories and concepts in the area of travel behaviour, to identify current state of art in scientific research base and the missing gaps. An overview of terminology and concepts is introduced in this chapter, starting from urban mobility and travel behaviour to the variety of determinants influencing the choice of transportation mode. There are still ongoing debates in academia about the role and nature of numerous factors determining travel behaviour.

Regardless the growing attention to cycling, a few gaps in the literature review could be distinguished. The framework of the individual choice to commute by bicycle is not shaped. Non-customary determinants in mode choice research need to be studied in order to explain the mode choice of potential cyclists. For example, the impact of weather conditions and bicycle facilities (as well as other bicycle-categorical factors) has not been studied adequately.

2.2 Mobility and travel behaviour

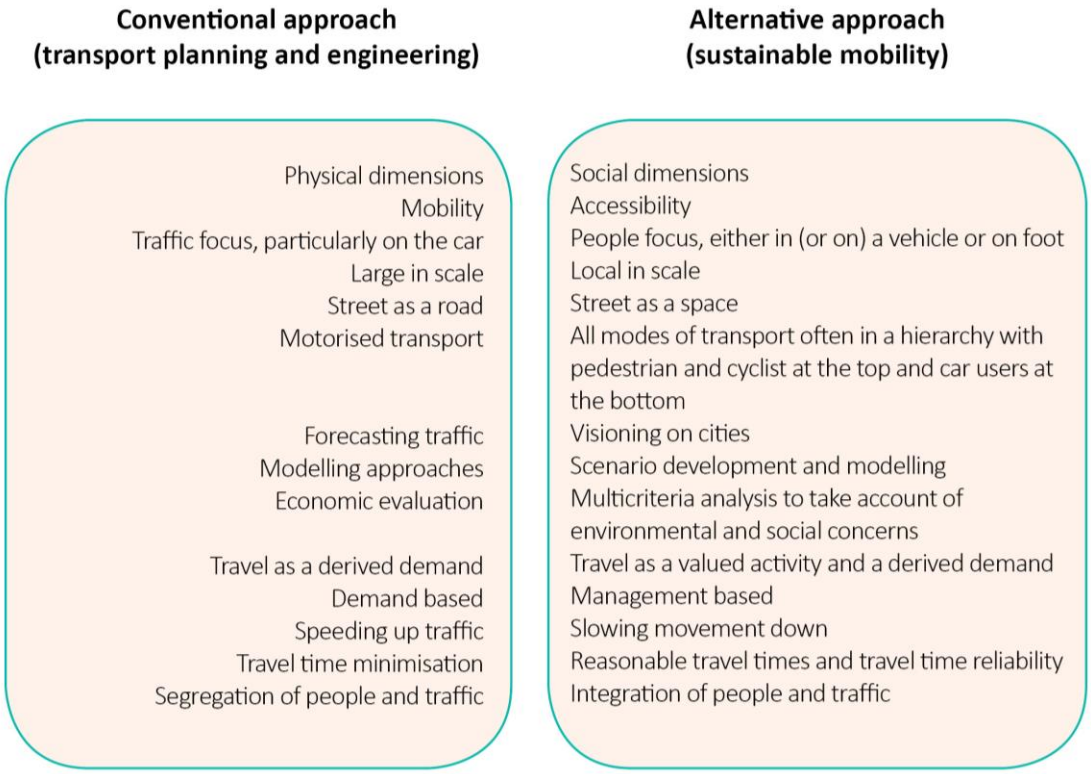
2.2.1 Sustainable urban mobility

In modern cities mobility is a key element of urbanization and an essential component in achieving sustainable growth. Urban mobility is essential for quality of life and economic and social development of cities. It is considerably shaped by the spatial factor – roads, buildings and landscape. However, the user is the one taking a travel decision, therefore there is a number of complex socio-demographic and psychological factors that should be taken into account.

Urban areas of all sizes nowadays are experiencing challenges – growth of population and development of economic activity, therefore negative effects from growing transportation are becoming evident. Congestion, increasing commute time, energy consumption, noise and air pollution, CO_2 emissions are taking place, and to minimize negative impact and ensure long-term viability another approach is needed. There is a lot of talk about the concept of sustainable mobility in academia. This type of mobility is based on the principles of preserving natural environment, supporting health and safety of citizens, meeting travel needs, contributing to economic development, maintaining energy security and ensuring long-term viability of the system. A model of sustainable mobility implies environmentally friendly (less pollution produced and more energy saved) and human-focused approach. Figure 5 illustrates two different approaches to transport planning: the conventional approach and an alternative approach of sustainable mobility. In the hierarchy of sustainable mobility modes, cycling occupies top place along with walking (Banister, 2008).

Bicycle is a cost-effective investment. It infrastructure is usually cheaper to build and maintain than car infrastructure, both for roads and parking (Habitat Platform Foundation, 2010). Bicycle use is also beneficial in use of space and transport capacity: it requires considerably less space than cars do. It is also a clean and silent means of transport contributing to combating environmental pollution (both air and noise pollution). Sometimes arguments can be found that cyclists are more exposed to the pollutant substances than motorists, however, several findings show evidence that it can be vice versa if the cyclists use low-traffic routes and if the bicycle infrastructure is separated from car roads. In general, it is found that the quality of life and public health are improving with the increased cycling.

Figure 5: Contrasting approaches to transport planning



Source: (Banister, 2008).

2.2.2 Travel behaviour and mode choice

It was noticed that the vast majority of travel behaviour research has focused on motorized and car travel rather than on active travel (which includes walking and cycling). Therefore, this research aims to add to the existing body of knowledge on bicycle use.

Nowadays the behavioural approach is playing an increasing role in public policies worldwide which makes it a good area for research. At the same time behavioural patterns are one of the major challenges in attaining sustainable travel behaviour (Garcia-Sierra et al., 2015). In this study an approach highlighting the importance of understanding human behaviour and social context rather than focusing merely on hard factors will be used.

2.2.3 Behavioural theories

This chapter provides an overview of behavioural theories which explain how behavioural choices are made and which factors influence this choice. One group of theories highlights the importance of internal factors determining individual behaviour, e.g. values, attitudes, personal norms, etc. According to another approach, external factors make a difference, e.g. incentives, social norms, institutional constraints. Another perspective implies that both internal and external factors influence on behaviour. It means that studying both the individual and his environment is important for building up a comprehensive research.

In order to clarify how choices are made, a number of behavioural theories have been formulated in academia. It used to be a common approach to use rational model of judgement and decision making, assuming that people rationally evaluate costs and benefits of their decisions. This perspective is changing nowadays, and a number of researchers consider that

using behavioural approach rather than rational agent models helps to depict transport more realistically (Garcia-Sierra et al., 2015; Kahneman, 2011).

The classic *utility theory* (it also often referred to as '*rational choice theory'*) takes its roots in microeconomic theory and implies that decision makers are risk-averse and that they choose an option which maximizes their expected utility. It suggests that individuals have an exhaustive knowledge of the alternatives and their qualities and that they make a rational choice (Adjei and Behrens, 2012).

The *prospect theory*, formulated by Daniel Kahneman and Amos Tversky (1979), is more psychologically accurate and it includes a certain degree of uncertainty about the outcome. According to this theory, gains and losses have different value for the decision maker (he or she is more sensitive to losses rather than gains). It also finds that framing options might result in considerably different choices.

Habit formation theory examines habitual and automatic behaviour. Learned sequences of acts with a certain goal become a habit. The habit becomes stronger with repetition, and the more often it is repeated, the less reflection is involved.

The *theory of reasoned action* (TRA) was developed by Martin Fishbein and Icek Ajzen (1967), aiming to explain the relationship between attitudes and behaviours within human action. Based on the pre-existing attitudes and behavioural intentions of an individual, TRA is used to predict how individuals will behave. According to it, intention to behave in a certain way precedes the actual behaviour. The stronger the intention, the bigger the effort to perform a certain behaviour and, therefore, leading to a higher chance of performing behaviour. The theory includes two factors determining intention: attitudes and subjective norms. Attitude is an individual's opinion about how positive or negative certain behaviour is, while subjective norm is an individual's perception of social pressure regarding (not) performing a certain behaviour. The theory is applied to health promotion and customer behaviour, e.g., stimulating coupon usage or redefining brand loyalty. In the transportation field it was applied for public transport use and road crossing (Adjei and Behrens, 2012).

Criticism towards TRA underlined that behavioural intention does not always lead to actual behaviour, which means that behavioural intention can't be an exclusive determinant of behaviour as the individual's control over behaviour is incomplete. Thus, Ajzen developed another theory from the TRA – the *theory of planned behaviour (TPB)*. The key difference between the two theories is that TPB adds the concept of perceived behavioural control as an additional determinant of intentions and behaviour. The model of this theory implies that individual's behaviour is guided by three kinds of consideration: behavioural beliefs, normative beliefs and control beliefs. Behavioural beliefs produce a positive or negative attitude towards the behaviour; normative beliefs result in subjective norm; and control beliefs evolve in perceived behavioural control.

While similarly recognizing significance of intention in behavioural process, *theory of interpersonal behaviour* (TIB) also examines the habits which explain or predict behaviour (Adjei and Behrens, 2012). Thus, according to TIB, the three main determinants of behaviour are the following: habit, intention and facilitating conditions. It also suggests that with the increasing habits strength, the effect of intentions decreases, and vice versa. Habit is determined by the frequency of the behaviour in the past. The TIB also includes affection (to which degree an individual likes or dislikes the behaviour) as a determinant of intention, which is a difference of this theory from TRA and TPB. The literature also suggests that the travel behaviour field has given less attention to TIB despite its greater predictive power over TPB.

Alternatively, Schwarz formulated the *norm activation theory* (NAT). It suggests that personal norms determining prosocial behaviour. By adapting social norms, personal norms are shaped. It is believed that these personal norms are only activated when a person is aware of the consequences of their behaviour and take responsibility for them. The researcher suggested a four-stages model of how decisions are made: attention, motivation, evaluation and denial.

Thus, this section covered a number of the most relevant and important behavioural theories which explain how decisions are made and which factors influence this choice.

2.3 Overview of determinants

From the point of view of economic science, urban transport as a derived demand means a trade-off between benefits from reaching the destination point and the costs of traveling to that point (Hensher and Dalvi, 1978). This trade-off is measured in money terms in classical demand theory. However, with historical development a broader vision on the determinants of travel choices has shaped. Nowadays academia unanimously agrees on significance of non-monetary factors, such as travel time, travel distance, land use, policies, ownership of transportation mode, socio-demographic characteristics and others. A broad overview of determinants will be introduced in this chapter.

2.3.1 Built environment

Most of the papers reveal the link between the environment and travel behaviour. That relationship has been reviewed in a number of studies (Crane, 2000; Ewing and Cervero, 2001).

Numerous studies attempted to measure the effect of *urban form* patterns on daily travel behaviour of individuals. Researchers demonstrate that urban mobility and the mode choice are closely connected with the characteristics of the spatial environment (Tyrinopoulos and Antoniou, 2013; Koglin, 2015; Cavill et al., 2008; Sener et al., 2009). In European cities urban planning and design control usually lead to a higher density urban form and compact city centre and hence an increased use of public transport (Meng et al., 2014). Therefore, *trip distance* has an important impact on a decision to use bicycle: distances longer than 10-15 km are highly discouraging for bicycle use (Heinen et al., 2010; Heinen et al., 2013; Pucher and Buehler, 2012).

It has been found that a solid design and availability of adequate *infrastructure* can encourage more cycling (Hull and O'Holleran, 2014; Pucher et al., 2010; Pucher and Buehler, 2012). Users rather prefer bicycle paths to both bicycle lanes and roads without bicycle facilities. Availability of facilities, such as *bicycle parking*, also matters, having an encouraging effect on bicycle use. *Car parking facilities* can be more problematic for cyclists, as they might need to cross bicycle facilities in order to park, as some studies suggest. Also, showers at the place of work or lack thereof influence the decision to use bicycle for commuting. *Continuity of bicycle infrastructure* matters for inexperienced cyclists: a route segment without cycling facilities could discourage them from cycling (Heinen et al., 2010).

2.3.2 Natural environment

The landscape is not thoroughly examined in mode choice studies. For car trips, hilly landscape would not be a very important factor. However, in case of cycling that would matter and impact the amount of effort that cyclists need to make (Oakil et al., 2014; Heinen, 2011; Heinen et al., 2010).

As a number of studies showed, *climate and weather* conditions have significant effects on the odds of travel by bicycle. Some studies suggest that cold is not a matter of concern for cyclists,

but icy roads do raise great safety concerns (Amiri and Sadeghpour, 2015). The same research showed that males are more likely to cycle in cold weather than females. Precipitation and temperature are significant for decision whether to commute to work by bicycle: a factor of precipitations does have a discouraging nature (Flynn et al., 2012).

2.3.3 Socio-economic and household factors

There is a strong link between travel behaviour and socio-economic and household characteristics.

According to most studies on *gender*, men use bicycle as their mode more than women (Steinbach et al., 2011; Heinen, 2011; Pucher and Buehler, 2012; Heinen et al., 2010). However, in high-cycling countries, such as the Netherlands and Belgium, commuter bicycling rates are equally high for both men and women (Garcia-Sierra et al., 2015; Pucher and Buehler, 2012). However, literature also shows evidence of more complex travel patterns among women than among men due to differing household and work roles. Such responsibilities might constrain women from cycling, however, this effect is considerably less in high-cycling countries (Pucher and Buehler, 2012). In Netherlands female utilitarian cycling is one of the highest among developed countries.
The cultural meanings of ethnicity and transport are less well explored than those of gender (Steinbach et al., 2011).
Individual's *employment status* matters for bicycle use. Part-time workers commute more frequently to work by bicycle than full-time workers (Boumans and Harms, 2004). *The household structure* also affects the modal choice. Having a high social status and having a young family decreases the probability of cycling (Moudon et al., 2005; Ryley, 2006).

Regarding *age*, there are still ongoing debates on this question but many studies conclude that it is not an important factor (Pucher and Buehler, 2012; Heinen, 2011). Relationship with *income* is even less clear, and studies provide controversial results on this topic (Heinen et al., 2010).

Car ownership has a strong negative effect on cycling mode share (Cervero, 1996; Kitamura et al., 1997; Banister and Gallant, 1999; Stinson and Bhat, 2004, 2005; Plaut, 2005; Pucher and Buehler, 2006; Dill and Voros, 2007; Guo et al., 2007; Parkin et al., 2008). At the same time, *bicycle ownership* logically increases the probability of bicycle use, as a number of studies has shown.

2.3.4 Psychological factors

A number of studies examined the impact of *attitudes and social norms* on mode choice (Maness et al., 2015; Domarchi et al., 2008; Heinen and Handy, 2012; Etminani-Ghasrodashti and Ardeshiri, 2015; Scheiner and Holz-Rau, 2007; Daley and Rissel, 2011). Attitudes play an important role in the theories which were applied in mode choice research studies: theory of planned behaviour (TPB) (Ajzen, 1991) and theory of interpersonal behaviour (TIB) (Triandis, 1980, 1997). According to the latter theory, both individual attitudes and perceived social norms are central in decision-making process (Heinen, 2011).

Attitudes in the workplace play a key role in determining the commuting mode choice: employees who are expected to use car for commuting are less likely to cycle (Heinen et al., 2013). But also *attitudes of friends and family members* sometimes play an even bigger role.

Social norm is important, and it partially c the bicycle culture. In countries with bicycle culture this mode of transport is more socially acceptable.

Transportation mode choice is often a matter of *habit*, and the potential of mode shift might lie in changing habits. It has been studied that the bicycle use in childhood often determines cycling behaviour in adult age (Heinen, 2011; Pucher et al., 2010).

2.3.5 Trip characteristics

Academic literature shows evidence of significance of the trip characteristics for mode choice and bicycle use.

For cycling, increased *travel time* results in a decline of perceived *inconvenience* and spending more efforts, which logically has a negative effect on bicycle use. Although the relationship between the cause and effect is not very clear.

According to the literature, *safety* appears to one of the most important factors determining mode choice in cities (Pucher and Buehler, 2012; Klinger and Lanzendorf, 2015; Bovy and Hoogendoorn-Lanser, 2005; Oakil et al., 2014). It especially plays a role for unskilled cyclists who are sensitive to the cycling safety.

2.4 Conclusion

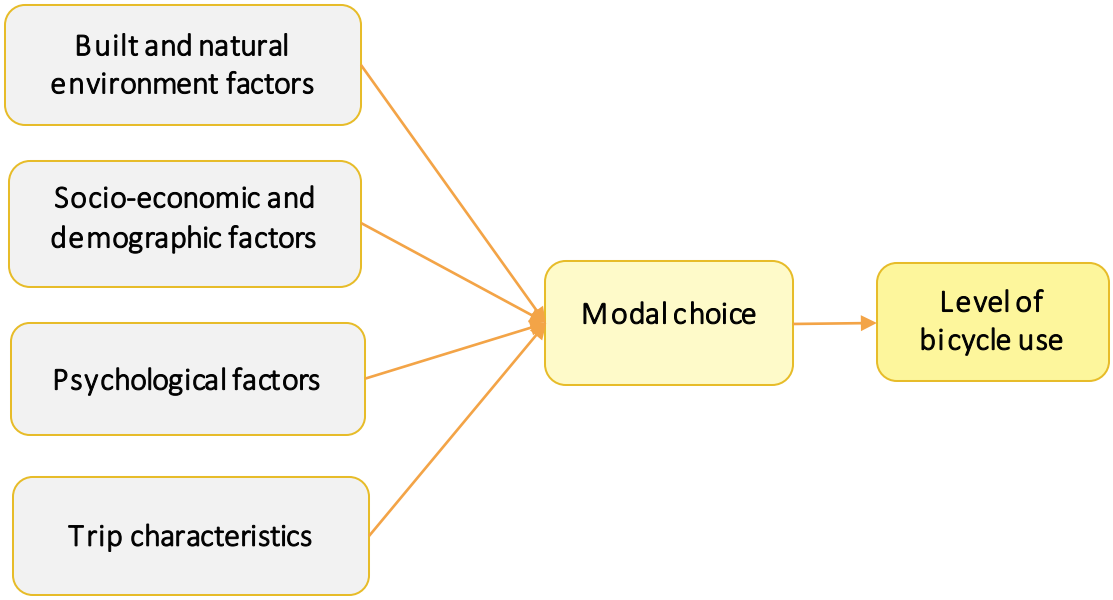
Extensive academic research on the topic of urban mobility and travel behaviour has been made. Existing literature thoroughly examines both external and internal factors and their influence on the transportation mode choice and bicycle use in particular. A number of groups of factors was discovered, each of them is having a different impact on bicycle use (encouraging or discouraging).

Traveling is a complex behavioural process, preceded by a complex decision-making process. The variety of numerous factors affecting the choice of mode of transport and sometimes hardly distinguishable causal relationship adds certain limitations to the study.

2.5 Conceptual framework

As a result of theory review, the major factors of travel behaviour were grouped together in the following four categories: factors of built and natural environment, socio-economic and demographic factors, psychological factors and trip characteristics. Each of these groups of factors influences the modal choice and, therefore, the level of bicycle use (figure 5).

Figure 6: Conceptual framework



Chapter 3: Research Design and Methods

3.1 Revised research question

As a result of detailed theory review, the research question has been revised. Therefore, the main research question was formulated as following:

Which factors explain the level of bicycle use for commuting in Rotterdam?

Research sub-questions:

1. *Which factors of built and natural environment have the biggest impact on the choice of bicycle as a means of commuting to work?*
2. *Which psychological factors influence commuters' decision to cycle?*
3. *Which socio-economic and demographic factors mostly affect the choice of bicycle for commuting?*
4. *Which trip characteristics have a considerable impact on the choice of bicycle for commuting?*

3.2 Research approach and techniques

In order to generalize results to a bigger population of the city commuters, survey was used as the main strategy in this research. Thus, it was expected to achieve breadth and generalization and collect quantitative data by conducting empirical research. The research topic covers a commuting population of a city, therefore, a large number of research units was required to ensure reliable and precise analysis. To achieve coverage of a large number of research units, extensive data generation by using online questionnaire was implemented. The cross-sectional approach was applied, which involved analysis of data collected from the same group of population at a particular moment in time. As a result, the use of survey strategy ensured wide scope and generally valid statements (Verschuren and Doorewaard, 2010).

However, the complex topic of travel behaviour entails the need in a comprehensive study. Thus, to obtain vision other than user perspective and a better understanding of human behaviour, perceptions and opinions, a number of interviews with the experts in the field of mobility were used as an important complementary method.

3.3 Operationalization: variables, indicators

The table below summarizes the most relevant to the research variables, indicators, their definition and values in which data collection was carried out.

The first part of the table covers the dependent variable of the level of bicycle use. The next part contains independent variables of travel behaviour factors: socio-economic and demographic factors, psychological factors, factors of built and natural environment, trip characteristics.

Since the research topic originates from viewing Rotterdam in the context of the Netherlands, a number of common for the entire country factors were not included in the operationalization (namely: landscape, climate and weather).

Table 1: Operationalization table

Variable	Indicators	Definition	Values	Source
Level of bicycle use	Frequency of bicycle use for commuting	Number of trips by bicycle to work divided by total number of trips to work	• 0 (non-cyclists) • 0 < … < 1 (part-time cyclists) • 1 (full-time cyclists)	N/A
	Intensity of bicycle use for commuting	Bicycle kilometres travelled for commuting divided by total kilometres travelled for commuting		N/A
TRAVEL BEHAVIOUR FACTORS: 1.Socio-economic and demographic factors	Age	Belonging to a particular age group	• Less than 20 • 21-30 • 31-40 • 41-50 • 51-60 • More than 61	N/A
	Gender	Gender of the commuter	• Female • Male • Other	N/A
	Education level	The highest level of education completed.	• primary (elementary school) • secondary (VWO, HAVO, VMBO) • senior secondary (MBO) • undergraduate (BA, BSc, Bachelor's degree, Associate degree) • postgraduate (MA, MSc, Master's degree) • postgraduate (Ph.D.)	(EP-Nuffic)
	Income level	The level of yearly income of the commuter after taxes (in euro).	• Less than 15,000 • 15,000-25,000 • 25,000-30,000 • 30,000-35,000 • 35,000-45,000 • More than 45,000 • Prefer not to reply.	N/A
	Household structure	Composition of people living in the same dwelling.	• single • student house • only with partner • with partner and children • only with children • other	(Heinen, 2011)

	Car or other motor vehicle ownership	Ownership of a car or other motor vehicle by a commuter.	• Yes • No	N/A
	Bicycle ownership	Number of bicycles owned by a commuter.	• None • One bicycle • 2 or more bicycles	N/A
	Nationality (by birth)	The status of belonging to a particular nation (by birth).	List of nationalities.	N/A
	Ethnicity	Identification of a person with a particular ethnic group based on racial, cultural, traditional and religious traits.	• Asian or Pacific Islander • Arabic or North African • Black or African American • Hispanic or Latino • White or European • Mixed/multiple ethnic groups • Other ethnic group	N/A
2. Psychological factors	**Attitudes:** 1. Attitudes towards different forms of mobility	• Attitudes towards car use for commuting • Attitudes towards bicycle use for commuting • Attitudes towards public transport use for commuting • Attitudes towards walking for commuting	Measured on five-point Likert scales, ranging from 1 'very negative' to 5 'very positive'.	(Abrahamse et al., 2009)
	2. Intention to decrease/ increase use of different modes for commuting		Measured on a five-point scales in which 1 indicated 'definitely not', 2 'probably not', 3 'neutral', 4 'probably yes', and 5 'definitely yes'.	(Abrahamse et al., 2009)
	Social norms 1. Subjective norm: • Colleagues' expectations • Friends' and family expectations	Whether respondents believe that other people (colleagues, friends and family) expect them to use a particular mode of transport to work:	• car • public transport • bicycle • walking • It doesn't matter.	
	2. Personal norm towards cycling	Measured with the following items: "I (would) feel good about cycling to work" and "I	Measured on five-point Likert scales, ranging from 1 'strongly	(Abrahamse et al., 2009)

		(would) feel guilty about not cycling to work".	disagree' to 5 'strongly agree'.	
	3. Awareness of consequences: • Health benefits • Environmental benefits	To what extent respondents evaluate different positive consequences of bicycle use. Measured with the following items: ''Cycling makes me more healthy" and "Using bicycle is environmentally friendly".	Measured on five-point Likert scales, ranging from 1 'strongly disagree' to 5 'strongly agree'.	(Abrahamse et al., 2009)
3. Factors of built and natural environment	Trip distance	Travel distance from home to work measured in km.	Interval variable	(Heinen et al., 2013)
	Availability of car parking	Available car parking in the proximity to home / work location	• Both close to work and home locations • Close to home location only • Close to work location only • Unavailable	N/A
	Availability of bicycle parking	Available car parking in the proximity to home / work location	• Both close to work and home locations • Close to home location only • Close to work location only • Unavailable	N/A
	Type of bicycle infrastructure	Type of bicycle infrastructure or a combination of types	• bicycle lanes only • bicycle paths only • a mix of bicycle paths and lanes • a mix of bicycle paths/lanes and a road without bicycle facilities • roads without bicycle facilities	(Heinen, 2011)
	Continuity of bicycle infrastructure	Availability of continuous and unbroken bicycle infrastructure (path/ lane/ road) on the way from home to work	• Yes • No	(Heinen, 2011)

	Traveling across the river	Necessity to cross the river (by bridge or tunnel) when commuting.	• Yes • No Estimated by the postcodes of original and destination locations.	N/A
4. Trip characteristics	Travel time	Average time spent on one-way commuting measured in minutes.	• Less than 10 minutes • 10-15 minutes • 15-20 minutes • 20-25 minutes • 25-30 minutes • 30-35 minutes • 35-40 minutes • 40-50 minutes • 50-60 minutes • More than 60 minutes	N/A
	Safety	Perception of safety of cycling in Rotterdam: "I think commuting by bicycle in Rotterdam is safe".	Measured on five-point Likert scales, ranging from 1 'strongly disagree' to 5 'strongly agree'.	N/A
	Convenience	Perception of convenience of cycling in Rotterdam: "I think commuting by bicycle in Rotterdam is convenient".	Measured on five-point Likert scales, ranging from 1 'strongly disagree' to 5 'strongly agree'.	N/A

3.4 Sample size and selection

According to the CBS data from 2015, the working population of Rotterdam consists of 273.000 people. Therefore, a representative sample size for the survey would be 384 respondents (considering confidence level of 95% and margin of error of 5%). However, due to the time constraints during the data collection and low response rate in summer vacation period, a total number of 228 responses was collected. 3 responses out of this amount were considered invalid since the respondents were not employed and their trip purpose was other than commuting, which doesn't fit the scope of this research. Thus, 225 responses were considered valid for further analysis (which means confidence level of 95% and margin of error of 7%).

To conduct a survey, employees of several organizations representing different industries (education, consumer goods, financial services, architecture, entertainment, art and culture, logistics and hotel industries) and located in different parts of the city were approached. Criteria to select respondents were the following: being currently employed and commuting to work to/in Rotterdam.

The biggest number of questionnaire responses was collected from Erasmus University Rotterdam (namely, the following faculties: Faculty of social sciences, Erasmus School of History, Culture and Communication, Institute of Health Policy & Management, Institute for Housing and Urban Development Studies, Erasmus University College) and Municipality of

Rotterdam. Among other institutions that took park in the survey were Enviu (consulting services) and Museum Boijmans Van Beuningen (art and culture).

For the interviews a purposive sample was selected, based on knowledge and experience of the respondents. A number of experts in the field of mobility were approached resulting in interviews with 6 experts from the following institutions:

- Municipality of Rotterdam (coordinator of cycling in Rotterdam, senior advisor on mobility, intern and researcher on cycling)
- The Dutch cyclists' union Fietsersbond Rotterdam+region (chairman)
- The department of Urban, Port and Transport Economics of Erasmus University Rotterdam (senior researcher and researcher).

3.5 Validity and reliability

Reliability of a survey strategy is often concerned with the consistency of measurement. Therefore, a big attention was given to a clear conceptualization of constructs, use of precise level of measurement and use of multiple indicators. Measurement instruments (questionnaire and interviews) were pilot tested. Provided questions and answers of the questionnaire were relevant to the local context (for example, the choice of education level was adjusted according to the Dutch educational system).

Although the survey strategy usually provides large scope and allows generalization (therefore, external validity), the main challenge was that the depth of the outcome would be limited (Verschuren and Doorewaard, 2010). In order to overcome this limitation, interviews were used as a complementing method helping to gain a full overview of the research object.

To achieve validity the accuracy of measurement was given a considerable attention. Content validity was ensured by representing the full content in a measure. Internal validity is also significant and in order to achieve it both quantitative and qualitative elements were included in the research.

3.6 Data collection methods

The research generated both quantitative and qualitative data. Quantitative data was collected by structured online survey to quantify behaviours of the commuters. An online option was adopted for several reasons. It is a cost-effective and inexpensive tool to distribute the survey. It is also time-saving: it allows to collect multiple responses at the same time and generates results in a convenient format for further analysis in statistic software. Finally, this tool is environmentally friendly and highly accessible, considering that 94% of the Dutch population have internet access.

An online questionnaire was provided both in English and Dutch languages, and the translation into Dutch was carried out by a native speaker.

To cope with the limited flexibility of questionnaire as a data collection method, special attention was given to ensure mutually exclusive and exhaustive attributes when designing it.

In order to increase response rate, an online platform Typeform with user-friendly design was chosen to make participation easy and engaging for the respondents. After a few comments received during the pilot testing of the questionnaire, it was adjusted, and the final version consisted of 41 question. According to the survey platform, the average time to complete it was 7 minutes 16 seconds. Snowball technique was used encouraging participants to share the survey with their colleagues or employed friends and family members.

In order to gain a broader perspective on commuters behaviour, research was complemented by qualitative data. It was collected by means of face-to-face interviews with open-ended questions. The interview questions were not aimed at grasping the user perspective but rather at a broader vision on the city dynamics, based on the expertise and knowledge of the interviewees from the field of urban mobility. All the interviews were conducted in English. A full database of the recorded interviews was kept and structured before processing the data.

In addition to questionnaires and interviews, secondary data was used. Information from reports of the Rotterdam municipality, CBS and Ministry of Infrastructure and Environment as well as informative websites and academic articles will help to improve internal validity and will serve as corroborate facts, additional support and evidence. Reports and papers in the Dutch language were translated and reviewed where necessary.

3.7 Data analysis methods

The data generated from online survey was downloaded in Excel format, edited, coded and then imported to SPSS. The questions were mainly marked as required, therefore respondents couldn't skip it, which resulted in absence of missing data. The data was analysed by means of both descriptive and inferential statistics. Descriptive statistics includes analysis of commuters and their characteristics using frequencies and crosstabs. Charts and graphs were created in Excel. Data was also visualized in InDesign.

Multiple linear regression was selected as a method of inferential statistics for causal analysis to explain the relationship between the dependent variable and a number of independent variables. The data meets following assumptions: the dependent variable is measured on a continuous scale, and the independent variables are mainly categorical. In order to have valid and trustworthy results, each regression model was ensured to meet the assumptions of homoscedasticity (by scatterplots of the standardized residuals against the standardized predicted values), linear relationship (by scatterplots of the actual outcome variable against the predicted outcome), independence of observations (using the Durbin-Watson statistics), absence of multicollinearity (by correlation matrix), no significant outliers, high leverage points or highly influential points, as well as approximately normal distribution of residuals (using a P-P plot).

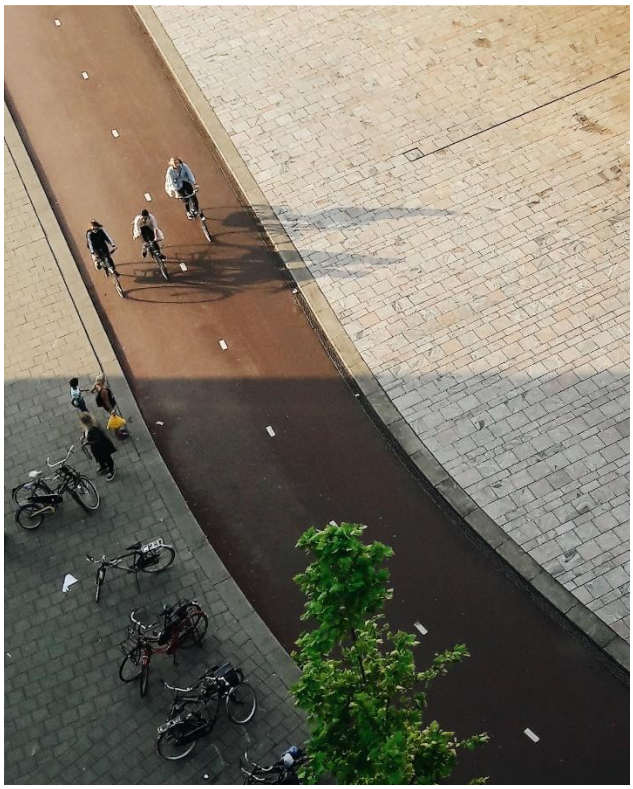
The survey was complemented by 6 semi-structured interviews, which generated 260 minutes of recorded audio. It was transcribed into a word-processed document for further content analysis.

Chapter 4: Research Findings

4.1 Bicycle use and commuting in Rotterdam

Rotterdam is very different from other cities in the Netherlands. It doesn't look like a typical cosy Dutch city with narrow streets and old houses. Instead, it is a modern city with a high-rise skyline, wide streets and very different atmosphere. That difference can be explained by a link from history. During the World War II Rotterdam was almost completely bombed and had to be rebuilt again. In the late 1940s, when the reconstruction plan was created, the mobility demands of that time were taken into consideration. This resulted in a city designed for cars, oriented toward fast traffic. In the 1960s prosperity in the Netherlands was increasing, and car ownership was growing progressively. Thus, motorized transportation became prioritized. In the 1970s with the oil crisis, dollar crisis and increasing traffic congestion, car-oriented policy became criticized. A huge movement and activism of the Dutch citizens was raised (including the Dutch cyclists' union, Fietsersbond), drawing attention to cycling.

Figure 7: Bicycle path next to Rotterdam central station



Source: Author, 2016.

The government responded by investing in bicycle infrastructure and safety, which resulted in a huge increase in cycling. Nowadays bicycle is playing an important role as a means of transportation in the city, and the level of bicycle infrastructure in the Netherlands is often considered exemplary (figures 6 and 7).

Figure 8: Separated bicycle path in Delfshaven neighbourhood

Source: Author, 2016.

However, cars still occupy an important place in Rotterdam (figures 8 and 9). At the same time, a number of actions have been done in order to motivate commuters to use public transport

more. One of the innovative solutions is a self-driving shuttle bus at Kralingse Zoom station allowing commuters to easily arrive at their office location from the station (figure 10).

Figure 9: Roads and bicycle paths in Delfshaven neighbourhood

Source: Author, 2016.

Figure 10: Car parking at Kralingse Zoom station

Source: Author, 2016.

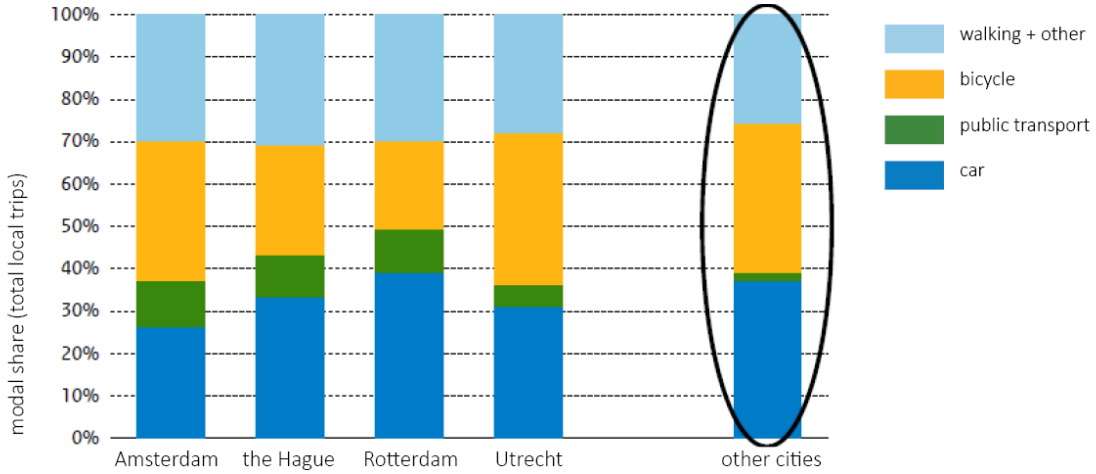
Figure 11: Self-driving shuttle bus at Kralingse Zoom station

Source: Author, 2016.

The bicycle infrastructure in the city is exceptional. According to the municipality of Rotterdam, there is 600 km of bicycle paths, 8500 free storage places (7000 of them are located at the central station) and 35 intersections where cyclists are given a priority and waiting time for them is shorter (which is especially appreciated in rainy weather).

According to the municipality, in the last 10 years, there has been a 60% growth in the number of bicyclists. However, the modal share of bicycle in Rotterdam is still lower than the country average (figure 11).

Figure 12: Modal shares in the four largest urban areas in the Netherlands

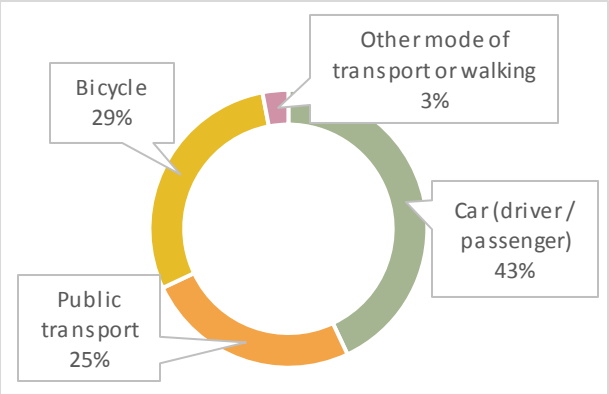


Source: (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2014).

In the report "Rotterdammers over het verkeer 2015" by the municipality of Rotterdam, it is stated that more than three-quarters of Rotterdam citizens (76%) have a bicycle. Modal share of bicycle use for commuting was 29% in 2015 (figure 12).

Non-western immigrants are much less likely to cycle than natives. Research also showed that bicycle ownership increases when the level of education and / or household income is higher. One out of five non-cyclists in Rotterdam states that he or she is not able to cycle.

Figure 13: Modal split in Rotterdam for commuting to work or study, 2015



Source: (Business Intelligence (OBI), 2015).

It was found that the bicycle share for commuting to work or study is lower at the left riverbank (17%) than at the right riverbank (32%) and thus cars or public transport are used more often at the left riverbank (south of Rotterdam).

Regarding parking, 81% of bicycle owners store their bicycle indoors: 7% at home and 74% in a shed, basement or garage. The rest keep it outdoors in a safe place (9%) or in an unsafe place (also 9%).

Figure 14: Underground bicycle parking next to Rotterdam central station: exit

Source: Author, 2016.

Figure 15: Bicycle parking outside of Rotterdam central station

Source: Author, 2016.

Figure 16: Underground bicycle parking next to Rotterdam central station

Source: Author, 2016.

Figure 17: Tunnel for pedestrians and cyclists at Rotterdam central station

Source: Author, 2016.

7% of citizens have an electric bike, and the ownership of electric bicycles in the city is moderately increasing.

Bicycle ownership is more common among car owners, and the opposite is also true: Rotterdammers who have a car, often have a bike, and locals who have a bicycle, also are more likely to have a car.

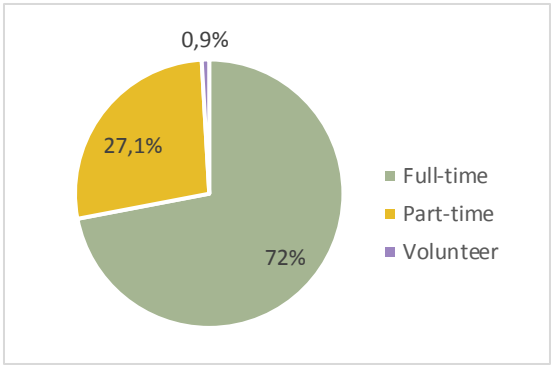
The report also predicts that in the long term the bicycle ownership in Rotterdam seems to slightly rise.

4.2 Sample description

4.2.1 Demographic characteristics of respondents

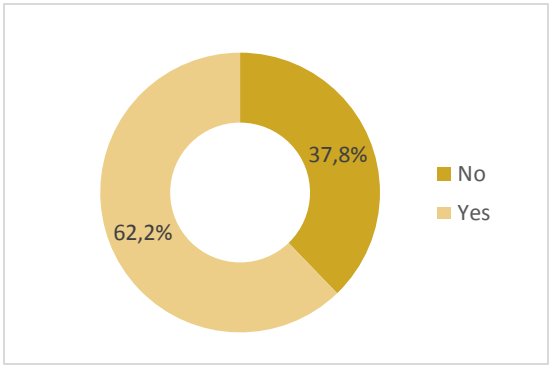
As the study implies, all the respondents to the survey should be employed. Their employment status varied as following: 162 respondents (72%) have full-time jobs, 61 (27,1%) work part-time, and 2 (0,9%) are volunteers (figure 18). As figure 19 shows, 140 (62,2%) of them reside in Rotterdam city, and the rest 85 (37,8%) reside in neighbouring cities and commute to work to Rotterdam.

Figure 18: Employment status of respondents



Source: Author, 2016. Calculated using Excel.

Figure 19: Residential status of respondents

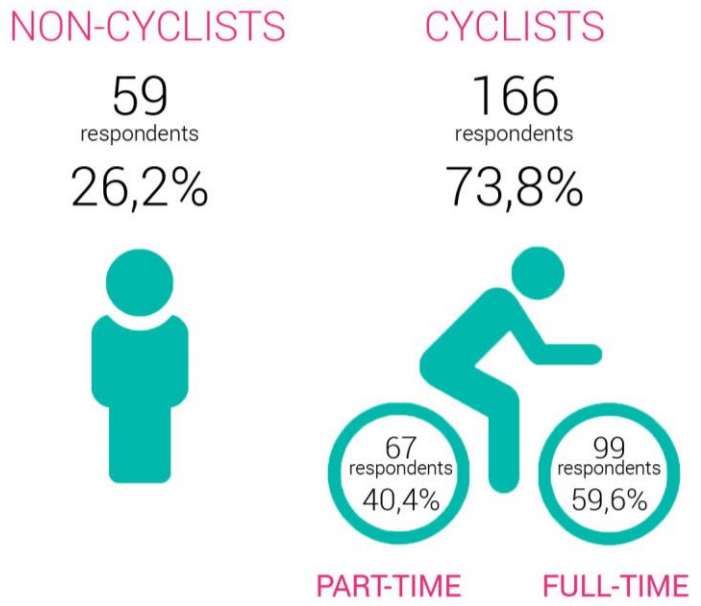


Source: Author, 2016. Calculated using Excel.

Based on their level of bicycle use, respondents were divided into three groups: non-cyclists, part-time cyclists and full-time cyclists for descriptive analysis. To calculate the level of bicycle use, this research includes both the frequency of cycling (measured by a number of trips by bicycle to work divided by a total number of trips to work) and intensity of cycling (measured by bicycle kilometres travelled for commuting divided by total kilometres travelled for commuting). Thus, the indicator of the level of bicycle use ranges from 0 to 1, where non-cyclists have '0', and all above means being a cyclist. Indicator '1' means being a full-time cyclist, and the range in between 0 and 1 (0<…<1) means being a part-time cyclist.

Thus, as figure 20 shows, 26,2% (or 59) of the respondents are non-cyclists, and the rest 73,8% (or 166 respondents) are cyclists. Out of the number of cyclists, 40,4% of them (67 respondents) cycle part-time or occasionally, and 59,6% (99 respondents) cycle full-time (full commuting distance, every working day).

Figure 20: Type of commuters by the level of bicycle use



Source: Author, 2016. Calculated using SPSS.

There were no respondents aged 20 or younger. 29,3% were 21-30 years old, 29,3% were aged 31-40, 17,3% were 41-50 years old, 21,3% were aged 51-60, and 2,7% of respondents were more than 60 years old. (table 2).

Table 2: Age and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
AGE								
21-30	18	8,0%	23	10,2%	25	11,1%	66	29,3%
31-40	20	8,9%	20	8,9%	26	11,6%	66	29,3%
41-50	11	4,9%	9	4,0%	19	8,4%	39	17,3%
51-60	9	4,0%	13	5,8%	26	11,6%	48	21,3%
More than 60	1	0,4%	2	0,9%	3	1,3%	6	2,7%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Regarding gender structure, the majority of respondents (64%) were female, 35,6% were male, and 0,4% of sample stated gender as 'other' (table 3).

Table 3: Gender and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
GENDER								
Female	34	15,1%	43	19,1%	67	29,8%	144	64,0%
Male	25	11,1%	23	10,2%	32	14,2%	80	35,6%
Other	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Respondents also vary by education level. Table 4 shows that most of the respondents have either postgraduate level (MA, MSc, Master's degree) or undergraduate level (BA, BSc, Bachelor's degree, Associate degree): 43,1% and 28,9% respectively. 15,6% have postgraduate degree (PhD), 6,7% completed senior secondary education (MBO), and the rest 5,8% have secondary education (VWO, HAVO, VMBO).

Table 4: Education level and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
EDUCATION LEVEL								
Secondary (VWO, HAVO, VMBO)	1	0,4%	6	2,7%	6	2,7%	13	5,8%
Senior secondary (MBO)	4	1,8%	6	2,7%	5	2,2%	15	6,7%
Undergraduate (BA, BSc, Bachelor's degree, Associate degree)	20	8,9%	13	5,8%	32	14,2%	65	28,9%
Postgraduate (MA, MSc, Master's degree)	25	11,1%	27	12,0%	45	20,0%	97	43,1%
Postgraduate (PhD)	9	4,0%	15	6,7%	11	4,9%	35	15,6%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

About a quarter of respondents (25,3%) preferred not to specify their income level (table 5). 20,4% of the respondents stated their yearly income as 35,000-45,000, 17,8% earn more than 45,000. 15,1% has income of 30,000-35,000 per year, 11,1% stated their income as 25,000-30,000. 7,6% earn in between 15,000 and 25,000, and the rest 2,7% earn less than 15,000 per year.

Table 5: Income level and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
INCOME LEVEL								
Less than 15,000	1	0,4%	2	0,9%	3	1,3%	6	2,7%
15,000-25,000	5	2,2%	3	1,3%	9	4,0%	17	7,6%
25,000-30,000	5	2,2%	10	4,4%	10	4,4%	25	11,1%
30,000-35,000	9	4,0%	7	3,1%	18	8,0%	34	15,1%
35,000-45,000	13	5,8%	19	8,4%	14	6,2%	46	20,4%
More than 45,000	10	4,4%	10	4,4%	20	8,9%	40	17,8%
Prefer not to reply	16	7,1%	16	7,1%	25	11,1%	57	25,3%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Regarding household structure, respondents mainly live only with partner (37,3%), single (28,9%) or with partner and children (23,1%), as table 6 shows. 4,9% live only with children, 4% live in a student house or shared apartment, and the rest 1,8% stated their household structure as 'other'.

Table 6: Household structure and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
HOUSEHOLD STRUCTURE								
Single	18	8,0%	19	8,4%	28	12,4%	65	28,9%
Student house or shared apartment	2	0,9%	4	1,8%	3	1,3%	9	4,0%
Only with partner	21	9,3%	25	11,1%	38	16,9%	84	37,3%
With partner and children	14	6,2%	15	6,7%	23	10,2%	52	23,1%
Only with children	3	1,3%	3	1,3%	5	2,2%	11	4,9%
Other	1	0,4%	1	0,4%	2	0,9%	4	1,8%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Car or other motor vehicle ownership divided in the following way: 44,4% of respondents mentioned they own a car or other motor vehicle, while 55,6% stated they don't own any (table 7).

Table 7: Car or other motor vehicle ownership and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
CAR OR OTHER MOTOR VEHICLE OWNERSHIP								
Yes	24	10,7%	36	16,0%	40	17,8%	100	44,4%
No	35	15,6%	31	13,8%	59	26,2%	125	55,6%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Bicycle ownership results are different: only 5,8% of respondents stated they don't own any bicycle. 46,2% own one bicycle, and 28% own two or more bicycles (table 8). It's interesting to observe that 12,9% of the respondents which own a bicycle don't use it for commuting to work (and 7,6% of those who own 2 or more bicycles are also non-cyclists).

Table 8: Bicycle ownership and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
BICYCLE OWNERSHIP								
None	13	5,8%	0	0,0%	0	0,0%	13	5,8%
1 bicycle	29	12,9%	29	12,9%	46	20,4%	104	46,2%
2 or more	17	7,6%	38	16,9%	53	23,6%	108	48,0%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Ethnically, the majority of respondents (83,6%) described themselves as 'white or European'. The rest responses were as following: 6,7% were Asian or Pacific islanders, 5,3% - mixed or multiple ethnic groups, 2,2% were Hispanic or Latino, 1,3% were Arabic or North African, 0,4% - black or African American, and the rest 0,4% stated their ethnicity as 'other' (table 9).

Table 9: Ethnicity and bicycle use

	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
ETHNICITY								
Asian or Pacific Islander	6	2,7%	5	2,2%	4	1,8%	15	6,7%
Arabic or North African	2	0,9%	0	0,0%	1	0,4%	3	1,3%
Black or African American	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Hispanic or Latino	3	1,3%	0	0,0%	2	0,9%	5	2,2%
White or European	42	18,7%	56	24,9%	90	40,0%	188	83,6%
Mixed/multiple ethnic groups	6	2,7%	4	1,8%	2	0,9%	12	5,3%
Other	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

Regarding nationality by birth, the majority of respondents were Dutch (77,3%). Among other nationalities were Chinese (2,2%), Belgian (1,8%), Mexican (1,8%), Indian (1,8%), Italian (1,3%), British (1,3%), American (1,3%), Irish (0,9%), Turkish (0,9%), Bulgarian (0,9%), Polish (0,9%). The following nationalities were represented by 1 person, or 0,4% each: Moroccan, Angolese, Finnish, Jordanian, Colombian, Greek, French, Portuguese, Czech, Surinamer, Canadian, Hungarian, German, Filipino, Romanian, Ukrainian and Spanish (table 10).

Table 10: Nationality and bicycle use

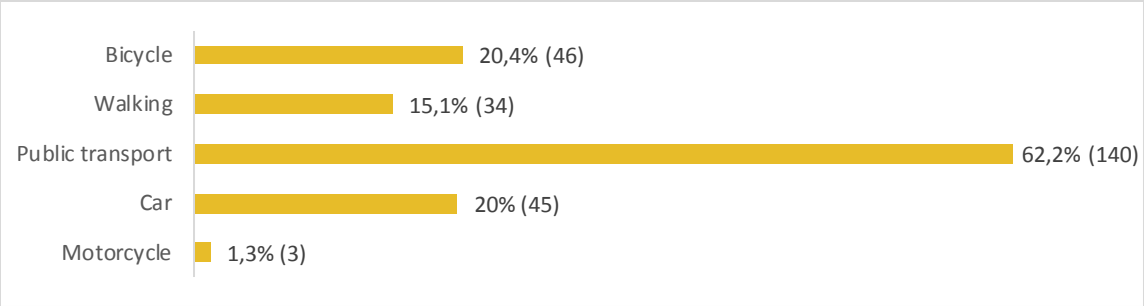
	LEVEL OF BICYCLE USE							
	0		0<...<1		1			
	Non-cyclists		Part-time cyclists		Full-time cyclists		Total	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
NATIONALITY								
Dutch	39	17,3%	49	21,8%	86	38,2%	174	77,3%
Belgian	0	0,0%	2	0,9%	2	0,9%	4	1,8%
Spanish	0	0,0%	0	0,0%	1	0,4%	1	0,4%
Mexican	3	1,3%	0	0,0%	1	0,4%	4	1,8%
Ukrainian	1	0,4%	0	0,0%	0	0,0%	1	0,4%
Polish	1	0,4%	0	0,0%	1	0,4%	2	0,9%
Romanian	1	0,4%	0	0,0%	0	0,0%	1	0,4%
Filipino	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Indian	3	1,3%	0	0,0%	1	0,4%	4	1,8%
German	0	0,0%	1	0,4%	0	0,0%	1	0,4%
American	1	0,4%	2	0,9%	0	0,0%	3	1,3%
Hungarian	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Canadian	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Chinese	2	0,9%	2	0,9%	1	0,4%	5	2,2%
Bulgarian	0	0,0%	1	0,4%	1	0,4%	2	0,9%
British	0	0,0%	1	0,4%	2	0,9%	3	1,3%
Italian	1	0,4%	1	0,4%	1	0,4%	3	1,3%
Surinamer	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Turkish	1	0,4%	1	0,4%	0	0,0%	2	0,9%
Irish	2	0,9%	0	0,0%	0	0,0%	2	0,9%
Czech	1	0,4%	0	0,0%	0	0,0%	1	0,4%
Portuguese	1	0,4%	0	0,0%	0	0,0%	1	0,4%

French	1	0,4%	0	0,0%	0	0,0%	1	0,4%
Greek	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Colombian	0	0,0%	0	0,0%	1	0,4%	1	0,4%
Jordanian	0	0,0%	0	0,0%	1	0,4%	1	0,4%
Finnish	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Angolese	0	0,0%	1	0,4%	0	0,0%	1	0,4%
Moroccan	1	0,4%	0	0,0%	0	0,0%	1	0,4%
Total	59	26,2%	67	29,8%	99	44,0%	225	100%

4.2.2 Travel characteristics of respondents

Out of all modes of transport, the most popular one among the sample is public transport (62,2%, or 140 respondents). The percentage of bicycle and car users is very similar: 20,4% (46 users) and 20% (45) respectively. 34 (15,1%) respondents commute by walking, and 3 (1,3%) use motorcycle (figure 21).

Figure 21: Use of modes of transport for commuting



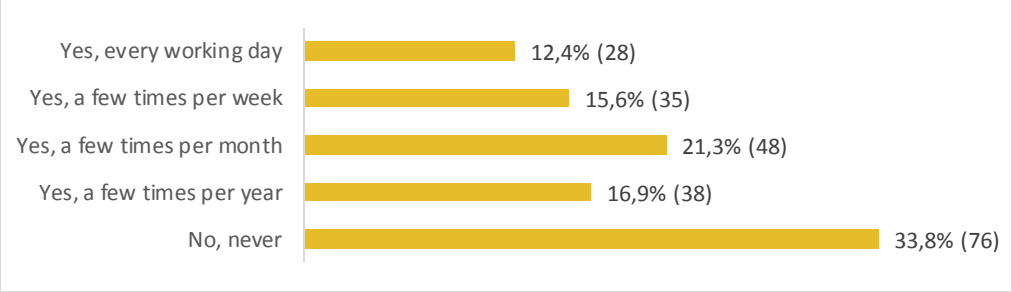
Trip distance, or kilometres travelled in total, varies from 1 km to 150 km, with the average score of 16,96 km and standard deviation of 24,55. Kilometres travelled by bicycle vary from 0 to 35 km, with the average score of 4,66 km, and standard deviation of 5,47 (table 11).

Table 11: Km travelled in total (trip distance) and km travelled by bicycle

	N	Mean	Std. Deviation	Range	Minimum	Maximum
Km travelled in total (trip distance, one way)	225	16,96	24,55	149	1	150
Km travelled by bicycle (one-way)	225	4,66	5,47	35	0	35

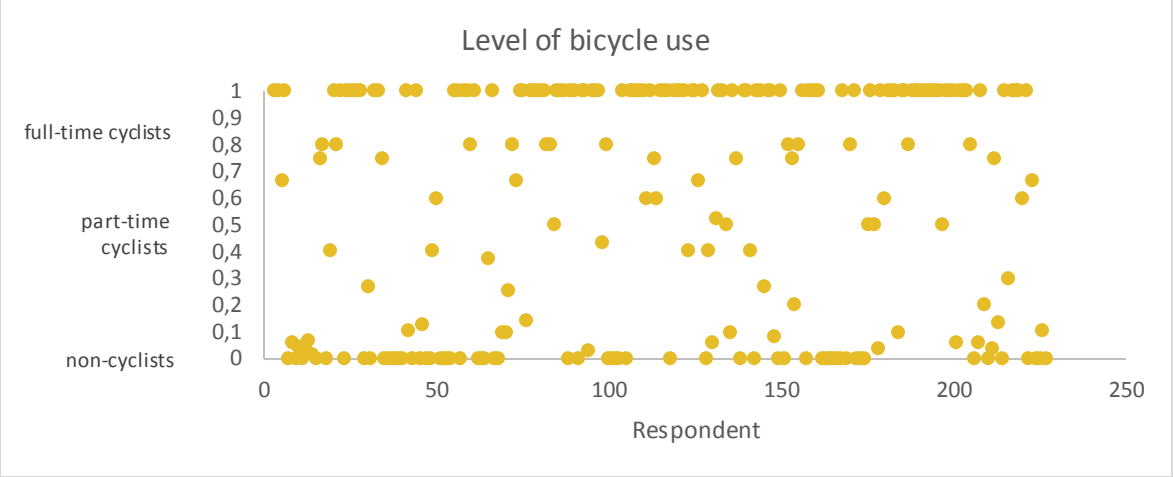
As figure 22 shows, 76 respondents (33,8%) don't use bicycle for work-related trips, 38 (16,9%) use it a few times per year. 48 (21,3%) cycles a few times per month, 35 (15,6%) use bicycle a few times per week. And the smallest group of 28 respondents (12,4%) use bicycle for work-related trips every working day.

Figure 22: Use of bicycle for work-related trips



As explained at the beginning of chapter 4.2, the dependent variable of level of bicycle use was calculated by considering both frequency and distance of cycling for commuting in Rotterdam. Distribution of the results can be seen at the figure 23.

Figure 23: Level of bicycle use (combined indicator)



4.3 Inferential analysis

This chapter contains outcomes of inferential analysis of data. Multiple linear regression was used in order to verify the association or relationship between a variable of level of bicycle use and explanatory variables of travel behaviour factors. It also helped to reduce a large number of variables to a smaller set of the most significant variables.

The final paragraphs of this chapter will put the questionnaire results together and highlight the most important factors, coming back to the main research question: "Which factors explain the level of bicycle use for commuting in Rotterdam?".

4.3.1 Factors of built and natural environment

A multiple linear regression with enter method was carried out to ascertain the extent to which the factors of built and natural environment can predict participants' level of bicycle use. Among these factors are: trip distance (scale variable, measured in km), availability of bicycle parking (nominal variable with more than two categories), type of bicycle infrastructure (nominal variable with more than two categories), continuity of bicycle infrastructure (dichotomous) and traveling across the river (dichotomous). Descriptive statistics for these variables can be found in annex 4.

Nominal variables of 'availability of bicycle parking' and 'type of bicycle infrastructure' were coded into new dichotomous "dummy" variables. The category 'bicycle parking available close to both home and work locations' contains the largest number of participants, so it was chosen as a reference category for the variable of 'availability of bicycle parking'. For the variable 'type of bicycle infrastructure' the category 'bicycle lanes only' was chosen as a reference.

A regression equation was found ($F(10,214) = 8.594$, $p < .001$), with an R^2 of .287. The coefficients for the explanatory variables are tabulated below:

Table 12: Factors of built and natural environment

		Unstandardized Coefficients		Standardized Coefficients			
		B	Std. Error	Beta	t	Sig.	
	(Constant)	,653	,056		11,601	,000	
	Trip distance (km)	-,009	,001	-,488	-8,207	,000	***
	Traveling across the river	,097	,074	,079	1,310	,192	
Availability of bicycle parking	*Close to both home and work locations (reference)*	0					
	Close to home location only	-,243	,225	-,063	-1,081	,281	
	Close to work location only	-,015	,071	-,012	-,206	,837	
	Not available	,325	,198	,097	1,639	,103	
Type of bicycle infrastructure	*Bicycle lanes only (reference)*	0					
	Mix of bicycle paths and lanes	-,038	,108	-,043	-,355	,723	
	Bicycle paths only	,060	,128	,042	,466	,642	
	A mix of bicycle paths/lanes and a road without bicycle facilities	,079	,120	,065	,662	,509	
	Roads without bicycle facilities	,020	,114	,019	,174	,862	
	Continuity of bicycle infrastructure	,006	,058	,007	,111	,911	

Significance: * p<0.05; ** p<0.01, ***p<0.001.

In this sample and with these variables, availability of bicycle parking, type of bicycle infrastructure, continuity of bicycle infrastructure and traveling across the river weren't significant.

Non-availability of bicycle parking wasn't a discouraging factors for the 4 participants who were still cycling full-time (their level of bicycle use indicator equals to 1), but this can either be considered an exception or it can probably be explained by different understanding of 'bicycle parking' among participants.

> *"We want to stimulate bicycling even more. It has grown, and we want to keep on growing. And we should be able to handle the growth, and bicycle parking is an important issue – people need to park the bike. But on the other hand, we want clean attractive streets. We don't want all those bike parks in front of the central station - it's a nice area. So we built a big parking garage underground. And we estimated the future growth because Rotterdam is an international train station, and it's growing. But the growth is much faster than we expected, so we have to expand."*
>
> - John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

Type of bicycle infrastructure doesn't show statistical significance either, and it doesn't seem to affect the level of the bicycle use of the sample. Participants' who stated not having any bicycle infrastructure on their road to work, still cycle slightly more often than those having bicycle lanes available (their 'level of bicycle use' indicator is 0.02 higher).

Availability of continuous and unbroken of bicycle infrastructure (path, lane or road) (β = -.007, $p > .005$) or traveling across the river (β = .079, $p > .005$) didn't have a statistically significant effect on the level of bicycle use either.

Rotterdam has a river separating it in two parts (figure 25). The survey data findings didn't show significance of this factor. However, all the experts stressed the potential influence of crossing the river when commuting in Rotterdam, expecting that this factor would have a discouraging nature:

"Rotterdam is a city with a river in the middle, and the river is quite broad. So for some people it might be an obstacle if you have to go from north to south. At the moment you have 2 or 3 connections, so you have the two bridges and the Maastunnel that you can cross by bike. And that of course can be an obstacle."

- Giuliano Mingardo, Senior researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

Figure 24: Map of Rotterdam

Source: (Blokplan, 2015).

"We've got a few opportunities to cross the river to the city centre, and they are quite distant from each other. So it's a long way around. (…) we want to offer more opportunities to cross the river by boats or a new bridge in a future. Also we've got a ferry in the east of Rotterdam. It's a bicycle ferry and also works for pedestrians."

- John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

"The river separates which means that people who don't have much experience with cycling will stay on their own side. If they have their destinations in the city center from the south they won't cross the bridge and will use public transport. So in that way it prevents a certain amount of potential cycling movements certainly."

- Jan Laverman, Chairman of Fietsersbond Rotterdam+region

Trip distance was the strongest predictor of the level of bicycle use, and it is the only statistically significant variable in the model ($p < .001$). With each extra km of distance, the indicator of the level of bicycle use decreases on 0,009. In order to explore this relationship further, another statistic model was built for trip distance. Based on findings in existing literature, trip distance was recoded into three variables: distances up to 7.5 km (set as a reference category as it has the biggest number of responses), distances from 7.5 to 15 km, distances which are more than 15 km. The results of the regression indicated the predictor explained 30.7% of the variance ($R^2 = .307$, $F(2, 222) = 49.230$, $p < .001$). It was found that

the behaviour among commuters with short and long trip distances differs significantly: those who commute for more than 15 km, use bicycle almost 60% less than those who commute for distances up to 7.5 km (B = -.589, β = -.577, p < .001).

Table 13: Trip distance and level of bicycle use

	Unstandardized Coefficients		Standardized Coefficients			
	B	Std. Error	Beta	t	Sig.	
(Constant)	,751	,033		22,641	,000	***
<7.5 km (reference)	0					
7.5-15 km	-,181	,066	-,159	-2,735	,007	
>15 km	-,589	,059	-,577	-9,923	,000	***

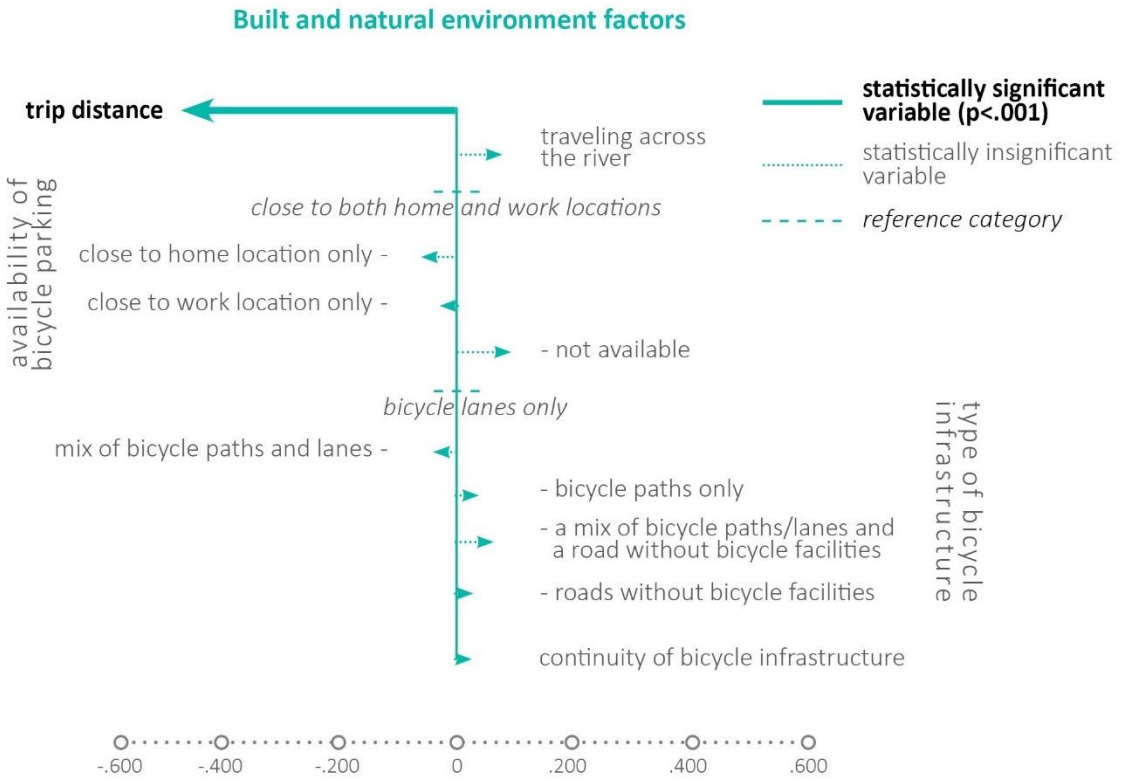
Significance: * p<0.05; ** p<0.01, ***p<0.001.

One of the interviewed experts mentioned differences for cycling for longer distances:

> *"For commuters who have to bike for more than five or seven kilometers perhaps 10-15 km, having showers is important."*
> - Will Clerx, Senior Advisor on Mobility, Municipality of Rotterdam

Summing up the findings of the full regression model of the factors of built and natural environment, figure 24 was created to visualize the nature of each variable (encouraging or discouraging bicycle use, based on β coefficient) and its statistical significance.

Figure 25: Factors of built and natural environment and their influence on the level of bicycle use



A number of factors of built and natural environment wasn't covered in the survey, but they were mentioned during expert interviews. E.g., weather conditions, such as rain, ice, snow, wind and temperature:

> *"...you can put a rain suit ... with all the apps and weather predictors that you have today - I don't think it's a real issue anymore.*
> *And in wintertime when it's snowing and freezing, we pay a lot of attention to keep the bicycle paths free of ice. We've got a very sophisticated system. There are some measurement tools in the coldest places in Rotterdam. And it can predict - ok, now it's going to freeze - they send cars covering all the major bicycle lanes with salt. So then we can prevent slippery."*
> - John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

> *"Also the wind is a factor which people describe as being important. If they already think cycling is scary or it's hard for them to cycle, wind is also a very important factor not to cycle. And also the temperature."*
> - Teun Kolner, Intern, Municipality of Rotterdam

Figure 26: Cycling in rainy weather in Rotterdam

Source: Author, 2015.

Among other factors of built environment, the influence of urban design and urban form on choosing the mode of transport was mentioned by all 6 experts:

> *"... in Rotterdam you can drive from the ring road very fast to the center of the city. There is enough place to park your car. So that's why I think Rotterdam is, as we say, a car city, compared to Delft, Groningen or Amsterdam."*
> - Will Clerx, Senior Advisor on Mobility, Municipality of Rotterdam

> *"...it was built as a car-oriented city. (...) And that has a huge influence on the fact that many people in Rotterdam use car rather than bike. So it is not that the urban design doesn't not facilitate the use of bike. But it facilitates the use of car more compared to other cities. So I would say it's easier to use the car in Rotterdam than in other cities. That could be a reason when urban design might push more people in the car rather than on the bike."*
> - Giuliano Mingardo, Senior researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

"…in the WWII the old layout of the city was completely bombed. It was terrible, but it was also an opportunity for a city to rebuild it again in a modern way that meets up with demands of the future mobilities. So, in Rotterdam we have a lot of space, much more than in cities like Amsterdam or Utrecht. That means that there's space for everyone. Space for bicyclists, space for cars, space for public transport. And because of this the alternatives work quite good as well, and that's why bicycling stays behind compared to other cities."

- John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

4.3.2 Psychological factors

In order to test if the psychological factors significantly predicted participants' ratings of aggression, multiple regression analysis was used. A full model with enter method was built, including the following variables: attitudes towards walking, car, bicycle and public transport use for commuting (treated as continuous each), subjective norm of colleagues' expectations (walking, car, bicycle and public transport use), subjective norm of friends' and family expectations (walking, car, bicycle and public transport use), personal norm and awareness of consequences (health and environmental benefits). Descriptive statistics for psychological factors can be found in annex 4.

The variables of subjective norm were coded into new dichotomous "dummy" variables with 'bicycle' as a reference category. Three Likert scale variables of attitudes (towards walking, car, bicycle and public transport use for commuting), personal norm and awareness of consequences (health and environmental benefits) were treated as continuous. The justification for that is that each item had at least 5 points and the intervals between points were approximately equal (1='strongly disagree', 2='disagree', 3='neutral', 4='agree', 5='strongly agree'). The other assumptions of applying multiple regression were ensured to be met.

68.4% of the variance in level of bicycle use can be explained from the variables of psychological factors. The model was suitable for predicting the outcome: $F(15, 209) = 30.184$, $p < .001$. Table 14 shows the coefficients for the explanatory variables.

Table 14: Psychological factors

		Unstandardized Coefficients		Standardized Coefficients			
		B	Std. Error	Beta	t	Sig.	
	(Constant)	,716	,189		3,779	,000	
Attitude	Attitude towards car use for commuting	-,041	,019	-,101	-2,168	,031	
	Attitude towards bicycle use for commuting	,054	,025	,114	2,134	,034	
	Attitude towards public transport use for commuting	-,083	,019	-,197	-4,405	,000	***
	Attitude towards walking for commuting	-,011	,015	-,030	-,712	,477	
Subjective norm (colleagues' expectations)	*Bicycle (reference)*	0					
	Car	-,255	,111	-,134	-2,291	,023	
	Public transport	-,079	,067	-,079	-1,172	,243	
	Walking	-,301	,167	-,090	-1,807	,072	

	It doesn't matter.	-,249	,091	-,198	-2,742	,007	
Subjective norm (friends' and family expectations)	*Bicycle (reference)*	0					
	Car	-,427	,098	-,285	-4,374	,000	***
	Public transport	-,546	,075	-,504	-7,283	,000	***
	Walking	-,401	,127	-,157	-3,164	,002	*
	It doesn't matter.	-,070	,088	-,058	-,801	,424	
	Personal norm	,033	,029	,065	1,117	,265	
Awareness of consequences	Awareness of consequences (health benefits)	,014	,035	,020	,386	,700	
	Awareness of consequences (environmental benefits)	,006	,041	,008	,156	,876	

Significance: * p<0.05; ** p<0.01, ***p<0.001.

The following variables make a statistically significant contribution to the predictive power of the model: attitude towards public transport use for commuting, subjective norm of friends' and family expectations for car use, public transport use and walking.

The more positive was the attitude towards public transport use, the lower was the level of bicycle use ($\beta = -.197$, $p < .001$).

Subjective norm (friends' and family expectations for public transport use) was the strongest predictor in the model with $\beta = -.504$, $p < .001$. Compared to commuters whose friends' and family expected them to cycle to work, those who were expected to use public transport, indeed, demonstrated 55% lower use of bicycle. Those who were expected to use a car, used bicycle 43% less than those who were expected to cycle ($\beta = -.285$, $p < .001$). And those who were expected to walk, cycled 40% less than those who were expected to commute by bicycle ($\beta = -.157$, $p < .05$).

The importance of subjective norm was also confirmed in the expert interview regarding different ethnic groups:

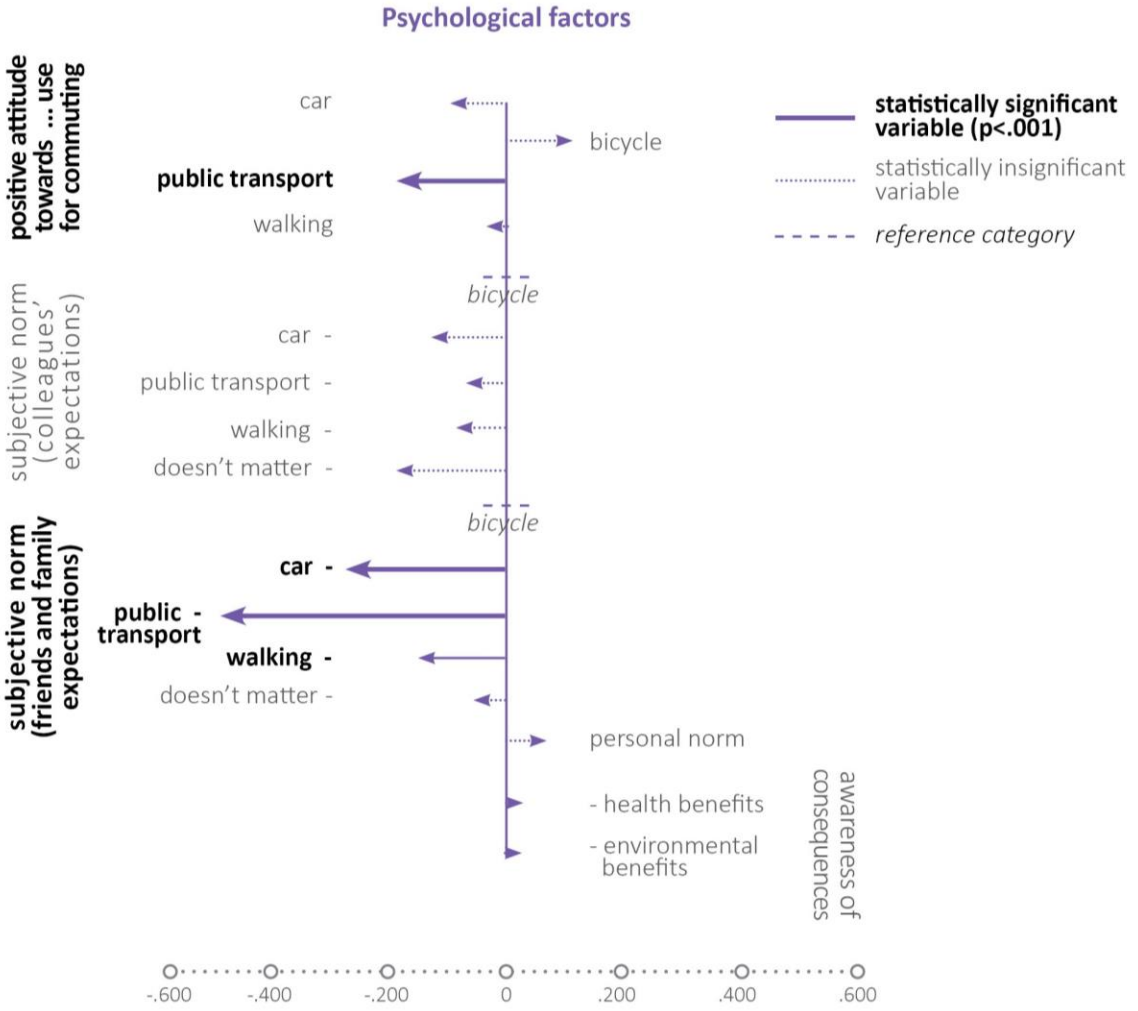
> *- Is there a different travel behaviour pattern between the natives and the people who were born outside of the Netherlands?*
> *"The subjective norm is that people in their social environments - their friends and the family - are also not cycling. So they're not used to it as well. And that's also I think is a problem in the south of Rotterdam because the people aren't cycling in their social environment. And there's also the decision why people don't take a bicycle. I think it has a large influence. (…)*
> *Some people are not motivated enough to integrate in the culture, but some of them are. So there is a big difference between and within the groups as well."*
> - Teun Kolner, Intern, Municipality of Rotterdam

An interesting opinion was expressed regarding cyclists' awareness of benefits of bicycle use:

> *"I don't think they are more aware but they value them more. I mean people that travel by car, they know that a car is not really good for the environment and they know that cycling is better for their health. So I don't think cyclists are more aware but they think it's more important. And I think it's the same for public transport users."*
> - Martijn Streng, Researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

As in the previous model, a figure was built to summarize the most relevant findings of this statistical test and show encouraging and discouraging factors:

Figure 27: Psychological factors and their influence on the level of bicycle use



4.3.3 Socio-economic and demographic factors

Another multiple regression full model was built for socio-economic and demographic factors. The model included the following variables: age, gender (categorical with the largest category of 'female' as a reference), education level, income level (categorical with 'less than 15,000' as a reference), household structure (categorical with 'single' as a reference), bicycle ownership (recoded into dichotomous variable), car or other motor vehicle ownership (dichotomous), nationality (dichotomous: 0='non-Dutch' and 1='Dutch') and ethnicity (with the largest category of 'white or European' as a reference).

A regression equation was found ($F(23, 176) = 2.054$, $p < .005$), with an R^2 of .212. The outcomes didn't reveal any statistical significance among socio-economic and demographic factors, except an obvious factor of bicycle ownership ($\beta = .342$, $p < .001$). Owning a bicycle increased the level of bicycle use to around 67%. As reported by some commuters traveling from other cities, they used a rental bicycle (OV-fiets). The coefficients for the explanatory variables are tabulated below:

Table 15: Socio-economic and demographic factors

		Unstandardized Coefficients		Standardized Coefficients			
		B	**Std. Error**	**Beta**	**t**	**Sig.**	
	(Constant)	-,754	,460		-1,637	,103	
	Age	,051	,032	,137	1,581	,116	
Gender	*Female (reference)*	0					
	Male	-,129	,067	-,140	-1,920	,056	
	Other	-,557	,440	-,089	-1,267	,207	
	Education level	,012	,033	,027	,363	,717	
Income level	*Less than 15,000 (reference)*	0					
	15,000-25,000	-,205	,238	-,129	-,859	,391	
	25,000-35,000	-,152	,222	-,129	-,685	,494	
	35,000-45,000	-,305	,223	-,290	-1,370	,172	
	More than 45,000	-,186	,225	-,168	-,826	,410	
	Prefer not to say	-,160	,217	-,162	-,737	,462	
Household structure	*Single (reference)*	0					
	Student house or shared apartment	,238	,173	,111	1,379	,170	
	Only with partner	-,031	,077	-,034	-,401	,689	
	With partner and children	-,074	,095	-,071	-,775	,439	
	Only with children	-,057	,151	-,028	-,378	,706	
	Other	,197	,241	,062	,819	,414	
	Bicycle ownership	,666	,153	,342	4,347	,000	***
	Car or other motor vehicle ownership	-,013	,075	-,014	-,168	,867	
	Nationality (non-Dutch versus Dutch)	,116	,095	,107	1,221	,224	
Ethnicity	*White or European (reference)*	0					
	Asian or Pacific Islander	,005	,155	,003	,032	,974	
	Arabic or North African	,293	,316	,066	,928	,355	
	Black or African American	-,413	,438	-,066	-,944	,346	
	Hispanic or Latino	,181	,212	,064	,851	,396	
	Mixed/multiple ethnic groups	-,240	,143	-,118	-1,678	,095	
	Other	-,176	,431	-,028	-,407	,684	

Significance: * p<0.05; ** p<0.01, ***p<0.001.

The variables of nationality and ethnicity didn't appear to be statistically significant for the studied sample, however, all the experts stated that it might be an important factor, especially when educating kids:

> *"Bicycling is very deep in the Dutch culture. If you've got small kids, the first thing you teach is how to swim and how to bike."*
> - John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

"We know that in some areas of Rotterdam probably more than half of the population is not Dutch. Of course, different cultures have different approaches. In some cultures they don't know how to bike, in some cultures it's prohibited for women to bike. So there is sure a cultural approach. For sure cultural approach also has to do with the weather. Dutch people are used to such weather, so for them it is normal to bike even if it rains. For other cultures it is not normal. (...) And the fact that Rotterdam is one of the cities in the Netherlands with the largest percentage of non-Dutch people. So this for sure may play an important role. (...)"

- Giuliano Mingardo, Senior researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

"We started the programme to work on the bicycle culture on the south of Rotterdam. (...) We work together with my colleagues from the health department. (...) So we were aimed especially at schools, education of bicycling, stimulating bicycling. And what I understand is that it's no use to teach only a kid how to bike - as parents don't think it's important to buy a bike for a kid or to invest in repairing a bike if you've got a flat tire. So it's not only the kid you have to address but also the parents."

- John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

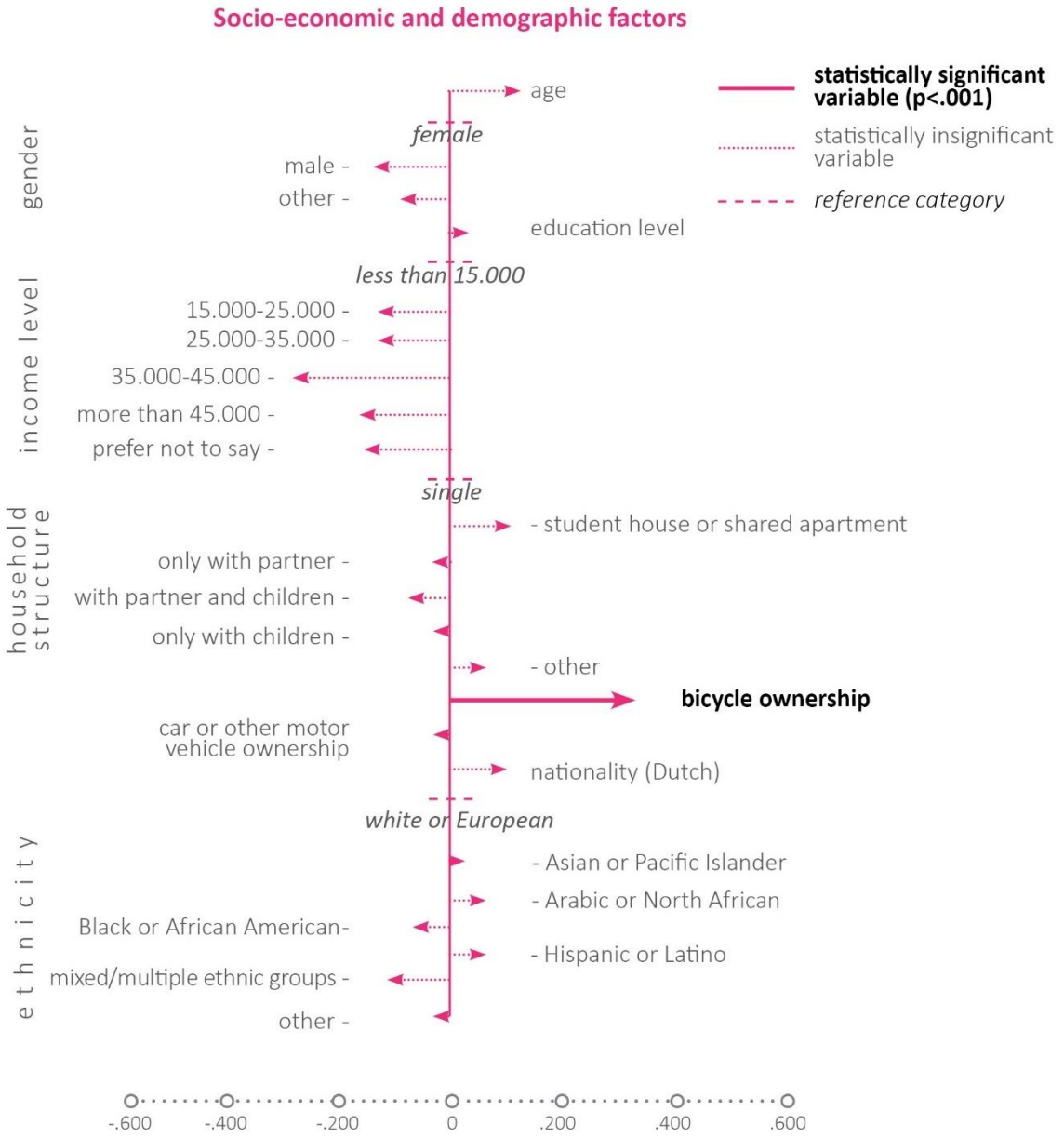
"Parents should give the example to their children. Often they find it too dangerous for their children. And they don't take the time to teach them and to travel with them to school."

"Instead of integration there's still a lot of segregation. (...) On the other hand, the fact that we have a flat country, that we have a good infrastructure and that cycling has a good status – that should also attract people from other ethnic groups."

- Jan Laverman, Chairman of Fietsersbond Rotterdam+region

The main findings of the model of socio-economic and demographic findings can be found on the figure 28.

Figure 28: Socio-economic and demographic factors and their influence on the level of bicycle use



4.3.4 Trip characteristics

For the trip characteristics a full model was created, which included the independent variables of travel time, safety and convenience. For the same reasons as in the case of psychological factors noted above, Likert scale variables of safety and convenience were treated as continuous (annex 4 includes descriptive statistics for the explanatory variables of trip characteristics).

Trip characteristics explained 41.5% of the variance ($F(3, 221) = 52.355$, $p < .001$). The test results from a multiple regression indicated that the independent variables of travel time and convenience of cycling to work statistically significantly explained the level of bicycle use (table 16 and figure 29).

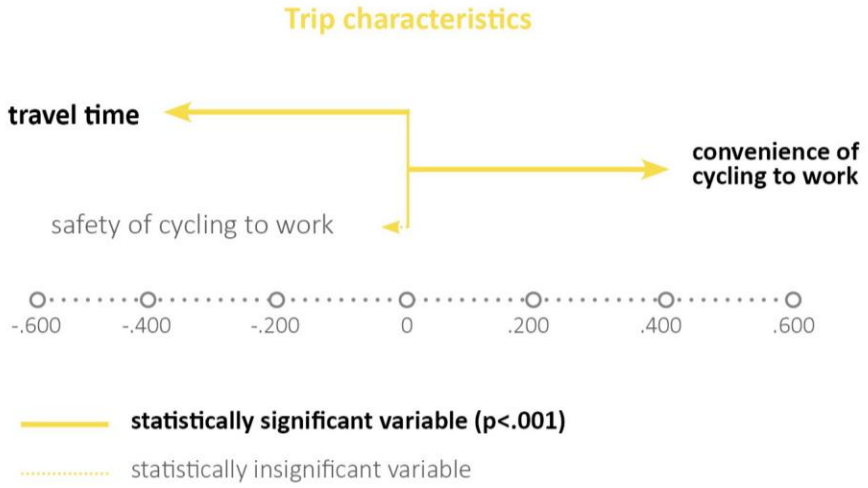
Table 16: Trip characteristics

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	,098	,136		,717	,474
Travel time	-,059	,008	-,394	-7,245	,000 ***
Convenience of cycling to work	,198	,030	,416	6,673	,000 ***
Safety of cycling to work	-,018	,027	-,040	-,677	,499

Significance: * p<0.05; ** p<0.01, ***p<0.001.

With each extra 5 minutes of travel time, the level of bicycle use decreased to almost 6% (β = -.394, p < .001). Convenience of cycling to work also significantly explained the level of bicycle use (β = .416, p < .001): the higher perceived convenience of cycling to work, the higher is bicycle use.

Figure 29: Trip characteristics and their influence on the level of bicycle use



4.3.5 Other factors

The survey also included a multiple choice question suggesting respondents to name discouraging reasons for commuting by bicycle. The results were the following: 'weather is not suitable' – 34,2%, 'the distance is too long' – 24%, 'health reasons' – 5,3%, 'preference for other modes of transport' – 4,9%, 'not being used to cycling' – 4,9%, 'traffic isn't safe for cycling' – 3,1%, 'cycling isn't fast enough' – 3,1%. 37,8% of respondents stated that they already cycle as often as possible. 21,3% of respondents stated discouraging factors for bicycle use as 'other'.

Table 17: Discouraging factors for bicycle use (multiple choice question)

	N	%
I already cycle as often as possible	85	37,8%
The distance is too long	54	24%
I am not used to cycling	11	4,9%
Cycling is not fast enough	7	3,1%

I prefer other modes of transport	11	4,9%
Weather is not suitable	77	34,2%
I think traffic isn't safe for cycling	7	3,1%
Health reasons	12	5,3%
Other	78	21,3%

When replying 'other', respondents could specify the reason. Some of them named factors related to the level of *cycling skills*: 'I don't know how to cycle' or 'I'm not good at cycling'.

Many of commuters mentioned *living too far and the need to commute from another city by public transport*: 'I have to travel by train', 'I cycle when I arrive in Rotterdam, the rest of the journey is by train', 'I live in another city, so I'm forced to use public transport (train, metro and bus) to come to work', 'I cycle 2 km every day to the station and then continue the journey by public transport', 'From home to train with bicycle, always. In Rotterdam with OV-bike but it is not always possible', 'From Rotterdam station I go with the folding bike to my work'.

Others have a different situation and *live very close to work*: 'I live so close to my work, it takes only 5min to walk', 'I walk to work and back most of the times, it's close',

Trip distance, travel time and inconvenience were also mentioned: 'Biking for 45 mins makes me sweat too much', 'Journey time by bicycle is longer than by public transport'.

A need to travel to other locations was also named: 'having appointments outside Rotterdam', 'other plans after work that are more accessible by public transport', 'If I have to travel far for a working arrangement'.

Some respondents stated their *preference for other modes of transport*: 'Walking is nicer and gives me the opportunity to taste the city', 'Metro is just next door to my place. So it's more attractive than the bike'.

A number of commuters specified discouraging *weather conditions*: 'rain or snow', 'when the weather is nice, I hope to bike more', 'hot weather', 'slippery'.

Safety reasons: 'To cycle to work, the route is through the Valkensteinse bos that I find scary to ride alone early in the morning'.

Broken bicycle was also mentioned: 'If my bike is broken or stolen', 'When both 'regular' and 'reserve' bikes are broken, I go by public transport', 'When both 'regular' and 'reserve' bike is broken, I go by public transport. Very occasionally, even if it is very bad weather. But cycling is my preference'.

Or *absence of a bicycle*: 'no bike yet, plan to buy a new one', 'just moved, no bike yet'.

Some mentioned *the need to bring kids to school*: 'I need to bring my child to school', 'Before I go to work, I first bring my kids to daycare / school. Travel by car is perfect for me.', 'Since I have to pick up my child from the work and that is not convenient by bike'.

Among *other reasons*: 'unable to do my 20mins meditation in the train', 'the bridge is too steep', 'strong muscular pain', 'For planning reasons which I do not have enough time to shower for the first appointment', 'working from home', 'I'm running in order to train for running two marathons a year', 'Awkward with business attire'.

During the interviews with experts, *alternative modes of transport* were mentioned, especially public transport and cars:

> *"Prices and conditions of public transportation are important. Because people who don't have a car use public transportation. And public transportation and cycling are certainly competitors."*
> - Jan Laverman, Chairman of Fietsersbond Rotterdam+region

> *"Especially the metro of Rotterdam is very good compared to other Dutch cities. ...the share of people using the public transport has increased quite a lot last year."*
> - Giuliano Mingardo, Senior researcher at the department of Urban, Port and

Rotterdam has one of the biggest *port*s in the world, and the experts addressed this factor as well:

> *"For Rotterdam you have to consider the role of the port. Rotterdam has a very large port, and it is also quite a large employer. And of course biking to the port is almost impossible, very difficult. And that means that a large part of employees has to go to work not by bike"*
> - Giuliano Mingardo, Senior researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

Finally, some experts gave interesting insights regarding *mobility policies* in Rotterdam:

> *"Up to 5-6 years ago bicycle was not really a priority for the city of Rotterdam. Still the motto of the city was "You're welcome by car". In the last few years that has changed drastically. And now (because there is a different political party in charge) now it's more about "We don't want more cars, we would like more people to have a bike". So in the last years there have been huge investments to facilitate to get more people on the bike."*
> - Giuliano Mingardo, Senior researcher at the department of Urban, Port and Transport Economics, Erasmus University Rotterdam

> *"By the today's administration it was completely achieved to have green politics. And now for the first time in decades choices are made not in favor of the car. So according to the European legislation we have to meet up with the air quality and we forbid dirty cars, trucks in the city center. We got environmental zone recently (...) you're not as free to go to the city center by car as it used to be. And there is a new mobility strategy. We want a modern city, much nicer to live in and to move in for slow traffic - pedestrians, bicyclists. There will be more space for them in the future. "*
> - John Akkerhuis, Coordinator cycling Rotterdam, Municipality of Rotterdam

4.3.5 Final regression model

To be able to reply to the main research question, "Which factors explain the level of bicycle use for commuting in Rotterdam?", the final model was built using multiple regression. Out of all the above mentioned models the independent variables with $p < 0.1$ and high R^2 coefficient were selected, namely: trip distance, attitudes towards bicycle, public transport and car use for commuting, subjective norm for colleagues (car and walking), subjective norm for friends and family (car, public transport, walking), bicycle ownership, travel time and convenience of cycling to work.

Using backward elimination method, starting with the full model, variables with large p-values (criterion: probability of F-to-remove >= .100) were sequentially deleted. As a result, 4 models were built. The first model explained 72.2% of the variance ($F(12, 212) = 45.838$, $p < .001$). Coefficients table from the model 1 can be found in annex 4. In the next models the following predictors were eliminated one by one: attitude towards bicycle use for commuting, travel time and subjective norm for colleagues (walking).

Thus, the final 4th regression model predicted 71.6% of the variance. The model was suitable for predicting the outcome ($F(9, 215) = 60.241$, $p < .001$). Most of the variables, except subjective norm for colleagues (car; $p > .05$) added statistically significantly to the prediction, with $p < .001$ (table 18).

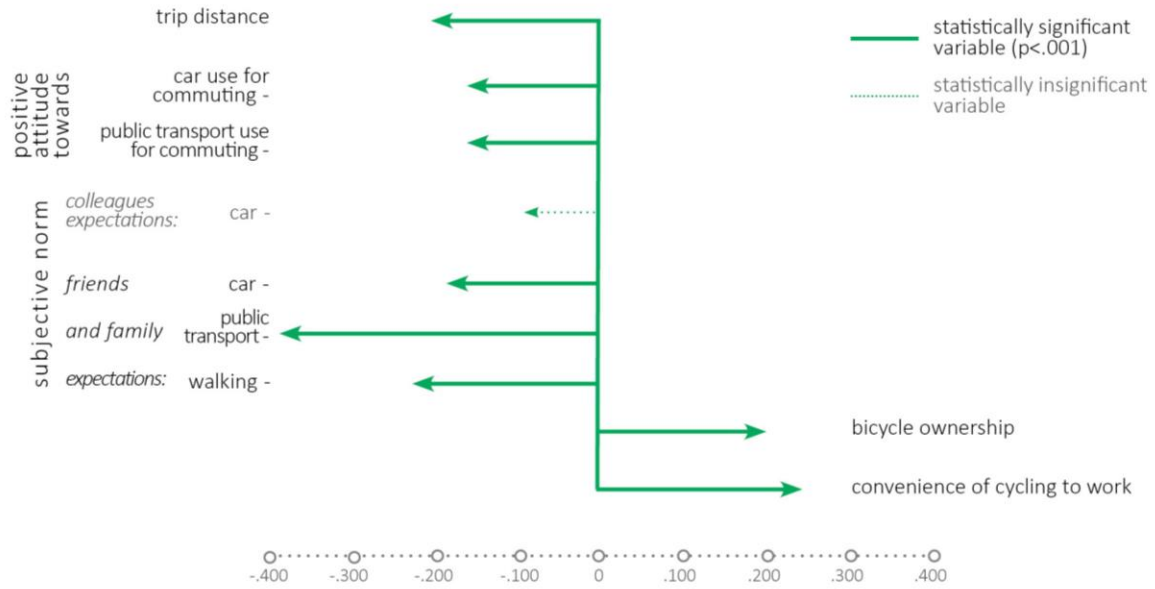
Table 18: Model 4 with the most significant variables of bicycle use

		Unstandardized Coefficients		Standardized Coefficients			
Model 4		B	Std. Error	Beta	t	Sig.	
	(Constant)	-,165	,168		-,981	,328	
	Trip distance	- ,004	,001	-,200	-4,609	,000	***
Attitude	Attitude towards car use for commuting	-,064	,017	-,158	-3,776	,000	***
	Attitude towards public transport use for commuting	-,066	,017	-,157	-3,806	,000	***
Subjective norm (colleagues)	Car	-,167	,098	-,088	-1,708	,089	
Subjective norm (friends and family)	Car	-,271	,084	-,181	-3,227	,001	**
	Public transport	-,413	,048	-,381	-8,621	,000	***
	Walking	-,567	,095	-,222	-5,991	,000	***
	Bicycle ownership	,387	,073	,203	5,295	,000	***
	Convenience of cycling to work	,116	,019	,244	6,070	,000	***

Significance: * p<0.05; ** p<0.01, ***p<0.001.

Based on β and its nature (encouraging or discouraging effect), a figure with the predictors from the final model was built (figure 30). Subjective norm for friends and family expectations (public transport) was the strongest predictor in the model ($\beta = -.381$, $p < .001$) resulting in a 41.3% lower bicycle use. Expectations from friends and family to use a car ($\beta = -.181$, $p < .01$) or walk ($\beta = -.222$, $p < .001$) also had a negative effect of bicycle use.

Figure 30: Most significant predictors of the level of bicycle use



It was found that attitude towards car use from commuting significantly explained the level of bicycle use (β = -.158, p<.001), as did attitude towards public transport use (β = -.157, p<.01). In both cases, the more positive was the attitude towards alternative modes of transport, the lower was the level of bicycle use.

Owning a bicycle increased bicycle use to 38.7% in this regression model (β = .203, p<.001).

Trip distance appeared to be another statistically significant predictor of variance (β = -.200, p<.001), with each extra km travelled decreasing the level of bicycle use to around 0,4%.

Commuters with a higher perceived convenience of cycling to work demonstrated higher bicycle use (β = .244, p<.001).

Each regression model from this chapter was tested and ensured to meet the assumptions of multiple linear regression. For the final 4th model the scatterplots of the standardized residuals against the standardized predicted values showed homoscedasticity, the scatterplots of the actual outcome variable against the predicted outcome demonstrated linear relationship and the normal distribution of residuals was observed using P-P plot. Independence of observations was proved by the Durbin-Watson statistics: d = 1,951, which is in between the values of 1.5<d<2.5. In the Correlations table Pearson's coefficient for each explanatory variable is less than 0.8. According to the collinearity statistics in the Coefficients table, Tolerance is <10. And the VIF is close to 1 for each statistically significant explanatory variable, which means no or little multicollinearity.

Chapter 5: Conclusions and Recommendations

Worldwide demand for urban mobility is increasing, which entails new challenges, especially for sustainability of the city: environmental, social and economic. The study focuses on travel behaviour, analysing its determinants and aiming to provide knowledge to facilitate further improvements in sustainable mobility. The phenomenon of cycling in Rotterdam, the Netherlands, was chosen as the case. The Netherlands is world renown for cycling, occupying the first place among European countries in rankings of both bicycle share and bicycle ownership. Amsterdam is often referred to as 'the bicycle capital of the world', competing for that title with Copenhagen. While 26% of all trips in the Netherlands are made by bicycle, in Rotterdam bicycle share is only 18%, with even lower percentage for work trips. Thus, the main objective of this research was to explain the determinants of the current level of bicycle use in Rotterdam, specifically focusing on commuters. To achieve it, a number of travel behaviour factors influencing the user's decision to (not) cycle were examined. The study included not only hard factors, such as factors of built and natural environment, socio-economic and demographic factors, trip characteristics, but it also covered often neglected soft factors – psychological.

Since no or little research was conducted in Rotterdam on the bicycle use for commuting, the outcome of this research is expected to add value to the existing literature by investigating a unique for the Dutch context city. The findings might also be helpful in developing policies on sustainable mobility since the current authorities of Rotterdam give high priority to cycling and sustainability of the city. Insights on the travel behaviour of commuters might be of use for tackling traffic congestion issue in Rotterdam by influencing demand and shifting to non-motorized modes of transport, in particular, bicycle.

For this research a number of limitations were identified. First, limited time frame and low response during data collection period in summer resulted in an insufficient variety of industries and organizational types taking part in the research. For this reason, the sample is unlikely to be representative of the employed population of Rotterdam. Second, the complex topic of travel behaviour in a complex urban environment implies a challenging variety of factors influencing commuters' travel decisions, as the literature review illustrated.

The survey was used as the main strategy in this empirical research, aiming to achieve breadth and collect quantitative data using online questionnaire. The cross-sectional approach was applied, which involved analysis of data collected from the same group of the population at a particular moment in time. To obtain vision other than user perspective and to avoid limited depth of the outcome, a number of interviews with the experts in the field of mobility were used as an important complementary method.

The quantitative data was analysed by means of both descriptive and inferential statistics in Excel and SPSS. Multiple linear regression was applied for causal analysis to explain the relationship between the dependent variable of the level of bicycle use and a number of independent variables of travel behaviour factors. The research findings fit the conceptual framework of chapter 2 explaining the current level of bicycle use.

Among the studied factors of *built and natural environment*, the multiple regression analysis showed that the trip distance has the biggest impact on the choice of bicycle for commuting to work. Distances of more than 15 km appeared to be highly discouraging for bicycle use: commuters who travel more than 15 km use bicycle almost 60% less than those who commute for up to 7.5 km distances. It was also found that each extra km travelled discouraged bicycle use by almost 1%. The importance of this factor was also confirmed during the interviews and

is illustrated in numerous studies (Heinen et al., 2010; Heinen et al., 2013; Pucher and Buehler, 2012).

During interviews, the experts stressed a potentially discouraging effect of crossing the Nieuwe Maas river when commuting in Rotterdam. The fact that the river is relatively wide and there are only 3 options to cross it (Erasmus bridge, Willemsbrug and Maastunnel) which are located far from each other, was expected to be discouraging for commuters' choice of bicycle, especially if they are not used to cycling much. This hypothesis wasn't confirmed by the data from the survey since no statistically significant relationship was found. But this factor might be interesting for further more detailed research.

The findings show that a number of *psychological factors* have a significant influence on the level of bicycle use.

The more positive the attitude towards car and public transport use commuters had, the less they were likely to cycle. The same discouraging nature of relationship was found for subjective norm (friends and family expectations). If they expect the commuter to use a car, public transport or walk to their work location, the less likely he or she is to use a bicycle. Out of all the above-mentioned expectations, the strongest relationship was found for public transport: compared to commuters whose friends' and family expected them to cycle to work, those who were expected to use public transport demonstrated 55% lower use of bicycle. It was stressed by one of the experts who stated that bicycle and public transport are highly competitive modes of transport. It raises a question for further investigation: is there the biggest share of potential cyclists among public transport users and vice versa? And how this relationship can be used for further sustainable mobility policies?

Among *socio-economic and demographic factors*, bicycle ownership was the only statistically significant factor. However, even among owners of 2 or more bicycle, a 15,7% of non-cyclists was observed, which might be explained by other than commuting bicycle use (recreational, shopping, etc.).

This research made a distinction between nationality by birth and ethnicity, assuming the importance of these factors. However, no statistically significant relationship was found between these variables. Most of the interviewed experts expected Dutch natives to cycle more than non-Dutch. It might be an influential determinant in Rotterdam, the most ethnically diverse city in the Netherlands with almost half of the population of non-Dutch origins. Although, this research is lacking the variety of nationalities or ethnicities for comparative distribution by countries or ethnic groups.

The findings from *trip characteristics* in this research indicate that convenience of cycling to work has the biggest impact on the level of bicycle use. As expected, higher perceived convenience resulted in higher bicycle use.

As literature suggests, increased travel time has a negative effect on cycling, which was confirmed by the multiple regression model of the trip characteristics (with each extra 5 minutes of travel time, the level of bicycle use decreased to almost 6%). However, this factor was later excluded from the final model of the most significant factors of travel behaviour.

To answer the *main research question*, as a result of multiple regression analysis, a number of statistically significant factors was found, which figure 30 of the previous chapter illustrates. Encouraging factors include bicycle ownership and convenience of cycling to work. Discouraging factors include long trip distance, positive attitude towards car use for commuting, positive attitude towards public transport for commuting, subjective norm (friends and family expectations) towards car use, public transport use and walking to work location.

Recommendations for further research:

It is recommended to include multi-modal trips and their characteristics in further research on this topic. Due to the limitations of an online survey as a method, this option couldn't be added to the questionnaire at a later stage of this research. But collecting this data is important for a comprehensive research of the travel behaviour topic.

Additionally, the statistical significance of crossing the river in Rotterdam wasn't confirmed by this study, but this factor seems to have a potential influence on the level of bicycle use. Therefore, a more detailed study would help to shed the light on this factor.

Moreover, a unique urban form of Rotterdam could be addressed comprehensively. It was hardly covered in the survey, but the experts assume that it stimulates the use of alternative modes of transport, especially cars.

Since human perceptions might vary considerably, the variable of convenience needs to be explored more and clarified in order to investigate ways how to address this significant factor in order to stimulate bicycle use.

Recommendations for policy:

The findings indicate a significant share of commuters traveling by train from other cities. Therefore, to address this group of commuters it is important to ensure that cycling facilities are well connected with the public transport and commuters-targeted rental programs are available.

Although tackling travel distance is difficult, policymakers or employees could provide incentives and stimulate choosing shorter locations for work and housing.

Additionally, considering the strong influence of subjective norm (especially of friends and family), promotion of cycling among potential target groups could contribute to increasing its share.

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Annex 1: Questionnaire in English

This research is conducted as a part of my Master's programme 'Urban Management and Development' at the IHS, Erasmus University Rotterdam. The aim of this survey is to gain new insights into the use of bicycle for commuting to/from work in Rotterdam.

You can make an important contribution to this research.

Just fill in the survey. It only takes 6-8 minutes. Data will be treated confidentially and used for scientific purposes only.

Please note: *This research is aimed at currently employed in Rotterdam population. If you are not currently employed, nor your work place is located in Rotterdam, please skip the questionnaire. Perhaps one of your fellow residents would fill it out?*

Good luck and thank you for your cooperation!

start

1 Are you currently employed? *

If you are not currently employed, completing this questionnaire is not possible because the questions are mainly related to commuting. Perhaps one of your fellow residents would fill out the questionnaire?

- ○ yes, full-time
- ○ yes, part-time
- ○ yes, as a volunteer
- ○ no

2 How many days per week do you usually commute to work? *

Please choose one option, based on your average week.

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7

3 How many days per week do you usually use bicycle for commuting to work? *

Please choose one option, based on your average week.

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7

4 Do you also use bicycle for work-related trips? *

For example, to business meetings during your working hours.

- ○ yes, every working day
- ○ yes, a few times per week
- ○ yes, a few times per month
- ○ yes, a few times per year
- ○ no, never

5 How many kilometers do you travel to work?

Please indicate the number of distance between your home and work locations.

6 How many kilometers do you *cycle* to work?

In a one-way trip, how many kilometers do you cycle? If you don't cycle, please write '0'.

7 When you don’t cycle to work, which mode of transport do you mainly use? *

- [ ] car
- [ ] motorcycle
- [ ] public transport
- [ ] walking
- [ ] I always commute by bicycle.

8 Why don't you commute to work by bicycle more often? *

Think of the trips when you traveled by other modes of transport - why didn't you choose bicycle?

- [ ] I already cycle as often as possible
- [ ] The distance is too long
- [ ] I am not used to cycling
- [ ] Cycling is not fast enough
- [ ] I prefer other modes of transport
- [ ] Weather is not suitable
- [ ] I think traffic isn't safe for cycling
- [ ] Health reasons
- [ ] Other

9 If you chose 'Other' in the previous question, could you please write down your *reasons not to cycle to work*?

If all your reasons were mentioned, just click 'Enter' to continue.

Great! Now let's think of the infrastructure...

10 Please indicate the postal code of your home. *

Enter your answer in "XXXXYY" format, where X is a number and Y is a character.

11 Please indicate the postal code of your regular place of work. *

Enter your answer in "XXXXYY" format, where X is a number and Y is a character.

12 Is there car parking available? *

- Yes, both close to my work and home locations
- Yes, close to my home location only
- Yes, close to my work location only
- No

13 Is there bicycle parking available? *

- Yes, both close to my work and home locations
- Yes, close to my home location only
- Yes, close to my work location only
- No

14 What type of bicycle infrastructure is there on your way from home to work? *

bicycle lane

bicycle path

- Bicycle lanes only
- Bicycle paths only
- A mix of bicycle paths and lanes
- A mix of bicycle paths/lanes and a road without bicycle facilities
- Roads without bicycle facilities

15 Is the bicycle infrastructure (path or lane) on your way from home to work continuous and unbroken?

- Yes
- No

16 How much time does it usually take to get from your home to work place? *

- Less than 10 minutes
- 10-15 minutes
- 15-20 minutes
- 20-25 minutes
- 25-30 minutes
- 30-35 minutes
- 35-40 minutes
- 40-50 minutes
- 50-60 minutes
- More than 60 minutes

17 I think commuting by bicycle in Rotterdam is *convenient*. *

Please agree or disagree with the statement.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

18 I think commuting by bicycle in Rotterdam is *safe*. *

Please agree or disagree with the statement.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

You're halfway there, only a few more questions to go!

19 Please agree or disagree with the following statements:

I like the idea of driving a car to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

I like the idea of cycling to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

I like the idea of using public transport to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

I like the idea of walking to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

24 Please agree or disagree with the following statements:

I intend to commute to work *by car* more often.

Please skip the question if you don't use car for commuting to work.

1	2	3	4	5
Definitely not		Neutral		Definitely yes

I intend to commute to work *by bicycle* more often.

Please skip the question if you don't use bicycle for commuting to work.

1	2	3	4	5
Definitely not		Neutral		Definitely yes

I intend to commute to work *by public transport* more often.

Please skip the question if you don't use public transport for commuting to work.

1	2	3	4	5
Definitely not		Neutral		Definitely yes

I intend to commute to work *by walking* more often.

Please skip the question if you don't normally commute to work by walking.

1	2	3	4	5
Definitely not		Neutral		Definitely yes

29 Which mode of transport do you think your *colleagues* expect you to use? *

- Car
- Public transport
- Bicycle
- Walking
- It doesn't matter

30 Which mode of transport do you think your *friends and relatives* expect you to use? *

- Car
- Public transport
- Bicycle
- Walking
- It doesn't matter

31 Please agree or disagree with the following statements:

I (would) feel good about cycling to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

I (would) feel guilty about not cycling to work. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

34 Please agree or disagree with the following statements:

Cycling makes me more healthy. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

Using bicycle is environmentally friendly. *

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

Almost done! A few last questions.

37 What is your age? *

- less than 20
- 21-30
- 31-40
- 41-50
- 51-60
- more than 65

38 What is your gender? *

- Female
- Male
- Other

39 What is your highest level of education completed? *

- Primary (elementary school)
- Secondary (VWO, HAVO, VMBO)
- Senior secondary (MBO)
- Undergraduate (BA, BSc, Bachelor's degree, Associate degree)
- Postgraduate (MA, MSc, Master's degree)
- Postgraduate (PhD)

40 What is the level of your yearly net income (in euro)? *

- Less than 15,000
- 15,000-25,000
- 25,000-30,000
- 30,000-35,000
- 35,000-45,000
- More than 45,000
- I prefer not to reply.

41 Who do you live in the same dwelling with? *

- Single
- Student house
- Only with partner
- With partner and children
- Only with children
- Other

42 Do you own a car or other motor vehicle (e.g., motorcycle)? *

- Yes
- No

43 How many bicycles do you own? *

- None
- 1 bicycle
- 2 or more

44 What is your nationality? *

Please choose your nationality by birth.

Ooops! You must make a selection ▼

45 What is your ethnicity? *

- Asian or Pacific Islander
- Arabic or North African
- Black or African American
- Hispanic or Latino
- White
- Mixed/multiple ethnic groups
- Other

46 That's it! Thank you for your contribution to this research.

Don't forget to click 'Submit' to complete this survey.

Can we contact you for a short follow-up interview of this survey? It would help to better understand your responses. We will also inform you about the results of this research. *If you are interested, please leave your email below.*

For questions or comments, please contact: *hanna.pintusava@student.eur.nl*

Submit

Annex 2: Questionnaire in Dutch

Dit onderzoek wordt uitgevoerd als onderdeel van mijn Master programma 'Urban Management and Development' aan de IHS, Erasmus Universiteit Rotterdam. Het doel is nieuwe inzichten te verkrijgen in het gebruik van de fiets voor woon-werk verkeer van en naar Rotterdam.

U kunt een belangrijke bijdrage leveren aan dit onderzoek door deze vragenlijst in te vullen. Het kost slechts 6-8 minuten. De data zullen vertrouwelijk behandeld worden en alleen gebruikt worden voor wetenschappelijk onderzoek.

Let op: *Het onderzoek is gericht op werkende inwoners van Rotterdam. Als u niet werkzaam bent in Rotterdam, vul dan a.u.b. de vragenlijst niet in. Wellicht dat een huisgenoot geïnteresseerd is het in te vullen.*

Succes met het invullen en alvast heel erg bedankt voor de medewerking!

start

1 Bent u momenteel werkzaam? *

Als u niet werkzaam bent is het niet mogelijk de vragenlijst in te vullen omdat het hoofdzakelijk over woonwerk verkeer gaat. Wellicht dat een werkzame huisgenoot geïnteresseerd is het in te vullen.

- ○ Ja, fulltime
- ○ Ja, parttime
- ○ Ja, als vrijwilliger
- ○ Nee

2 Hoeveel dagen per week reist u normaalgesproken naar uw werk? *

Kies één antwoord, gebaseerd op het gemiddelde per week

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7

3 Hoeveel dagen per week reist u normaalgesproken per fiets naar uw werk? *

Kies één antwoord, gebaseerd op het gemiddelde per week

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7

4 Gebruikt u ook een fiets voor ander werk-gerelateerde vervoer? *

Bijvoorbeeld naar vergaderingen tijdens werktijd.

- ○ Ja, iedere werkdag
- ○ Ja, een paar keer per week
- ○ Ja, een paar keer per maand
- ○ Ja, een paar keer per jaar
- ○ Nee

5 Hoeveel kilometer reist u naar uw werk?

Vul de afstand tussen thuis en uw werk in.

6 Hoeveel kilometer *fiets* u naar uw werk?

Het gaat om een enkele reis. Als u niet fietst, vul dan '0' in.

7 Als je niet met de fiets gaat, welk transportmiddel gebruikt u dan? *

- [ ] Auto
- [ ] Motor
- [ ] Openbaarvervoer
- [ ] Lopen
- [ ] Ik fiets altijd.

8 Waarom gaat u niet vaker per fiets naar het werk? *

Denk aan de keren dat u met een ander vervoer gegaan bent; waarom koos u toen niet voor de fiets?

- [ ] Ik ga al zo vaak mogelijk met de fiets
- [ ] Het is te ver
- [ ] Ik fiets niet vaak/goed
- [ ] Het is niet snel genoeg
- [ ] Mijn voorkeur gaat uit naar andere manieren van vervoer
- [ ] Het was slecht weer
- [ ] Het verkeer is te onveilig om te fietsen
- [ ] Wegens gezondheidsredenen
- [ ] Anders

9 Als u bij de vorige vraag 'Anders' heeft gekozen, vul dan a.u.b. de redenen in om niet naar het werk te fietsen

Als al uw redenen al genoemd zijn, klik dan 'Enter' om door te gaan.

Geweldig! Laten we nu even stilstaan bij de infrastructuur…

10 Vul alstublieft de postcode van uw woning in. *

Doe dit als 'XXXXYY' waarbij X een cijfer is en Y een letter.

11 Vul alstublieft de postcode van uw gebruikelijke werk adres in. *

Doe dit als 'XXXXYY' waarbij X een cijfer is en Y een letter.

12 Zijn er parkeerplekken voor auto's beschikbaar? *

- ( ) Ja, zowel dichtbij mijn woning als mijn werk.
- ( ) Ja, alleen dichtbij mijn woning.
- ( ) Ja, alleen dichtbij mijn werk.
- ( ) Nee

13 Zijn er stallingen voor fietsen beschikbaar? *

- Ja, zowel dichtbij mijn woning als mijn werk.
- Ja, alleen dichtbij mijn woning.
- Ja, alleen dichtbij mijn werk.
- Nee

14 Wat voor type fietsbanen zijn er tussen uw woning en uw werk? *

fietsstrook

fietspad

- Alleen fietsstroken
- Alleen fietspaden
- Een mix van fietsstroken en fietspaden
- Een mix van fietsstroken/-paden en een weg zonder speciale fietsbanen
- Alleen wegen zonder speciale fietsbanen

15 Zijn de fietsbanen (strook of pad) tussen uw woning en werk ononderbroken?

- Ja
- Nee

16 Hoe lang bent u normaalgesproken onderweg van uw woning naar uw werk? *

- Minder dan 10 minuten
- 10-15 minuten
- 15-20 minuten
- 20-25 minuten
- 25-30 minuten
- 30-35 minuten
- 35-40 minuten
- 40-50 minuten
- 50-60 minuten
- Meer dan 60 minuten

Ik denk dat het gebruik van de fiets voor woon-werk verkeer in Rotterdam *handig* is.*

Geef van de volgende stellingen aan in hoe verre u het er mee eens bent:

1	2	3	4	5

Sterk oneens Neutraal Sterk eens

Ik denk dat het gebruik van de fiets voor woon-werk verkeer in Rotterdam *veilig* is.*

Geef van de volgende stellingen aan in hoe verre u het er mee eens bent:

1 2 3 4 5

Sterk oneens Neutraal Sterk eens

U bent al halverwege, nog maar een paar vragen te gaan!

19 Geef van de volgende stellingen aan in hoe verre u het er mee eens bent:

Ik vind het een prettig idee om met de *auto* naar het werk te rijden. *

1 2 3 4 5

Sterk oneens Neutraal Sterk eens

Ik vind het een prettig idee om naar het werk te *fietsen*. *

1 2 3 4 5

Sterk oneens Neutraal Sterk eens

Ik vind het een prettig idee om met het *openbaarvervoer* naar het werk te gaan.*

1 2 3 4 5

Sterk oneens Neutraal Sterk eens

Ik vind het een prettig idee om te *voet* naar het werk te gaan. *

1 2 3 4 5

Sterk oneens Neutraal Sterk eens

24 Geef van de volgende stellingen aan of u het er mee eens of oneens bent.

Ik ben van plan vaker met *de auto* naar het werk te reizen.

Sla een stelling over als u deze manier van vervoer nooit gebruikt voor woon-werk verkeer.

1 2 3 4 5

Zeker niet Neutraal Zeker wel

Ik ben van plan vaker met *de fiets* naar het werk te reizen.

Sla een stelling over als u deze manier van vervoer nooit gebruikt voor woon-werk verkeer.

1	2	3	4	5
Zeker niet		Neutraal		Zeker wel

Ik ben van plan vaker met *het openbaarvervoer* naar het werk te reizen.

Sla een stelling over als u deze manier van vervoer nooit gebruikt voor woon-werk verkeer.

1	2	3	4	5
Zeker niet		Neutraal		Zeker wel

Ik ben van plan vaker *te voet* naar het werk te reizen.

Sla een stelling over als u deze manier van vervoer nooit gebruikt voor woon-werk verkeer.

1	2	3	4	5
Zeker niet		Neutraal		Zeker wel

29 Welk vervoersmiddel denken uw *collega*'s dat u meestal gebruikt? *

- Auto
- Openbaarvervoer
- Fiets
- Te voet
- Maakt niet uit.

30 Welk vervoersmiddel denken uw *vrienden en kennissen* dat u meestal gebruikt? *

- Auto
- Openbaarvervoer
- Fiets
- Te voet
- Maakt niet uit.

31 Bent u het eens of oneens met de volgende stellingen:

Het voelt goed als ik naar het werk (zou) fiets(en). *

1	2	3	4	5
Sterk oneens		Neutraal		Sterk eens

Ik voel mij schuldig als ik niet naar het werk (zou) fiets(en). *

1	2	3	4	5
Sterk oneens		Neutraal		Sterk eens

34 Bent u het eens of oneens met de volgende stellingen:

Fietsen is goed voor mijn gezondheid. *

1	2	3	4	5
Sterk oneens		Neutraal		Sterk eens

Het gebruik van fietsen is milieuvriendelijk. *

1	2	3	4	5
Sterk oneens		Neutraal		Sterk eens

Bijna klaar! Nog een paar laatste vragen.

37 Wat is uw leeftijd? *

- Minder dan 20
- 21-30
- 31-40
- 41-50
- 51-60
- Meer dan 65

38 Wat is uw geslacht? *

Vrouw Man Anders

39 Wat is uw hoogst afgeronde onderwijsniveau? *

- Basisschool
- Middelbare school (VWO, HAVO, VMBO)
- Middelbaar beroepsonderwijs (MBO)
- Hoger beroepsonderwijs (BA, BSc, Bachelor, Associate)
- Wetenschappelijk onderwijs (MA, MSc, Master)
- Doctoraat (PhD)

40 Wat is uw jaarlijks inkomen (in Euro)? *

- Minder dan 15,000
- 15,000-25,000
- 25,000-30,000
- 30,000-35,000
- 35,000-45,000
- Meer dan 45,000
- Zeg ik liever niet.

41 Wat is uw woonsituatie? *

- Alleen
- Studentenhuis
- Alleen met partner
- Met partner en kinderen
- Alleen met kinderen
- Anders

42 Bent u eigenaar van een auto or ander gemotoriseerd voertuig (zoals een motor)? *

Ja Nee

43 Hoeveel fietsen heeft u? *

Geen 1 2 of meer

44 Wat is uw nationaliteit? *

Kies alstublieft uw nationaliteit bij geboorte.

Oeps! Je moet een keuze maken ▼

45 Wat is uw etniciteit? *

- Aziatisch
- Arabisch of Nood-Afrikaans
- Midden- of Zuid-Afrikaans
- Latijns-Amerikaans
- Westers
- Gemengd/meerdere etnische groepen
- Anders

46 Dat was het! Bedankt voor uw deelname aan dit onderzoek.

Vergeet niet op 'Verzenden' te klikken om de laatste antwoorden door te sturen en het onderzoek af te ronden.

Mogen we eventueel contact met u opnemen voor een kort vervolggesprek met betrekking tot dit onderzoek? Het zou helpen om de antwoorden te interpreteren. We zullen u dan tevens informeren over de resultaten van het onderzoek. *Als u geïnteresseerd bent, vul dan hieronder uw e-mailadres in.*

Voor vragen of opmerkingen kunt u contact opnemen via: *hanna.pintusava@student.eur.nl*

Verzenden

Annex 3: Interview Guide

- Introduce myself and explain the purpose of the interview and the research
- Explain format of the interview (semi-structured with open-ended questions)
- Indicate how long the interview will take
- Address terms of confidentiality and explain who will get access to the answers. Ask permission to quote and to record the interview
- Provide contact details in case of any further questions or comments
- Ask respondent if they have any questions before the interview is started

BACKGROUND:

- Name of respondent
- Name of institution
- Position and background of respondent

BUILT AND NATURAL ENVIRONMENT:

1. Do you think that the urban design of Rotterdam dictates the choice of mode of transport?
2. Which role does the bicycle infrastructure play for choosing bicycle as a mode of transport (e.g., racks, covered parking, showers at the work location)?
3. Which other conditions of the built environment are more influential in Rotterdam?
4. Do you think the natural environment (climate and weather) influence the decision to bicycle for commuting to work?

PSYCHOLOGICAL FACTORS:

5. Is it true that cyclists are more aware of the benefits of cycling (e.g., for health or environment)?
6. Do you think the expectations of colleagues, friends or family might influence the decision which mode of transport to choose?

SOCIO-ECONOMIC AND DEMOGRAPHIC FACTORS:

7. For the people who were born outside of the Netherlands, is there a different travel behaviour pattern and different preferences for the mode of transport? If yes, do you think their travel behaviour have changed across the time (the more they stay in the Netherland)?
8. Have you observed patterns among your acquaintances regarding their cultural or ethnic background and the mode of transport they use?
9. Do you think there is a relation between the income level and the choice of bicycle as a mode of transport?

TRIP CHARACTERISTICS:

10. Do you think safety of cycling in Rotterdam plays a role when choosing a mode of transport for commuting?

EXTRAS:

11. How do you think car facilities and policies (such as parking policy, for example) influence the decision to use bicycle to commute to work?
12. How do you think the prices and conditions of public transport in Rotterdam influence the decision to use bicycle to commute to work?
13. Do you think there is another important factor of bicycle use for commuting that we are missing? Or would you like to add an extra comment to conclude?

Annex 4: Data analysis: descriptive statistics for each group of factors

Table 19: Descriptive statistics for factors of built and natural environment

Categorical variables			
		Frequency	Percent
Travels across the river	No	190	84,4
	Yes	35	15,6
	Total	225	100,0
Availability of bicycle parking	Yes, both close to my work and home locations	181	80,4
	Yes, close to my home location only	3	1,3
	Yes, close to my work location only	37	16,4
	No	4	1,8
	Total	225	100,0
Type of bicycle infrastructure	Bicycle lanes only	15	6,7
	Bicycle paths only	24	10,7
	A mix of bicycle paths and lanes	98	43,6
	A mix of bicycle paths/lanes and a road without bicycle facilities	35	15,6
	Roads without bicycle facilities	53	23,6
	Total	225	100,0
Continuity of bicycle infrastructure	No	79	35,1
	Yes	146	64,9
	Total	225	100,0

Continuous variables		
		Trip distance (km)
N	Valid	225
	Missing	0
Mean		16,96
Median		6,00
Mode		5
Std. Deviation		24,547
Variance		602,575
Minimum		1
Maximum		150

Table 20: Descriptive statistics for psychological factors

Continuous variables								
		Attitude towards				Personal norm	Awareness of consequences	
		car use for commuting	bicycle use for commuting	public transport use for commuting	walking for commuting		health benefits	environ-mental benefits
N	Valid	225	225	225	225	225	225	225
	Missing	0	0	0	0	0	0	0
Mean		1,92	3,96	2,81	2,53	4,39	4,54	4,75
Median		2,00	4,00	3,00	3,00	5,00	5,00	5,00
Mode		1	4	3	3	5	5	5
Std. Deviation		1,101	,934	1,057	1,221	,880	,654	,528

Variance	1,213	,873	1,117	1,491	,775	,428	,279
Minimum	1	1	1	1	1	1	1
Maximum	5	5	5	5	5	5	5

Categorical variables

		Frequency	Percent
Subjective norm (colleagues expectations)	Car	13	5,8
	Public transport	61	27,1
	Bicycle	114	50,7
	Walking	4	1,8
	It doesn't matter.	33	14,7
	Total	225	100,0
Subjective norm (friends and family expectations)	Car	22	9,8
	Public transport	48	21,3
	Bicycle	113	50,2
	Walking	7	3,1
	It doesn't matter.	35	15,6
	Total	225	100,0

Table 21: Descriptive statistics for trip characteristics

Categorical variables

		Frequency	Percent
Travel time	Less than 10 minutes	27	12,0
	10-15 minutes	18	8,0
	15-20 minutes	47	20,9
	20-25 minutes	16	7,1
	25-30 minutes	26	11,6
	30-35 minutes	11	4,9
	35-40 minutes	18	8,0
	40-50 minutes	22	9,8
	50-60 minutes	11	4,9
	More than 60 minutes	29	12,9
	Total	225	100,0

Continuous variables

		Convenience of cycling to work	Safety of cycling to work
N	Valid	225	225
	Missing	0	0
Mean		4,25	3,66
Median		5,00	4,00
Mode		5	4
Std. Deviation		,937	,970
Variance		,878	,940
Range		4	4
Minimum		1	1
Maximum		5	5

Annex 5: Data analysis: regression model 1 for the most significant variables of bicycle use

Table 22: Model 1 with the most significant variables of bicycle use

Model 1		Unstandardized Coefficients		Standardized Coefficients			
		B	Std. Error	Beta	t	Sig.	
	(Constant)	-,095	,177		-,538	,591	
	Trip distance	-,003	,001	-,157	-2,886	,004	**
Attitude	Attitude towards car use for commuting	-,061	,017	-,151	-3,548	,000	***
	Attitude towards bicycle use for commuting	,017	,023	,036	,727	,468	
	Attitude towards public transport use for commuting	-,070	,017	-,165	-3,985	,000	***
Subjective norm (colleagues)	Car	-,159	,098	-,084	-1,626	,105	
	Walking	-,230	,153	-,068	-1,499	,135	
Subjective norm (friends and family)	Car	-,268	,084	-,179	-3,197	,002	*
	Public transport	-,396	,049	-,365	-8,011	,000	***
	Walking	-,472	,113	-,185	-4,192	,000	***
	Bicycle ownership	,383	,074	,201	5,189	,000	***
	Travel time	-,011	,008	-,075	-1,334	,184	
	Convenience of cycling to work	,096	,023	,202	4,183	,000	***

Significance: * p<0.05; ** p<0.01, ***p<0.001.