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Perceived safety of cyclists

The role of road attributes

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PERCEIVED SAFETY OF CYCLISTS

THE ROLE OF ROAD ATTRIBUTES

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ABSTRACT

Objectives

Although the lack of perceived safety is an important deterrent to cycling, available knowledge is not comprehensive enough. The aim of this research is to contribute to academic knowledge by exploring the role of road section attributes in perceived safety of cyclists and to develop a method to use the theoretical results in practice.

Methods

A stated choice survey is carried out to estimate the effects of selected infrastructure attributes on perceived safety. A multinomial logit (MNL) model is used to estimate the effects. Results are used to develop an infrastructure assessment tool by counting aggregate perceived safety utility values of road sections.

Results

Cyclists perceive the presence of dedicated cycling facilities and physical separation similarly important, while other attributes (traffic volume, speed reduction and adjacent car parking) turned out to be less important. The Subjective Safety Score can be consciously used to evaluate existing and planned road sections and compare different design alternatives.

Conclusions

The results give a strong support for using physically separated cycling facilities (cycle tracks for example) to engage people to cycling. Further research is recommended to explore the effects of intersection attributes and to include interaction effects of attributes as well.

PREFACE

I would like to express my gratitude to those who have helped me during my master thesis.

I would like to thank KTH, the university, teachers and students together for giving me this two-year-long experience of the Sustainable Urban Planning and Design programme. Special thanks go to Todor for being my academic supervisor and Peter for making the entire procedure smooth.

I would like to thank all colleagues at Goudappel for hosting me in the Netherlands. I would like to thank Laura for giving me a daily support as my company supervisor, Daphne for the never-ending guidance and Lennert for keeping me socialised.

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Last but not least, I would like to thank Shaghayegh for bringing me to Amsterdam and for the endless support she gave me.

GLOSSARY

Terms related to safety

Safety

In this thesis the general term of safety is used as a measure of cyclists being protected from injuries, collisions and accidents. Further differentiation of objective and perceived/subjective safety is applied however. Such a differentiation of safety is supported by the World Health Organisation (WHO) as well (Nilsen et al., 2004).

Objective safety

"Objective or statistic road safety is a measure for road safety which is based on the recorded numbers of road accidents and injuries." (Sørensen and Mosslemi, 2009, p.6). Heinen et al. (2010) use a similar approach to define objective safety in the case of cyclists as well. They define objective or real safety of cyclists as a measure based on the statistics of bicycle-related incidents.

In this thesis the term objective safety is used as a measure of cyclists being protected from injuries, collisions and accidents, based on statistical data.

Perceived or subjective safety

The term perceived or subjective safety refers to human perceptions and experiences regarding safety, and it is mostly measured by stated experience of individuals (Heinen et al., 2010). Sørensen and Mosslemi (2009) describe subjective safety as feeling of safety, insecurity or anxiety. They refer to perceived safety as a synonym of subjective safety. Similar to Sørensen and Mosslemi, SWOV, the Dutch Institute for Road Safety Research defines subjective traffic safety as the anxiety of people regarding being unsafe in traffic (SWOV, 2012).

In this thesis the term perceived safety is used as a measure of cyclists' perception of being protected from injuries, collisions and accidents. The terms perceived and subjective safety are used as synonyms.

Risk and safety

Many researchers refer to risk instead of safety. For a better understanding the term safety is used in this thesis by assuming high safety level in case of low risk level and vice versa.

Terms related to infrastructure

The following is a simplified list of the cycling infrastructure types used inside built-up areas in the Netherlands based on the Dutch Design Manual for Bicycle Traffic (CROW, 2006).

Carriageway for combined traffic

The function is providing access for all vehicle types on an estate access road. A 30 km/h speed limitation must be applied. Traffic volume of motor vehicles must be relatively low.

Cycle street

The function is providing a high-quality bicycle connection on an estate access road, partly used by motor vehicles as well. A 30 km/h speed limitation and preferably red pavement are applied. High cyclist volume and low motor vehicle volume is required. Right of way regulation is applied at intersections.

Cycle lane

The function is indicating and securing the position of the cyclist on estate and district access roads. Red pavement and bicycle symbols are applied. Separated by continuous or interrupted marking line (latter in the case of exits and parking bays).

Suggestion lane

The function is visual narrowing of the carriageway, indicating and securing the position of the cyclist on estate access roads. Separated by interrupted marking line, neither red pavement, nor bicycle symbols are applied.

Separate cycle track

The function is separation of motorised and bicycle traffic on estate and district access roads for the safety and comfort of cyclists. A partition verge between the cycle track and main carriageway, and preferably red pavement are applied. Cycle tracks may be used by light mopeds as well.

In this thesis the term cycle path is used as a synonym to cycle track.

Terms related to stated choice surveys

The following definitions are based on the lecture slides of Molin (2015).

Choice situation

The main task of a stated choice survey, in a choice situation the respondent is supposed to choose between different choice alternatives.

Choice alternative

Different options that the respondent can choose of. Choice alternatives may represent real or hypothetical options.

Attribute

A characteristic of the alternative. There may be multiple attributes to describe the choice alternative.

Attribute level

The attribute level is the value of the attribute. Respondents are supposed to make their choices based on the attribute levels of the choice alternatives.

Level balance

Level balance occurs in a questionnaire if all attribute levels (values) are shown equal times, thus the overrepresentation of attribute levels is avoided.

SUMMARY

Perceived, subjective safety of cyclists is not only important as a main factor of cyclist preferences (Heinen et al., 2010), it also influences which route cyclists take (Klobucar and Fricker, 2007; Lawson et al., 2013), or whether they would choose cycling at all (Heinen et al., 2010). Despite this importance, objective and subjective safety are not equally emphasised (Nilsen et al., 2004) and comprehensive knowledge is also lacking (Sørensen and Mosslemi, 2009). The aim of this research is to create new knowledge to fill this gap, and to provide an easy method for the practical use of the outcomes. As the Netherlands is a leading country in cycling development, the research is carried out at Goudappel Coffeng, a Dutch mobility agency.

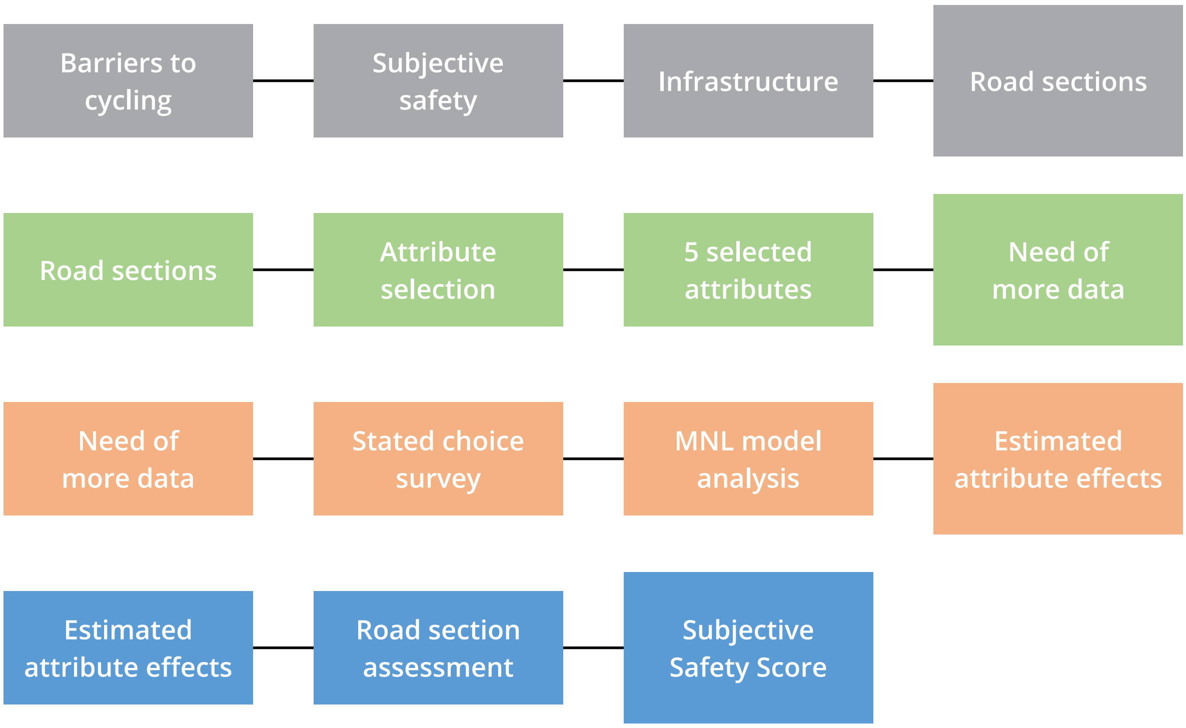

Figure 1: Research process

Figure 1 shows the process of the research. The rather broad topic of perceived safety of cyclists is focused precisely on road sections, excluding intersections, and other aspects of safety related to the cyclists and the bicycles. A comprehensive research review and the outcomes of a workshop with experts lead to the **attribute selection** of the research. The selected attributes are not only important for cyclists, but also relevant for planners and designers. The aim of the research is to estimate how these infrastructure attributes affect perceived safety of cyclists. The estimation is based on a **stated choice survey**, where respondents are asked to choose between different choice alternatives. The alternatives are constructed by the combination of different attribute levels. A multinomial logit (MNL) model is used to attach a distinct utility value to all attributes. This utility value represents the contribution of the attribute to the subjective safety of the cyclists. Based on the estimated attribute effects,

the **Subjective Safety Score** (SSS) is developed. The SSS is applicable to evaluate existing or planned road sections, to compare different alternatives regarding the estimated subjective safety of cyclists. The SSS is based on the aggregate subjective safety utility of the investigated road section and on the normalisation of this utility value to a scale between 0 and 100. Road sections with higher Subjective Safety Score are perceived safer by cyclists.

Table 1: Estimated main effects and their statistical parameters

Attribute	Estimated effect	Standard error	T-test	P-value
Facility	0.766	0.0216	35.41	0.00
Separation	0.697	0.0166	41.88	0.00
Volume	-0.0812	0.00954	-8.52	0.00
Speed reduction	0.144	0.0107	13.41	0.00
Parking	-0.117	0.0104	-11.19	0.00

The results of the stated choice survey show that cyclists perceive the presence of dedicated cycling facilities and physical separation similarly important, and all other included attributes (high traffic volume, speed reduction and adjacent car parking) are less relevant. The presence of dedicated cycling facility and physical separation both have a strong positive effect, while the effect of speed reduction is also positive, but weaker. The presence of high traffic volume and adjacent car parking both have a negative effect, however, these attributes have the weakest effect.

Results are used in practice to assess the subjective safety of road sections in Amsterdam. As the presence of high traffic volume turned out to be the weakest effect, the tool may be used to compare road section alternatives in similar environments, meaning that distributor roads and residential roads should not be compared. This is a major disadvantage of the tool, however, with a conscious use it still provides valuable information regarding the perceived safety of cyclists.

Further research is recommended to explore the interaction effects of attributes and by widening the topic, the relation of objective and perceived safety in case of road section attributes. Additionally, it needs to look at the effects of intersection attributes too. New knowledge about perceived safety of cyclists can help policy makers and planners to create attractive and encouraging environment for cyclists, thus to contribute to increased share of cycling.

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INTRODUCTION

1. 1. Context

Shifting towards a sustainable future is one of the most important goals of the 21st century. Human activities, use of resources, consumption, and travel patterns have reached a level that seriously threatens the quality of the environment. Transportation is one of the key issues. In the European Union, fuel combustion for transport was the second most important source of CO_2 emission by representing 23.2% of total emission in 2014 (Eurostat, 2016). The transport sector has similar importance in the United States of America (32% in 2015) and globally (14% in 2010) as well (EPA, 2017). Improving mobility provides a great chance to shift from an irresponsible present to an environmentally conscious future.

Cycling is a green alternative of motorised traffic, which provides various **benefits** on both individual and societal levels. Cycling provides affordable mobility options for those who cannot maintain the costs of having a car. Cycling is also flexible, giving the freedom to the cyclist of choosing the departure and destination point of the journey. For short-distance urban travel, particularly when the length of the trip is less than 5 kilometres, cycling is often the quickest alternative (ECMT, 2004). Cycling means an environmentally friendly mobility option without pollution and noise nuisance. Replacing the use of cars with cycling could contribute to decreasing the energy demand, congestions and external costs of transport without necessarily reducing the mobility of people (ECMT, 2004). Many researchers highlight the benefits of cycling in various health-related problems such as cardiovascular diseases (Hamer and Chida, 2008; Oja et al., 2011), obesity (Gordon-Larsen et al., 2005; Lindström, 2008; Wen and Rissel, 2008) or high blood pressure and insulin level (Gordon-Larsen et al., 2005). Hartog et al. (2010) note that the health benefits of cycling overweigh the injury risks both on the individual and the societal level. Already 30 minutes walking or cycling in a daily basis can lead to halve the risk of developing coronary heart diseases, developing adult diabetes, becoming obese, and to reduce the risk of developing hypertension by 30% (ECMT, 2004). Improving health conditions does not only mean individual benefits but also reduces the costs of health care. Installing and maintaining cycling infrastructure is also less pricey than building roads for cars, due to less space requirement and softer infrastructure elements (ECMT, 2004). Cycling may contribute to a livelier urban environment and thus a prospering economy as well.

Despite the benefits, there are significant **barriers** to cycling as well. Increased distances, hilly terrain, inconvenient weather conditions, exposure to exhaust gases, just like the concerns about security and social status can be deterrents to cycling (ECMT, 2004). Safety, better said risk is also an important deterrent to cycling (Chataway et al., 2014; Heinen et al., 2010; Noland and Kunreuther, 1995; Parkin et al., 2007; Pucher and Buehler, 2008a; Reynolds et al., 2009; Taylor and Mahmassani, 1996; Wardman et al., 1997). The concept of safety does not only mean actual, objective safety, but also includes perceived, subjective safety. Safety perceptions of potential cyclists affect their decisions whether to cycle or not (Heinen et al., 2010) and which route to take (Klobucar and Fricker, 2007; Lawson et al., 2013). General preferences of cyclists are also based on their safety perceptions (Heinen et al., 2010). Improvements of perceived safety create an even greater contribution to the modal share of cycling (Noland, 1995). The complex approach of safety promotion should not only focus on injury prevention but on subjective safety as well (Nilsen et al., 2004).

1. 2. Problem formulation

Despite the previously cited importance of subjective safety, actual and perceived safety are not equally emphasised (Nilsen et al., 2004). Moreover there is also a significant lack of knowledge regarding the topic (Sørensen and Mosslemi, 2009). Policy makers, planners and designers cannot fight effectively against perceived risks if the required knowledge is not available. The appropriate policies, developments strategies and infrastructure measures can only be applied if we learn about subjective safety. This thesis research addresses the **lack of knowledge about perceived safety** of cyclists as its main problem field. Lack of safety is an important barrier to cycling, and to handle this issue effectively, focus should be taken on both objective and subjective safety of cyclists.

1. 3. Scope and focus

Bike culture and role of cycling change from country to country. While in countries like the USA or Canada, cycling in general has lower rates, and cycling with a recreational purpose is dominant compared to utilitarian cycling, there are countries, like the **Netherlands** or Denmark where cycling is part of daily life and it is an available mobility option for citizens. The Netherlands has very high cycling rates and relatively low accidents rates (Pucher and Buehler, 2008a; Pucher and Dijkstra, 2003; Wegman et al., 2012), and acts as the role model of successful bicycle policies and development in general. Given these arguments, and as the author of this thesis has had the opportunity to spend a semester in the Netherlands, this thesis research focuses on the Netherlands and tries to learn from the outstanding Dutch experience. The research is carried out at **Goudappel Coffeng**, a Dutch mobility consultancy.

Safety of cyclists can be related to various aspects, respectively to the cyclist (behaviour, personal conditions, use of safety gears related to the cyclist, etc.), to the bicycle (technical conditions, safety gears related to the bicycle, etc.), and to the **infrastructure** (intersections, road sections, etc.). These are relatively well separated fields of bicycle safety with similar importance. Given the background and previous studies of the author this thesis focuses on safety of cyclists related to infrastructure only.

Wijlhuizen et al. (2014) differentiate two types of bicycle accidents: cyclists-only crashes and crashes involving a collision with another road user. While in the Netherlands 90% of reported cyclist injuries do not involve a **motor vehicle** (meaning a collision with a physical obstacle or another cyclist), 75% of cyclist fatalities are the results of crashes involving a motorist (SWOV, 2013). The high importance of cyclist-motorist relations is leading to focus on infrastructure situations where both cyclists and motorists are present.

Infrastructure may be divided into two categories, namely **road sections** and intersections. Road sections and intersections can be described by very different attributes, which makes their combined analysis complicated. Although in the Netherlands only 35% of cycling crashes occur in road sections (Wijlhuizen et al., 2014), the research focuses on road sections. The reason behind this decision is the assumption that road sections, as the place of the majority of a cyclist's journey (both timewise and distance-wise), have a great influence on perceptions, thus on the subjective safety of a cyclists. However, it does not mean that intersections are not important. On the contrary, further research should address this aspect as well.

1. 4. Research objective and questions

This thesis research has a **dual objective**. The first is to create new knowledge about the perceived safety of cyclists and contribute to the academic field. The second is to help to utilise this knowledge in practice, and give policy makers, planners and designers the Subjective Safety Score, an easy-to-use tool to evaluate cycling facilities on road sections.

Given the previously presented scope and focus, the main research question investigates the role of infrastructure in perceived safety of cyclists. A special focus is applied on road sections. Different descriptive characteristics are also considered, the second question explores the role of these. The third research question controls the relevance of the topic, it explores how important different factors (including traffic safety) are in cyclists' decisions when it comes to choose between routes with different infrastructure features.

1) What is the role of infrastructure on subjective safety of cyclists in the Netherlands?

2) How do descriptive characteristics of cyclists (age, gender, etc.) influence the effect of infrastructure on subjective safety of cyclists in the Netherlands?

3) How important is traffic safety in the route choice of cyclists in the Netherlands?

To address the second research objective, an infrastructure assessment tool is developed based on the result of the first research question. The tool can be used to evaluate road sections according to the subjective safety of cyclists.

1. 5. Purpose and aim

The main purpose of this research is to contribute to the expansion of urban cycling in cities with relatively lower cycling rate by increasing the perceived safety of cyclists. As it is cited in the first section, safety perceptions have a great influence on cycling rates. Expanding knowledge of perceived safety may help cities to build roads that encourage people to cycle. The focus is mostly on European cities that have similar characteristics to Dutch cities (considering size, density, mobility pattern, topology and distances) thus the potential to develop cycling is similar. Given that in a EU15 basis 50% of car trips are shorter than 5 kilometres and 30% of them are shorter than 2 kilometres (ECMT, 2004), there is a great possibility to shift from using cars to cycling. Cities with ambitious goals to develop cycling could learn from the outcomes of the research and encourage people to choose cycling by improving their subjective safety.

The secondary aim is to improve cyclists' safety in the Netherlands. Although Dutch statistics are relatively good in the international comparison, and the number of fatalities decreased between 2000 and 2009, injury rates of cyclists increased and car occupants performed better in both rates. In 2015 in 30% of all traffic fatalities, 185 people died on bicycles (SWOV, 2013; 2016). Because of these statistics, the development of road safety is considered not sufficient (SWOV, 2013). The government urges the focus on both objective and subjective safety (Ministerie van Verkeer en Waterstraat and Fietsberaad, 2009). As the research is based on the Dutch case, the results will be the most appropriate to use in the Netherlands. Preferably, this thesis can contribute to the improvement of cyclists' safety in the Netherlands too.

1. 6. Thesis outline

This master thesis consists of six chapters and an appendix. The introduction chapter presents the research question, the purpose and the context of the research. The second chapter gives the theoretical base of the thesis, supporting the methods being later used. The third chapter explains how the research process is executed, providing relevant technical details for better understanding. The fourth chapter presents the results of the research. The fifth chapter discusses the findings, the strengths and the weaknesses of the research. The final chapter draws conclusions and gives recommendations for further research.

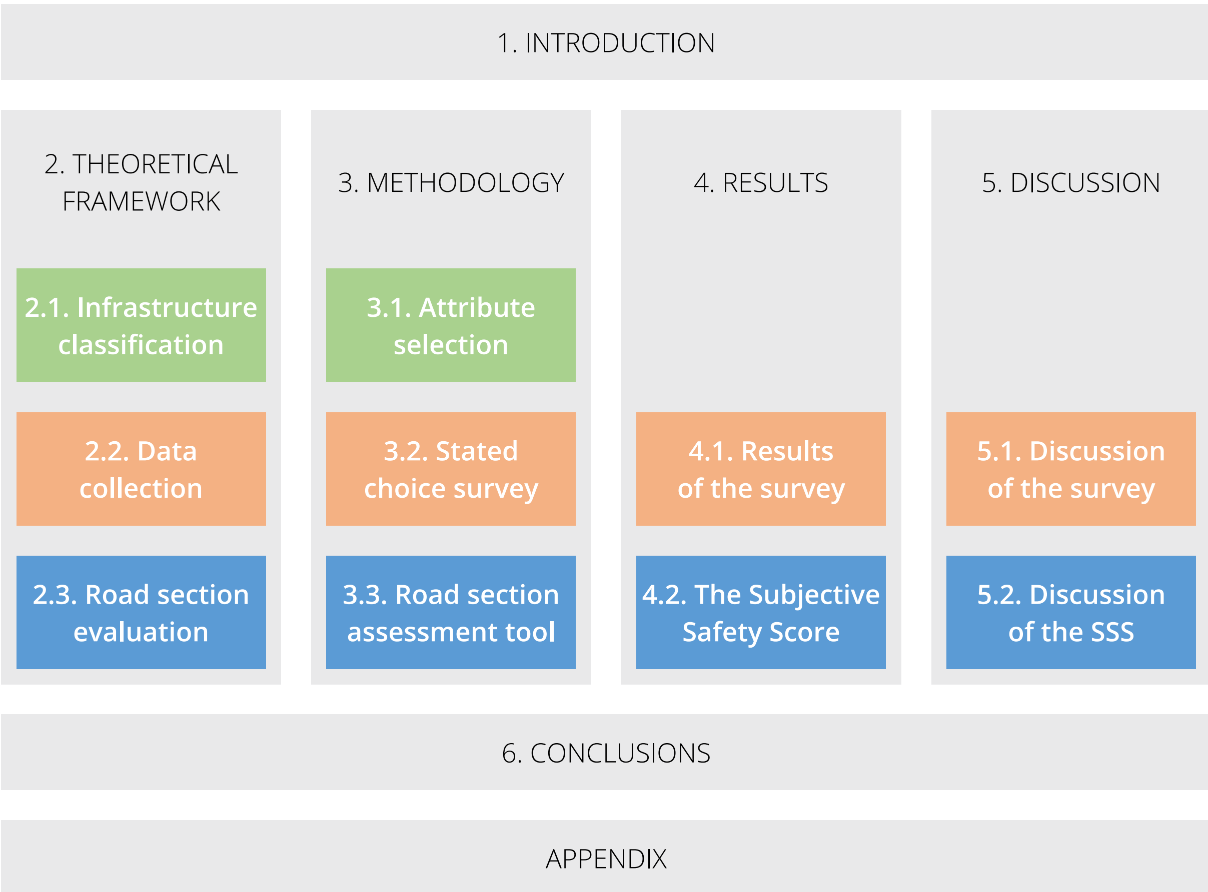

Figure 2: Thesis outline

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THEORETICAL FRAMEWORK

This chapter sketches up the underlying theories of this research. The first section describes principles for infrastructure classification. The second section focuses on data collection and enumerates the different alternatives that are considered during the research process. The third section presents earlier developed methods that assess road sections based on the perceived safety of cyclists. The concepts of the reviewed methods provide a good starting point for a new infrastructure assessment tool.

2. 1. Infrastructure classification

The word infrastructure refers to a broad understanding of different physical elements, transportation facilities and other measures. To discover the role of infrastructure in subjective safety of cyclists, a clear classification is needed. A practical approach is to use classifications of different **infrastructure types** that are used by Dutch authorities and policies. Although using the results in the Dutch context would be smoother this way, applying the results in other countries would be harder. Researchers as Reynolds et al. (2009) argue that different categorisation of infrastructure types makes comparing different studies hard. Additionally, an analyses based on infrastructure types cannot discover direct impacts of specific policy measures on subjective safety. A more theoretical approach is used here that defines different **infrastructure attributes**. Using attributes means a more straightforward analysis, and enables looking at effects that might have remained hidden otherwise. Although one should always consider the effects of the different contexts, the attribute-based results are more applicable also in other countries, which gives higher quality to the research. The research review of similar studies also supports choosing attributes, many researchers focused rather on attributes than on official policy categories (Dill and Voros, 2007; Heinen et al., 2010; Noland and Kunreuther, 1995; Petritsch et al., 2006; Stinson and Bhat, 2003; Taylor and Mahmassani, 1996; Wardman et al., 1997). Although a comprehensive view at different attributes is rare, taking single issues in focus is more common. When researchers are focusing on the presence of cycling lanes or cycling tracks for example (Abraham et al., 2002; Heinen et al., 2010; Stinson and Bhat, 2003; Taylor and Mahmassani, 1996), the real focus is on spatial and physical separation, which can be seen as attributes of the infrastructure. Considering the supporting examples and the possible advantages, this thesis is focusing on infrastructure attributes.

The infrastructure classification starts with **reviewing attributes** from relevant earlier studies that focused on similar issues. As existing literature of subjective safety and infrastructure is limited, other studies about infrastructure and cycling in general are included as well. Only attributes regarding road sections are considered. Table 2 contains the reviewed attributes, the second column contains the literature sources.

Table 2: Reviewed attributes

Attribute	Sources
Presence of cycling facility	Reynolds et al., 2009; Stinson and Bhat, 2003; Taylor and Mahmassani, 1996
Presence of spatial or physical separation of cyclists and motorists	Heinen et al., 2010; Nebiyou et al., 2007; Reynolds et al., 2009; Stinson and Bhat, 2003; Taylor and Mahmassani, 1996
Traffic volume of motorists on adjacent road	Dill and Voros, 2007; Noland and Kunreuther, 1995; Petritsch et al., 2006, Stinson and Bhat, 2003
Speed of motorists on adjacent road	Noland and Kunreuther, 1995; Petritsch et al., 2006; Stinson and Bhat, 2003
Number of lanes on the carriageway	Heinen et al., 2010; Petritsch et al., 2006
Width of lanes on the carriageway	Stinson and Bhat, 2003
Percentage of heavy vehicles	Stinson and Bhat, 2003
Presence of adjacent car parking	Heinen et al., 2010; Nebiyou et al., 2007; Stinson and Bhat, 2003
Volume of cycling traffic	CROW, 2016
Speed of cyclists	Noland and Kunreuther, 1995
Width of cycling facility	Petritsch et al., 2006; Stinson and Bhat, 2003
Direction of facility	Noland and Kunreuther, 1995
Surface quality	Heinen et al., 2010; Noland and Kunreuther, 1995, Stinson and Bhat, 2003
Pedestrian volume	Petritsch et al., 2006
Width of segregation verge	Petritsch et al., 2006
Type of segregation verge	CROW, 2016
Curviness	CROW, 2016
Bendiness	CROW, 2016
Evenness	CROW, 2016
Colour of pavement	CROW, 2016
Type of surface	CROW, 2016
Presence of bicycle symbol	CROW, 2016
Direction of carriageway	CROW, 2016
Presence of mopeds	CROW, 2016

In total 25 infrastructure attributes are considered. The next step involves a careful **selection of attributes**. The attribute selection should consider some important criteria. The selected attributes should cover factors that are both important for cyclists and relevant in urban and traffic planning. This means that factors that may be important for the cyclists, but less relevant for planners (for example because they are hard to change/influence) might be excluded. The selected attributes are expected to cover more or less the variety of infrastructure types that may be applied in road sections. Attributes should be independent, meaning that each attribute should be defined without depending on another attribute. For the sake of better understanding, the combinations of attributes should be realistic and meaningful. The final criterion is to keep the number of attributes relatively low due to a manageable research process. However, the number of attributes should not be too low either, since that would threaten the validity of the research. The final step of the infrastructure classification is defining the levels of the attributes. The attribute levels refer to those values that an attribute can take. The higher the number of attribute levels, the more complex the survey is. To make the selection, a workshop is organised with colleagues from Goudappel Coffeng, experts with background in mobility, biking and psychology. The process and the results of the workshop consultations are described in the Methodology chapter, under section 3. 1. Attribute selection.

2. 2. Data collection

Molin (2015) differentiates two types of **data collection paradigms**: revealed preference and stated preference methods. While revealed preference surveys focus on how people have chosen between existing, real-world alternatives, stated preference surveys explore human decisions on hypothetical alternatives (Hensher, 1994). The biggest strength of revealed preference techniques is that they show what people actually do, which may be different from what people say they would do (Taylor and Mahmassani, 1996). At the same time revealed preference techniques are only able to explore real-world alternatives, and they do not provide information about the unchosen alternatives. Stated preference techniques, in contrast, can explore hypothetical situations, which give greater freedom to researchers (Hensher, 1994). The complexity of real-world situations might make many of the possibly influential factors hidden, while stated preference methods can more freely focus on specific factors (Hensher, 1994; Molin, 2015). A final advantage of stated preference surveys is that they are usually less pricey and less time consuming to conduct compared to revealed preference techniques. The strongest point to choose stated preference techniques is that the specific focus on the selected infrastructure attributes requires specific alternatives that may be significantly harder to find in real world, where no other factors affect the situation. **Stated preference methods** "use individual respondents' statements about their preferences in a set of transport options to estimate utility functions" (Kroes and Sheldon, 1988, p11.). Stated preference surveys are widely used both in travel behaviour research in general (Hensher, 1994) and in studies with a special focus on cycling (see examples: Abraham et al., 2002; Krabbenborg, 2015; Nebiyou et al., 2007; Stinson and Bhat, 2003; Taylor and Mahmassani 1996).

Kroes and Sheldon (1988), Hensher (1994), and Molin (2015) differentiate three types of stated preference surveys based on the measurement tasks. In **ranking experiments** respondents are asked to rank a selection of alternatives. This method provides full scale answers on preferences, however, the quality of results may be questionable due to the decreasing interest of respondents on the lower ranked alternatives (Hensher, 1994). Molin (2015) adds also that ranking experiments are not used widely anymore (as a relevant example, see: Abraham et al., 2002). In **rating experiments** (also called conjoint analysis) respondents need to rate each alternative separately. The strength of this method is that both order data and direct utility are measured. However, rating might be demanding and requiring too much effort from respondents, as they need to give consistent answers on all parts of the rating scale (Hensher, 1994; Molin, 2015). In **stated choice experiments** respondents are asked to choose

between at least two choice alternatives. It is a popular technique due to the similarity to real-world situations when people need to make actual choices (Hensher, 1994). Additionally, choosing may be simpler for the respondents than rankings or ratings (Molin, 2015). The experiment task should also reflect on the topic of the survey. Subjective safety is based on perceptions of cyclists, thus the chosen approach should imitate similar decision-making situations. Thus the stated choice survey is selected for studying subjective safety.

To be able to analyse the outcomes of the stated choice survey, a suitable model should be applied. Discrete choice models (DCMs) are dominant in the transportation field (among others) for decades (Chorus, 2012). "DCMs use observed choices between different options (...) to derive the underlying preferences of individuals" (Chorus, 2012, p7.). As a result, discrete choice models can provide quantitative estimations on individuals' preferences. This means that the effects of each included attributes can be estimated based on the choices that respondents make in the stated choice survey. One type of discrete choice models is the random utility maximisation (RUM) model. The assumption of these models is that respondents attach a utility to each alternative and choose the one with the highest utility (Chorus, 2012). The random part of the name comes from an unobserved, error component. The overall utility of a choice alternative (besides an unobserved error part) is the result of a linear-additive function of the effects of the included factors (Chorus, 2012).

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum \beta_k \times X_{ijk} + \varepsilon_{ij}$$

Where:

U_{ij}	total utility (*i = individual*, *j = choice alternative*)
V_{ij}	systematic (observed) component of utility
ε_{ij}	random (unobserved) component of utility
β_k	model parameter to be estimated (*k = attribute*)
X_{ijk}	attribute level

The aim is to estimate the model parameters (β_k) in the case of each attribute. As using multinomial logit (MNL) models is a standard way of random utility maximisation modelling (for examples of similar master theses see: Hurk, 2017; Krabbenborg, 2015), the analysis of the survey outcomes is done with an MNL model. The technical details of using the MNL model, also, the construction and the conduction of the stated choice survey is described in the Methodology chapter under section 3. 2. Stated choice survey.

2. 3. Road section evaluation

Infrastructure assessment tools are commonly used to compare various design options (for existing and planned locations), to prioritise bicycle facility projects, and to evaluate projects, different road sections. Three roadway suitability measures are presented in the followings. Both the **BLOS** (Bicycle Level of Service) and the **IHS** (Interaction Hazard Score) methods are developed by Bruce W. Landis, while the **BCI** (Bicycle Compatibility Index) is created by the US Federal Highway Administration. All methods are meant to evaluate road sections based on hazard/safety perceptions of cyclists (Barsotti and Kilgore, 2001; Landis, 1994). All methods reflect the North American context, meaning that they focus mainly on on-road cycling. This means that these methods are not so easily applicable to the European context, since they do not consider attributes that are important for Europeans. Table 3 shows the attributes in the tools.

Table 3: Infrastructure assessment tools based on subjective safety of cyclists

	Factors included in the evaluation tools	Developers
BLOS	Traffic volume of motorists, number of lanes on the carriage-way, speed limit, truck volume, roadside land use, frequency of uncontrolled crossings (driveways, etc.), pavement quality, width of outside lane	Bruce W. Landis and others
IHS	Traffic volume of motorists, number of lanes on the carriageway, usable width of outside lane, roadside land use, curb cut frequency, pavement factor, speed limit, presence of trucks	Bruce W. Landis
BCI	Traffic volume of motorists, presence and width of bicycle lane or paves shoulder, curb lane width, traffic speed, presence of parking lane, roadside land use, truck volume, parking and right-turn movements	Federal Highway Administration, USA

Sources: Barsotti and Kilgore (2001), Klobucar and Fricker (2007) and Landis (1994)

While the IHS contains quadratic, and the BLOS contains both quadratic and logarithmic components, the BCI formula is based on linear components (Barsotti and Kilgore, 2001; Landis, 1994), which makes it similar to the RUM model that is used for analysing the outcomes of the stated choice survey (not considering the random error component). The model parameters of the BCI model are estimated based on a stated preference survey (Barsotti and Kilgore, 2001). These similarities make the BCI method a good role model for developing the **Subjective Safety Score**. The Subjective Safety Score is based on the results of the MNL model. The MNL model estimates the attribute effects by attaching utility values to each attribute, and assumes that respondents make their choices according to the aggregate utilities of the choice alternatives. Using the estimated attribute effects, an aggregate subjective safety utility value is calculated for each road sections to evaluate. The aggregate subjective safety utilities show how safe cyclists would perceive the evaluated road sections.

$$U_{Sub.Safety} = \sum \beta_k \times X_k$$

Where:

$U_{Sub.Safety}$	subjective safety utility to be estimated
β_k	attribute parameters (k = *attribute*)
X_k	attribute level

3

METHODOLOGY

The methodology chapter describes in details how the selected theories are applied during the research process. The first section concludes the infrastructure classification by carrying out the attribute selection. A brief research review then allows the reader to get a picture about the role of the selected infrastructure attributes on cycling. The second section presents the detailed process of constructing and conducting the stated choice survey. The third section describes how the exact formula of the Subjective Safety Score is developed.

3. 1. Attribute selection

The attribute selection is carried out in a **workshop** with professionals from Goudappel Coffeng with relevant experience in cycling, psychology and mobility. The workshop takes place in the Deventer office of Goudappel Coffeng on the 3rd of April, and lasts for 90 minutes approximately. As the aim is to select attributes that are not only relevant for cyclists, but for planners as well, only colleagues are invited. The invitees are selected according to the recommendations of the company supervisor. In total seven people are invited, however, at the end, only three of them (and the author) are present. The first step is to determinate the number of attributes to choose. Due to the need to keep the survey complexity manageable the number of attributes is chosen to be five. The participants look at the list and remove any attribute that is found to be less important/relevant than others. This process continues until only five attributes remain on the list. Table 4 explains the reasons why the following attributes are excluded.

Table 4: Excluded attributes and the reasons to exclude them

Excluded attributes	Reason to exclude
Speed of cyclists	Dominant social and individual factors, role of available destinations among the route and the general sociability of the urban space.
Volume of cyclists	
Volume of pedestrians	
Bendiness, curviness, evenness	Too detailed technical and geometrical parameters, considered to be of secondary importance.
Type and quality of surface	
Bicycle symbols	Basic requirements of a well-designed infrastructure in the Netherlands, should not be considered as an optional factor.
Width of cycling facility	
Pavement colour	
Presence of mopeds	Very specific, hardly depends on policy differences.
Heavy vehicle traffic	Considered to be important, however, due to the limited number of attributes, other are found to be more crucial.
Number and width of lanes on carriageway	
Direction of adjacent road	
Direction of cycling facility	The Dutch approach is to build unidirectional facilities in urban environments, thus found to be less important.
Width and type of segregation lane	Hard to apply in all choice alternatives, only relevant in case of physical separation.
Spatial separation	Connected to physical separation, latter is found to be more important.

The participants consider the presence of dedicated cycling facility, the presence of physical separation, high traffic volume of motorists, speed of motorists and the presence of adjacent car parking the most important attributes. The importance of these attributes is supported by authors of earlier studies as well (see: Chataway et al, 2014; Dill and Carr, 2003; Heinen et al., 2010; Hunt and Abraham, 2007; Noland and Kunreuther, 1995; Parkin et al., 2007; Petritsch et al., 2006; Winters et al., 2012). In favour of a simpler survey structure, each attribute is defined by its presence and absence, which makes every attribute having two attribute levels. Speed of motorists is defined by the presence of 30 km/hour speed reduction facilities, which is a good indicator of residential roads. Traffic volume is defined by the presence of high traffic volume. Table 5 shows the final outcomes of the attribute selection process.

Table 5: Selected attributes

Presence of dedicated cycling facility
Presence of physical separation between cyclists and motorists
Presence of high traffic volume of motorists on adjacent road
Presence of speed reduction facilities of 30 km/hour on adjacent road
Presence of adjacent car parking on adjacent road

The selected attributes are researched in **earlier studies** as well. However, both the extent of the research and the methods are widely different. The following five paragraphs provide the reader a quick overview on the role of these attributes on cycling. Not only perceived safety, but the effects on actual, objective safety and cyclists' preferences are also considered. Information regarding objective safety and cyclists' preferences is coming from various sources. However, the findings about perceived safety are mostly based on three studies. The study of Winters et al. (2012) explores cyclists' perceived risk in the cases of Toronto and Vancouver. The authors considered 14 different infrastructure types that are found in the two Canadian cities. The results are based on the answers of 690 respondents. Parkin et al. (2007) estimate the effects of particular infrastructure attributes based on the answers of 144 respondents from Bolton, UK. The results are used to develop an evaluation tool to assess infrastructure on an area-wide level. The literature study of Sørensen and Mosslemi (2009) gathers information about the effects of various road safety measures on objective and subjective safety of vulnerable road users (pedestrians and cyclists). The study includes 54 road safety measures, however only 14 measures are studied directly and another 14 indirectly. The assessment of the remaining 26 measures is based on "speculation". For further information about other aspects of perceived safety, see: driver-cyclist interactions (Chaurand and Delhomme, 2013), behaviour and personal characteristics (Lawson et al., 2013), roundabouts (Møller and Hels, 2008), near miss and collision experiences (Sanders, 2015). The paper of Joshi and Smith (1992) draws a general image of perceived risks of cyclists based on diaries. For a detailed literature overview on the impact of infrastructure and policy improvements on cycling rates see the study of Pucher et al. (2010) based on 139 studies.

Winters et al. (2012) found that major streets without **dedicated cycling facility** are perceived with the highest risks, similar locations, where bike lanes are installed receive somewhat better perceived risk scores. In their combined study, based on Copenhagen and Brisbane, Chataway et al. (2014) argue that the presence of cycle lanes improves safety perceptions of cyclists. Parkin et al. (2007) add that although the presence of bicycle lanes does not neutralise the effect of motor traffic, the perception of risks decreases. However, bicycle and bus lanes, providing greater space than bicycle lanes, decrease the perceived risks to a greater extent. Dill and Carr (2003) use the assumption that the presence of dedicated cycling facility increases the subjective safety of cyclists. Regarding the objective safety of

cyclists, earlier research shows a mixed picture. There are researchers who claim that on-road cycling is safer compared to cycling on off-road facilities (Aultman-Hall and Hall, 1998; McClintock and Cleary, 1996), while other researchers could not find a clear effect of installing dedicated cycling infrastructure (Chen et al., 2012; Smith et al., 1988). Others claim that the presence of dedicated cycling facilities does reduce the risks of cyclists (Harris et al., 2013; Pucher, 2001). This is supported by the Dutch experience as well (SWOV, 2010a). Regarding preferences, researchers have found clear evidence of cyclists preferring dedicated facilities (Abraham et al., 2002; Hunt and Abraham, 2007; Stinson and Bhat, 2003), and that the presence of dedicated cycling infrastructure encourages people to cycle (Dill and Carr, 2003; Moudon et al., 2005; Nelson and Allen, 1997; Noland and Kunreuther, 1995; Pucher et al., 2010). The level of experience may be an important factor though (Taylor and Mahmassani, 1996).

Infrastructure types of Winters et al. (2012) that are built away from streets were perceived very safe, however, **physically separated** cycle tracks alongside major roads are perceived less safe than bike lanes alongside major roads. Sørensen and Mosslemi (2009) however, found the opposite in their literature review: physically separated tracks increase cyclists' subjective safety. Jensen et al. (2007) found that cyclists in Copenhagen perceive separated cycling tracks the safest and roads with mixed traffic the least safe. Cycling lanes are perceived somehow less safe than cycle tracks. Cycle lanes may be experienced less safe than separated tracks in the Netherlands as well (CROW, 2004; SWOV, 2012). While it is often assumed that cycling on bicycle tracks is safer compared to cycling on bicycle lanes and roads without cycling facilities (Heinen et al., 2010), there are certain concerns about physical separation creating visibility issues at intersections (DiGioia et al., 2017; McClintock and Cleary, 1996). This visibility issue may affect the safety of separated cycling infrastructure and create dangerous situations at intersections (SWOV, 2010a). However, Zeegers and With (2008) note that speed reduction facilities at crossings may further improve the safety of separated cycle tracks. The earlier study of Welleman and Dijkstra in the Netherlands indicates that separated cycle tracks are the safest (SWOV, 2010a). Regarding preferences, earlier research shows evidence for cyclists preferring physical separation in the case of Leeds (Wardman et al., 1997), Dublin (Caulfield, 2012), and Copenhagen (Snizek, 2013). Stinson and Bhat (2005) name the level of experience as an important factor in this case as well.

Both **traffic** calmed residential areas and traffic free routes reduce the perceived risks for cyclists (Parkin et al., 2007; Winters et al., 2012), while increased motor vehicle volume lowers perceived safety of cyclists (Jensen et al., 2007). High volume of heavy traffic is considered as unsafe in the Netherlands as well (SWOV, 2012). Dutch experience shows that while the degree of exposure to motorised traffic is related to cyclist accidents, the more cyclists use residential areas instead of cycling among distributor roads, the less likely for fatal accidents to occur (SWOV, 2013). Regarding the preferences, low traffic volume is preferred by cyclists (Abraham et al., 2002; Stinson and Bhat, 2003), while the presence of high traffic volume may make cyclists alter their route (Lawson et al., 2013).

In the study of Winters et al. (2012) residential streets with traffic calming measures are perceived safer than without traffic calming. Sørensen and Mosslemi (2009) found that area-wide traffic calming increases the subjective safety of vulnerable road users. These measures aim to reduce both the volume and the **speed** of motor vehicles. However, they also note that the effect of speed reduction facilities is positive only if the mean speed of motorists decreases actually, speeding offences may decrease subjective safety (SWOV, 2012). Speed of vehicles has a great impact on the severity of bicycle-motor vehicle accidents. By increasing the speed of vehicles further than 32.3 km/h the probability of injury or fatality in an accident greatly increases (Kim et al., 2007). Dutch experience shows that the number of injuries drops in average 25% when a residential area is redesigned from 50 km/h to 30 km/h speed limitation (SWOV, 2010b). Regarding preferences, low adjacent traffic speed is preferred by cyclists (Caulfield, 2012), and high traffic speed may make cyclists alter their routes (Lawson et al., 2013).

Winters et al. (2012) found that most major streets are perceived safer if **adjacent car parking** is not present. Parkin et al. (2007) found out that the presence of parking in case of residential roads increases the perceived risks, while in the case of busier roads, parking cars do not have an effect. The first finding is supported by Chataway et al. (2014) as well. Stinson and Bhat (2003) highlight the threat that adjacent car parking means as cyclists can be severely injured by the collisions with the opening doors of cars. For the same reasons the installation of separated cycling tracks is recommended in the Netherlands when adjacent car parking is present (Zeegers and With, 2008). Cyclists may even alter their routes to avoid adjacent car parking (Lawson et al., 2013; Stinson and Bhat, 2003).

Many of the cited studies are carried out in different context (namely in North America) that makes the direct application of the results difficult. Not only bicycle use and mobility patterns are fundamentally different in North America and in Europe, but the different approaches result in building different infrastructure types. As different studies may use different methods, the combination of data with different sources can be questioned.

3. 2. Stated choice survey

There are three steps of constructing and conducting the stated choice survey. The first is determining the **model specification** which lays down the mathematical bases of the survey. The second step is generating the **experimental design**, which defines the detailed technical parameters of the survey. The final step is **constructing the questionnaire**, which results in the final survey what the respondents receive. This process is very much based on the Ngene Manual (ChoiceMetrics, 2014) which is not only a guide for using the software Ngene, but also gives a comprehensive theoretical background for experimental design. Ngene is also used to generate then the experimental design. A pilot survey is constructed and conducted prior the final survey. The purpose of the pilot survey is to test the final design of it and to provide priors of the model parameters where it is necessary. Findings and considerations of the pilot survey are only presented where it is relevant. For details, see the Appendix.

The model specification defines the characteristics of the attributes, the assumed relations between them, and the features of the choice alternatives. The choice situations consist of **unlabelled** choice alternatives described by **generic attributes**. The latter means that all attributes apply to all alternatives in all choice situations with a generic value and utility weight, there are no alternative-specific features applied. This also means that choice situations consist of unlabelled alternatives: respondents are asked to choose between 'option 1' and 'option 2', there is no general categorisation of the alternatives (like 'train' versus 'car' for example). **Interaction effects** are assumed to either not to exist or not to play a significant role, which is a general assumption of researchers due to time limits of studies (Molin, 2015). However, one should always be aware of excluded interaction effects when it comes to interpreting the results. By defining the attributes by their presence and absence, there is no need to include nonlinear components in the model specifications. This definition of the attributes also means that the results can be interpreted as **utility differences** between the considered two attribute levels. It shows how much the utility of an attribute increases by the presence or decreases by the absence of the attribute (Molin, 2015). Since the attributes can take only two, non-numerical values they are nominal attributes. The above described features form together the following **utility function**.

$$U_j = \beta_{FAC} \times FAC_j + \beta_{SEP} \times SEP_j + \beta_{VOL} \times VOL_j + \beta_{SPE} \times SPE_j + \beta_{PAR} \times PAR_j$$

Where:

U_j	total utility of the choice alternative (*j = choice alternative*)
$\beta_{FAC - PAR}$	utility values (model parameters) to be estimated
FAC	effect coded variable for the presence (1) or the absence (-1) of dedicated cycling facility
SEP	effect coded variable for the presence (1) or the absence (-1) of physical separation of cyclists and motorists
VOL	effect coded variable for the presence (1) or the absence (-1) of high traffic volume on adjacent road
SPE	effect coded variable for the presence (1) or the absence (-1) of speed reduction facilities of 30 km/h
PAR	effect coded variable for the presence (1) or the absence (-1) of adjacent parking on the adjacent road

Experimental designs are used to construct the survey, namely the hypothetical choice alternatives and choice situations that the respondents are faced during the survey. Full factorial experimental designs contain all possible attribute combinations. Considering time and space limits of the survey, fractional factorial designs are used to decrease the number of choice situations (ChoiceMetrics, 2014). Using **orthogonal design** is a classical method of researchers that focuses on minimising the correlation of attributes, which results in low standard errors, thus in a reliable estimation (Molin, 2015). Efficient design, on the other hand, is a recently developed method that focuses on reducing standard errors by using priors and intended utility function. **Efficient design** provides usually better results in terms of efficiency, meaning that more reliable parameters can be estimated with the same sample size, or the number of choice situations can be decreased while maintaining the same reliability (Molin, 2015). Both options can maintain attribute level balance, which means that all levels appear an equal number of times in the choice situations (ChoiceMetrics, 2014). Attribute level balance ensures that the reliability of parameters regarding all attribute levels are the same (Molin, 2015). Being fractional factorial designs, both orthogonal and efficient designs can only estimate main effects of attributes, interaction effects cannot be estimated (Molin, 2015). An important benefit of efficient design is that it avoids dominance of choice alternatives in the choice sets, which may be a serious threat on the validity of the survey. If an alternative has better values in case of all or most attributes than the other, then it is hard to draw clear conclusions on the role of attributes. This is the main reason to choose efficient design in the final survey, as alternative dominance occurred in the pilot survey. The necessary priors are taken from the results of the orthogonal pilot survey.

Table 6: Priors used in the final experimental design

FAC	SEP	VOL	SPE	PAR
1.15	0.584	0.00	0.137	-0.241

The result regarding high traffic volume (0.0502) turned out to be insignificant, thus it is considered to be unknown (0.00)

Using efficient experimental design does have some **disadvantages** however. Some of the choice alternatives occurred more than once, one choice set is even repeated. Presumably, as a result of using priors, some combinations of attribute levels are overrepresented. These features remain after regenerating the design as well. As only main effects are to estimate (not the interaction of different

attributes), the latter problem was considered to be less relevant. The dominant alternative problem is considered to be more important, thus the survey is based finally on an efficient design method.

Regarding the number of **choice alternatives** there are no real guidelines available (Molin, 2015), thus for the sake of simplicity each choice situation consisted of two alternatives. The minimal number of choice sets is determined by the number of parameters to estimate (Molin, 2015). However, one should also be aware that respondents can only evaluate a limited number of choice situations. According to Kroes and Sheldon (1988) this limit is between 9 and 16. For other reasons (see Appendix) the pilot survey consisted of 16 choice situations. As there are no complaints received regarding the length of the pilot survey, the final survey is designed with 16 choice sets as well. The choice sets are constructed in a sequential way which suits well unlabelled alternatives and generic attributes (Molin, 2015).

A final step of the experimental design is **coding**, which represents the values of the attribute levels. Dummy coding uses (1; 0), while effect coding uses (1; -1). Effect coding gives all attribute levels a distinct part-worth utility, while dummy coding reference levels have all zero part-worth utility (Molin, 2015). Using effect coding makes the interpretation of the results and the comparison of different attributes easier and more illustrative. Here comes an example: if someone is considering to remove 30 km/h speed limitation and physical separation of cyclists in a road section, it is easier to compare the effects if they both have a distinct utility value other than zero. Effect coding provides these values, while dummy coding would give zero utility for the absence of attributes. Using effect coding does not distort the results, the utility differences between the attribute levels are the same with effect and dummy coding. Table 7 shows the level values for all attributes.

Table 7: Attribute level values with effect coding

	Presence	Absence
FAC	1	-1
SEP	1	-1
VOL	1	-1
SPE	1	-1
PAR	1	-1

The experimental design is generated with the software Ngene (ChoiceMetrics, 2014), with using the following utility functions (the whole syntax may be seen in the Appendix).

$$U_{alt1} = \beta_{FAC} \,.\, \mathit{effects}\,[1.15] \times FAC\,[1,-1] + \beta_{SEP} \,.\, \mathit{effects}\,[0.58] \times SEP\,[1,-1] + \beta_{VOL} \,.\, \mathit{effects}\,[0] \times VOL\,[1,-1] + \beta_{SPE} \,.\, \mathit{effects}\,[0.14] \times SPE\,[1,-1] + \beta_{PAR} \,.\, \mathit{effects}\,[-0.24] \times PAR\,[1,-1]$$

$$U_{alt2} = \beta_{FAC} \times FAC + \beta_{SEP} \times SEP + \beta_{VOL} \times VOL + \beta_{SPE} \times SPE + \beta_{PAR} \times PAR$$

The aim of **constructing the questionnaire** is to create an easy to understand representation of the experimental design and the choice situations (ChoiceMetrics, 2014). The questionnaire consists of the choice situations, a second part with two additional questions regarding the choices and a third part focusing on personal and background information. One can choose visualisations, textual descrip-

tions or the mix of these two to **represent the choice situations**. As the nature of subjective safety – based on individuals' perceptions – assumes a rather unconscious situation, visualisation is chosen over textual descriptions. Visualisations represent complex situations with quick and direct approach. The first impression can be determinative. The questionnaire uses computer-created images to represent the choice situations. However, other options are considered too. Although showing short video-clips animates the respondents to visually experience the choice situation, the complex contexts of the video-clips may bias respondents' answers, which should be prevented by focusing only on the selected attributes. This is also true for traditional photos, even though the presented situations are easier to control, the context (just like weather or time of the day) may still create misleading settings. The images are taken in a 3D model created in SketchUp, a 3D modelling software of Trimble Navigation. By using a computer-designed 3D model, small adjustments of the images could be done, even after analysing the results of the pilot survey. The environment of all choice alternatives is the same: an average urban street surrounded by a line of trees and four-storey buildings. A carriageway and sidewalks on both sides with pedestrians are further included in all images. The background of the images indicated a sunny day with clear sky. Attributes are either represented on their own (traffic volume, speed reduction and adjacent parking) or by the combination of them (presence of facility and physical separation). The presence of high traffic volume is illustrated by the number of cars on the carriageway. The presence of speed reduction facilities is shown by speed bumps, road surface markings and additional speed limit signs. The presence of adjacent parking is depicted with parked cars on the road. Based on comments on the pilot survey, cars in the traffic are shown with different colour than parking cars. The presence of dedicated cycling facilities and the presence of physical separation are presented by their combination. A cyclist is cycling on a cycle track when both attributes are present, and on the carriageway when both are absent. Cycling on a bike lane assumes the presence of biking facility, cycling on the sidewalk assumes the presence of physical separation. The features of infrastructure elements are based on the Dutch Design Manual for Bicycle Traffic (CROW, 2016). A main principle is to use recommended measures in all cases of infrastructure elements, thus respondents would not base their choices on poorly designed elements. A red surface and cycle symbols are applied to all cases where dedicated cycling facilities are present. The position of the images reflected on the position of the cyclists, in practice, a cycling person is always in the centre of the pictures. Images of both the pilot and the final survey are included in the Appendix.

Two additional questions are asked after the choice situations to discover the reasons behind the choices of respondents. Choice situations are rather unconscious situation meaning that respondents may not pay special attention to every detail, but decide according to the complex images of the choice set. Thus the first background question – How important were the following factors in your answers regarding subjective traffic safety? – aims to explore the effect of each attribute in the choice situation. The reason to ask about the importance of the attributes also in a direct question is that the results may be different in an unconscious situation (choice situation) than in a conscious situation (direct question). The second question – How important are the following factors when you decide which route to take to your destination? – focuses on cyclists' route choice. The aim is to discover the importance of traffic safety as a factor of choosing between route alternatives. Factors are taken from the Dutch Design Manual for Bicycle Traffic (CROW, 2016), cited as the main requirements for bicycle-friendly infrastructure. These are attractiveness, cohesion, comfort, directness and safety. The Design Manual does not make difference between safety and security. To make this distinction traffic safety and security (from crimes) are differentiated in the questionnaire. The role of traffic safety is clearer by adding this distinction. Both questions are presented in a question grid, where respondents see all options (the five attributes and the six main requirements). Respondents are asked to rate the options in a scale from Not important to Very important. The survey concludes with a series of questions regarding **personal and background information**. Gender, age and highest completed

education are asked to draw an image of the respondents' personal characteristics. Background questions are aimed to discover any relation between cycling habits and subjective safety. Respondents are asked to answer questions about their place of residence, how often they ride their bike, what type of bicycles they ride, and on what purpose they cycle usually.

The survey is conducted by an online market research company called PanelClix between the 15th and18th of May (in 2017). Respondents are recruited from PanelClix members, who are payed by PanelClix for participating online surveys. The selection of participants more or less represents the adult Dutch population. In total 823 respondents answer the questions. Since the survey is exploring subjective safety of cyclists, a criterion of cycling at least once in the past one year is applied to the respondents. The criterion is chosen to be very loose. This makes possible for both experienced and unexperienced cyclists to participate. The survey is created with a software called Snap Survey. The pilot survey is created in a Google Forms format and distributed mostly among employees of Goudappel Coffeng. Surveys are written in Dutch. Both surveys are included in the Appendix. Figure 3 shows the first choice situation of the questionnaire.

Figure 3: The first two choice alternatives of the survey

3. 3. Road section assessment tool

The results of the stated choice survey are used to develop a road section assessment tool. The tool is to be used to evaluate road sections according to the perceived safety of cyclists using that route. The evaluation has two steps. Based on the estimated attribute effects and a five-point checklist, the aggregate subjective safety utility is calculated for the route section. The aim of the checklist is to describe the route section, whether the five selected attributes are present or not. The value of the attribute is +1 if it is present, and -1 if it is absent. The aggregated subjective safety utility describes how much utility cyclists are assumed to attach to the route section.

$$U_{Sub.Safety} = \sum \beta_k \times X_k = \beta_{FAC} \times FAC + \beta_{SEP} \times SEP + \beta_{VOL} \times VOL + \beta_{SPE} \times SPE + \beta_{PAR} \times PAR$$

Where:

$U_{Sub.Safety}$	aggregate subjective safety utility of the road section (to be estimated)
β_k	estimated attribute parameters (*k* = *attribute*)
FAC	value for the presence (1) or absence (-1) of dedicated cycling facility
SEP	value for the presence (1) or absence (-1) of physical separation
VOL	value for the presence (1) or absence (-1) of high traffic volume
SPE	value for the presence (1) or absence (-1) of speed reduction facilities
PAR	value for the presence (1) or absence (-1) of adjacent car parking

The second step is **normalising** this utility value on a clear scale. This gives a better understanding of values, and makes easier to compare different road sections. To be able to differentiate all the 32 possible attribute combinations, the scale needs to be wide enough. The scale is chosen to be between 0 and 100. The normalisation of the results is simply done by giving zero to the lowest possible value and giving 100 to the highest possible value. All other values are proportionally distributed in the scale. The result is the Subjective Safety Score, which can be generally used to estimate subjective safety of cyclists on road sections.

$$SSS = (U_{Sub.Safety} + a) * b = (\sum \beta_k \times X_k + a) \times b$$

Where:

SSS	Subjective Safety Score (to be estimated)
$U_{Sub.Safety}$	aggregate subjective safety utility of the road section
β_k	estimated attribute parameters (*k* = *attribute*)
X_k	values for the presence (1) or the absence (-1) of the attributes
'*a*' and '*b*'	constants of the normalisation

The constants are easily counted from the results. Constant 'a' is the difference of zero and the lowest possible aggregate utility (U_{MIN}), constant 'b' is the quotient of the sum of the highest possible aggregate utility (U_{MAX}) and a.

$$a = 0 - U_{MIN}$$

$$b = 100 \div (U_{MAX} + a)$$

A sample of road sections from Amsterdam is presented in section 4.2. The Subjective Safety Score to show examples how the assessment tool can be used in practice.

4

RESULTS

This chapter presents the results of the stated choice survey and the infrastructure assessment tool. Road sections from Amsterdam are selected and evaluated in the second section to demonstrate how to use the Subjective Safety Score in practice. The selection of the road sections reflects on a wide variety of Amsterdam's infrastructure types.

4. 1. Results of the survey

Goudappel Coffeng commissioned PanelClix, an international online market research company to conduct the final survey, which is filled in by 823 respondents in total. Table 8 shows the **descriptive characteristics** of the respondents compared to the Dutch average values.

Table 8: Descriptive characteristics of the survey sample and the Netherlands

	Descriptive characteristics	
	Gender	
	Survey sample	The Netherlands
Male	50.3% (414)	49.6%
Female	49.7% (409)	50.4%
	Age	
	Survey sample	The Netherlands
<20	2.7% (22)	22.5%
20 – 39	32.6% (268)	24.5%
40 – 64	47.3% (389)	34.8%
65 – 79	16.6% (137)	13.8%
>80	0.9% (7)	4.4%
	Highest completed education	
	Survey sample	The Netherlands*
Primary	1.7% (14)	8.9%
VMBO/MAVO	19.2% (158)	19.3%
HAVO/VWO/MBO	47,9% (395)	41.6%
HBO (Bachelor)	23.1% (190)	18.3%
WO (Master)	6.7% (55)	10.6%
PhD	0.9% (7)	No data
Other	0.5% (4)	No data

	Frequency of riding bike	
	Survey sample	The Netherlands
Daily	36.9% (304)	43%
Few times a week	32.3% (266)	28%
Weekly	10.8% (89)	
Few times a month	7.5% (62)	29%
Monthly or less frequent	12.4% (102)	
	Most frequently used type of bicycle (survey sample)	
City bike	71.8% (591)	
Electric bike	16.2% (133)	
Cargo bike	1.5% (12)	
Race bike	1.2% (10)	
Mountain bike	2.8% (23)	
Folding bike	0.5% (4)	
Shared bike	0.4% (3)	
Other	5.7% (47)	
	Most frequent purpose of cycling (survey sample)	
Commuting to work or school	33.7% (277)	
Commuting to other activities	36.0% (296)	
Recreational	29.3% (241)	
Sport	1.1% (9)	

*Source: CBS (2014, 2016), European Commission (2013). * total population aged 15 - 64*

Table 9 shows the results of the statistical analysis made of the choice situations. The second column contains the estimated attribute effects, the third column the standard error values. The fourth column shows statistical relevance calculated by a t-test, the fifth column shows statistical significance counted as a p-value. All attributes turn out statistically significant with a p-value lower than 0.01.

Table 9: Estimated main effects and their statistical parameters

Attribute	Estimated effect	Standard error	T-test	P-value
Facility	0.766	0.0216	35.41	0.00
Separation	0.697	0.0166	41.88	0.00
Volume	-0.0812	0.00954	-8.52	0.00
Speed reduction	0.144	0.0107	13.41	0.00
Parking	-0.117	0.0104	-11.19	0.00

The estimated effects describe the utility difference that occurs when an attribute is present. Given that effect coding (1, -1) is used in the utility model, the utility difference between two levels of an attribute is the double of the estimated effect. The following example helps to interpret the effects.

The estimated attribute effect of dedicated cycling facility is 0.766. If a dedicated facility is present, the aggregate utility increases 0.766. If there is no dedicated cycling facility present, the aggregate utility decreases 0.766. Thus the utility difference between the two levels of the attribute is 1.532. Figure 4 presents the estimated attribute effects. The presence of positive effects (dedicated facility, physical separation, speed reduction) increases the subjective safety of cyclists, the presence of negative effects (high traffic volume, adjacent parking) decreases the subjective safety of cyclists.

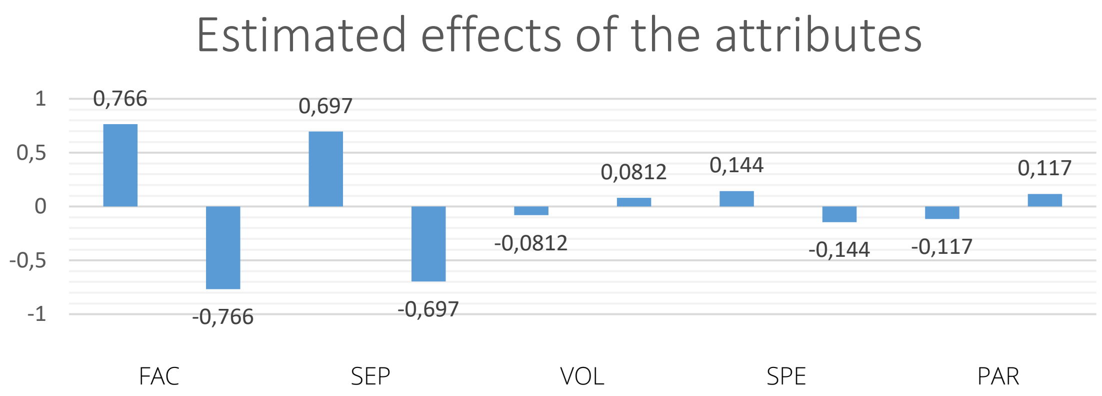

Figure 4: Estimated attribute effects. In the experimental design effect coding was used. Each attribute has two bars, the left one applies to the presence of the attribute, the right one to the absence of the attribute.

The presence of a **dedicated cycling facility** has a strong and positive effect on the perceived safety of cyclists. This attribute has turned out to be the most important factor. The estimated effect is 5-10 times higher than the effects of any other attributes besides physical separation. **Physical separation** has also a strong and positive effect on the safety perceptions of cyclists. The importance of the effect is almost as high as for dedicated cycling facility. The presence of **high traffic volume** decreases the subjective safety of cyclists. Therefore this attribute is given a negative effect. However among all attributes this effect has turned out to be the weakest. The presence of **speed reduction facilities** increases the subjective safety of cyclists, however this effect is approximately five times weaker than the two strongest effects. **Cars parking** along the road decrease the perceived safety of cyclists. However, the strength of the effect is rather low, somewhat weaker than the effect of speed reduction facilities. Besides the presence of high traffic volume, this is the only other attribute that has a negative effect on safety perceptions of cyclists.

Table 10 shows the effect coding scheme of the descriptive characteristics. The same MNL model is used as in the case of the main effects, however, extra factors are included to discover the effects of the descriptive characteristics. For details of the syntaxes and the MNL model see the Appendix.

Table 10: Effect coding scheme of the descriptive characteristics

Gender	GENDER						
Female	1						
Male	-1						
Age	AGE1	AGE2	AGE3	AGE4			
<20	1	0	0	0			
20-39	0	1	0	0			
40-64	0	0	1	0			
65-79	0	0	0	1			
>80	-1	-1	-1	-1			
Highest completed education	EDU1	EDU2	EDU3	EDU4	EDU5	EDU6	
Primary	1	0	0	0	0	0	
VMBO/MAVO	0	1	0	0	0	0	
HAVO/VWO/MBO	0	0	1	0	0	0	
HBO (Bachelor)	0	0	0	1	0	0	
WO (Master)	0	0	0	0	1	0	
PhD	0	0	0	0	0	1	
Other	-1	-1	-1	-1	-1	-1	
Frequency of biking	FREQ1	FREQ2	FREQ3	FREQ4			
Daily	1	0	0	0			
Few times a week	0	1	0	0			
Weekly	0	0	1	0			
Few times a month	0	0	0	1			
Monthly or less frequent	-1	-1	-1	-1			
Most frequently used type of bike	TYP1	TYP2	TYP3	TYP4	TYP5	TYP6	TYP7
City bike	1	0	0	0	0	0	0
Electric bike	0	1	0	0	0	0	0
Cargo bike	0	0	1	0	0	0	0
Race bike	0	0	0	1	0	0	0
Mountain bike	0	0	0	0	1	0	0
Folding bike	0	0	0	0	0	1	0
Shared bike	0	0	0	0	0	0	1
Other	-1	-1	-1	-1	-1	-1	-1
Purpose of biking	PUR1	PUR2	PUR3				
To work or school	1	0	0				
Other commuting	0	1	0				
Recreation	0	0	1				
Sport	-1	-1	-1				

Table 11 and 12 show the results of analysing the effects of the descriptive subgroups. Significant results (p-value smaller than 0.05) are marked with red colour. In many cases the size of the subgroups are smaller than optimal (< 30). These subgroups are marked with * sign. In the case of these subgroups the results are not considered valid due to the very small sample size. In all cases the attributes have the same sign, only the weight of the effects may be different: there is no subgroup perceiving an attribute negative what other subgroups perceive positive or vice versa. Female cyclists seem to be more aware of the presence of dedicated cycling facility, the presence of high traffic volume of motorists and the presence of adjacent car parking. The presence of physical separation seems to be more important for male cyclists. There is almost no difference between the effect of speed reduction among females and males. However, all of these differences are insignificant. The importance of dedicated cycling infrastructure decreases, the effect of physical separation increases as the age of the respondent is increasing. This might be the result of older respondents tending to prefer cycling on sidewalks compared to any other option. However, only cyclists between 20 and 39 have significantly different results than the others. Respondents between 65 and 79 are more aware of the presence of high traffic volume and adjacent car parking than younger cyclists. The presence of speed reduction facilities seems to be almost equally important for cyclists between 20 – 39 and 65 – 70, while cyclists between 40 – 64 are more aware than the average respondent. These differences are also insignificant. It is hard to find clear relations between the highest completed education level and the safety perceptions of cyclists. Although respondents holding a VMBO/MAVO or WO certificate are significantly more aware of the presence of dedicated cycling facilities, it is hard to understand why. Other differences are also hard to explain while they are all insignificant. Respondents who cycle on a daily basis are less aware of the presence of dedicated cycling facilities (significant), physical separation (significant) and speed reduction facilities (insignificant) compared to the others. People who cycle weekly perceive physical separation less important, while those who cycle just a few times a month perceive it more important (significant in both cases). It is hard to draw a conclusion from other attributes. Cyclists who use ordinary city bikes or electric bikes perceive the presence of dedicated facilities significantly more important, and vast majority of respondents belongs to this group. Recreational cyclists seem to be less aware of dedicated cycling facilities (insignificant) but more aware of physical separation (significant). Finding clear relations in the case of the other attributes seems to be hard. The complete tables with statistical parameters are included in the Appendix.

Table 11: Estimated effects in the full sample and in descriptive subgroups (FAC, SEP)

	Dedicated facility		Physical separation	
	Difference	Value	Difference	Value
Gender				
Main parameter		0.768		0.698
Female	0.0416	0.810	-0.0258	0.672
Male	-0.0416	0.726	0.0258	0.724
Age				
Main parameter		0.704		0.746
<20*	0.1650	0.869	-0.1020	0.644
20-39	**0.2270**	**0.931**	**-0.1980**	**0.548**
40-64	0.0490	0.753	0.0312	0.777
65-79	-0.1270	0.577	0.0904	0.836
>80*	-0.3140	0.390	0.1784	0.924
Highest completed education				
Main parameter		0.685		0.776
Primary*	-0.2820	0.403	-0.0553	0.721
VMBO/MAVO	**0.1640**	**0.849**	-0.0697	0.706
HAVO-VWO-MBO	0.0578	0.743	-0.0834	0.693
HBO (Bachelor)	0.0576	0.743	-0.0851	0.691
WO (Master)	**0.2750**	**0.960**	-0.0638	0.712
PhD*	-0.0988	0.586	0.4130	1.189
Other*	-0.1736	0.511	-0.0557	0.720
Frequency of biking				
Main parameter		0.796		0.746
Daily	**-0.1070**	**0.689**	**-0.1300**	**0.616**
Few times a week	0.0234	0.819	-0.0182	0.728
Weekly	0.0147	0.811	**-0.1040**	**0.642**
Few times a month	0.0396	0.836	**0.1880**	**0.934**
Monthly or less	0.0293	0.825	0.0642	0.810
Type of most frequently used bike				
Main parameter		0.524		0.610
City bike	**0.2480**	**0.772**	0.0981	0.708
Electric	**0.2790**	**0.803**	0.1000	0.710
Cargo bike*	0.1600	0.684	-0.1000	0.510
Racebike*	0.0980	0.622	-0.0805	0.530
Mountainbike*	0.2030	0.727	-0.1140	0.496
Folding bike*	-0.0988	0.425	**-0.4270**	**0.183**
Shared bike*	**-1.1800**	**-0.656**	0.3270	0.937
Other	0.2908	0.815	0.1964	0.806
Most frequent purpose of biking				
Main parameter		0.805		0.679
To work or school	-0.0029	0.802	-0.0587	0.620
To a free time activity	-0.0188	0.786	0.0366	0.716
Recreational	-0.0957	0.709	**0.1030**	**0.782**
Sport*	0.1174	0.922	-0.0809	0.598

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Table 12: Estimated effects in the full sample and in descriptive subgroups (VOL, SPE, PAR)

	High traffic volume		Speed reduction		Adjacent car parking	
	Difference	Value	Difference	Value	Difference	Value
Gender						
Main parameter		-0.081		0.145		-0.117
Female	-0.0145	-0.096	-0.0001	0.145	-0.0154	-0.132
Male	0.0145	-0.067	0.0001	0.145	0.0154	-0.102
Age						
Main parameter		-0.100		0.164		-0.142
<20*	-0.0149	-0.115	-0.0572	0.107	0.0847	-0.057
20-39	0.0304	-0.070	-0.0344	0.130	0.0465	-0.096
40-64	0.0115	-0.089	0.0107	0.175	0.0106	-0.131
65-79	-0.0071	-0.107	-0.0398	0.124	-0.0031	-0.145
>80*	-0.0199	-0.120	0.1207	0.285	-0.1387	-0.281
Highest completed education						
Main parameter		-0.120		0.149		-0.131
Primary*	0.0523	-0.068	0.0635	0.213	**0.1670**	**0.036**
VMBO/MAVO	0.0118	-0.108	-0.0166	0.132	0.0020	-0.129
HAVO-VWO-MBO	0.0504	-0.070	-0.0025	0.147	0.0123	-0.119
HBO (Bachelor)	0.0294	-0.091	0.0064	0.155	0.0313	-0.100
WO (Master)	0.0615	-0.059	-0.0236	0.125	-0.0119	-0.143
PhD*	-0.1190	-0.239	-0.0926	0.056	-0.0177	-0.149
Other*	-0.0864	-0.206	0.0654	0.214	-0.1830	-0.314
Frequency of biking						
Main parameter		-0.080		0.152		-0.121
Daily	0.0010	-0.079	-0.0356	0.116	0.0172	-0.104
Few times a week	-0.0075	-0.088	0.0096	0.162	0.0007	-0.120
Weekly	0.0109	-0.070	0.0362	0.188	0.0065	-0.115
Few times a month	0.0127	-0.068	-0.0169	0.135	0.0131	-0.108
Monthly or less	-0.0170	-0.097	0.0067	0.159	-0.0375	-0.158
Type of most frequently used bike						
Main parameter		-0.084		0.106		-0.116
City bike	0.0038	-0.081	0.0439	0.150	-0.0011	-0.117
Electric	0.0010	-0.083	0.0441	0.150	0.0077	-0.108
Cargo bike*	0.0025	-0.082	0.0579	0.164	0.0237	-0.092
Racebike*	0.0962	0.012	-0.0594	0.047	-0.0475	-0.164
Mountainbike*	-0.0104	-0.095	0.0024	0.108	-0.0346	-0.151
Folding bike*	0.0148	-0.070	0.0500	0.156	0.2240	0.108
Shared bike*	-0.0478	-0.132	-0.1490	-0.043	-0.1570	-0.273
Other	-0.0601	-0.145	0.0101	0.116	-0.0151	-0.131
Most frequent purpose of biking						
Main parameter		-0.074		0.164		-0.144
To work or school	0.0003	-0.074	-0.0308	0.133	0.0391	-0.105
To a free time activity	-0.0232	-0.097	-0.0176	0.146	0.0485	-0.096
Recreational	-0.0068	-0.081	-0.0062	0.158	-0.0096	-0.154
Sport*	0.0297	-0.044	0.0546	0.219	-0.0780	-0.222

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Additional questions are supposed to discover the background of respondents' answers. Figure 5 shows how respondents evaluate the **role of the attributes on subjective safety**. Respondents are asked to answer how important the selected five attributes are during the choice situations. The aim of this question is to control the unconscious choice situation with a consciously answered question. The results are aligned with the estimated effects, they show a fairly similar pattern. Cycling facilities and physical separation turn out to be the two most important factors followed by the presence of speed reduction facilities. High traffic volume and adjacent car parking are rated with a somewhat similar importance. The most important factor is the presence of dedicated cycling facilities. Not only because more than 85% of respondents choose it either important or very important, but also because this is the only attribute that is described 'very important' by the relative majority of respondents. Physical separation finishes just behind dedicated cycling facilities, which shows a more equal relation of the attributes than the estimated effects suggest. The relative majority chose 'neutral' in the cases of high traffic volume and adjacent car parking, which explains why the estimated effects of these attribute became low. The presence of speed reduction facilities, however, is chosen to be important by almost every second respondent, while the weight of the effect is more comparable to high traffic volume and adjacent car parking. This shows a bit of inconsistency between the two sources of results.

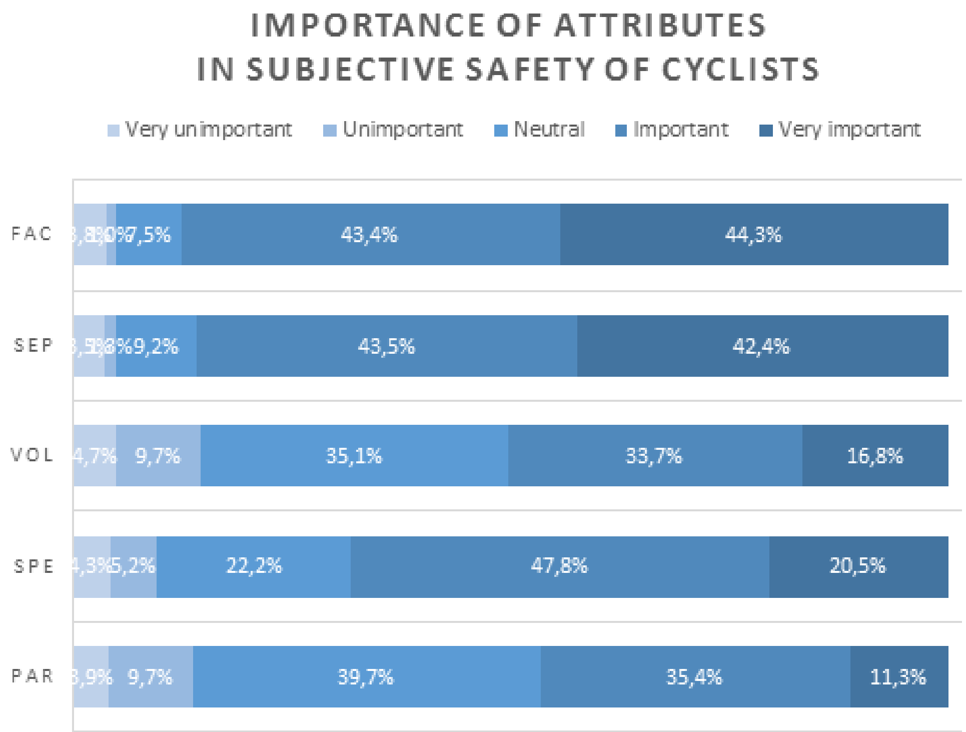

Figure 5: The importance of attributes in the choices of respondents

The second additional question (see results in Figure 6) discovers how important selected factors are in **cyclists' route choice**. Respondents are asked to answer how important the following factors are when they decide which route to take for their commuting trip. Although the Netherlands has one of the best scores both in cycling volumes and safety rates, traffic safety still turned out to be the most important factor. More than 85% of respondents answer either important or very important, and traffic safety is also the only factor where the relative majority chooses 'very important' as their answer.

In general all factors receive a very high rate (over 75%) of answers important or very important except attractiveness, which is chosen to be neutral, unimportant or very unimportant by more than half of the respondents. One reason can be that the opinion of cyclists is based on their own perceptions and exposure, they do not consider the relative safety of Dutch cyclists compared to other countries. And since almost every third person who is killed in a traffic accident is a cyclist, safety remains an important issue for cyclists.

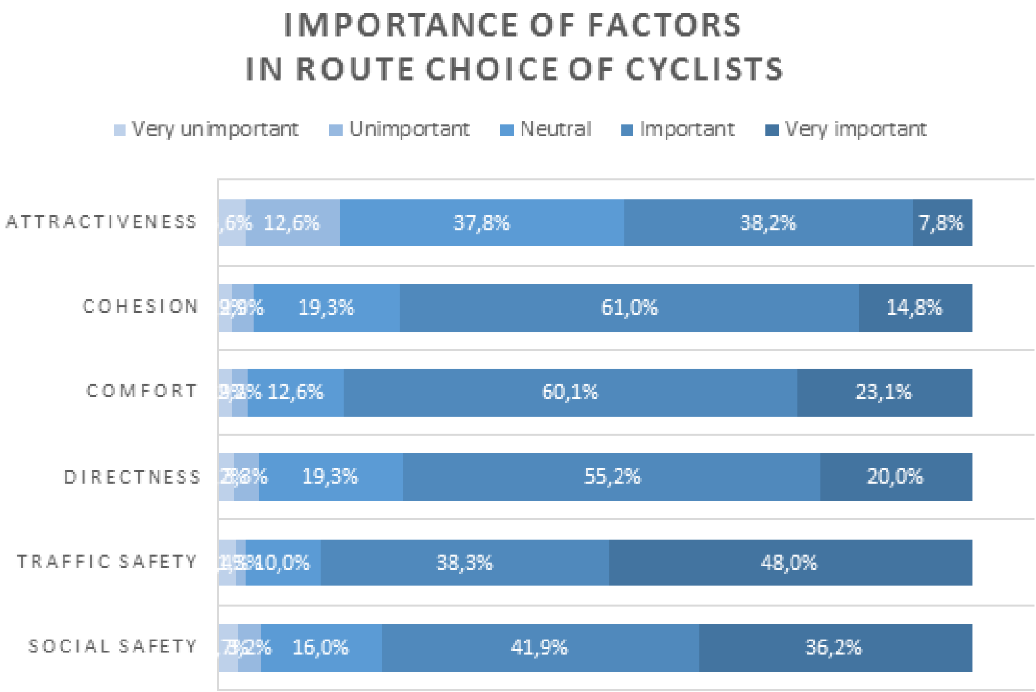

Figure 6: The importance of different factors in cyclists' route choice

4. 2. The Subjective Safety Score

The infrastructure assessment tool is based on the outcomes of the survey. Table 13 shows how the **Subjective Safety Score** is calculated. Each possible combination of the attribute levels have an aggregate subjective safety utility value calculated from the estimated effects. Given the five attributes with 2 levels, in total there are 32 possible combinations, with 32 different aggregate utilities. The minimum and the maximum values are used to calculate the constants to normalise the utility values on a scale between 0 and 100. Given the constants, the Subjective Safety Score can be calculated.

$$SSS = (U_{Sub.Safety} + a) \times b$$

$$U_{Sub.Safety} = \sum \beta_k \times X_{k,l} = \beta_{FAC} \times FAC_l + \beta_{SEP} \times SEP_l + \beta_{VOL} \times VOL_l + \beta_{SPE} \times SPE_l + \beta_{PAR} \times PAR_l$$

$$a = 0 - U_{MIN} = 1.8052$$

$$b = 100 \div (U_{MAX} + a) = 27.69776$$

Where:

SSS	Subjective Safety Score (to be estimated)
$U_{Sub.Safety}$	aggregate subjective safety utility of the road section
β_k	estimated attribute parameters (*k = attribute*, *l = road section to evaluate*)
X_k	attribute values for the presence (1) or the absence (-1) of the attributes
'*a*' and '*b*'	constants of the normalisation

Table 13: The determination of the Subjective Safety Score

Infrastructure attributes					Calculation of SSS	
Dedicated facility	Physical separation	High traffic volume	Speed reduction	Adjacent parking	Aggregate utility	Subjective Safety Score
-1	-1	1	-1	1	**-1.8052**	0.0
-1	-1	-1	-1	1	-1.6428	4.5
-1	-1	1	-1	-1	-1.5712	6.5
-1	-1	1	1	1	-1.5172	8.0
-1	-1	-1	-1	-1	-1.4088	11.0
-1	-1	-1	1	1	-1.3548	12.5
-1	-1	1	1	-1	-1.2832	14.5
-1	-1	-1	1	-1	-1.1208	19.0
-1	1	1	-1	1	-0.4112	38.6
1	-1	1	-1	1	-0.2732	42.4
-1	1	-1	-1	1	-0.2488	43.1
-1	1	1	-1	-1	-0.1772	45.1
-1	1	1	1	1	-0.1232	46.6
1	-1	-1	-1	1	-0.1108	46.9
1	-1	1	-1	-1	-0.0392	48.9
-1	1	-1	-1	-1	-0.0148	49.6
1	-1	1	1	1	0.0148	50.4
-1	1	-1	1	1	0.0392	51.1
-1	1	1	1	-1	0.1108	53.1
1	-1	-1	-1	-1	0.1232	53.4
1	-1	-1	1	1	0.1772	54.9
1	-1	1	1	-1	0.2488	56.9
-1	1	-1	1	-1	0.2732	57.6
1	-1	-1	1	-1	0.4112	61.4
1	1	1	-1	1	1.1208	81.0
1	1	-1	-1	1	1.2832	85.5
1	1	1	-1	-1	1.3548	87.5
1	1	1	1	1	1.4088	89.0
1	1	-1	-1	-1	1.5172	92.0
1	1	-1	1	1	1.5712	93.5
1	1	1	1	-1	1.6428	95.5
1	1	-1	1	-1	**1.8052**	100.0

U_{MIN} and U_{MAX} are marked with bold letters

Figure 7 and 8 visualise what the normalisation means in practice. The relative relations and the **distribution** of the distinct values remain the same, just the scale as a whole is stretched between 0 and 100. In this way users can understand the scores easier. However, one should keep in mind that a zero score on the SSS-scale does not mean an absolute zero level of safety, but the possible worst option considering the selected attributes. The figures show that the distribution of the Subjective Safety Score is not equal, there are three well-separated groups. This is the reason of two attributes being dominant compared to the others. The presence of dedicated cycling facilities and physical separation have so high effects compared to the others, that the combination of these two attributes creates three groups. The highest values apply to the cases where both attributes are present, the lowest where neither of them is present. The values in the middle occur when one of them is present and the other one is absent. The differences between each group come from the other attributes (traffic volume, speed reduction, adjacent parking). The small differences within the groups have proved choosing the scale to be between 0 and 100, as the minor differences would be harder to capture in a smaller scale.

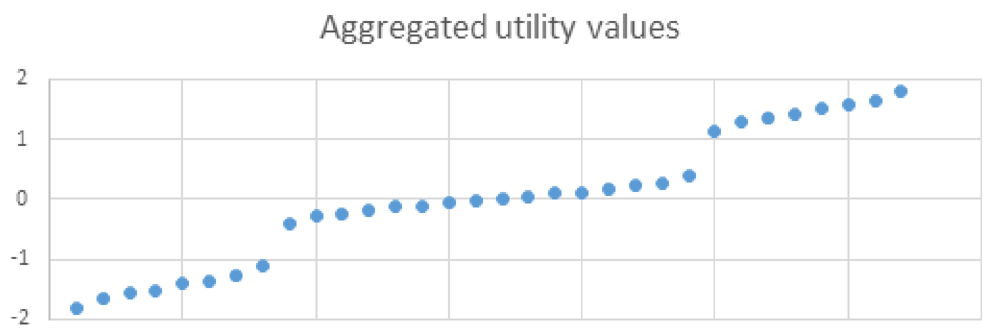

Figure 7: Aggregated utility values

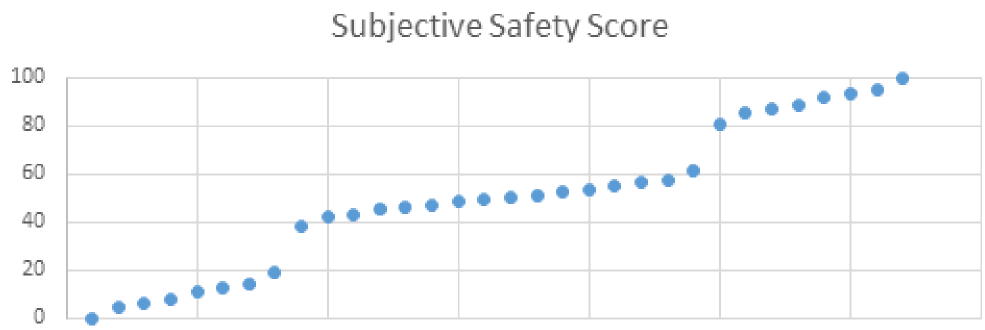

Figure 8: Subjective Safety Scores

The use of the Subjective Safety Score is illustrated by examples taken from Amsterdam. The following pages contain a selection of different road sections of the Dutch capital, each evaluated with the Subjective Safety Score. The evaluation starts with a five-step checklist, determining the values (1 or -1) of the five attributes. The value is '1' if the attribute is present, and '-1' if the attribute is absent. Table 13 gives guidance on how to determine the values of the attributes.

Table 14: Guidance for choosing the attribute values for calculating the Subjective Safety Score

Determining the values of the attributes		
	Presence = 1	Absence = -1
Dedicated cycling facility	If there is an infrastructure element that is dedicated for cyclists (cycle track, cycle lane).	If there is no such element available.
Physical separation	If cyclists and motorists are physically separated from each other.	If they are not separated.
High traffic volume	Based on traffic volume register, above 4000 motor vehicle/day*	Based on register, below 4000 motor vehicle/day*. In cases where the register was not available, roads with residential street label were considered to have low traffic volume. Label was taken from the Dutch road safety statistics**.
Speed reduction	If speed reduction facilities for 30 km/h speed limit (speed bumps and humps, 30 km/h zone signs etc.) are installed.	If there are no such facilities installed.
Adjacent parking	If cars are parking alongside the road.	If there are no cars parking alongside the road.

** Source: Gemeente Amsterdam (2017); ** Source: VIA (2017)*

Table 15 – 40 show infrastructure examples from Amsterdam. Each case is described by the five attributes, and based on this the SSS is calculated. Short notes are taken at each example. The examples follow each other in alphabetical order. The examples were chosen in a way to show a diverse spectrum of different infrastructure layouts, however, as a result of planning practice, there are options that can be seen more frequently than others. The following selection contains 15 different combinations of the attributes. The rest might be less frequently or not used at all in Amsterdam, this is why they are not included in this selection.

The examples show excellently how the two dominant attributes overrule the others. The question whether a road section receives a low, a medium or a high SSS value depends only on the presence of dedicated facility and physical separation. Road sections with separated cycle tracks all receive relatively high SSS values, streets where cyclists are supposed to go on the carriageway receive low values. The other attributes (traffic volume, speed limitations, adjacent parking) affect the SSS only in a limited extent. This shows serious limitations in the use of the Subjective Safety Score. Further and more detailed thoughts may be found in the Discussion chapter.

Table 15: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Baarsjesweg 224-226. Notes: Traffic calmed residential street with adjacent car parking. The lack of dedicated cycling facility and physical separation make the SSS low.	SSS:	12.5

Table 16: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Eerste Van Swindenstraat 4. Notes: Street with separated cycle track, 30 km/h speed limitation and low traffic volume. The favourable values of 4 attributes indicate an outstanding SSS.	SSS:	93.5

Table 17: Subjective Safety Score in practice, example for medium SSS in Amsterdam

	FAC:	1
	SEP:	-1
	VOL:	1
	SPE:	-1
	PAR:	1
Location: Ferdinand Bolstraat 190. Notes: Cycle lane along a road with high traffic volume and adjacent car parking: the result is a medium Subjective Safety Score.	SSS:	42.4

Table 18: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Jan Tooropstraat 1. Notes: Traffic calmed street with adjacent car parking, 30 km/h speed limitation and separated cycle track, the SSS has a high value.	SSS:	93.5

Table 19: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	-1
	SPE:	-1
	PAR:	-1
Location: Jodenbreestraat 96A. Notes: Separated cycle track alongside a road with low traffic volume and no cars parking. The lack of 30 km/h speed limitation makes the SSS lower than the previous infrastructure set.	SSS:	92.0

Table 20: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	1
	SPE:	-1
	PAR:	-1
Location: Kruislaan 3. Notes: Separated cycle track alongside a road with high traffic volume. Parking is not allowed. The SSS remains relatively high.	SSS:	87.5

Table 21: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	1
	SPE:	-1
	PAR:	-1
Location: Mauritskade 28. Notes: Road where parking is not allowed with high traffic volume and separated cycle track. The SSS is relatively high.	SSS:	87.5

Table 22: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	-1
Location: Omval 453. Notes: On-road cycling with 30 km/h speed limitation (not shown on the picture) and without cars parking alongside the road. The lack of dedicated cycling facility and physical separation makes the SSS low.	SSS:	19.0

Table 23: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	-1
	PAR:	-1
Location: Omval 589. Notes: Street with low traffic volume and without any parking or cycling infrastructure. The lack of dedicated cycling facility and physical separation makes the SSS low.	SSS:	11.0

Table 24: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	1
	SPE:	-1
	PAR:	1
Location: Oosterpark 10. Notes: Separated cycling track alongside road with high traffic volume. Adjacent parking is allowed. The SSS stays relatively high.	SSS:	81.0

Table 25: Subjective Safety Score in practice, example for medium SSS in Amsterdam

	FAC:	1
	SEP:	-1
	VOL:	1
	SPE:	-1
	PAR:	1
Location: Paulus Potterstraat 10. Notes: Cycle lane on street with high traffic volume and adjacent car parking. The lack of physical separation indicates a medium SSS.	SSS:	42.4

Table 26: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Populierenweg 35A. Notes: Traffic calmed road with adjacent car parking. Cyclists and motorists are supposed to share the space, which makes the SSS low.	SSS:	12.5

Table 27: Subjective Safety Score in practice, example for high SSS in Amsterdam

<table>
<tr><td rowspan="5"></td><td>FAC:</td><td>1</td></tr>
<tr><td>SEP:</td><td>1</td></tr>
<tr><td>VOL:</td><td>1</td></tr>
<tr><td>SPE:</td><td>-1</td></tr>
<tr><td>PAR:</td><td>1</td></tr>
<tr><td>Location: President Steynstraat 5.
Notes: Road with high traffic volume, separated cycle track and adjacent car parking. The presence of separated cycle track keeps the SSS relatively high.</td><td>SSS:</td><td>81.0</td></tr>
</table>

Table 28: Subjective Safety Score in practice, example for low SSS in Amsterdam

<table>
<tr><td rowspan="5"></td><td>FAC:</td><td>-1</td></tr>
<tr><td>SEP:</td><td>-1</td></tr>
<tr><td>VOL:</td><td>-1</td></tr>
<tr><td>SPE:</td><td>1</td></tr>
<tr><td>PAR:</td><td>-1</td></tr>
<tr><td>Location: Radioweg.
Notes: Traffic calmed road with 30 km/h speed limitations. The lack of separation indicates a low SSS value.</td><td>SSS:</td><td>19.0</td></tr>
</table>

Table 29: Subjective Safety Score in practice, example for medium SSS in Amsterdam

	FAC:	1
	SEP:	-1
	VOL:	-1
	SPE:	-1
	PAR:	1
Location: Ruyschstraat 27. Notes: Cycle lane on a road with adjacent car parking and without high traffic volume and 30 km/h speed limitation. The lack of physical separation indicates a medium SSS value.	SSS:	46.9

Table 30: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	1
	SPE:	1
	PAR:	1
Location: Sarphatipark 91. Notes: Street with separated cycle track, adjacent parking and high traffic volume. The presence of separated cycle track results in a high SSS value.	SSS:	89.0

Table 31: Subjective Safety Score in practice, example for low SSS in Amsterdam

<table>
<tr><td rowspan="5"></td><td>FAC:</td><td>-1</td></tr>
<tr><td>SEP:</td><td>-1</td></tr>
<tr><td>VOL:</td><td>-1</td></tr>
<tr><td>SPE:</td><td>1</td></tr>
<tr><td>PAR:</td><td>1</td></tr>
<tr><td>Location: Sarphatipark 105.
Notes: Street with on-road cycling, adjacent car parking and 30 km/h speed limitation. The lack of spatial and physical separation indicates a low SSS value.</td><td>SSS:</td><td>12.5</td></tr>
</table>

Table 32: Subjective Safety Score in practice, example for high SSS in Amsterdam

<table>
<tr><td rowspan="5"></td><td>FAC:</td><td>1</td></tr>
<tr><td>SEP:</td><td>1</td></tr>
<tr><td>VOL:</td><td>1</td></tr>
<tr><td>SPE:</td><td>-1</td></tr>
<tr><td>PAR:</td><td>1</td></tr>
<tr><td>Location: Schalk Burgerstraat 10.
Notes: Street with separated cycle track, adjacent parking and high traffic volume. The cycle track keeps a relatively high SSS value.</td><td>SSS:</td><td>81.0</td></tr>
</table>

Table 33: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Tweede Boerhaavestraat 77. Notes: Street with adjacent car parking and 30 km/h speed limitation. The lack of separation indicates a low SSS value.	SSS:	12.5

Table 34: Subjective Safety Score in practice, example for medium SSS in Amsterdam

	FAC:	1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Valeriusplein 12. Notes: Traffic calmed street with adjacent car parking and on-road cycle lane. The presence of dedicated cycling facility keeps the SSS value medium.	SSS:	54.9

Table 35: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	1
Location: Vrolikstraat 559. Notes: Street with adjacent car parking and 30 km/h speed limitation. On-road cycling indicates a low SSS value.	SSS:	12.5

Table 36: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	-1
	SPE:	-1
	PAR:	1
Location: Weesperzijde 243. Notes: Street with separated cycle track and adjacent car parking, without 30 km/h speed limitation and high traffic volume. The SSS value is relatively high.	SSS:	85.5

Table 37: Subjective Safety Score in practice, example for high SSS in Amsterdam

<table>
<tr><td rowspan="5">
</td><td>FAC:</td><td>1</td></tr>
<tr><td>SEP:</td><td>1</td></tr>
<tr><td>VOL:</td><td>-1</td></tr>
<tr><td>SPE:</td><td>1</td></tr>
<tr><td>PAR:</td><td>-1</td></tr>
<tr><td>Location: Wembleylaan 331.
Notes: Separated cycle track in a traffic calmed street with 30 km/h speed limitation and without adjacent car parking. The SSS has its maximum value.</td><td>SSS:</td><td>100.0</td></tr>
</table>

Table 38: Subjective Safety Score in practice, example for medium SSS in Amsterdam

<table>
<tr><td rowspan="5">
</td><td>FAC:</td><td>1</td></tr>
<tr><td>SEP:</td><td>-1</td></tr>
<tr><td>VOL:</td><td>-1</td></tr>
<tr><td>SPE:</td><td>-1</td></tr>
<tr><td>PAR:</td><td>-1</td></tr>
<tr><td>Location: Weteringschans 159.
Notes: Street without adjacent car parking and high traffic volume. The on-road cycle lane indicates a medium SSS value.</td><td>SSS:</td><td>53.4</td></tr>
</table>

Table 39: Subjective Safety Score in practice, example for high SSS in Amsterdam

	FAC:	1
	SEP:	1
	VOL:	1
	SPE:	-1
	PAR:	-1
Location: Wibautstraat 112. Notes: Road with high traffic volume and separated cycle track. The dedicated facility and the separation make the SSS value high.	SSS:	87.5

Table 40: Subjective Safety Score in practice, example for low SSS in Amsterdam

	FAC:	-1
	SEP:	-1
	VOL:	-1
	SPE:	1
	PAR:	-1
Location: Wolvenstraat 4. Notes: Street without adjacent car parkind, high traffic volume and any dedicated cycling facility. As a result, the SSS value is low.	SSS:	19.0

5

DISCUSSION

The discussion covers the effect estimation and the road section assessment tool as well. For better understanding, results are taken in context, related to theories regarding infrastructure and cycling. Strengths and weaknesses of the methodology are discussed, and also the limitations of the results are presented.

5. 1. Discussion of the effect estimation

An essential question is whether cyclists should use dedicated cycling facilities or share the space with motorists. The concept of vehicular cycling is calling for treating bicycles as vehicles and cyclists as drivers of vehicles (Forester, 2014). The main point of the concept is that cycling will only be competitive and safe if cyclists have equal rights to motorists. Although Forester (2014) criticises this comparison, Pucher and Buehler (2008b) argue that dedicated and separated cycling infrastructure is an important reason behind the high cycling rates in European countries such as the Netherlands, Denmark or Germany. The estimated effects give a strong evidence that not only dedicated cycling facilities, but physical separation also has a **great effect on perceived safety** of cyclists. The results suggest that dedicated and separated cycling facilities in the Netherlands had an important role in achieving such high cycling rates. It is an important learning for other European cities that they need to invest in building dedicated facilities for cyclists, and physical separation is similarly important as well. However, one should keep in mind, that physical separation may cause visibility issues, and additional measures may be needed to install at intersections. The research review also supports this finding, as many of earlier studies found that cyclists prefer dedicated (Abraham et al., 2002; Hunt and Abraham, 2007; Stinson and Bhat, 2003) and physically separated facilities (Caulfield, 2012; Snizek, 2013; Wardman et al., 1997).

The estimated effects of high traffic volume and speed reduction facilities open many questions. Although earlier research proves the evidence of cyclists preferring low traffic volumes (Abraham et al., 2002; Stinson and Bhat, 2003) and traffic speed (Caulfield, 2012), the estimated effects **do not show this importance**. However, even the additional questions support the assumption of cyclists considering these attributes important when it comes to traffic safety. As respondents (based on their answers to the additional questions) are aware of these attributes, but this did not turn out in the estimated effects, one can assume that the survey is not able to discover these effects correctly. The choice situations presented complex situations where respondents might have focused only on a few attributes (dedicated facilities, physical separation) and ignored the others. Also bad visualisation may have caused the same effect. Speed reduction facilities for 30 km/hour are represented only by traffic signs, speed bumps and surface paintings, while in the Netherlands it is common to use modular paving instead of asphalt in these cases. At the same time, high traffic volume is presented clearly with cars specially coloured to catch the attention of respondents, but still, the results suggest that the respondents ignored them.

The case of adjacent parking is also similar, the additional questions implied a greater importance than the estimated effects. The visualisation of the attribute meant two lanes of cars parking among the road which must have been noticeable for respondents. As the estimated effect (β_{PAR} = -0.117) is the second lowest among all attributes, it means that respondents did not pay attention to this attribute

either. It is most probable that respondents **focused only on the type of cycling facility**, which is represented by the combination of dedicated facilities and physical separation. Cycle tracks (FAC = +1; SEP = +1), cycle lanes (FAC = +1; SEP = -1), cycling on the sidewalk (FAC = -1; SEP = +1) and cycling on the road (FAC = -1; SEP = -1) are supposed to visualise the two dominant attributes. This is also supported by the results of the first additional question (regarding the importance of the five road section attributes), as respondents only attach primary importance to dedicated facilities and physical separation. Although all attributes are rather found important than not important, the remaining three attributes receive only secondary importance. This explains the imbalance of the effect estimations: when it comes to the choice situations, respondents consider attributes with primary importance only.

One should also consider the role of **interaction effects** as well. Due to the available time and resources, this research project assumed that interaction effects either do not exist or do not have a significant effect. However, it can be questioned as the relevance of some attributes may depend on the value of another attribute. Adjacent car parking may be important only when cyclists need to ride on the carriageway for example. The representation of the choice alternatives might have created additional issues regarding the interaction of the attributes. Although a simple image does create an unconscious choice situation (as it is the aim of the questionnaire), the interaction of the different attributes might be essential as the attributes are not presented separately but all together in the form of an image. Based on these, one should be aware of the possible importance of interaction effects, and further research should address this issue as well.

There are certain issues with the **experimental design** of the survey as well. The software, Ngene is used to generate an efficient design, which uses priors to create the choice situations with the lowest possible standard errors. However, the generated choice sets contain some features that one may find contradictory. Several choice alternatives, but even a complete choice situation are repeated in the design. The reason behind may be that efficient design does not aim for "mathematically nice", clear structure (as orthogonal design does) but tries to find the design with the lowest standard error. This may produce a result that one would find questionable. Another concern is the overrepresentation of specific combinations. Namely, cycling on sidewalks is shown many more times than other options. As other fractional factorial designs, efficient design is used to explore the main effects of attributes. For this purpose, the attribute level balance is maintained (each attribute level appeared the same times), but not the combination of attribute levels. As the research focuses only on main effects, the overrepresentation of specific combination of attributes is assumed not to be a major problem. After all, the main reason is to choose efficient design because it avoids having dominant choice alternatives. Dominant alternatives (when all or almost all attributes have the preferred values) are unable to draw clear conclusions about the effects of the attributes. As the orthogonal design of the pilot survey produces a high level of alternative dominance, efficient design, despite the problems described above, remains the better option.

A final issue is the **generalisability** of the research process and the results. Although the research is based on the Dutch context, the same methodology may be used in countries with similar urban characteristics (including size of the cities, land use and mobility patterns, etc.). This involves mainly European countries. In countries with fundamentally different context the same research methodology may be invalid (focusing on the wrong attributes for instance). An example of using the same research methodology in Hungary is shown in the Appendix. However, that research involves a considerably smaller sample size, which makes the direct comparison of the results not recommended. Another concern is the generalisability of the results themselves. As the results very much depend on human factors, the differences of mobility cultures may lead the researchers to wrong conclusions. Specially, since the Dutch cycling culture is more an exception than an average attitude, even in Europe.

To sum up the findings, there are **clear limitations** of the effect estimation. Respondents are most probably ignoring all attributes but the type of the cycling infrastructure – which is the result of the combination of dedicated facility and physical separation. Other attributes turned out to be less important. Another reason for this is that some attributes (like adjacent parking) are only relevant if other attributes are present or absent. This calls future researchers to include interaction effects as well. The experimental design contains repeated choice alternatives and choice situations, which might be the effect of using efficient design. Efficient design does not aim to have mathematically clear structure but the lowest standard errors. As the problems remain after the regeneration of the design and for other reasons, orthogonal design is not an option to choose, the research proceeds with the efficient design. However, as only main effects are to explore, the above cited problems may have not threatened the validity of the results at all. While the same research process may be used in other countries as well (with certain similarities), the results themselves are not directly generalisable.

5. 2. Discussion of the Subjective Safety Score

The same problems of the effect estimation affect the assessment tool as well. As the Subjective Safety Score is based on the estimated attribute effects the **dominance** of dedicated facilities and physical separation appears in the SSS as well. As a result, instead of a continuous scale, the Subjective Safety Score rather forms three different groups. The best scores appear when a cycle track is present, the worst when cyclists are riding on the carriageway. Other alternatives, when cyclists use cycle lanes or ride on the sidewalks are scored within the two other groups. This is the effect of only two attributes being dominant over the others.

As the effects of high traffic volume and speed reduction facilities for 30 km/h became very low, the comparison of distributor roads and residential roads is very limited. A residential road with low traffic volume has way lower Subjective Safety Score than a busy distributor road with cycle lane. Although this is in accordance with the estimated effects, one could assume it the other way around. For this reason the SSS should be used only in cases where the **traffic volume is similar**, hence different options of distributor roads and different alternatives for residential roads can be evaluated and compared, but not distributor roads with residential roads.

The SSS clearly shows that separated cycle tracks are perceived as the safest options, while cycle lanes have got medium scores. This is an important sign for cities to invest in **building cycling tracks** if they want to engage people in cycling. Although there are some concerns that cities should keep in mind. First of all, this research is focused on road sections, the effect of intersections remains unknown. Even though they follow these results, they should handle the intersections carefully and avoid possible problems (visibility issue for example). The second is that cyclists may get involved in dangerous situations even when they perceive their journeys very safe. As Hedlund (2000) indicates, safety improvements, just like wearing helmets or using seatbelts may have a contradictory effect on objective safety. This may be the case in improving subjective safety as well. As individuals feel themselves in greater safety, they tend to take more risk (Hedlund, 2000). This is the theory of risk compensation which is a type of behavioural adaptation to the changed situation. Traffic planners and urban designers should be aware of this effect and focus not only on subjective safety of cyclists, but also on objective safety as well.

To sum up this section, there is a clear limit of using SSS to compare different infrastructure alternatives. The SSS should be used only when traffic volumes are similar to each other. Decision makers should also make sure that both objective and subjective safety are considered, as improving safety perceptions may lead to greater risks taken, thus to decrease objective safety.

6

CONCLUSIONS AND FURTHER RESEARCH

This chapter summarizes the findings of the research. The first section returns to the research questions and objectives. The second section gives directions for further research in the topic.

6. 1. Conclusions

This thesis project has a dual objective. The first objective is to contribute to new knowledge about the role of infrastructure in perceived safety of cyclists. The presence of **dedicated cycling facilities** and **physical separation** turn out to be the most important attributes (β_{FAC} = 0.766 and β_{SEP} = 0.697) having a strong positive effect on safety perceptions. The effects of other attributes are 5–10 times smaller (0.144 for **speed reduction facilities**, 0.117 for **adjacent parking** and 0.081 for **high traffic volume**). Only high traffic volume and adjacent car parking have negative effects, the other three attributes increase subjective safety. To sum up the most important factors to increase subjective safety of cyclists, they need to be provided dedicated facilities. Physical separation of cyclists and motorists has almost the same importance. 30 km/hour speed reduction facilities also increase perceived safety, while high traffic volume and adjacent car parking decrease it. However, these effects are weaker. Further analysis is carried out to estimate the effects of descriptive characteristics over the main results, however, in most cases there is no significant difference found. It is hard to draw a complex image about these effects based on the results. **Additional questions** are supposed to explore the background of respondents' choices. The results supported the estimated attribute values and only minor differences could be found. Traffic safety is the most important factor when it comes to choosing between different route alternatives. Social safety, directness, comfort, cohesion and attractiveness have only secondary importance.

The second research objective is to develop an **easy-to-use tool to evaluate road sections** based on the estimated perceived safety of cyclists. The estimated attribute effects provided a good starting point to develop the tool. Each road section is described by the presence and the absence of the five attributes. Based on the attribute values (+1 or -1) and the estimated attribute effects, an aggregated subjective safety utility is calculated. The results are projected on a scale between 0 and 100, which gives the Subjective Safety Score (SSS) of the road section. One can easily calculate the SSS, which makes easy to evaluate or to compare different road sections. However, there are certain limitations that one should keep in mind. As it is based on the estimated attribute effects, the SSS ignores the role of traffic volume at a great extent. This is the result of the attributes of dedicated cycling facilities and physical separation being dominant over other attributes. Hence the SSS should not be used to compare road sections with very different traffic volumes. Different alternatives for roads with high traffic volume, as well as options for routes with limited traffic can be easily compared by this tool.

6. 2. Further research

The following recommendations consider both **methodological issues** and possibilities to cover a wider scope. Although interaction effects of the attributes are not considered in this research, when the necessary time and resources are given, a future research should cover these aspects as well. Especially, because the images of the choice situations represent complex situations where respondents are not necessarily able to distinguish between the different attributes. If exploring interaction effects is also included in the research, the problem of overrepresented attribute combinations should be addressed as well. The experimental design of the stated choice survey should be revised more consciously with a special focus on repeating choice alternatives and choice situations, however, it may not be a relevant concern as other researchers may choose other data collection methods for their research.

A **wider scope** may contribute to higher validity and relevancy of the research. Other attributes of road sections should also be concerned, and intersections too. Infrastructure is a complex system, and general conclusions can be drawn only if all aspects (road and intersections) are considered. Solutions that perform well in road sections may cause problems in intersections and vice versa.

The personal interest of the author leads to a wider research area of the topic. Comparing the objective and the subjective safety of cyclists in case of different infrastructure elements (described as infrastructure types or attributes) could not only contribute to knowledge but also give traffic planners and designers relevant support for their daily practice. Safety promotion should focus on both objective and subjective safety, thus the direct comparison of the two aspects is essential. Although there are studies available on the topic, but both the research of Winters et al. (2012) and Sørensen and Mosslemi (2009) call for further research. The research of Winters et al. (2012) explores the current situation in Canada, which is not directly applicable to the European context given the differences in both cycling culture and the available infrastructure types. Also, subjective safety values are based on interviews with cyclists who recently have had accidents during cycling. Although the researchers tried to exclude the effects of experiencing an accident (the analysis is based on control sites, not on the accident sites), the results still might be biased. The study of Sørensen and Mosslemi (2009) provides a detailed research review on both aspects of safety, however, the results of almost half of the considered safety measures are based on "speculations". This highlights the need for a research that directly addresses the problem and produce primarily data of the issue. A future research may cover comprehensively objective and subjective safety of cyclists, focusing not only on road sections, but intersections as well, giving a clear understanding of the current European case.

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APPENDIX

The Appendix chapter provides further details of the research process. Information which is not necessarily needed for the basic understanding, or does not fit in the main chapters, is presented here. Three sections cover the pilot and the final survey conducted in the Netherlands, and an additional survey conducted in Hungary, with a considerably smaller sample size.

Content of the Appendix

A

PILOT SURVEY

A1: Ngene syntax of the pilot survey

The syntax is used to generate the experimental design. The syntax determines the number of choice alternatives, the number of choice situations, and includes the five attributes. Alt1 and alt2 represent the two choice alternatives. The number of rows determines the number of choice situations. However, since a foldover design is used (to avoid possible interaction effects), the final number of choice situations is 16, instead of 8. Since both alternatives are unlabelled and consist only of generic attributes, a sequential construction method is used. The model enumerates the attributes (FAC, SEP, VOL, SPE, PAR) and describes their relations with each other. The model also contains the effects to estimate (β_{FAC}, β_{SEP}, β_{VOL}, β_{SPE}, β_{PAR}). The model uses an effect coding scheme [-1, 1].

Design

;alts = alt1, alt2

;rows = 8

;orth = seq

;foldover

;model:

U(alt1) = β_{FAC} * FAC[-1,1] + β_{SEP} * SEP[-1,1] + β_{VOL} * VOL[-1,1] + β_{SPE} * SPE[-1,1] + β_{PAR} * PAR[-1,1]/

U(alt2) = β_{FAC} * FAC + β_{SEP} * SEP + β_{VOL} * VOL + β_{SPE} * SPE + β_{PAR} * PAR $

A2: Experimental design (orthogonal design)

The experimental design describes the precise content of the choice situations. In total there are 16 choice situations, each with two choice alternatives. The table shows the attribute values [-1, 1] in each alternative. The final, visualised content of the alternatives is derived from the combination of the attribute values.

Table 41: Experimental design of the pilot survey (orthogonal design)

	Choice alternative 1					Choice alternative 2					
	FAC	SEP	VOL	SPE	PAR	FAC	SEP	VOL	SPE	PAR	Fold-over block
1	-1	-1	-1	-1	-1	1	1	-1	1	-1	1
2	-1	1	1	1	-1	-1	-1	1	-1	1	1
3	1	-1	1	-1	-1	-1	1	-1	1	1	1
4	1	1	-1	1	-1	1	1	1	-1	1	1
5	1	1	1	-1	1	1	-1	-1	-1	1	1
6	1	-1	-1	1	1	-1	1	-1	-1	1	1
7	-1	1	-1	-1	1	-1	-1	1	1	1	1
8	-1	-1	1	1	1	-1	1	1	1	-1	1
9	1	1	1	1	1	-1	-1	-1	-1	-1	2
10	1	-1	-1	-1	1	-1	1	1	-1	-1	2
11	-1	1	-1	1	1	1	-1	-1	1	1	2
12	-1	-1	1	-1	1	1	-1	1	-1	-1	2
13	-1	-1	-1	1	-1	1	1	-1	-1	-1	2
14	-1	1	1	-1	-1	1	-1	1	1	-1	2
15	1	-1	1	1	-1	-1	-1	-1	1	-1	2
16	1	1	-1	-1	-1	1	1	1	1	1	2

A3: Pilot questionnaire

The questionnaire is written in Dutch, however the English translation is also included here (in grey). The respondents access the questionnaire through an online surface of Google Forms. Due to the lack of space, reasonable shortening is applied where it is necessary.

Enquête: Subjectieve verkeersveiligheid van fietsers

Survey: Subjective traffic safety of cyclists

Beste respondent,

Dear Respondent,

Dit onderzoek wordt uitgevoerd door Samu Márton Balogh, master student aan de Universiteit van Stockholm (KTH Royal Institute of Technology) en afstudeerstagiair bij Goudappel Coffeng BV, een adviesbureau op het gebied van mobiliteit.

This is a survey conducted by Samu Márton Balogh, master student at KTH Royal Institute of Technology, Stockholm and Goudappel Groep BV, a Dutch mobility consultancy.

Het onderzoek richt zich op de subjectieve verkeersveiligheid van fietsers in Nederland. Subjectieve veiligheid beschrijft de perceptie van fietsers en hoe veilig zij hun reis beleven. Onderzoek focust zich op verkeersveiligheid, dus sociale veiligheid en criminaliteit maken hier geen onderdeel van uit.

The survey explores subjective traffic safety of cyclists in the Netherlands. The term subjective safety (or perceived safety) describes the perception of the cyclists, how safe they perceive their journey. This survey focuses on traffic safety, thus neither social safety, nor security against crimes should be considered.

De enquête bestaat uit drie onderdelen:
• Deel 1: Fietsroutes
• Deel 2: Verdiepende vragen over uw keuzes
• Deel 3: Persoonlijke achtergrondkenmerken

The survey is consists of three parts.
• Part 1: Cycling routes
• Part 2: Additional questions regarding Part 1
• Part 3: Personal and background questions

Hartelijk dank voor uw medewerking,

Thank you for your participation,

Samu Márton Balogh

Samu Márton Balogh

KTH Stockholm / Goudappel Coffeng BV

KTH Stockholm/Goudappel Groep BV

Deel 1 - Fietsroutes

Part 1 – Cycling routes

In dit deel worden telkens twee hypothetische alternatieven van fietsroutes getoond.

In this part you will see hypothetical alternatives of cycling routes.

Stelt u zich voor elk alternatief voor dat u op een dagelijkse reis bent naar uw werk of opleiding. Uw herkomst of bestemming bevinden zich beide in een stedelijke omgeving, bijvoorbeeld zoals in een gemiddelde stad. U fietst alleen. De routes verschillen niet qua reistijd, afstand, etc.

Imagine you are on your daily commute trip to work or school. Your home and your destination are both in urban environment, like in an average Dutch city. You cycle alone. The routes do not differ in any other sense (travel time, distance, etc.) than you see in the figures.

U wordt telkens gevraagd om tussen twee alternatieve routes te kiezen. Uw keuze moet worden gebaseerd op de route die u veiliger lijkt.

The alternatives will be shown in pairs, you will be asked to choose between them. Your choice should be based on which alternative you would perceive safer.

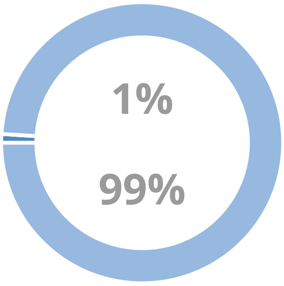
Welke route vindt u veiliger?
Kies tussen route A of route B.

Which route would you perceive safer? Choose between Route A and Route B!

Belangrijk: uw keuze moet niet worden gebaseerd op de route die u zou kiezen, maar op de route die u veiliger lijkt.

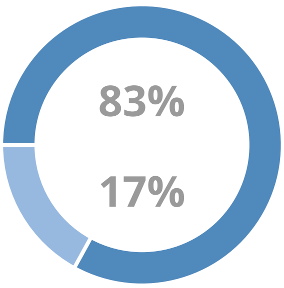
Important: your decision should not be based on which route you would prefer to take! You should base your answer on which route you would perceive safer! Only traffic safety matters!

1/A



1/B

2/A



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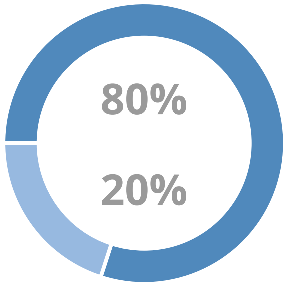

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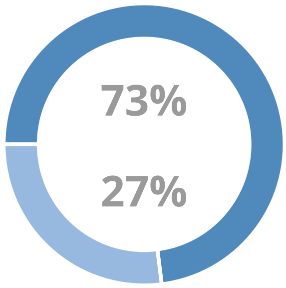
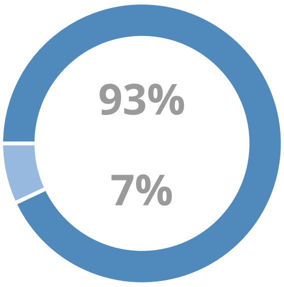


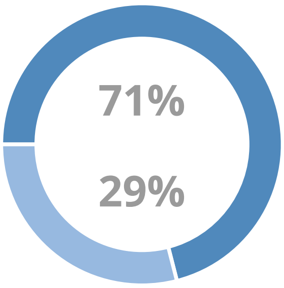
4/B

5/A



5/B

6/A



6/B

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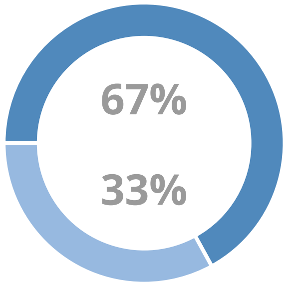

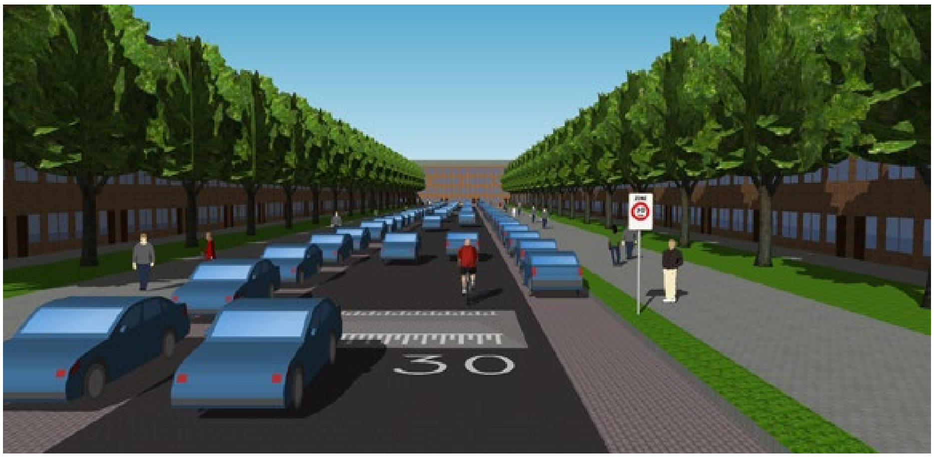

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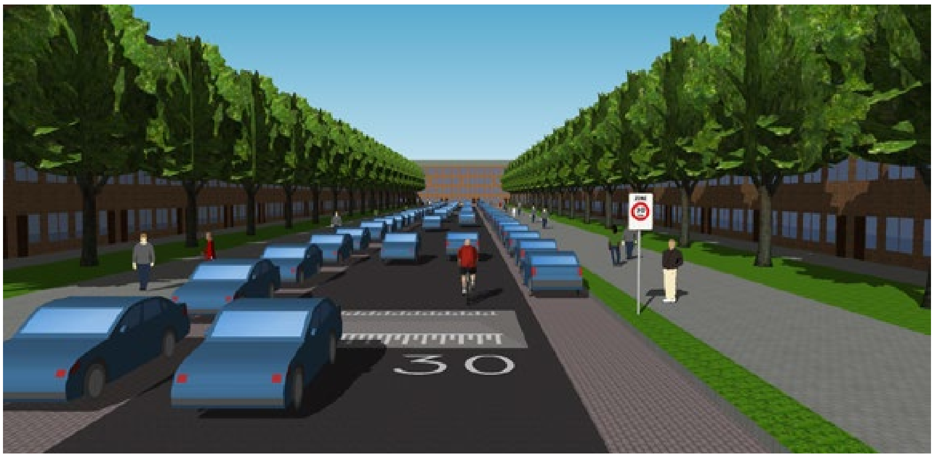
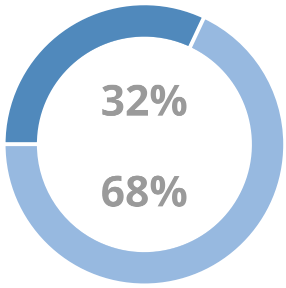
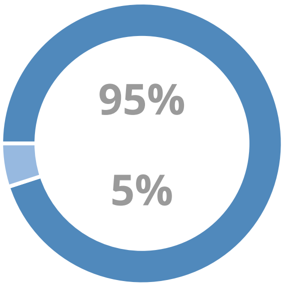
8/A





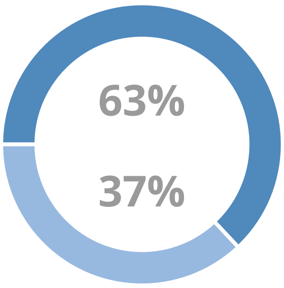
8/B

9/A



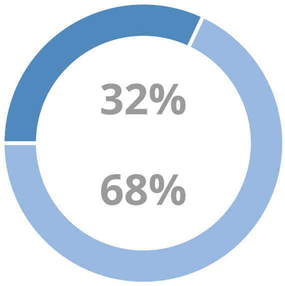
9/B

10/A



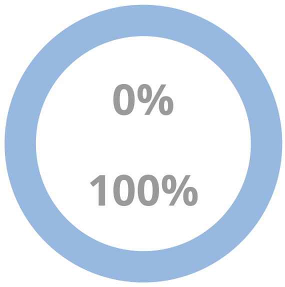
10/B

11/A



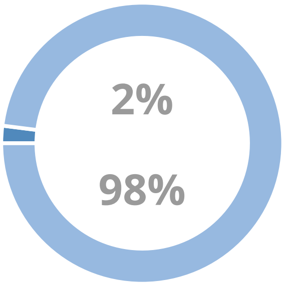
11/B

12/A



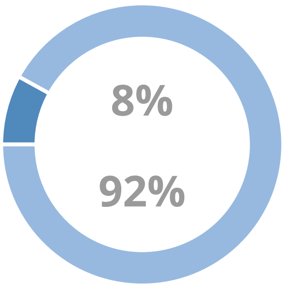
12/B

13/A



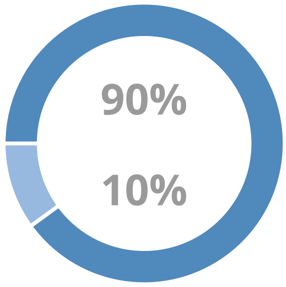
13/B

14/A



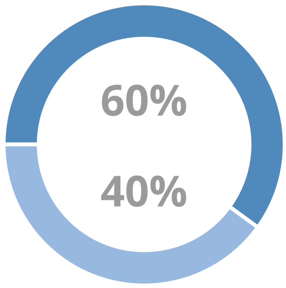
14/B

15/A



15/B

16/A



16/B

Deel 2 – Verdiepende vragen

Part 2 – Additional questions

In dit deel wordt u gevraagd een aantal verdiepende vragen te beantwoorden op basis van uw antwoorden in deel 1.

In this part you will be asked to answer two additional questions about the background of your decisions in Part 1.

1) Hoe belangrijk waren de volgende aspecten in uw keuzes voor de veiligste fietsroute?

1) How important were the following factors in your answers regarding subjective traffic safety?

	Zeer onbelangrijk Not important	Onbelangrijk Not that important	Neutraal Neutral	Belangrijk Rather important	Zeer belangrijk Very important
Aanwezigheid van een fietspad of fietsstrook Presence of dedicated cycling facility					
Fysieke scheiding tussen de weg en het fietspad Presence of physical separation between cyclists and motorists					
Veel autoverkeer op de naastgelegen weg Presence of high traffic volume of motorists on adjacent road					
Aanwezigheid van snelheidsverlagende maatregelen op een 30 km/h uur straat Presence of speed reduction facilities of 30 km/hour on adjacent road					
Aanwezigheid van parkeerplaatsen op de naastgelegen weg Presence of adjacent parking on adjacent road					

Deel 2 – Verdiepende vragen

Part 2 – Additional questions

In dit deel wordt u gevraagd een aantal verdiepende vragen te beantwoorden op basis van uw antwoorden in deel 1.

In this part you will be asked to answer two additional questions about the background of your decisions in Part 1.

2) Hoe belangrijk zijn de volgende aspecten in uw keuze voor een fietsroute naar uw werk of opleiding?

2) How important are the following factors when you decide which route to take to work or school?

	Zeer onbelangrijk Not important	Onbelangrijk Not that important	Neutraal Neutral	Belangrijk Rather important	Zeer belangrijk Very important
Aantrekkelijkheid (mooie omgeving) Attractiveness (in terms of fascinating environment)					
Samenhang (doorgaande fietsroute) Cohesion (in terms of a continuous network)					
Comfortabel fietspad (prettige reis) Comfort (in terms of a pleasant journey)					
Directe fietsroute (qua afstand) Directness (in terms of time and distance)					
Verkeersveiligheid (bijv. ongevallen) Safety (in terms of traffic accidents)					
Sociale veiligheid (bijv. criminaliteit) Security (in terms of crimes)					

Deel 3 – Persoonlijke achtergrondkenmerken?

1) Wat is uw geslacht?
- Man
- Vrouw

2) Wat is uw leeftijd?
- < 20 jaar
- 20 - 39 jaar
- 40 – 64 jaar
- 65 – 79 jaar
- > 80 jaar

3) Wat is uw hoogst afgeronde opleiding?
- Basisschool
- VMBO/MAVO
- HAVO
- VWO
- Bachelor
- Master
- PhD
- Anders

4) Wat is uw postcode (4 cijfers)?

5) Hoe vaak maakt u gebruik van de fiets?
- Dagelijks
- Een aantal keer per week
- Wekelijks
- Een aantal keer per maand
- Maandelijks of minder vaak
- Nooit

6) Wat voor fiets gebruik je?
U kunt meer antwoorden kiezen.
- Stadsfiets
- Elektrische fiets
- Bakfiets
- Racefiets
- Mountainbike
- Vouwfiets
- OV-fiets/Deelfiets
- Anders
- Ik maak geen gebruik van de fiets

Part 3 – Personal and background information

1) What is your gender?
- Female
- Male

2) What is your age?
- <20
- 20 - 39 years
- 40 – 64 years
- 65 – 79 years
- >80

3) What is your highest completed education?
- Primary school
- VMBO/MAVO
- HAVO
- VWO
- Bachelor
- Master
- PhD
- Other

4) What is your post code (4 digits)?

5) How often do you bike?
- Every day
- Few times a week
- Weekly
- Few times a month
- Monthly or less frequent
- Never

6) What type of bike do you ride?
You can choose more options.
- City bike
- Electric bike
- Cargo bike
- Touring/racing/trekking bike
- Mountain bike
- Folding bike
- Bike sharing
- Other
- I don’t ride a bike

7) Waarvoor maakt u gebruik van de fiets?
U kunt meer antwoorden kiezen.
• Fietsen naar werk of opleiding
• Fietsen naar een vrijetijdsbeste ding
• Recreatief fietsen
• Fietsen als sport (bijv. wielren nen/mountainbiken)

7) On what purpose do you cycle usually?
You can choose more options.
• To go to work or school
• Leisure
• Fun
• Sport

A4: The results of the pilot survey

Table 42: Statistical parameters of the MNL model (pilot survey)

Model:	Logit
Number of estimated parameters:	5
Number of observations:	1344
Number of individuals:	1344
Null log likelihood:	-931.590
Cte log likelihood:	-928.836
Init log likelihood:	-931.590
Final log likelihood:	-582.798
Likelihood ratio test:	697.584
Rho-square:	0.374
Adjusted rho-square:	0.369
Final gradient norm:	+4.213e-006
Diagnostic:	Convergence reached...
Iterations:	5
Run time:	00:00
Variance-covariance:	from analytical hessian
Sample file:	data01.dat

Table 43: Estimated utility parameters and statistical features (pilot survey)

Name	Value	Standard error	T-test	P-value	Robust std. error	Robust t-test	P-value
β_{FAC}	1.15	0.0648	17.70	0.00	0.0626	18.32	0.00
β_{SEP}	0.584	0.0553	10.57	0.00	0.0553	10.57	0.00
β_{VOL}	0.0502	0.0474	1.06	0.29*	0.0464	1.08	0.28*
β_{SPE}	0.137	0.0477	2.88	0.00	0 0477	2.88	0.00
β_{PAR}	-0.241	0.0516	-4.67	0.00	0.0526	-4.58	0.00

B

FINAL SURVEY

B1: Ngene syntax of the final survey

The syntax is used to generate the experimental design. The syntax determines the number of choice alternatives, the number of choice situations, and includes the five attributes. Alt1 and alt2 represent the two choice alternatives. The number of rows determines the number of choice situations. An efficient design is used to construct the final experimental design. The model enumerates the attributes (FAC, SEP, VOL, SPE, PAR) and describes their relations with each other. The model also contains the effects to estimate (β_{FAC}, β_{SEP}, β_{VOL}, β_{SPE}, β_{PAR}) and uses priors for a more efficient result. The priors are taken from the results of the pilot survey. The prior of traffic volume is chosen to be zero, as the pilot survey gave an insignificant result. The model uses an effect coding scheme [-1, 1].

Design

;alts = alt1, alt2

;rows =16

;eff = (mnl,d)

;model:

U(alt1) = β_{FAC}.effects[1.15] * FAC[1,-1] + β_{SEP}.effects[0.58] * SEP[1,-1] + β_{VOL}.effects[0] * VOL[1-,1] + β_{SPE}.effects[0.14] * SPE[1,-1] + β_{PAR}.effects[-0.24] * PAR[1,-1]/

U(alt2) = β_{FAC} * FAC + β_{SEP} * SEP + β_{VOL} * VOL + β_{SPE} * SPE + β_{PAR} * PAR $

B2: Experimental design (efficient design)

The experimental design describes the precise content of the choice situations. In total there are 16 choice situations, each with two choice alternatives. The table shows the attribute values [-1, 1] in each alternative. The final, visualised content of the alternatives is derived from the combination of the attribute values.

Table 44: Experimental design of the final survey (efficient design)

	Choice alternative 1					Choice alternative 2				
	FAC	SEP	VOL	SPE	PAR	FAC	SEP	VOL	SPE	PAR
1	-1	1	-1	-1	-1	1	-1	1	1	1
2	1	-1	-1	1	-1	1	1	1	-1	1
3	1	1	-1	-1	-1	1	-1	1	1	1
4	1	-1	-1	1	1	1	1	1	-1	-1
5	1	-1	1	1	-1	-1	1	-1	-1	1
6	1	-1	1	-1	-1	-1	1	-1	1	1
7	-1	1	-1	1	1	-1	-1	1	-1	-1
8	1	-1	-1	-1	-1	1	1	1	1	1
9	-1	1	1	1	1	1	-1	-1	-1	-1
10	-1	1	1	-1	1	-1	-1	-1	1	-1
11	-1	1	1	-1	-1	1	-1	-1	1	1
12	-1	1	1	1	-1	1	-1	-1	-1	1
13	1	-1	-1	1	1	-1	1	1	-1	-1
14	-1	-1	1	1	1	-1	1	-1	-1	-1
15	1	-1	1	-1	1	-1	1	-1	1	-1
16	-1	1	-1	-1	1	-1	-1	1	1	-1

B3: MNL Utilities and MNL choice probabilities

The following table shows the MNL utilities of each choice alternative (counted from the priors) and based on these values the probabilities of being chosen for each alternative. The probabilities are important to check whether alternative dominance occurs. There is no choice alternative with an MNL probability value higher than 0.9, and there is only one higher than 0.8. This shows a better distribution of choice probabilities compared to the pilot survey.

Table 45: MNL Utilities and probabilities of the choice alternatives

	MNL Utilities		MNL probabilities	
	ALT1	ALT2	ALT1	ALT2
1	-0.47	0.47	0.2809	0.7191
2	0.95	1.35	0.401312	0.598688
3	1.83	0.47	0.79576	0.20424
4	0.47	1.83	0.20424	0.79576
5	0.95	-0.95	0.869892	0.130108
6	0.67	-0.67	0.79249	0.20751
7	-0.67	-1.63	0.723122	0.276878
8	0.67	1.63	0.276878	0.723122
9	-0.67	0.67	0.20751	0.79249
10	-0.95	-1.35	0.598688	0.401312
11	-0.47	0.47	0.2809	0.7191
12	-0.19	0.19	0.406127	0.593873
13	0.47	-0.47	0.7191	0.2809
14	-1.83	-0.47	0.20424	0.79576
15	0.19	-0.19	0.593873	0.406127
16	-0.95	-1.35	0.598688	0.401312

B4: Final questionnaire

The questionnaire is written in Dutch, however the English translation is also included here (in grey). The respondents access the questionnaire through an online surface of Snap Surveys. Due to the lack of space, reasonable shortening is applied where it is necessary.

Enquête: Subjectieve verkeersveiligheid van fietsers	Survey: Subjective traffic safety of cyclists
Beste respondent,	Dear Respondent,
Dit onderzoek wordt uitgevoerd door Samu Márton Balogh, master student aan de KTH Royal Institute of Technology in Stockholm en afstudeerstagiair bij Goudappel Coffeng BV, een adviesbureau op het gebied van mobiliteit.	This is a survey conducted by Samu Márton Balogh, master student at KTH Royal Institute of Technology, Stockholm and Goudappel Groep BV, a Dutch mobility consultancy.
Het onderzoek richt zich op de subjectieve verkeersveiligheid van fietsers in Nederland. Subjectieve veiligheid beschrijft de perceptie van fietsers en hoe veilig zij hun reis beleven. Dit onderzoek focust zich op verkeersveiligheid, dus sociale veiligheid en criminaliteit maken hier geen onderdeel van uit.	The survey explores subjective traffic safety of cyclists in the Netherlands. The term subjective safety (or perceived safety) describes the perception of the cyclists, how safe they perceive their journey. This survey focuses on traffic safety, thus neither social safety, nor security against crimes should be considered.
De enquête bestaat uit drie onderdelen: • Deel 1: Fietsroutes • Deel 2: Verdiepende vragen over uw keuzes • Deel 3: Persoonlijke achtergrondkenmerken	The survey is consists of three parts. • Part 1: Cycling routes • Part 2: Additional questions regarding Part 1 • Part 3: Personal and background questions
Hartelijk dank voor uw medewerking,	Thank you for your participation,
Samu Márton Balogh	Samu Márton Balogh
KTH Stockholm / Goudappel Coffeng BV	KTH Stockholm/Goudappel Groep BV

Deel 1 – Fietsroutes

In dit deel worden telkens twee hypothetische alternatieven van fietsroutes getoond.

Stelt u zich voor elk alternatief voor dat u op een dagelijkse reis bent naar uw bestemming (werk, opleiding, supermarkt of een andere activiteit). Uw herkomst of bestemming bevinden zich beide in een stedelijke omgeving, bijvoorbeeld zoals in een gemiddelde stad. U fietst alleen. De routes verschillen niet qua reistijd, afstand, etc.

U wordt telkens gevraagd om tussen twee alternatieve routes te kiezen. Uw keuze moet worden gebaseerd op de route die u veiliger lijkt.

Welke route vindt u veiliger?
Kies tussen route A en route B.

Belangrijk: uw keuze moet niet worden gebaseerd op de route die u zou kiezen, maar op de route die u veiliger lijkt.

Part 1 – Cycling routes

In this part you will see hypothetical alternatives of cycling routes.

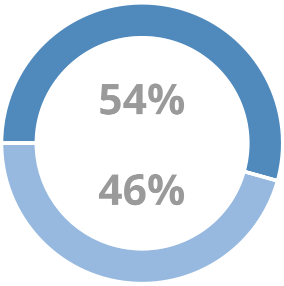
Imagine you are on your daily commute trip to your destination (work, school, supermarket or the place of any other activity). Your home and your destination are both in urban environment, like in an average Dutch city. You cycle alone. The routes do not differ in any other sense (travel time, distance, etc.) than you see in the figures.

The alternatives will be shown in pairs, you will be asked to choose between them. Your choice should be based on which alternative you would perceive safer.

Which route would you perceive safer? Choose between Route A and Route B!

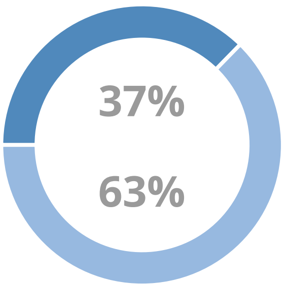
Important: your decision should not be based on which route you would prefer to take! You should base your answer on which route you would perceive safer! Only traffic safety matters.

1/A



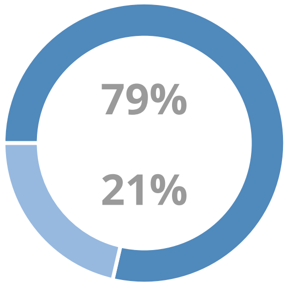
1/B

2/A



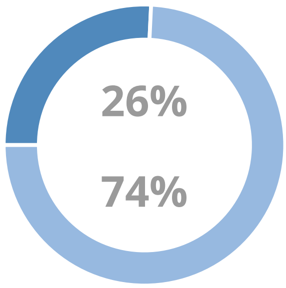
2/B

3/A



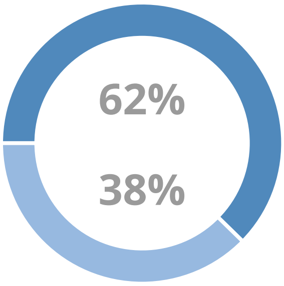
3/B

4/A



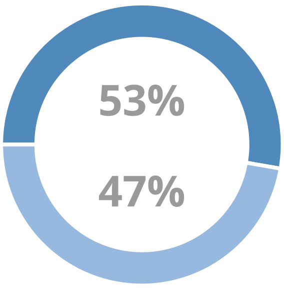
4/B

5/A



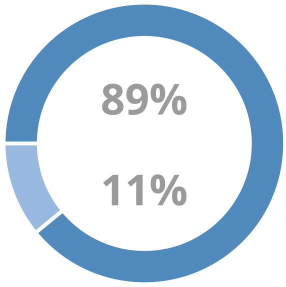
5/B

6/A



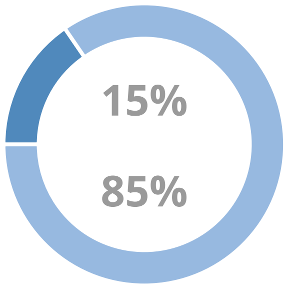
6/B

7/A



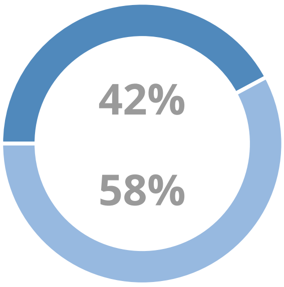
7/B

8/A



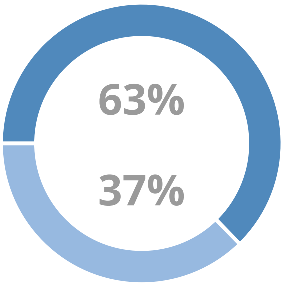
8/B

9/A



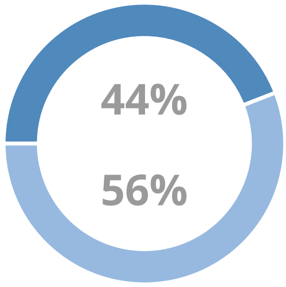
9/B

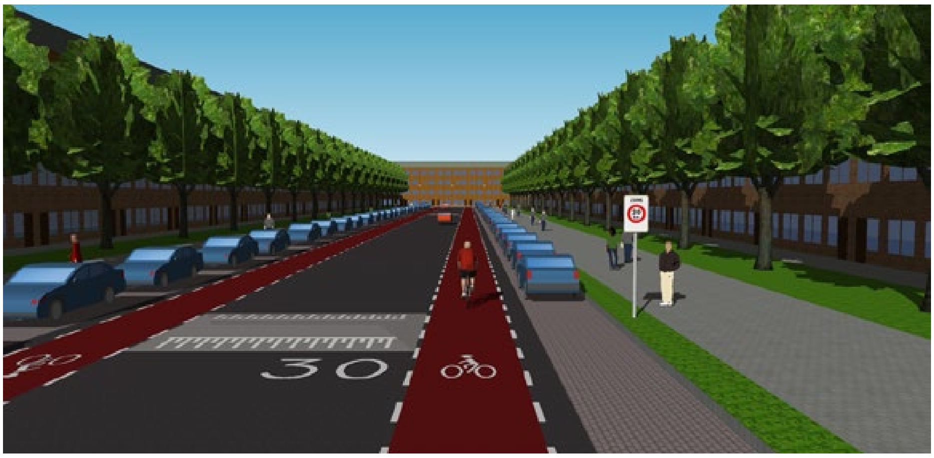
10/A



10/B

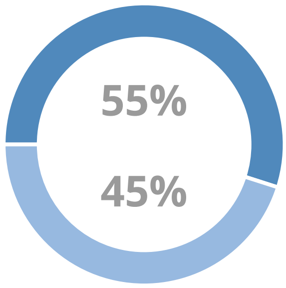
11/A





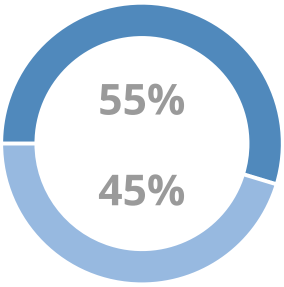
11/B

12/A



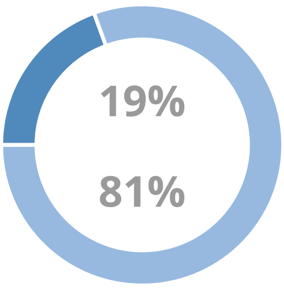
12/B

13/A



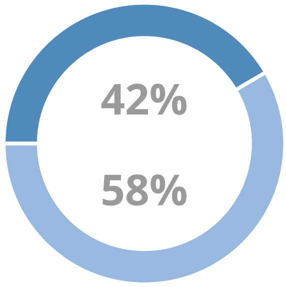
13/B

14/A



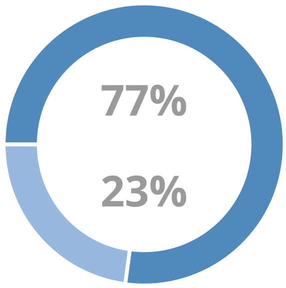
14/B

15/A



15/B

16/A



16/B

Deel 2 – Verdiepende vragen

In dit deel wordt u gevraagd een aantal verdiepende vragen te beantwoorden op basis van uw antwoorden in deel 1.

1) Hoe belangrijk waren de volgende aspecten in uw keuzes voor de veiligste fietsroute?

Part 2 – Additional questions

In this part you will be asked to answer two additional questions about the background of your decisions in Part 1.

1) How important were the following factors in your answers regarding subjective traffic safety?

	Zeer onbelangrijk Not important	Onbelangrijk Not that important	Neutraal Neutral	Belangrijk Rather important	Zeer belangrijk Very important
Aanwezigheid van een fietspad of fietsstrook Presence of dedicated cycling facility					
Fysieke scheiding tussen de weg en het fietspad Presence of physical separation between cyclists and motorists					
Veel autoverkeer op de naastgelegen weg Presence of high traffic volume of motorists on adjacent road					
Aanwezigheid van snelheidsverlagende maatregelen op een 30 km/h uur straat Presence of speed reduction facilities of 30 km/hour on adjacent road					
Aanwezigheid van parkeerplaatsen op de naastgelegen weg Presence of adjacent parking on adjacent road					

Deel 2 – Verdiepende vragen

In dit deel wordt u gevraagd een aantal verdiepende vragen te beantwoorden op basis van uw antwoorden in deel 1.

2) Hoe belangrijk zijn de volgende aspecten in uw keuze voor een fietsroute naar uw bestemming (werk, opleiding, supermarkt of een andere activiteit)?

Part 2 – Additional questions

In this part you will be asked to answer two additional questions about the background of your decisions in Part 1.

2) How important are the following factors when you decide which route to take to your destination (work, school, supermarket or the place of any other activity)?

	Zeer onbelangrijk Not important	Onbelangrijk Not that important	Neutraal Neutral	Belangrijk Rather important	Zeer belangrijk Very important
Aantrekkelijkheid (mooie omgeving) Attractiveness (in terms of fascinating environment)					
Samenhang (doorgaande fietsroute) Cohesion (in terms of a continuous network)					
Comfortabel fietspad (prettige reis) Comfort (in terms of a pleasant journey)					
Directe fietsroute (qua afstand) Directness (in terms of time and distance)					
Verkeersveiligheid (bijv. ongevallen) Safety (in terms of traffic accidents)					
Sociale veiligheid (bijv. criminaliteit) Security (in terms of crimes)					

Deel 3 – Persoonlijke achtergrondkenmerken?

1) Wat is uw geslacht?
• Man
• Vrouw

2) Wat is uw leeftijd?
• < 20 jaar
• 20 - 39 jaar
• 40 – 64 jaar
• 65 – 79 jaar
• > 80 jaar

3) Wat is uw hoogst afgeronde opleiding?
• Basisschool
• VMBO/MAVO
• HAVO
• VWO
• Bachelor
• Master
• PhD
• Anders

4) Wat is uw postcode (4 cijfers)?

5) Hoe vaak maakt u gebruik van de fiets?
• Dagelijks
• Een aantal keer per week
• Wekelijks
• Een aantal keer per maand
• Maandelijks of minder vaak

6) Wat voor fiets gebruik u het meest?
• Stadsfiets
• Elektrische fiets
• Bakfiets
• Racefiets
• Mountainbike
• Vouwfiets
• OV-fiets/Deelfiets
• Anders

Part 3 – Personal and background information

1) What is your gender?
• Female
• Male

2) What is your age?
• <20
• 20 - 39 years
• 40 – 64 years
• 65 – 79 years
• >80

3) What is your highest completed education?
• Primary school
• VMBO/MAVO
• HAVO
• VWO
• Bachelor
• Master
• PhD
• Other

4) What is your post code (4 digits)?

5) How often do you bike?
• Every day
• Few times a week
• Weekly
• Few times a month
• Monthly or less frequent

6) What type of bike do you ride the most?
• City bike
• Electric bike
• Cargo bike
• Touring/racing/trekking bike
• Mountain bike
• Folding bike
• Bike sharing
• Other

7) Waarvoor maakt u het meest gebruik van de fiets?
• Fietsen naar werk of opleiding
• Fietsen naar een vrijetijdsbeste ding
• Recreatief fietsen
• Fietsen als sport (bijv. wielren nen/mountainbiken)

7) On what purpose do you cycle the most?
• To go to work or school
• Leisure
• Fun
• Sport

B5: Syntaxes used for the MNL analysis of the final survey

The following pages contain the Biogeme syntaxes that were used to analyse the raw results of the questionnaire. Different syntaxes were used for analysing the main effects and the different descriptive subgroups. In the syntaxes Beta1-5 stand for β_{FAC}, β_{SEP}, β_{VOL}, β_{SPE}, β_{PAR}

.

Analysis of the main attribute effects. This syntax was also used for analysing the pilot survey.

```
[Choice]
CHOICE

[Beta]
// Name Value    LowerBound    UpperBound    status (0=variable, 1=fixed)
beta1        0       -10000         10000          0
beta2        0       -10000         10000          0
beta3        0       -10000         10000          0
beta4        0       -10000         10000          0
beta5        0       -10000         10000          0

[Utilities]
// Id   Name   Avail   linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
  1     A1     AV1     beta1 * FAC1 + beta2 * SEP1 + beta3 * VOL1 + beta4 * SPE1 + beta5 * PAR1
  2     A2     AV2     beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2


[Model]
$MNL
```

Syntax for analysing the gender subgroups

```
[Choice]
CHOICE

[Beta]
// Name Value    LowerBound    UpperBound    status (0=variable, 1=fixed)
gender        0    -10000    10000    0
beta1         0    -10000    10000    0
beta2         0    -10000    10000    0
beta3         0    -10000    10000    0
beta4         0    -10000    10000    0
beta5         0    -10000    10000    0
beta1gender   0    -10000    10000    0
beta2gender   0    -10000    10000    0
beta3gender   0    -10000    10000    0
beta4gender   0    -10000    10000    0
beta5gender   0    -10000    10000    0

[Utilities]
// Id   Name   Avail   linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
   1    A1     AV1     gender * GENDER + beta1 * FAC1 + beta2 * SEP1 + beta3 * VOL1 + beta4 * SPE1 +
beta5 * PAR1
   2    A2     AV2     beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2

[GeneralizedUtilities]
1 beta1gender * FAC1 * GENDER
+ beta2gender * SEP1 * GENDER
+ beta3gender * VOL1 * GENDER
+ beta4gender * SPE1 * GENDER
+ beta5gender * PAR1 * GENDER

2 beta1gender * FAC2 * GENDER
+ beta2gender * SEP2 * GENDER
+ beta3gender * VOL2 * GENDER
+ beta4gender * SPE2 * GENDER
+ beta5gender * PAR2 * GENDER

[Model]
$MNL
```

```
[Choice]
CHOICE

[Beta]
// Name  Value     LowerBound        UpperBound        status (0=variable, 1=fixed)
age1          0         -10000            10000            0
age2          0         -10000            10000            0
age3          0         -10000            10000            0
age4          0         -10000            10000            0
beta1         0         -10000            10000            0
beta2         0         -10000            10000            0
beta3         0         -10000            10000            0
beta4         0         -10000            10000            0
beta5         0         -10000            10000            0
beta1age1     0         -10000            10000            0
beta1age2     0         -10000            10000            0
beta1age3     0         -10000            10000            0
beta1age4     0         -10000            10000            0
beta2age1     0         -10000            10000            0
beta2age2     0         -10000            10000            0
beta2age3     0         -10000            10000            0
beta2age4     0         -10000            10000            0
beta3age1     0         -10000            10000            0
beta3age2     0         -10000            10000            0
beta3age3     0         -10000            10000            0
beta3age4     0         -10000            10000            0
beta4age1     0         -10000            10000            0
beta4age2     0         -10000            10000            0
beta4age3     0         -10000            10000            0
beta4age4     0         -10000            10000            0
beta5age1     0         -10000            10000            0
beta5age2     0         -10000            10000            0
beta5age3     0         -10000            10000            0
beta5age4     0         -10000            10000            0

[Utilities]
// Id     Name     Avail     linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
   1      A1       AV1       age1 * AGE1 + age2 * AGE2 + age3 * AGE3 + age4 * AGE4 + beta1 * FAC1 + beta2 *
SEP1 + beta3 * VOL1 + beta4 * SPE1 + beta5 * PAR1
   2      A2       AV2       beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2

[GeneralizedUtilities]
1 beta1age1 * FAC1 * AGE1 + beta1age2 * FAC1 * AGE2 + beta1age3 * FAC1 * AGE3 + beta1age4 * FAC1 * AGE4
+ beta2age1 * SEP1 * AGE1 + beta2age2 * SEP1 * AGE2 + beta2age3 * SEP1 * AGE3 + beta2age4 * SEP1 * AGE4
+ beta3age1 * VOL1 * AGE1 + beta3age2 * VOL1 * AGE2 + beta3age3 * VOL1 * AGE3 + beta3age4 * VOL1 * AGE4
+ beta4age1 * SPE1 * AGE1 + beta4age2 * SPE1 * AGE2 + beta4age3 * SPE1 * AGE3 + beta4age4 * SPE1 * AGE4
+ beta5age1 * PAR1 * AGE1 + beta5age2 * PAR1 * AGE2 + beta5age3 * PAR1 * AGE3 + beta5age4 * PAR1 * AGE4

2 beta1age1 * FAC2 * AGE1 + beta1age2 * FAC2 * AGE2 + beta1age3 * FAC2 * AGE3 + beta1age4 * FAC2 * AGE4
+ beta2age1 * SEP2 * AGE1 + beta2age2 * SEP2 * AGE2 + beta2age3 * SEP2 * AGE3 + beta2age4 * SEP2 * AGE4
+ beta3age1 * VOL2 * AGE1 + beta3age2 * VOL2 * AGE2 + beta3age3 * VOL2 * AGE3 + beta3age4 * VOL2 * AGE4
+ beta4age1 * SPE2 * AGE1 + beta4age2 * SPE2 * AGE2 + beta4age3 * SPE2 * AGE3 + beta4age4 * SPE2 * AGE4
+ beta5age1 * PAR2 * AGE1 + beta5age2 * PAR2 * AGE2 + beta5age3 * PAR2 * AGE3 + beta5age4 * PAR2 * AGE4

[Model]
$MNL
```

```
[Choice]
CHOICE

[Beta]
// Name        Value   LowerBound   UpperBound   status (0=variable, 1=fixed)
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edu2           0       -10000       10000        0
edu3           0       -10000       10000        0
edu4           0       -10000       10000        0
edu5           0       -10000       10000        0
edu6           0       -10000       10000        0
beta1          0       -10000       10000        0
beta2          0       -10000       10000        0
beta3          0       -10000       10000        0
beta4          0       -10000       10000        0
beta5          0       -10000       10000        0
beta1edu1      0       -10000       10000        0
beta1edu2      0       -10000       10000        0
beta1edu3      0       -10000       10000        0
beta1edu4      0       -10000       10000        0
beta1edu5      0       -10000       10000        0
beta1edu6      0       -10000       10000        0
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beta2edu4      0       -10000       10000        0
beta2edu5      0       -10000       10000        0
beta2edu6      0       -10000       10000        0
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beta3edu2      0       -10000       10000        0
beta3edu3      0       -10000       10000        0
beta3edu4      0       -10000       10000        0
beta3edu5      0       -10000       10000        0
beta3edu6      0       -10000       10000        0
beta4edu1      0       -10000       10000        0
beta4edu2      0       -10000       10000        0
beta4edu3      0       -10000       10000        0
beta4edu4      0       -10000       10000        0
beta4edu5      0       -10000       10000        0
beta4edu6      0       -10000       10000        0
beta5edu1      0       -10000       10000        0
beta5edu2      0       -10000       10000        0
beta5edu3      0       -10000       10000        0
beta5edu4      0       -10000       10000        0
beta5edu5      0       -10000       10000        0
beta5edu6      0       -10000       10000        0

[Utilities]
// Id   Name   Avail   linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
   1    A1     AV1     edu1 * EDU1 + edu2 * EDU2 + edu3 * EDU3 + edu4 * EDU4 + edu5 * EDU5 + edu6 *
EDU6 + beta1 * FAC1 + beta2 * SEP1 + beta3 * VOL1 + beta4 * SPE1 + beta5 * PAR1
   2    A2     AV2     beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2
```

[GeneralizedUtilities]
1 beta1edu1 * FAC1 * EDU1 + beta1edu2 * FAC1 * EDU2 + beta1edu3 * FAC1 * EDU3 + beta1edu4 * FAC1 * EDU4 + beta1edu5 * FAC1 * EDU5 + beta1edu6 * FAC1 * EDU6
+ beta2edu1 * SEP1 * EDU1 + beta2edu2 * SEP1 * EDU2 + beta2edu3 * SEP1 * EDU3 + beta2edu4 * SEP1 * EDU4 + beta2edu5 * SEP1 * EDU5 + beta2edu6 * SEP1 * EDU6
+ beta3edu1 * VOL1 * EDU1 + beta3edu2 * VOL1 * EDU2 + beta3edu3 * VOL1 * EDU3 + beta3edu4 * VOL1 * EDU4 + beta3edu5 * VOL1 * EDU5 + beta3edu6 * VOL1 * EDU6
+ beta4edu1 * SPE1 * EDU1 + beta4edu2 * SPE1 * EDU2 + beta4edu3 * SPE1 * EDU3 + beta4edu4 * SPE1 * EDU4 + beta4edu5 * SPE1 * EDU5 + beta4edu6 * SPE1 * EDU6
+ beta5edu1 * PAR1 * EDU1 + beta5edu2 * PAR1 * EDU2 + beta5edu3 * PAR1 * EDU3 + beta5edu4 * PAR1 * EDU4 + beta5edu5 * PAR1 * EDU5 + beta5edu6 * PAR1 * EDU6

2 beta1edu1 * FAC2 * EDU1 + beta1edu2 * FAC2 * EDU2 + beta1edu3 * FAC2 * EDU3 + beta1edu4 * FAC2 * EDU4 + beta1edu5 * FAC2 * EDU5 + beta1edu6 * FAC2 * EDU6
+ beta2edu1 * SEP2 * EDU1 + beta2edu2 * SEP2 * EDU2 + beta2edu3 * SEP2 * EDU3 + beta2edu4 * SEP2 * EDU4 + beta2edu5 * SEP2 * EDU5 + beta2edu6 * SEP2 * EDU6
+ beta3edu1 * VOL2 * EDU1 + beta3edu2 * VOL2 * EDU2 + beta3edu3 * VOL2 * EDU3 + beta3edu4 * VOL2 * EDU4 + beta3edu5 * VOL2 * EDU5 + beta3edu6 * VOL2 * EDU6
+ beta4edu1 * SPE2 * EDU1 + beta4edu2 * SPE2 * EDU2 + beta4edu3 * SPE2 * EDU3 + beta4edu4 * SPE2 * EDU4 + beta4edu5 * SPE2 * EDU5 + beta4edu6 * SPE2 * EDU6
+ beta5edu1 * PAR2 * EDU1 + beta5edu2 * PAR2 * EDU2 + beta5edu3 * PAR2 * EDU3 + beta5edu4 * PAR2 * EDU4 + beta5edu5 * PAR2 * EDU5 + beta5edu6 * PAR2 * EDU6

[Model]
$MNL

```
[Choice]
CHOICE

[Beta]
// Name        Value   LowerBound   UpperBound   status (0=variable, 1=fixed)
freq1          0       -10000       10000        0
freq2          0       -10000       10000        0
freq3          0       -10000       10000        0
freq4          0       -10000       10000        0
beta1          0       -10000       10000        0
beta2          0       -10000       10000        0
beta3          0       -10000       10000        0
beta4          0       -10000       10000        0
beta5          0       -10000       10000        0
beta1freq1     0       -10000       10000        0
beta1freq2     0       -10000       10000        0
beta1freq3     0       -10000       10000        0
beta1freq4     0       -10000       10000        0
beta2freq1     0       -10000       10000        0
beta2freq2     0       -10000       10000        0
beta2freq3     0       -10000       10000        0
beta2freq4     0       -10000       10000        0
beta3freq1     0       -10000       10000        0
beta3freq2     0       -10000       10000        0
beta3freq3     0       -10000       10000        0
beta3freq4     0       -10000       10000        0
beta4freq1     0       -10000       10000        0
beta4freq2     0       -10000       10000        0
beta4freq3     0       -10000       10000        0
beta4freq4     0       -10000       10000        0
beta5freq1     0       -10000       10000        0
beta5freq2     0       -10000       10000        0
beta5freq3     0       -10000       10000        0
beta5freq4     0       -10000       10000        0

[Utilities]
// Id   Name   Avail   linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
   1    A1     AV1     freq1 * FREQ1 + freq2 * FREQ2 + freq3 * FREQ3 + freq4 * FREQ4 + beta1 * FAC1 +
beta2 * SEP1 + beta3 * VOL1 + beta4 * SPE1 + beta5 * PAR1
   2    A2     AV2     beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2

[GeneralizedUtilities]
1 beta1freq1 * FAC1 * FREQ1 + beta1freq2 * FAC1 * FREQ2 + beta1freq3 * FAC1 * FREQ3 + beta1freq4 * FAC1
* FREQ4
+ beta2freq1 * SEP1 * FREQ1 + beta2freq2 * SEP1 * FREQ2 + beta2freq3 * SEP1 * FREQ3 + beta2freq4 * SEP1 *
FREQ4
+ beta3freq1 * VOL1 * FREQ1 + beta3freq2 * VOL1 * FREQ2 + beta3freq3 * VOL1 * FREQ3 + beta3freq4 * VOL1
* FREQ4
+ beta4freq1 * SPE1 * FREQ1 + beta4freq2 * SPE1 * FREQ2 + beta4freq3 * SPE1 * FREQ3 + beta4freq4 * SPE1 *
FREQ4
+ beta5freq1 * PAR1 * FREQ1 + beta5freq2 * PAR1 * FREQ2 + beta5freq3 * PAR1 * FREQ3 + beta5freq4 * PAR1
* FREQ4
```

2 beta1freq1 * FAC2 * FREQ1 + beta1freq2 * FAC2 * FREQ2 + beta1freq3 * FAC2 * FREQ3 + beta1freq4 * FAC2 * FREQ4
+ beta2freq1 * SEP2 * FREQ1 + beta2freq2 * SEP2 * FREQ2 + beta2freq3 * SEP2 * FREQ3 + beta2freq4 * SEP2 * FREQ4
+ beta3freq1 * VOL2 * FREQ1 + beta3freq2 * VOL2 * FREQ2 + beta3freq3 * VOL2 * FREQ3 + beta3freq4 * VOL2 * FREQ4
+ beta4freq1 * SPE2 * FREQ1 + beta4freq2 * SPE2 * FREQ2 + beta4freq3 * SPE2 * FREQ3 + beta4freq4 * SPE2 * FREQ4
+ beta5freq1 * PAR2 * FREQ1 + beta5freq2 * PAR2 * FREQ2 + beta5freq3 * PAR2 * FREQ3 + beta5freq4 * PAR2 * FREQ4

[Model]
$MNL

Syntax for analysing the bicycle type subgroups

```
[Choice]
CHOICE

[Beta]
// Name Value    LowerBound    UpperBound    status (0=variable, 1=fixed)
typ1        0    -10000    10000    0
typ2        0    -10000    10000    0
typ3        0    -10000    10000    0
typ4        0    -10000    10000    0
typ5        0    -10000    10000    0
typ6        0    -10000    10000    0
typ7        0    -10000    10000    0
beta1       0    -10000    10000    0
beta2       0    -10000    10000    0
beta3       0    -10000    10000    0
beta4       0    -10000    10000    0
beta5       0    -10000    10000    0
beta1typ1   0    -10000    10000    0
beta1typ2   0    -10000    10000    0
beta1typ3   0    -10000    10000    0
beta1typ4   0    -10000    10000    0
beta1typ5   0    -10000    10000    0
beta1typ6   0    -10000    10000    0
beta1typ7   0    -10000    10000    0
beta2typ1   0    -10000    10000    0
beta2typ2   0    -10000    10000    0
beta2typ3   0    -10000    10000    0
beta2typ4   0    -10000    10000    0
beta2typ5   0    -10000    10000    0
beta2typ6   0    -10000    10000    0
beta2typ7   0    -10000    10000    0
beta3typ1   0    -10000    10000    0
beta3typ2   0    -10000    10000    0
beta3typ3   0    -10000    10000    0
beta3typ4   0    -10000    10000    0
beta3typ5   0    -10000    10000    0
beta3typ6   0    -10000    10000    0
beta3typ7   0    -10000    10000    0
beta4typ1   0    -10000    10000    0
beta4typ2   0    -10000    10000    0
beta4typ3   0    -10000    10000    0
beta4typ4   0    -10000    10000    0
beta4typ5   0    -10000    10000    0
beta4typ6   0    -10000    10000    0
beta4typ7   0    -10000    10000    0
beta5typ1   0    -10000    10000    0
beta5typ2   0    -10000    10000    0
beta5typ3   0    -10000    10000    0
beta5typ4   0    -10000    10000    0
beta5typ5   0    -10000    10000    0
beta5typ6   0    -10000    10000    0
beta5typ7   0    -10000    10000    0
```

```
[Utilities]
// Id      Name    Avail     linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
   1       A1      AV1       typ1 * TYP1 + typ2 * TYP2 + typ3 * TYP3 + typ4 * TYP4 + typ5 * TYP5 + typ6 * TYP6 +
typ7 * TYP7 + beta1 * FAC1 + beta2 * SEP1 + beta3 * VOL1 + beta4 * SPE1 + beta5 * PAR1
   2       A2      AV2       beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2

[GeneralizedUtilities]
1 beta1typ1 * FAC1 * TYP1 + beta1typ2 * FAC1 * TYP2 + beta1typ3 * FAC1 * TYP3 + beta1typ4 * FAC1 * TYP4 +
beta1typ5 * FAC1 * TYP5 + beta1typ6 * FAC1 * TYP6 + beta1typ7 * FAC1 * TYP7
+ beta2typ1 * SEP1 * TYP1 + beta2typ2 * SEP1 * TYP2 + beta2typ3 * SEP1 * TYP3 + beta2typ4 * SEP1 * TYP4 +
beta2typ5 * SEP1 * TYP5 + beta2typ6 * SEP1 * TYP6 + beta2typ7 * SEP1 * TYP7
+ beta3typ1 * VOL1 * TYP1 + beta3typ2 * VOL1 * TYP2 + beta3typ3 * VOL1 * TYP3 + beta3typ4 * VOL1 * TYP4 +
beta3typ5 * VOL1 * TYP5 + beta3typ6 * VOL1 * TYP6 + beta3typ7 * VOL1 * TYP7
+ beta4typ1 * SPE1 * TYP1 + beta4typ2 * SPE1 * TYP2 + beta4typ3 * SPE1 * TYP3 + beta4typ4 * SPE1 * TYP4 +
beta4typ5 * SPE1 * TYP5 + beta4typ6 * SPE1 * TYP6 + beta4typ7 * SPE1 * TYP7
+ beta5typ1 * PAR1 * TYP1 + beta5typ2 * PAR1 * TYP2 + beta5typ3 * PAR1 * TYP3 + beta5typ4 * PAR1 * TYP4 +
beta5typ5 * PAR1 * TYP5 + beta5typ6 * PAR1 * TYP6 + beta5typ7 * PAR1 * TYP7

2 beta1typ1 * FAC2 * TYP1 + beta1typ2 * FAC2 * TYP2 + beta1typ3 * FAC2 * TYP3 + beta1typ4 * FAC2 * TYP4 +
beta1typ5 * FAC2 * TYP5 + beta1typ6 * FAC2 * TYP6 + beta1typ7 * FAC2 * TYP7
+ beta2typ1 * SEP2 * TYP1 + beta2typ2 * SEP2 * TYP2 + beta2typ3 * SEP2 * TYP3 + beta2typ4 * SEP2 * TYP4 +
beta2typ5 * SEP2 * TYP5 + beta2typ6 * SEP2 * TYP6 + beta2typ7 * SEP2 * TYP7
+ beta3typ1 * VOL2 * TYP1 + beta3typ2 * VOL2 * TYP2 + beta3typ3 * VOL2 * TYP3 + beta3typ4 * VOL2 * TYP4 +
beta3typ5 * VOL2 * TYP5 + beta3typ6 * VOL2 * TYP6 + beta3typ7 * VOL2 * TYP7
+ beta4typ1 * SPE2 * TYP1 + beta4typ2 * SPE2 * TYP2 + beta4typ3 * SPE2 * TYP3 + beta4typ4 * SPE2 * TYP4 +
beta4typ5 * SPE2 * TYP5 + beta4typ6 * SPE2 * TYP6 + beta4typ7 * SPE2 * TYP7
+ beta5typ1 * PAR2 * TYP1 + beta5typ2 * PAR2 * TYP2 + beta5typ3 * PAR2 * TYP3 + beta5typ4 * PAR2 * TYP4 +
beta5typ5 * PAR2 * TYP5 + beta5typ6 * PAR2 * TYP6 + beta5typ7 * PAR2 * TYP7

[Model]
$MNL
```

Syntax for analysing the purpose subgroups

```
[Choice]
CHOICE

[Beta]
// Name        Value   LowerBound   UpperBound   status (0=variable, 1=fixed)
pur1           0       -10000       10000        0
pur2           0       -10000       10000        0
pur3           0       -10000       10000        0
beta1          0       -10000       10000        0
beta2          0       -10000       10000        0
beta3          0       -10000       10000        0
beta4          0       -10000       10000        0
beta5          0       -10000       10000        0
beta1pur1      0       -10000       10000        0
beta1pur2      0       -10000       10000        0
beta1pur3      0       -10000       10000        0
beta2pur1      0       -10000       10000        0
beta2pur2      0       -10000       10000        0
beta2pur3      0       -10000       10000        0
beta3pur1      0       -10000       10000        0
beta3pur2      0       -10000       10000        0
beta3pur3      0       -10000       10000        0
beta4pur1      0       -10000       10000        0
beta4pur2      0       -10000       10000        0
beta4pur3      0       -10000       10000        0
beta5pur1      0       -10000       10000        0
beta5pur2      0       -10000       10000        0
beta5pur3      0       -10000       10000        0

[Utilities]
// Id   Name   Avail   linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)
  1     A1     AV1     pur1 * PUR1 + pur2 * PUR2 + pur3 * PUR3 + beta1 * FAC1 + beta2 * SEP1 + beta3 *
VOL1 + beta4 * SPE1 + beta5 * PAR1
  2     A2     AV2     beta1 * FAC2 + beta2 * SEP2 + beta3 * VOL2 + beta4 * SPE2 + beta5 * PAR2

[GeneralizedUtilities]
1 beta1pur1 * FAC1 * PUR1 + beta1pur2 * FAC1 * PUR2 + beta1pur3 * FAC1 * PUR3
+ beta2pur1 * SEP1 * PUR1 + beta2pur2 * SEP1 * PUR2 + beta2pur3 * SEP1 * PUR3
+ beta3pur1 * VOL1 * PUR1 + beta3pur2 * VOL1 * PUR2 + beta3pur3 * VOL1 * PUR3
+ beta4pur1 * SPE1 * PUR1 + beta4pur2 * SPE1 * PUR2 + beta4pur3 * SPE1 * PUR3
+ beta5pur1 * PAR1 * PUR1 + beta5pur2 * PAR1 * PUR2 + beta5pur3 * PAR1 * PUR3

2 beta1pur1 * FAC2 * PUR1 + beta1pur2 * FAC2 * PUR2 + beta1pur3 * FAC2 * PUR3
+ beta2pur1 * SEP2 * PUR1 + beta2pur2 * SEP2 * PUR2 + beta2pur3 * SEP2 * PUR3
+ beta3pur1 * VOL2 * PUR1 + beta3pur2 * VOL2 * PUR2 + beta3pur3 * VOL2 * PUR3
+ beta4pur1 * SPE2 * PUR1 + beta4pur2 * SPE2 * PUR2 + beta4pur3 * SPE2 * PUR3
+ beta5pur1 * PAR2 * PUR1 + beta5pur2 * PAR2 * PUR2 + beta5pur3 * PAR2 * PUR3

[Model]
$MNL
```

B6: The results of the final survey

Table 46: Statistical parameters of the MNL model (final survey)

Number of estimated parameters:	5
Number of observations:	13168
Number of individuals:	13168
Null log likelihood:	-9127.362
Cte log likelihood:	-9125.813
Init log likelihood:	-9127.362
Final log likelihood:	-8019.721
Likelihood ratio test:	2215.281
Rho-square:	0.121
Adjusted rho-square:	0.121
Final gradient norm:	+3.194e-002
Diagnostic:	Convergence reached...
Iterations:	3
Run time:	00:01
Variance-covariance:	from analytical hessian
Sample file:	data.txt

Table 47: Estimated utility parameters and statistical features (final survey)

Name	Value	Standard error	T-test	P-value	Robust std. error	Robust t-test	P-value
β_{FAC}	0.766	0.0216	35.41	0.00	0.0214	35.72	0.00
β_{SEP}	0.697	0.0166	41.88	0.00	0.0163	42.77	0.00
β_{VOL}	-0.0812	0.00954	-8.52	0.00	0.00954	-8.51	0.00
β_{SPE}	0.144	0.0107	13.41	0.00	0.0105	13.68	0.00
β_{PAR}	-0.117	0.0104	-11.19	0.00	0.0106	-11.02	0.00

Table 48: Estimated effects in the full sample and in different descriptive subgroups (FAC)

	Dedicated facility (FAC)			
	Value	St error	t-test	p-value
Gender				
Main parameter	**0.768**	**0.0217**	**35.42**	**0.00**
Female	0.0416	0.0217	1.92	0.05
Male	-0.0416	-	-	-
Age				
Main parameter	**0.704**	**0.0601**	**11.71**	**0.00**
<20*	0.1650	0.119	1.39	0.16
20-39	**0.2270**	**0.0669**	**3.39**	**0.00**
40-64	0.0490	0.0650	0.75	0.45
65-79	-0.1270	0.0740	-1.72	0.09
>80*	-0.3140	-	-	-
Highest completed education				
Main parameter	**0.685**	**0.0700**	**9.78**	**0.00**
Primary*	-0.2820	0.158	-1.79	0.07
VMBO/MAVO	**0.1640**	**0.0818**	**2.01**	**0.04**
HAVO-VWO-MBO	0.0578	0.0748	0.77	0.44
HBO (Bachelor)	0.0576	0.0796	0.72	0.47
WO (Master)	**0.2750**	**0.101**	**2.73**	**0.01**
PhD*	-0.0988	0.274	-0.36	0.72
Other*	-0.1736	-	-	-
Frequency of biking				
Main parameter	**0.796**	**0.0271**	**29.39**	**0.00**
Daily	**-0.1070**	**0.0382**	**-2.81**	**0.01**
Few times a week	0.0234	0.0403	0.58	0.56
Weekly	0.0147	0.0575	0.26	0.80
Few times a month	0.0396	0.0715	0.55	0.58
Monthly or less	0.0293	-	-	-
Type of most frequently used bike				
Main parameter	**0.524**	**0.0973**	**5.38**	**0.00**
City bike	**0.2480**	**0.0998**	**2.49**	**0.01**
Electric	**0.2790**	**0.108**	**2.58**	**0.01**
Cargo bike*	0.1600	0.178	0.90	0.37
Racebike*	0.0980	0.190	0.51	0.61
Mountainbike*	0.2030	0.146	1.39	0.17
Folding bike*	-0.0988	0.269	-0.37	0.71
Shared bike*	**-1.1800**	**0.575**	**-2.06**	**0.04**
Other	0.2908	-	-	-
Most frequent purpose of biking				
Main parameter	**0.805**	**0.0553**	**14.57**	**0.00**
To work or school	-0.0029	0.0611	-0.05	0.96
To a free time activity	-0.0188	0.0609	-0.31	0.76
Recreational	-0.0957	0.0624	-1.53	0.12
Sport*	0.1174	-	-	-

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Table 49: Estimated effects in the full sample and in different descriptive subgroups (SEP)

	Physical separation (SEP)			
	Value	St error	t-test	p-value
Gender				
Main parameter	**0.698**	**0.0167**	**41.89**	**0.00**
Female	-0.0258	0.0167	-1.55	0.12
Male	0.0258	-	-	-
Age				
Main parameter	**0.746**	**0.0483**	**15.44**	**0.00**
<20*	-0.1020	0.0913	-1.12	0.26
20-39	**-0.1980**	**0.0528**	**-3.75**	**0.00**
40-64	0.0312	0.0521	0.60	0.55
65-79	0.0904	0.0593	1.52	0.13
>80*	0.1784	-	-	-
Highest completed education				
Main parameter	**0.776**	**0.0563**	**13.77**	**0.00**
Primary*	-0.0553	0.124	-0.45	0.66
VMBO/MAVO	-0.0697	0.0650	-1.07	0.28
HAVO-VWO-MBO	-0.0834	0.0599	-1.39	0.16
HBO (Bachelor)	-0.0851	0.0635	-1.34	0.18
WO (Master)	-0.0638	0.0787	-0.81	0.42
PhD*	0.4130	0.228	1.82	0.07
Other*	-0.0557	-	-	-
Frequency of biking				
Main parameter	**0.746**	**0.0213**	**35.06**	**0.00**
Daily	**-0.1300**	**0.0295**	**-4.42**	**0.00**
Few times a week	-0.0182	0.0313	-0.58	0.56
Weekly	**-0.1040**	**0.0437**	**-2.37**	**0.02**
Few times a month	**0.1880**	**0.0577**	**3.26**	**0.00**
Monthly or less	0.0642	-	-	-
Type of most frequently used bike				
Main parameter	**0.61**	**0.0614**	**9.94**	**0.00**
City bike	0.0981	0.0637	1.54	0.12
Electric	0.1000	0.0712	1.41	0.16
Cargo bike*	-0.1000	0.126	-0.80	0.43
Racebike*	-0.0805	0.137	-0.59	0.56
Mountainbike*	-0.1140	0.101	-1.13	0.26
Folding bike*	**-0.4270**	**0.189**	**-2.25**	**0.02**
Shared bike*	0.3270	0.337	0.97	0.33
Other	0.1964	-	-	-
Most frequent purpose of biking				
Main parameter	**0.679**	**0.0403**	**16.85**	**0.00**
To work or school	-0.0587	0.0448	-1.31	0.19
To a free time activity	0.0366	0.0449	0.81	0.42
Recreational	**0.1030**	**0.0462**	**2.22**	**0.03**
Sport*	-0.0809	-	-	-

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Table 50: Estimated effects in the full sample and in different descriptive subgroups (VOL)

	High traffic volume (VOL)			
	Value	St error	t-test	p-value
Gender				
Main parameter	**-0.0811**	**0.00955**	**-8.49**	**0.00**
Female	-0.0145	0.00958	-1.51	0.13
Male	0.0145	-	-	-
Age				
Main parameter	**-0.1**	**0.0272**	**-3.68**	**0.00**
<20*	-0.0149	0.0531	-0.28	0.78
20-39	0.0304	0.0301	1.01	0.31
40-64	0.0115	0.0293	0.39	0.70
65-79	-0.0071	0.0334	-0.21	0.83
>80*	-0.0199	-	-	-
Highest completed education				
Main parameter	**-0.12**	**0.0314**	**-3.84**	**0.00**
Primary*	0.0523	0.0713	0.73	0.46
VMBO/MAVO	0.0118	0.0365	0.32	0.75
HAVO-VWO-MBO	0.0504	0.0335	1.51	0.13
HBO (Bachelor)	0.0294	0.0356	0.82	0.41
WO (Master)	0.0615	0.0446	1.38	0.17
PhD*	-0.1190	0.122	-0.98	0.33
Other*	-0.0864	-	-	-
Frequency of biking				
Main parameter	**-0.0804**	**0.0118**	**-6.80**	**0.00**
Daily	0.0010	0.0168	0.06	0.95
Few times a week	-0.0075	0.0177	-0.43	0.67
Weekly	0.0109	0.0253	0.43	0.66
Few times a month	0.0127	0.0312	0.41	0.68
Monthly or less	-0.0170	-	-	-
Type of most frequently used bike				
Main parameter	**-0.0844**	**0.0400**	**-2.11**	**0.03**
City bike	0.0038	0.0411	0.09	0.93
Electric	0.0010	0.0450	0.02	0.98
Cargo bike*	0.0025	0.0773	0.03	0.97
Racebike*	0.0962	0.0829	1.16	0.25
Mountainbike*	-0.0104	0.0626	-0.17	0.87
Folding bike*	0.0148	0.120	0.12	0.90
Shared bike*	-0.0478	0.226	-0.21	0.83
Other	-0.0601	-	-	-
Most frequent purpose of biking				
Main parameter	**-0.0739**	**0.0239**	**-3.10**	**0.00**
To work or school	0.0003	0.0265	0.01	0.99
To a free time activity	-0.0232	0.0264	-0.88	0.38
Recreational	-0.0068	0.0271	-0.25	0.80
Sport*	0.0297	-	-	-

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Table 51: Estimated effects in the full sample and in different descriptive subgroups (SPE)

	Speed reduction (SPE)			
	Value	St terror	t-test	p-value
Gender				
Main parameter	**0.145**	**0.0108**	**13.43**	**0.00**
Female	-0.0001	0.0108	-0.01	1.00
Male	0.0001	-	-	-
Age				
Main parameter	**0.164**	**0.0317**	**5.17**	**0.00**
<20*	-0.0572	0.0601	-0.95	0.34
20-39	-0.0344	0.0349	-0.98	0.32
40-64	0.0107	0.0340	0.32	0.75
65-79	-0.0398	0.0382	-1.04	0.30
>80*	0.1207	-	-	-
Highest completed education				
Main parameter	**0.149**	**0.0345**	**4.32**	**0.00**
Primary*	0.0635	0.0828	0.77	0.44
VMBO/MAVO	-0.0166	0.0403	-0.41	0.68
HAVO-VWO-MBO	-0.0025	0.0369	-0.07	0.95
HBO (Bachelor)	0.0064	0.0394	0.16	0.87
WO (Master)	-0.0236	0.0494	-0.48	0.63
PhD*	-0.0926	0.129	-0.72	0.47
Other*	0.0654	-	-	-
Frequency of biking				
Main parameter	**0.152**	**0.0133**	**11.43**	**0.00**
Daily	-0.0356	0.0189	-1.88	0.06
Few times a week	0.0096	0.0199	0.48	0.63
Weekly	0.0362	0.0287	1.26	0.21
Few times a month	-0.0169	0.0345	-0.49	0.62
Monthly or less	0.0067	-	-	-
Type of most frequently used bike				
Main parameter	**0.106**	**0.0440**	**2.40**	**0.02**
City bike	0.0439	0.0453	0.97	0.33
Electric	0.0441	0.0498	0.89	0.38
Cargo bike*	0.0579	0.0876	0.66	0.51
Racebike*	-0.0594	0.0920	-0.65	0.52
Mountainbike*	0.0024	0.0700	0.03	0.97
Folding bike*	0.0500	0.138	0.36	0.72
Shared bike*	-0.1490	0.246	-0.61	0.55
Other	0.0101	-	-	-
Most frequent purpose of biking				
Main parameter	**0.164**	**0.0273**	**6.01**	**0.00**
To work or school	-0.0308	0.0302	-1.02	0.31
To a free time activity	-0.0176	0.0301	-0.58	0.56
Recreational	-0.0062	0.0308	-0.20	0.84
Sport*	0.0546	-	-	-

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

Table 52: Estimated effects in the full sample and in different descriptive subgroups (PAR)

	Adjacent parking (PAR)			
	Value	St error	t-test	p-value
Gender				
Main parameter	**-0.117**	**0.0105**	**-11.20**	**0.00**
Female	-0.0154	0.0105	-1.48	0.14
Male	0.0154	-	-	-
Age				
Main parameter	**-0.142**	**0.0302**	**-4.70**	**0.00**
<20*	0.0847	0.0578	1.47	0.14
20-39	0.0465	0.0333	1.40	0.16
40-64	0.0106	0.0325	0.33	0.74
65-79	-0.00312	0.0368	-0.08	0.93
>80*	-0.13868	-	-	-
Highest completed education				
Main parameter	**-0.131**	**0.0345**	**-3.81**	**0.00**
Primary*	**0.1670**	**0.0770**	**2.17**	**0.03**
VMBO/MAVO	0.0020	0.0400	0.05	0.96
HAVO-VWO-MBO	0.0123	0.0367	0.34	0.74
HBO (Bachelor)	0.0313	0.0390	0.80	0.42
WO (Master)	-0.0119	0.0491	-0.24	0.81
PhD*	-0.0177	0.132	-0.13	0.89
Other*	-0.1830	-	-	-
Frequency of biking				
Main parameter	**-0.121**	**0.0129**	**-9.36**	**0.00**
Daily	0.0172	0.0184	0.94	0.35
Few times a week	0.0007	0.0193	0.04	0.97
Weekly	0.0065	0.0275	0.23	0.81
Few times a month	0.0131	0.0339	0.39	0.70
Monthly or less	-0.0375	-	-	-
Type of most frequently used bike				
Main parameter	**-0.116**	**0.0481**	**-2.41**	**0.02**
City bike	-0.0011	0.0492	-0.02	0.98
Electric	0.0077	0.0531	0.14	0.89
Cargo bike*	0.0237	0.0868	0.27	0.78
Racebike*	-0.0475	0.0942	-0.50	0.61
Mountainbike*	-0.0346	0.0719	-0.48	0.63
Folding bike*	0.2240	0.130	1.72	0.09
Shared bike*	-0.1570	0.286	-0.55	0.58
Other	-0.0151	-	-	-
Most frequent purpose of biking				
Main parameter	**-0.144**	**0.0266**	**-5.41**	**0.00**
To work or school	0.0391	0.0295	1.33	0.19
To a free time activity	0.0485	0.0293	1.65	0.10
Recreational	-0.0097	0.0301	-0.32	0.75
Sport*	-0.0780	-	-	-

*Only values with red colour have statistical significance ($p < 0.05$). Subgroups that are smaller than 30 respondents are marked with **

C

ADDITIONAL SURVEY FROM HUNGARY

C1: Description of the additional survey

Additionally, a survey is distributed in Hungary. The survey has the same features and questionnaire as the final survey in the Netherlands, only the questions and the descriptions are translated to Hungarian. The same experimental design, Ngene syntax and Biogeme syntax are used, thus these are not shown again (see them in Appendix B). The questionnaire is distributed on the personal Facebook page of the author, and in a Facebook group of people engaged to cycling (both planners and ordinary riders). The direct comparison of the Dutch and the Hungarian survey is not recommended though. Both the sample size and the descriptive characteristics are very different. While the Dutch survey represents more or less the adult population of the country, this additional survey does not. Furthermore, people who are working with cycling (planners, activists, etc.) may be overrepresented. However, there is something to note. While the other attributes are more or less the same, the presence of physical separation turned out to be less important. This might be the result of the planning practice of Budapest preferring building on-road cycling lanes.

C2: Hungarian questionnaire

The questionnaire is written in Hungarian, however the English translation is also included here (in grey). The respondents access the questionnaire through an online surface of Google Forms. Due to the lack of space, reasonable shortening is applied where it is necessary.

Kérdőív: kerékpárosok szubjektív közlekedésbiztonsága	Survey: Subjective traffic safety of cyclists
Kedves válaszadó!	Dear Respondent,
Az alábbi kérdőív a diplomamunkám kiegészítéseként, egy hollandiai felmérés magyar változataként készül el. Bízom benne, hogy az eredmények tanulságosak lesznek, és segítenek összevetni a holland és a magyar kerékpározási viszonyokat.	This is a survey conducted by Samu Márton Balogh, master student at KTH Royal Institute of Technology, Stockholm and Goudappel Groep BV, a Dutch mobility consultancy.
A kérdőív a kerékpárosok szubjektív közlekedésbiztonságát, másképpen fogalmazva közlekedési biztonságérzetét kívánja felmérni. Amíg az objektív közlekedésbiztonság baleseti statisztikákon alapszik, addig a szubjektív biztonság az emberek biztonságérzetétől függ. A felmérés a közlekedési biztonságra fókuszál, így a biztonságérzet más aspektusai (közbiztonság) nem tárgyai ennek a kérdőívnek.	The survey explores subjective traffic safety of cyclists in the Netherlands. The term subjective safety (or perceived safety) describes the perception of the cyclists, how safe they perceive their journey. This survey focuses on traffic safety, thus neither social safety, nor security against crimes should be considered.
A kérdőív három részből áll: • 1. rész: Útvonalválasztás • 2. rész: Kiegészítő kérdések az útvonalválasztás sal kapcsolatban • 3. rész: Személyes és háttérkérdések	The survey is consists of three parts. • Part 1: Cycling routes • Part 2: Additional questions regarding Part 1 • Part 3: Personal and background questions
Minden válaszadónak köszönöm a részvételét, Balogh Samu Márton KTH Stockholm	Thank you for your participation, Samu Márton Balogh KTH Stockholm/Goudappel Groep BV

1. rész - Útvonalválasztás

Az első részben kerékpáros útvonalak között kell választania a vélt biztonságérzete alapján.

Képzelje, hogy munkába, iskolába vagy egyéb célállomása felé tart napi kerékpáros útján. Mind az ön otthona, mind a célállomása városi környezetben található. Egyedül kerékpározik. Az útvonal-alternatívák a képeken láthatókon kívül semmiben sem különböznek (megegyező távolság és utazási idő).

Az útvonal-alternatívák párokba lesznek rendezve, önnek mindig egyet kell kiválasztania. Azt válassza, amelyik biztonságosabbnak tűnik.

Melyik útvonalat véli biztonságosabbnak? Válaszszon az 'A' és a 'B' jelű útvonalak közül!

Fontos: döntését ne arra alapozza, hogy melyik utat választaná, hanem hogy melyiket véli biztonságosabbnak! Csak a közlekedésbiztonsággal számoljon.

Part 1 – Cycling routes

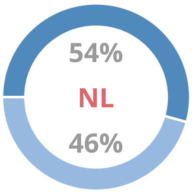
In this part you will see hypothetical alternatives of cycling routes.

Imagine you are on your daily commute trip to your destination (work, school, supermarket or the place of any other activity). Your home and your destination are both in urban environment, like in an average Dutch city. You cycle alone. The routes do not differ in any other sense (travel time, distance, etc.) than you see in the figures.

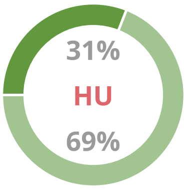
The alternatives will be shown in pairs, you will be asked to choose between them. Your choice should be based on which alternative you would perceive safer.

Which route would you perceive safer? Choose between Route A and Route B!

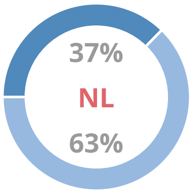
Important: your decision should not be based on which route you would prefer to take! You should base your answer on which route you would perceive safer! Only traffic safety matters.



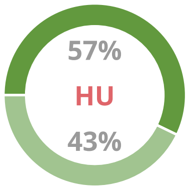
1/A



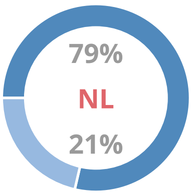
1/B



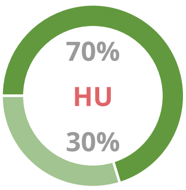
2/A



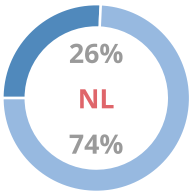
2/B



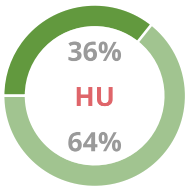
3/A



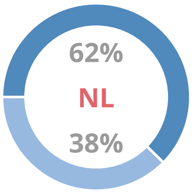
3/B



4/A

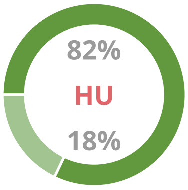


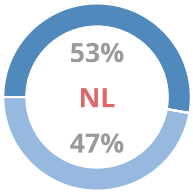
4/B



5/A

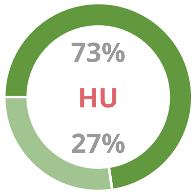
5/B

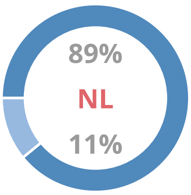




6/A

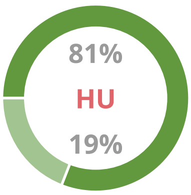
6/B

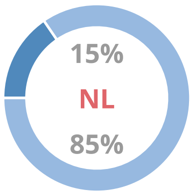




7/A

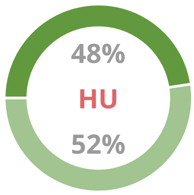
7/B



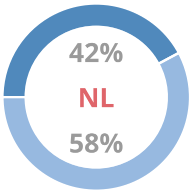


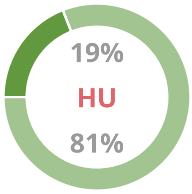
8/A

8/B



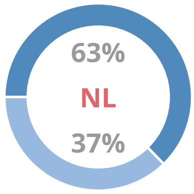
9/A

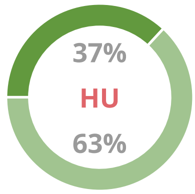




9/B

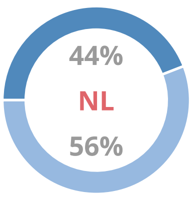
10/A

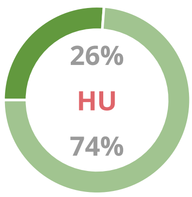




10/B

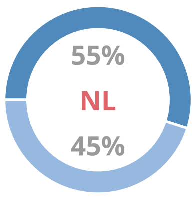
11/A

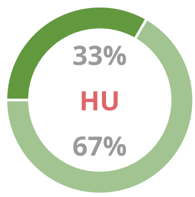




11/B

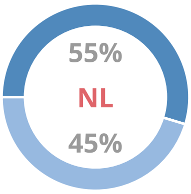
12/A

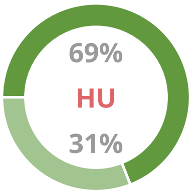




12/B

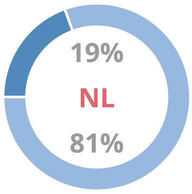
13/A

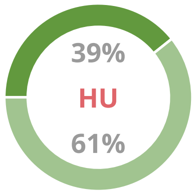




13/B

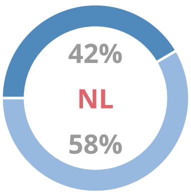
14/A

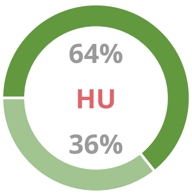




14/B

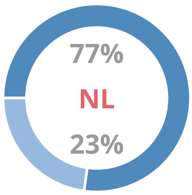
15/A

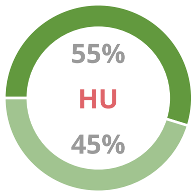




15/B

16/A





16/B

C3: The results of the additional survey from Hungary

Table 53: Descriptive characteristics of the additional survey from Hungary

	Descriptive characteristics
	Gender
Male	59.5% (50)
Female	40.5% (34)
	Age
<20	2.4% (2)
20 – 39	63.1% (53)
40 – 64	34.5% (29)
65 – 79	0.0% (0)
>80	0.0% (0)
	Highest completed education
Primary	3.6% (3)
Secondary	9.5% (8)
University of applied sciences	27.4% (23)
University	56.0% (47)
Other	3.6% (3)
	Frequency of riding bike
Daily	34.5% (29)
Few times a week	32..% (27)
Weekly	13.1% (11)
Few times a month	13.1% (11)
Monthly or less frequent	7.1% (6)
	Most frequently used type of bicycle
City bike	61.9% (52)
Electric bike	1.2% (1)
Cargo bike	0.0% (0)
Race bike	13.1% (11)
Mountain bike	13.1% (11)
Folding bike	1.2% (1)
Shared bike	2.4% (2)
Other	7.1% (6)
	Most frequent purpose of cycling
Commuting to work or school	50.0% (42)
Commuting to other activities	21.4% (18)
Recreational	22.6% (19)
Sport	6.0% (5)

Table 54: Results of the two additional questions (additional survey from Hungary)

	Very unimportant	Unimportant	Neutral	Important	Very important
Dedicated facility	2.4%	7.1%	15.5%	28.6%	46.4%
Physical separation	10.7%	9.5%	16.7%	27.4%	35.7%
High traffic volume	3.6%	6.0%	22.6%	31.0%	36.9%
Speed reduction	7.1%	3.6%	25.0%	40.5%	23.8%
Adjacent parking	3.6%	11.9%	23.8%	42.9%	17.9%
Attractiveness	6.0%	11.9%	26.2%	46.4%	9.5%
Cohesion	3.6%	10.7%	10.7%	36.9%	38.1%
Comfort	0.0%	6.0%	15.5%	48.8%	29.8%
Directness	0.0%	0.0%	7.1%	35.7%	57.1%
Traffic safety	0.0%	0.0%	4.8%	35.7%	59.5%
Social safety	3.6%	3.6%	26.2%	31.0%	35.7%

Table 55: Statistical parameters of the MNL model (additional survey from Hungary)

Number of estimated parameters:	5
Number of observations:	1344
Number of individuals:	1344
Null log likelihood:	-931.590
Cte log likelihood:	-931.160
Init log likelihood:	-931.590
Final log likelihood:	-833.655
Likelihood ratio test:	195.869
Rho-square:	0.105
Adjusted rho-square:	0.100
Final gradient norm:	+6.257e-004
Diagnostic:	Convergence reached...
Iterations:	3
Run time:	00:00
Variance-covariance:	from analytical hessian
Sample file:	data (1).txt

Table 56: Estimated utility parameters and statistical features (additional survey from Hungary)

Name	Value	Standard error	T-test	P-value	Robust std. error	Robust t-test	P-value
β_{FAC}	0.795	0.0673	11.82	0.00	0.0675	11.79	0.00
β_{SEP}	0.265	0.0454	5.84	0.00	0.0448	5.92	0.00
β_{VOL}	-0.101	0.0295	-3.44	0.00	0.0295	-3.43	0.00
β_{SPE}	0.128	0.0337	3.81	0.00	0.0333	3.85	0.00
β_{PAR}	-0.159	0.0328	-4.85	0.00	0.0327	-4.86	0.00

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