Investigating the different preferences of bicycle lane designs under different road characteristics

A case study of Tirana, Albania

Master thesis

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INVESTIGATING THE DIFFERENT PREFERENCES OF BICYCLE LANE DESIGNS UNDER DIFFERENT ROAD CHARACTERISTICS

A CASE STUDY OF TIRANA, ALBANIA

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PREFACE

This report sums up the research done for my final project, which in turn sums up my two years as a master's student in Transport, Infrastructure, and Logistics program at Delft University of Technology. The project focused mainly on investigating the preferences on link-level bicycle infrastructure design. The combination of the topic and the method of study in particular is what interest me the most. I often thought that (which might be untrue for most cases, of course) designers were selfish in a way; the designs they make often are only manifestations of what *they* thought of ideal, instead of stemming from the users' opinions of ideal. The method used in this project allows for objective elicitation of users' preferences on cycling infrastructure design, which can be useful for urban designers and practitioners to develop designs for the people, from the people.

First and foremost, I would like to thank my thesis committee: Caspar Chorus, Jan Anne Annema, and Winnie Daamen. I would like to thank Prof. Chorus who gave the opportunity to conduct the project in a very interesting city, Tirana. I cannot speak highly enough on how the city amazed me more on each day I spent there when conducting my survey. I would also like to thank my daily supervisor Dr. Annema for the guidance and feedbacks throughout the entire project, but mostly for your positivity which to be honest is one of the main things that kept me going on with the project. Last but obviously not least, I would like to thank Dr. Daamen as my second supervisor, for your constructive criticism which broaden my understandings on the topic (and also made me panicked several times when realizing how little I knew).

The research would not have been possible to be done without the supports of the friends in Tirana who helped me distribute the survey and gave valuable insights on the city's cycling culture. Related to that, I would like to also thank Dorina Pllumbi for connecting me with these amazing people.

I am also very grateful for the supports from my friends here in the university. Thank you guys for also being busy working on our own thesis in those bright summer days. Thank you for letting me run the models on your computer since my eight-year-old laptop cannot be burdened with those things anymore. Thank you all also for the lunches and laughs!

Most of all, I cannot express my gratitude more for having the most supportive and understanding parents and also to my brother.

SUMMARY

Cycling has been recognized as a transport mode which have enormous potential benefits to the urban environment and the society, such as reducing congestions, air pollution, and emission, requiring significantly less fuel energy than motorized transport, improving road safety, as well as bringing various health benefits as it encourages a more active lifestyle (Boulange et al., 2017; Fraser & Lock, 2011; Lovelace, Beck, Watson, & Wild, 2011; Meschik, 2012). Infrastructure intervention is a common measure implemented by various municipalities to promote bicycle usage in their area. Parallel with the emerging practices of providing cycling infrastructure in cities, many bicycle infrastructure design guidebooks have been written to provide practical information for decision makers or municipalities on how the facilities should be designed on different road types. This implies a supposition that different link-level design features might be needed on different roads. Nevertheless, literature concerning how the effects of bike lane designs on the road's attractivity to cycle might vary upon different contexts of urban environments is still scarce. The scarcity of cycling infrastructure-related studies, let alone those more specific urban environment-dependent preference researches, is even more prominent in the context of Southeastern European countries who are currently striving toward a more developed cycling-supportive environment in their cities.

The main research question below is formulated for the research being able to fill the knowledge gaps related to link-level design of bicycle infrastructure:

To what extent do the preferences of travelers on link-level design features of cycling infrastructure differ across roads with different characteristics?

A discrete choice experiment to elicit the preferences of travelers on the link-level design features of cycling infrastructure by the means of a context-dependent stated preference survey in an area of case study is used as the main method to answer the research question. Due to concerns of time constraint and language barrier, the respondents are scoped to university students instead of having more heterogenous sample of the population.

Prior to constructing the experiment, relevant link-level design features to be studied and urban environment variables to characterize road types are firstly identified by reviewing the current body of scientific literature, existing grey literature i.e. design guidebooks on cycling infrastructure design, interviewing urban design experts, and observing the actual road conditions in the Tirana, Albania, as the city of case study. The identified relevant attributes used in this research are as follows:

Design attributes	Levels
Type of separation with motorized traffic	1. Colored lane with painted stripes only 2. Colored lane with concrete curb 3. Colored lane with bollards

Type of separation with pedestrians	1. Level separation only 2. Level separation and fence
Bicycle lane width	1. Wide (1,5 m) 2. Narrow (1 m)
Context attributes	**Levels**
Road types	1. Primary 2. Secondary 3. Local
Pedestrian volume	1. Low 2. High
Presence of heavy vehicles	1. Yes 2. No

The road type attribute is intended to act as a proxy for width, average traffic speed, and traffic volume. From the combinations of context attributes, six context descriptions are generated.

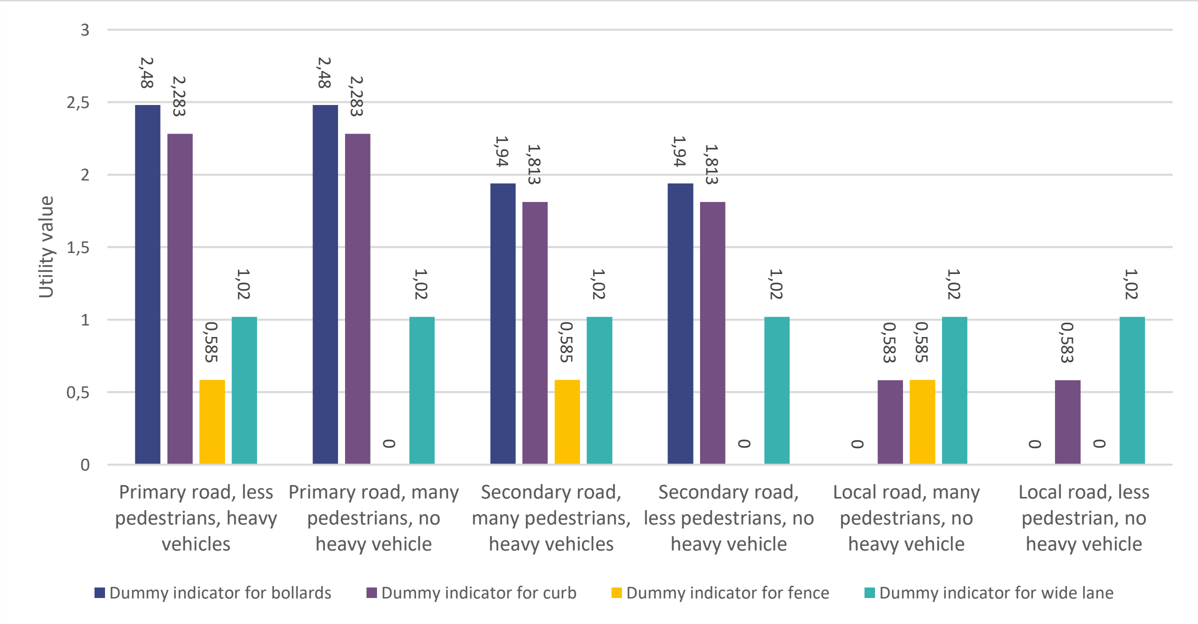
Since the research will be focused on the link-level attributes which more often relate to the physical design features of infrastructure which might be difficult to explain solely by words, images will be used to represent the options to the respondents. However, there are issues of potential bias due to accidental details in the images and possible difference of perception of attribute levels when presented only visually. A number of iterations were made in the process of developing the images to minimize the issues. Potentially distracting details were removed, and to clarify level specifications which were stated to be "vague" in the pilot survey text descriptions are added for some of the variables to the main survey.

In addition to the stated preference experiment, questions to identify the personal characteristic and travel habits of the respondents are included in the survey following the results of literature review which highlights the possible influence those variables might have on the choice behavior. The included personal characteristics are age, gender, bike ownership, distance from home to campus, ability to cycle, and cycling frequency.

The experiment data is collected through a web-based survey, which was made available for two weeks in the summer of 2018. The administered web-based survey gathered a total of 205 responses. Filtering out incomplete responses and the responses from non-targeted audience, i.e. those who are not familiar with the typical road situations in Tirana or not university students, 108 valid responses were collected and led to a total of 1.944 observations. The assumption of respondents' familiarity of Tirana was based on the data of the geographical area from which they filled in the survey. Due to the snowball sampling method for the survey distribution, the respondents are biased toward respondents who already cycle on a relatively regular basis.

Since there are categorical attributes and context attributes, for instance the type of separation with motorized traffic and road types, the attribute levels are recoded using dummy coding scheme. Multinomial logit (MNL) model is firstly estimated to obtain the base parameter values as reference. However, the model cannot capture the taste heterogeneity and panel effect which may occur due to the multiple choices made by each of the respondents. A panel mixed logit (ML) model is then estimated to take those into account.

The discrete choice model estimation shows that **people attach different values on certain design features of a cycling infrastructure under different urban contexts**, which answers the main research question of this study. To illustrate, the figure below summarizes the changes of mean utility values of the tested design attributes under the six roads with distinct characteristics.



Changes in utility values on different roads

We can conclude that people preferences on link-level design features of cycling infrastructure vary across roads with different characteristics. The preferences of design features which are sensitive to the contexts are of the type of separation with motorized traffic and type of separation with pedestrians, and the extent of the changes is dependent upon the road type and volume of pedestrians on the road, respectively. Curbs are on average more preferred than bollards in local roads. However, the context effect of being in secondary or primary road changes the mean utility value of bollards to be greater than of curbs and therefore bollards become more preferable on the higher hierarchy roads. Secondly, cyclists hold opposing views on having fences to introduce physical segregation between cycling and pedestrian lanes or just having grade separation. Nevertheless, when the context changes i.e. when there is a higher volume of pedestrians, travelers are more inclined to have the fence as an additional separator system.

The findings that bollards, which arguably contribute to most sense of separation and thus safety to the cyclists compared to other tested types of separator, are chosen as the preferred type of separation on primary and secondary roads show that the respondents value higher separation greatly. Given the group of respondents are biased toward people who already cycle more, which by some studies (Sener et al., 2009; Stinson & Bhat, 2003) are shown to be less sensitive to safety risks, studies with more non-cyclists are not expected to produce results with less preference on greater separations.

Having wide lane, on the other hand, is valued the same across contexts. In other words, cyclist's appreciation on having wider lane do not increase even on roads with higher hierarchy. Meanwhile, although the model result indicates that the heavy vehicle presence on the road prompts people to be more inclined towards having bollards, it is not statistically significant at the 95% level cutoff.

We should also note that there is significant heterogeneity on the preferences across respondents which still cannot be explained by the variation of contexts. Segmenting the data based on personal characteristic attributes, we found that differences in traveler's personal characteristics are associated with certain differences in valuation of design features and also in sensitivity toward context effects.

The research outcomes, nevertheless, have several limitations and hence need to be interpreted with cautions. Firstly, the sample group does not illustrate the complete heterogeneity of the city's population since it is scoped for university students and biased toward group of cyclists. Therefore, conservatively, this implies that the results might be not suitable to derive design recommendations which straightforwardly could encourage non-cyclists to cycle more, but rather to accommodate people who already cycle to have better experiences in cycling. Secondly, from the verification test it is apparent that some perception distortions still occur to some extent on the "speed" and "width of bicycle lane" variables. Undoubtedly, it is important to note the presence of those perception distortions since they may affect the outcomes of estimated models. Future researches which find similar distortions may explicitly take that into account by, for instance, estimating them as interaction variables in their model to get insight on how those distortions influence the observed choice behavior.

The recommendations for future research are as follows. *Firstly*, future researches can investigate the context effects of urban elements beyond those related to the road e.g. adjacent building functions, building density, surface material of the road, or even presence of vegetations. *Secondly*, future research to also examine the preferences of other road users, since in this research we only focus on the viewpoint of cyclists. A road is shared between multiple users such as car drivers and also pedestrians on the adjacent pedestrian path. It is possible that there are differences of view between the user groups and a design compromise should be made, rather than only implementing the ideal design according to cyclists. *Thirdly*, we have shown the possibility to use images for stated preference surveys and have elaborated the process of developing the images in this report. Therefore, studies which investigate preferences on physical designs can largely benefit from it, both from or outside the transport domain such as urban design or architecture studies. *Fourthly*, we note that some attributes indeed still cannot be sufficiently presented by static images. For example, since it is evident here that speed attribute levels are rather difficult to be conveyed by static images, motion pictures can be used instead. Although more complicated, the use of video will also increase the realism of the choices which in turn expectedly will contribute to a more reliable data. Given the rapid development of virtual reality (VR) devices in the recent years, it is also interesting to explore the possibility of using them to present the choice situations in a much more realistic manner.

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CHAPTER 1.

INTRODUCTION

Cycling has been recognized as a transport mode which has enormous potential benefits to the urban environment and the society, such as reducing congestions, air pollution, and emission, requiring significantly less fuel energy than motorized transport, improving road safety, as well as bringing various health benefits as it encourages a more active lifestyle (Boulange et al., 2017; Fraser & Lock, 2011; Lovelace et al., 2011; Meschik, 2012). Bicycle usage, especially for utilitarian travels, is favorable to address the environmental and health issues which are increasingly found in cities in the present days. A European-level declaration has been made by the EU ministers of transport, pushing actions to be made by the European Commission and the members of the European Union to support cycling in cities (Ministére du Développement durable et des Infrastructures, 2015).

A range of measures have been implemented by many local and regional government bodies in Europe to promote bicycle usage with varying results. Individualized marketing interventions, which target specific communities (for instance, neighborhoods, schools, or groups of people with certain health issues) by the means of tailored information provisions, events, and incentives (Pucher, Dill, & Handy, 2010), are observed to be effective although only have modest effects from a population perspective (Ogilvie, 2004; Pucher et al., 2010; Yang, Sahlqvist, McMinn, Griffin, & Ogilvie, 2010). Large-scale efforts are therefore deemed to potentially have more impact when the subject is the general population (Yang et al., 2010), such as by having policies restricting motorized vehicle access in city centers, congestion charging, public bicycle trainings, travel awareness programs, applying speed limits for motorized traffic, or organizing public cycling events (Pucher et al., 2010). However, some studies have put forth some points which should be considered regarding the effects of these cycling demand-related interventions. Firstly, the evidence on the long-term sustainability of the results of those interventions, especially the individualized marketing, are still limited (Müller-Riemenschneider, Reinhold, Nocon, & Willich, 2008). Secondly, the type of intervention is also argued to "only be applicable to people who are already interested in changing their behavior" (Yang et al., 2010). Thirdly, although their effects are the most difficult to estimate, comprehensive packages of measures which bundle demand-increasing interventions with provision of supply (i.e. cycling infrastructure) appear to have the most significant effects (Nazelle et al., 2011; Pucher & Buehler, 2008; Pucher et al., 2010).

The findings above have implied that supplying appropriate infrastructure is a part of the equation of promoting bicycle usage in cities which should not be left out. The notion is further supported by a vast array of literatures suggesting associations between cycling infrastructure provision and the level of cycling within the area (Dill & Carr, 2003; Heinen, van Wee, & Maat, 2010; Pucher et al., 2010). Dense bicycle network correlates positively with the level of cycling within an area (Dill & Carr, 2003; Fraser & Lock, 2011; Pucher & Buehler, 2008), since continuity of cycling facility and less travel time are favored by their subjects of study (Abraham, McMillany, Brownlee, & Hunt, 2002; Caulfield, Brick, & McCarthy, 2012; Titze, Stronegger, Janschitz, & Oja, 2008). In accordance, link-level studies typically showed the general preference towards segregated cycling facilities (Abraham et al., 2002; Akar & Clifton, 2009; Sener, Eluru, & Bhat, 2009). The lack of appropriate cycling infrastructure may hinder people to cycle due to safety concerns, even more so in the areas where cycling culture has yet to be developed (Pojani, Bakija, Shkreli, Corcoran, & Mateo-Babiano, 2017; Yang et al., 2010).

Increasingly more European cities are installing cycling infrastructure such as shared or dedicated cycle lanes, cycle tracks, cycle ways, as well as bicycle boulevards. Apart from local municipalities in countries with prominent bicycling culture such as the Netherlands, Denmark, and Germany which have been continuously investing huge sums of funding to cycling infrastructure projects especially since the mid 1970s (Pucher & Buehler, 2008), the momentum of providing cycling infrastructure is also gaining in the eastern and southeastern parts of Europe. Installment of well-designed cycling infrastructure becomes a part of the measures to revive the cycling culture which thrived there in the socialist era (Spencer, 2014). The city of Zagreb installed 231 km of cycling facilities in its inner city area between the year of 1995 and 2014 (Pilko, Tepeš, & Brezina, 2015). By 2016, Ljulbljana has an extensive 133 km of cycle lanes and 70 km of cycle tracks, and has achieved 12% modal share of bicycles (Istenič, 2016), while Budapest added 6,6 km cycle ways, 2,4 km cycle lanes, 6,4 km shared cycle/bus lanes, and 12 km contraflow bike lanes (Kerényi, 2013). In the Balkan area, the city of Tirana also takes action by building 44 km of bicycle lanes on the city's twelve main roads (Hoxha, 2015).

Parallel with the emerging practices of providing cycling infrastructure in cities, the number of published scientific researches and practical cycling infrastructure design guidebooks to be used or written by road authorities has been increasing (Parkin & Koorey, 2012). A number of the guidebooks such as the ones published by the British Department of Transport (Arup, 2008), the PRESTO project for Intelligent Energy-Europe program (Dufour, 2010), and the French Ministry of Ecology, Sustainable Development and Spatial Planning (CERTU, 2008) assess and provide explicit recommendations of cycling infrastructure design on network- and, especially, link-levels. Different types of separations and types of surface treatments, such as the pavement colors and materials, are commonly suggested by the guidebooks based on the existing road types, such as primary, secondary, or local road. Similar distinctions have also been made based on the characteristics of the existing road segment, for instance the width of adjacent road, intensity or speed of car traffic, function of the road, and the surrounding spatial environment.

1.1 Problem statement

Infrastructure intervention is a common measure implemented by various municipalities to promote bicycle usage in their area. Taking the preferences of travelers into account when designing infrastructure interventions is crucial since studies have found positive correlations between the presence of a dedicated cycling infrastructure and a road's attractiveness for cycling. As mentioned before, a number of countries in Southeastern Europe are developing their cycling infrastructure to revive their formerly popular cycling culture, especially in their capital cities where traffic jams have become a daily issue. Meanwhile, budgets to finance those developments are limited and the decision-makers are faced with the challenge of choosing appropriate designs of the infrastructure from as early as possible.

To aid the decision-makers plan the development, there have been many bicycle infrastructure design guidebooks published to provide practical information on how the facilities should be designed, especially in the link-level. Nevertheless, it is interesting to note that the many of the link-level design suggestions are based only on the objective safety features, such as the dimension of lane needed by a bicycle to take over (CERTU, 2008), minimum distance to fixed objects (Dufour, 2010), or analysis of accident statistics (CROW, 2007). There is a scarcity of guides which designs stem from travelers' actual preferences. The tendency might partly be attributable to the scarcity of updated studies focusing on cycling infrastructure design on the link-level, particularly the ones investigating in more detail specific design features such as the type of separation, width, or coloring of the facility. While studies on the network-level have typically shown the obvious preference towards highly connected network of cycling infrastructure and separation from motorized traffic (Caulfield et al., 2012; Dill & Carr, 2003; Fraser & Lock, 2011; Pucher & Buehler, 2008; Sanders, 2013), a similar level of consensus has yet to be reached on the results of more detailed link-level studies concerning specific design features of the cycling infrastructure link.

One common format of the recommendations is to differentiate the designs based on the road contexts along which the cycling infrastructure will be installed. This implies a supposition that different link-level design features are needed on different roads. However, literature concerning how the effects of bike lane designs on the road's attractivity to cycle might vary upon different contexts of urban environments is also still scarce. Little is known about the merits of having different cycling infrastructure on different roads, whether it is indeed necessary to have those variations or not. Given the gaps, more insight is needed in travelers' behavior particularly on their preferred link-level design features subject to the conditions of existing urban surroundings.

Furthermore, the scarcity of cycling infrastructure-related studies, let alone those more specific urban environment-dependent preference researches, is even more prominent in Southeastern European countries who are currently striving toward a more developed cycling-supportive environment in their cities. Since as found by Pojani, et al. (2017) there are differences of attitudes and perceptions on cycling between people in Northwestern and Southeastern Europe, the appropriateness of direct transfer of study findings or, in the more practical area, design guidelines across the regions is therefore questioned. This adds more urgency for researches done in the particular context.

To clarify matters before going further to the next subsection, the term "link" used in this paper is analogous with the one defined by Stinson & Bhat (2003) which is "*a segment of throughway between two intersections*". Therefore, junctions, traffic lights and stop signs, travel time, path continuity, and other network-level attributes both on the design aspects and traffic-related (Stinson & Bhat, 2003) are out of scope in this research. The term "travelers" is also used since the study is inclusive to both cyclists and non-cyclists.

The city of Tirana, Albania, is used as the case study of this research. As one of the capital cities in the Southeastern Europe, Tirana exhibits typical cycling conditions as the others: it still has underdeveloped cycling infrastructure, where the cyclists have to share the roads with high volume of motorized traffic. Cycling itself has not yet be the mode of choice of the travelers who mainly prefer cars more, hence the daily traffic jams throughout the urban roads. Sharing similar traits with the other main Southeastern European cities, choosing Tirana to be a case study arguably will produce results which are generalizable to those cities as well. A more thorough description of the case study is made on Chapter 4.

1.2 Research objective and questions

Following the problem statement, the main objective of this research is to gain knowledge on the preferred link-level cycling infrastructure designs from Southeastern European travelers' perspective, by investigating whether travelers value certain link-level cycling infrastructure design features differently across road segments with distinctive existing characteristics. A literature review and an expert interview with urban design practitioners are done to identify the link-level design attributes and relevant urban environment contexts in a road segment which might affect the cycling behavior of travelers, and a survey is done to test the importance of those variables more specifically for Southeastern European travelers.

Considering the timeframe of the study, the research is scoped to address the following scientific objective:

1. Investigate how the utility values travelers attached to certain attributes of link-level cycling infrastructure design depend on certain existing characteristics of a road segment.

The research also aims to achieve a practical objective, which is:

2. Provide recommendations on the design of cycling infrastructure on the link-level at different road types, based on travelers' preferences.

A number of research questions are formulated to achieve the objectives. The main research question below is made for the research being able to fill the knowledge gaps related to link-level design of bicycle infrastructure:

To what extent do the preferences of travelers on link-level design features of cycling infrastructure differ across roads with different characteristics?

To answer the main research question, several sub-questions are proposed as follows.

- What are the relevant link-level design features used to characterize cycling infrastructure?
- What are the relevant urban environment characteristics used to typify road segments?
- What are the main types of road commonly present in an urban area, and to what extent they can act as a proxy for urban environment characteristics?
- To what extent the urban environment characteristics influence the values perceived by Tiranian travelers from the design attributes of a cycling infrastructure?

1.3 Scientific and practical contributions of the thesis

The thesis enriches the insights into link-level bicycle infrastructure design preferences from travelers' perspective, which is a research focus with relatively scarce updated researches compared to its network-level studies counterpart (Buehler & Dill, 2016). Within Europe, the scarcity of literature in the area is more apparent on the Southeastern Europe context since most cycling infrastructure-related studies are done in the northwestern countries.

In this thesis, the link-level cycling infrastructure is described to the level of its design features, thus gaining more detailed insights on the preferred design of cycling infrastructure such as how the bicycle lane is segregated with motorized traffic as well as pedestrians, the width of the lane, and other relevant design variables which are identified in Chapter 3. A relation is also drawn in this research between the preferences and the physical contexts in which the choices are made, i.e. characteristics of the roads where the cycling infrastructure are built. Since many previous cycling infrastructure preference researches (Caulfield et al., 2012; Hull & O'Holleran, 2014; Hunt & Abraham, 2007; Tilahun, Levinson, & Krizek, 2007) did not investigate the probable interaction effects between the specific design features preferences and the context, this thesis contributes to the current body of literature by examining those effects.

Although a recent research by Ghekiere et al. (2018) has included similar interaction effects in their model estimation, this study differs in at least two ways: 1) urban roads with their distinctive characteristics are used as the contexts in this study, as opposed to the previous study which used cycle path types as their contexts; and 2) this study investigates the preference of travelers in a developing region with a low cycling level, while the previous study was done in Flanders, Belgium, which is a developed country with a fairly high cycling level.

More specific description of design variables, which is the case of this research, potentially introduces more unobserved variations. However, this drawback can be countered by depicting the description visually using images in the survey (Aldred, Elliott, Woodcock, & Goodman, 2017). Therefore, this research utilizes images to convey alternatives in its stated preference experiment. Similar approach of image utilization in an stated preference experiment was used by Mertens, et al. (2016) and Hurtubia, Guevara, & Donoso (2015). The two differences of this study to those previous researches are as follows: 1) more than one "basic" images are used since the effects of urban environment contexts to the utility of the attributes are aimed to be investigated in this study, while Mertens, et al. (2016) only used one "basic" image; and 2) the characteristics of the road segments are represented as contexts of the alternatives, instead of also being attributes as done by Hurtubia, Guevara, & Donoso (2015). Thus, the study also adds nuance to the emerging field of researches with visual stated choice experiments.

The insights which are gained in this research can be used to derive practical recommendations on link-level cycling infrastructure design, which consider travelers' preferences. The design recommendations can be useful for the decision-making process of building future cycling infrastructure, especially for Southeastern European municipalities where such guidebooks have yet to exist, hence the practical contribution of this research.

1.4 Structure of the Thesis

After the background which motivates this study and the problems addressed have been stated in this **Chapter 1**, the next parts of the thesis document are structured as follows. In **Chapter 2**, the methodology of this study is presented. The chapter is followed by a literature study concerning previous works and theories on cycling behavior and infrastructure in **Chapter 3**. In **Chapter 4**, a brief overview about the case study is made. Next, the process of designing the discrete choice experiment, the resulting survey design, and the data collection plan are presented in **Chapter 5**. The collected data is used to estimate discrete choice models, and the estimation results as well as the process are discussed in **Chapter 6**. Finally, the study is concluded, limitations are discussed, and recommendations for further research and practice are made in the final **Chapter 7**.

CHAPTER 2.
METHODOLOGY

In this chapter, the methods used to achieve the objectives stated in Chapter 1 are elaborated. The research sub-questions are used as a framework to develop the methodology. A review of the current literature forms the first part of the methodology used in this research. A discrete choice experiment to elicit the preferences of travelers on the link-level design features of cycling infrastructure by the means of a stated preference survey in an area of case study is used as the main method.

2.1 USE OF LITERATURE IN THE RESEARCH

A review on the current body of literature is firstly done to understand the factors influencing cycling behavior, especially those related to the design of link-level cycling infrastructure. Scientific papers which focus in reviewing the state-of-the-art of cycling behavior studies are useful as starting points when conducting the research in order to get references to relevant literatures. Some examples of them include Buehler & Dill (2016), Aldred, Elliott, Woodcock, & Goodman (2016), and Heinen, van Wee, & Maat (2010). The first focus of the study on those literature is to get an overview on the influence of cycling infrastructure on cycling behavior of travelers in urban areas. The second focus is to obtain a list of link-level cycling infrastructure design features which have been used as survey attributes in prior studies. Since the main method used in this research is stated preference experiment, a choice which is elaborated further in Section 2.2, the review puts more emphasis on studies having the same approach. To limit the number of attributes examined in this research, the study done also identifies the attributes which have been shown to be significant determinants of cycling habits in an urban area and the most commonly examined attributes to be prioritized. Those filtered attributes are the outcomes of this first part of literature review and are presented in Section 3.3.

Research on the grey literature, such as bicycle infrastructure design guidelines and Tiranian urban planning documents, is also done to answer the second and third research subquestions related to the types of road commonly present in an urban area and the relevant attributes to characterize them. This is done to gain insights on how practitioners typify road segments, to be used in the stated preference experiment. The information from grey literature sources is also used to enhance the realism and the relevance of the survey, by gaining insights on the dimension and other actual characteristics of the roads present in the urban area of study and the feasible choices which have to be made by practitioners on the design features of link-level cycling infrastructure. The findings from this second part of literature review are also summarized in Section 3.3.

Lastly, grey literature is also used as the source to gain an overview on the area of case study, especially regarding its existing cycling infrastructure, policy, and travel behavior which motivate the selection of the area for this study. As mentioned in Chapter 1, the city of Tirana in Albania is selected as a case study for this research. An overview of the case study forms the content of Chapter 5.

2.2 Use of survey in the research

Discrete choice modelling has often been used in prior works researching cycling behavior and is also used in this research. The data is gained through a stated preference survey which was conducted in the area of case study, which is designed to allow investigation on whether the characteristics of the road segment where the cycling infrastructure is situated affect travelers' choice behavior. The background variables are allowed to vary instead of being constant as in a typical stated preference experiment. The varying variables in the context description are referred to "context attributes" from this point onwards. In preparation for the stated preference survey, expert interviews are also done to refine the survey setup.

2.2.1 Expert interviews

Before setting up a stated choice experiment, the attributes, context attributes, and their levels should be determined. A list of design features and urban characteristics possible to be included as attributes and contexts in the stated preference survey is obtained through the literature study explained before. However, in order to prevent combinatorial explosion which will burden the respondents with too many choices, the number of attributes and context attributes is further reduced to the most relevant ones. In addition to descriptive analysis made on the attributes in previous literature, expert interviews are conducted to help pinpoint those most relevant attributes.

For the generic attributes, the interviews are done by asking how the design process of the current and future cycling infrastructure is done in Tirana. Insights on the actual design choices which are considered by local practitioners and/or implemented in Tirana and also the cycling infrastructure features which are viewed to matter the most can therefore be obtained. On the other hand, for the context attributes, some of the interviewees are asked to confirm if the road types presented are actually present in the case study area, and are asked for their opinions to how further enhance the realism of the context options presented. Due to that latter objective of the expert interview in this research, it is more favorable to have interviewees which are also familiar with the urban settings of the case study area. Results of the attribute selection process are presented in Section 5.4.

The first interview is done with Dorina Pllumbi, a lecturer from Polytechnic University of Tirana, guest researcher and PhD candidate at Delft University of Technology. The interviewee provided information about the typical characteristics of urban environment in Tirana, in particular the roads, and additionally shared her own experience of being a regular cyclist in Tirana. The second interviewee is Nevin Bilali, a project director of cycling infrastructure at the Municipality of Tirana. From this interview, we gain information about the typical urban settings, the design process of cycling infrastructure, and the municipality's future infrastructure plan of further supporting cycling in Tirana.

A number of interviews are also made to further verify the realism of tested contexts and link-level design features. The interviews are not necessarily conducted on people with expertise on urban transport or cycling studies, as long as they are familiar with the urban environment of Tirana.

2.2.2 Travelers surveys

After the relevant attributes have been further short-listed and the context attributes have been confirmed to realistically convey the road types present in the case study area, the main survey is constructed. The survey consists of three parts: a stated preference experiment, a set of questions examining the socio-demographic background of the respondents, and a set of questions to verify the questionnaire. The stated preference experiment is constructed using Ngene software (Choice Metrics, 2018).

After the stated preference data has been obtained, firstly a multinomial logit (MNL) model is estimated using BIOGEME (Bierlaire, 2009) software. Following the work by Molin & Timmermans (2010), the interaction effects between the context variables with attribute coefficients are estimated to gain insights on how a context affects the utility value people attach to a certain attribute. The model is used due to its simplicity and will pose as a benchmark. Following the first model, a mixed logit (ML) model which can capture taste heterogeneity among respondents is estimated, since ignoring the heterogeneity which may present in users' preferences "may lead to biased estimates and incorrect predictions" (Rossetti, Saud, & Hurtubia, 2017).

In this study, two surveys are conducted: firstly, a small-scale preliminary survey which was administered in Netherlands, followed by the main survey which was done in the city of case study. The small-scale survey is done mainly to test the questionnaire presented to the respondents, in order to design a more refined main survey. The respondents of the preliminary survey gave feedbacks on the questions, choice sets, and the length of the survey, as well as how well the images portray the alternatives presented in the stated preference part of the survey. The inputs were collected, and the main survey was modified accordingly. Detailed explanation of the survey and questionnaire construction is presented in Chapter 5.

A. Stated preference experiment

Compared to a revealed preference survey, an stated preference survey has several advantages. For instance, as mentioned by Broach, Dill, & Gliebe (2012), it is generally less complicated and less costly to collect data using the method compared to revealed preference surveys. Although in stated preference surveys hypothetical choices are made, previous studies which compared the values of attributes gained from stated preference surveys and the ones from revealed preference surveys show that the values rarely contradicted each other (Abraham, McMillan, Brownlee, & Hunt, 2002). Furthermore, it also allows the testing of options which are rarely encountered in reality or not yet exist (Broach, Dill, & Gliebe, 2012), a situation which will be encountered in the city of study whose bicycle network has yet to be fully developed. Another advantage of using stated preference survey is that the researcher has higher amount of control on the attributes and attribute levels which are conveyed in each option, making it possible to prevent multicollinearity between the attributes (Stinson & Bhat, 2003) and interference of latent attributes (Rossetti, Saud, & Hurtubia, 2017).

Since the research focuses on the link-level attributes which more often relate to the physical design features of infrastructure which might be difficult to explain solely by words, images are used to represent the options to the respondents. As stated by Hurtubia, Guevara, & Donoso (2015), the use of images in stated preference survey can show physical features more explicitly. In the survey, respondents are given alternatives of images portraying a road segment which has been equipped with a cycling infrastructure. More detailed explanation about the construction of the stated preference experiment is given in Chapter 5.

B. Socio-demographic background questions

In the survey, a part is dedicated for questions to gain the socio-demographic data of the respondents, such as their gender, age, and cycling habit or frequency. The background data is needed since a number of previous studies found that certain socio-demographic characteristics may have influence on the choices made in cycling behavior surveys. Some examples of the studies are Caulfield, Brick, & McCarthy (2012) and Sanders (2013) which showed that frequent and non-frequent cyclists have different preferences, and also Garrard, Rose, & Lo (2008) as well as Titze, Stronegger, Janschitz, & Oja (2008) which found the moderating effect of gender difference on the relationship between attributes and the choice to cycle.

C. Survey design verification

Molin & Timmermans (2010), Orzechowski, Arentze, Borgers, & Timmermans (2005), and Hurtubia, Guevara, & Donoso (2015) highlighted the drawbacks of using images in a stated preference experiment. Two of the main concerns are the potential bias due to accidental details in the images and possible difference of perception of attribute levels when presented only visually. Those issues may cause bias in the estimated values and lead to questions in the study's reliability. In addition to careful selection of basic images and manipulation of the images to minimize distracting details, a verification test is conducted in the preliminary study to further refine the survey instruments. Considering the timeframe, it is decided to have the main survey design already complete prior to going to the city of case study. Therefore, the pilot study to test the correctness of respondent's perception is done in the Netherlands with Dutch university students as respondents.

Another verification test is again included in the main survey to check if the issues still occur. The results of the test in the main survey also indicate the extent context attributes are correctly represented, related to the second part of the third research sub-question.

2.3 Conclusion

To summarize the approaches stated in the previous sections, the research framework for this study is developed as follows:

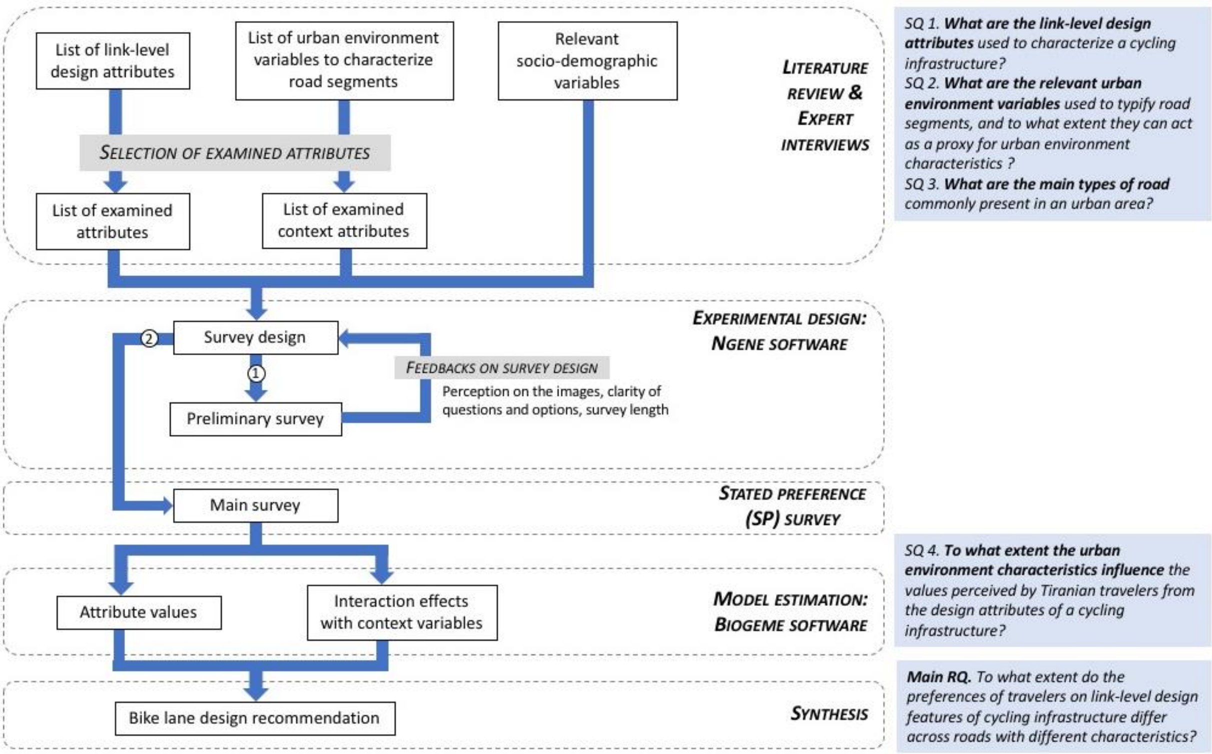

Figure 1 Research framework

CHAPTER 3.

INFRASTRUCTURE AND CYCLING BEHAVIOR

The greater influence municipality-level interventions, such as policies, campaigns, and cycling infrastructure provision, have on cycling promotion compared to individual-level approaches is shown in a systematic review of twenty-five controlled studies from seven countries (Yang, Sahlqvist, McMinn, Griffin, & Ogilvie, 2010). Among the interventions, introduction of bicycle-friendly infrastructure which separates cyclists and motor traffic is one of the most popular (Pucher, Dill, & Handy, 2010; Ogilvie, et al., 2011). From an economical perspective, the action is somewhat justifiable to be done by municipalities since the calculated benefits outweigh the costs, even up to ten times the investment (MacMillan, et al., 2014).

This chapter starts with a review on the literature concerning how infrastructure influence cycling behavior of travelers. Theories supporting the relation between the two aspects as well as an overview on the results of a number of empirical studies about cycling behavior are presented. The next section addresses the key design principles of cycling infrastructure and its relation to surrounding urban environment contexts to elaborate further the motivation of this research. Following that, a list of attributes related to link-level design features of cycling infrastructure which were used by prior empirical studies and a discussion on how the link-level cycling infrastructure and road segments as urban environment contexts are categorized in scientific and grey literature are presented in Section 3.3. The list provides initial candidates of possible answers for the first and second research sub-questions: "*What are the relevant link-level design features used to characterize cycling infrastructure?*" and "*What are the relevant urban environment variables used to characterize road segments?*". Finally, a conclusion about the discussion made on this chapter is made in Section 3.4.

3.1 INFLUENCE OF INFRASTRUCTURE ON CYCLING BEHAVIOR

A number of studies have associated the level of cycling in cities with the availability and quality of cycling infrastructure network and paths, and some have postulated the mechanism behind those empirical findings. The discussion in this section highlights how infrastructure could affect cycling behavior, justifying the importance on conducting a study on the topic.

3.1.1 THEORETICAL BACKGROUND OF THE INFLUENCE

It has to be acknowledged that there are indeed many factors other than the presence and quality of infrastructure which also influence the level of commuting by bicycle. As an active mode, cycling in cities is more affected by external conditions such as weather and many physical features of the urban environment itself, compared to motorized transport (Motoaki & Daziano, 2015; Wardman, Hatfield, & Page, 1997). Socio-demographic and household characteristics have also been cited to significantly influence the level of cycling (Garrard et al., 2008; Stinson & Bhat, 2003; Tilahun et al., 2007). In addition, other studies identify difference of habits, local norms, and attitudes toward cycling as other factors influencing cycling behavior (Dill & Voros, 2007; Pojani et al., 2017; Sanders, 2013; Whalen, Páez, & Carrasco, 2013).

Heinen, van Wee, & Maat (2010) explicitly divided the determinants of utilitarian cycling into five categories: built environment, natural environment, socio-economic variables, psychological factors, and factors related to trip utility which includes cost, time, effort, and safety. Cycling infrastructure itself is, in a sense, simply one of the factors in the built environment group of determinants along with two other factors: urban forms, which affect the trip distance, and facilities at work.

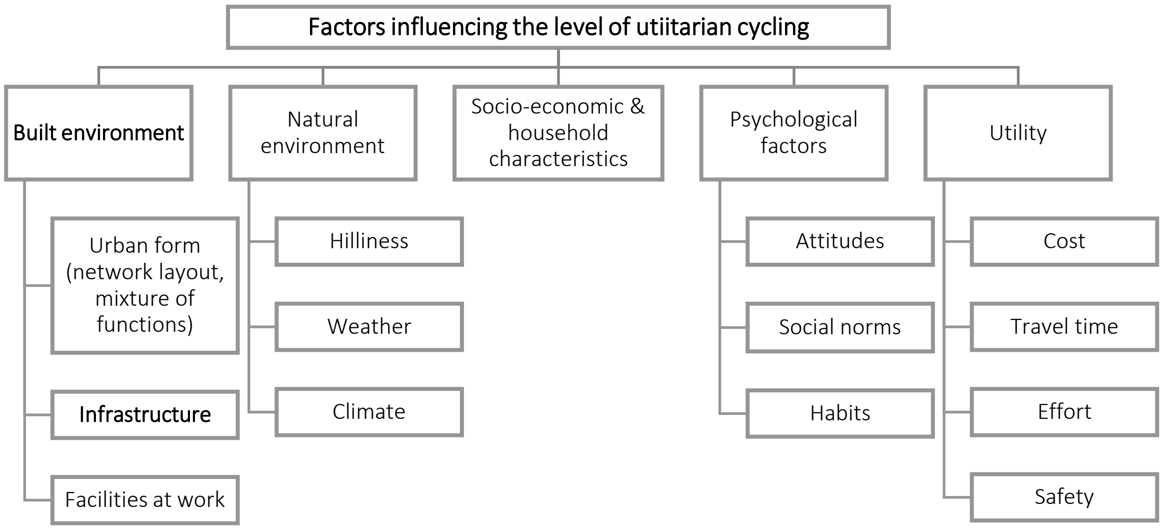

Figure 2 Factors influencing the level of utilitarian cycling (Heinen et al., 2010)

The notion that environment plays a role in the adoption of active modes is also evident in ecological models developed by Saelens, Sallis, & Frank (2003) and Ogilvie, et al. (2011). In a more eminent model by Saelens, Sallis, & Frank (2003), presence of cycling and walking infrastructure as well as other physical features of the area such as street connectivity and land use mixture are shown to be some of the factors which influence active transport mode usage. The model was derived from the findings of previous regressional designs or correlational analyses studies which analyzed the correlations between various neighbourhood characteristics with rates of walking or cycling in an area such as Kitamura, Mokhtarian, & Laidet (1997), Cervero & Kockelman (1997), and others which exact number is not specified (Saelens, Sallis, & Frank, 2003). However, the model is not capable to indicate the direction of causality yet and only presents correlations between examined variables.

The more recent model by Ogilvie, et al. (2011) specifically aims to explain how interventions alter behavior, particularly the decision to use active modes. The model was built upon the previous ecological model of Saelens, Sallis, & Frank (2003) by having the factors listed in the previous model re-categorized into macro-contextual groups of factors. As shown in Figure 3, physical environmental factors are recognized as one group of the macro-contextual factors, along with individual factors such as age, sex, and distance to work, household factors, and social environment factors which include social norms (Ogilvie, et al., 2011). It also incorporates intention as a factor which might induce changes in actual observed behavior, based on the Theory of Planned Behavior (Ajzen, 1991). Those models support the notion that appropriate infrastructure availability and quality are related to the number of active mode trips made by citizens.

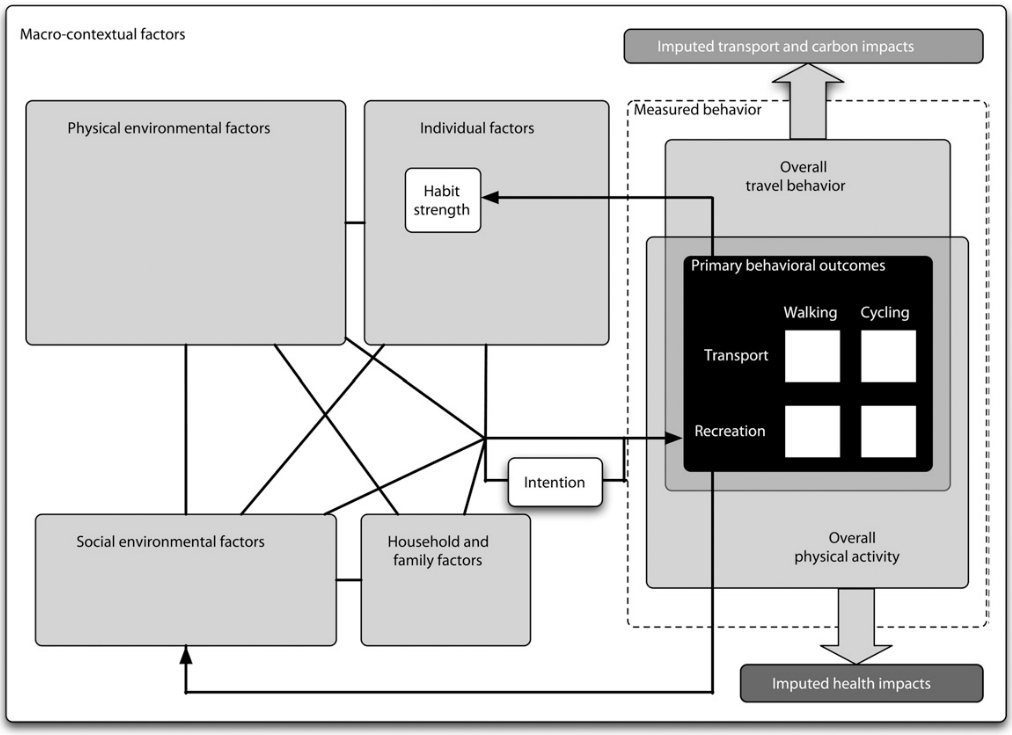

Figure 3 General theoretical model of intervention effects on cycling and walking (Ogilvie et al., 2011)

3.1.2 Empirical studies on infrastructure provision and cycling level

From the previous discussion, it is evident that there are many factors other than cycling infrastructure which could affect travelers' choice to cycle. However, often improvement of built environment factors by providing cycling infrastructure is the most feasible action which can be done by government authorities since some of the other factors, such as natural environment or socio-demographic characteristic, cannot be altered (Krabbenborg, 2015). The statement by no means undermines the importance of other measures such as cycling promotional campaigns, trainings, or transport-related policies which require citizens to cycle, since as suggested in a recent study (Kroesen, Handy, & Chorus, 2017) the use of bicycle induces positive attitude toward the mode. In fact, comprehensive implementation of infrastructure provision and those measures is found to have far more dramatic impact (Pucher et al., 2010). Nevertheless, provision of dedicated cycling infrastructure separating cyclists and other traffic remains one of the common measures to promote bicycle usage (Pucher, Dill, & Handy, 2010; Ogilvie, et al., 2011). Moreover, the huge sum of investment required to develop the facilities makes it crucial to get it done in the right direction from the beginning, hence the numerous studies done to investigate cycling infrastructure.

Studies about the influence of cycling infrastructure provision to the level of cycling can be classified in a broad manner into two broad categories based on the type of empirical data analyzed. The first one, the aggregate-level studies, generally analyzed the level of cycling in cities, countries, or other geographical scales by linking them with various variables ranging from level of infrastructure provision to socio-demographic characteristics of the population. A weakness of this type of study is that no causal relationship can be adequately concluded, except when time-series data is used in the study (Dill & Carr, 2003). Other studies used the second approach by analyzing data on individual or disaggregate level using, for instance, discrete choice models. Regarding the results, a review paper (Pucher, Dill, & Handy, 2010) analyzing 139 international works on the topic found that in general the examined studies resulted in “a positive and statistically significant relationship between bike lanes and the level of bicycling”. Examined aggregate level studies are found to show similar results more consistently compared to disaggregate (individual) level studies. One example of the studies which show the stated relationship is a study of socio-demographic data, commuter cycling level, and the length of bicycle infrastructure in 35 major cities in the USA using regression analyses (Dill & Carr, 2003). The study finds strong correlation between the modal share of bicycle for commute trips and bicycle infrastructure variables. The strongest association is found between the number of commuter cyclists and on-street bike lanes in the cities: approximately one percent increase in the number of cyclists is associated with each additional mile of bike lane.

3.1.3 THE CYCLISTS

In a research about selecting cycling infrastructure design treatment (Wilkinson et al., 1994), three main variables are cited to affect the suitability of a cycling infrastructure design, which are as follows:

1. *The type of roadway project involved.* Certain designs might be more feasible to be constructed on new road project, compared to when they have to be retrofitted to existing road geometry which has fixed width. In the latter case, minor improvements are more favorable without sacrificing the needs of cyclists.
2. *Traffic operation factors*. The factors commonly used to define design guides include traffic volume, average motor vehicle operating speeds, traffic mix, presence of on-street parking, sight distance, and the number of intersections and entrances. Traffic mix factor concerns the regular presence of heavy vehicles such as busses of trucks, which is argued to discourage cyclists from using a route unless sufficient separation is made.
3. *Type of cyclists.* It is emphasized in the study for planners to investigate the target group of cyclists mainly using the route, whether it is designed for advanced cyclists who desire the most direct routes or basic cyclists and children who prefer more comfortable cycling conditions.

From the list above, it is apparent that the characteristics of the users matter for the infrastructure design. Therefore, it would be useful to identify the group of cyclists, or potential cyclists, in the design phase of cycling infrastructure.

As with the cycling infrastructure design itself, many attributes can be used to characterize the users or potential users of a facility. Those differences of cyclists’ characteristics might be some of the variables explaining the potential variation of preferences observed in the research, hence including them in a model estimation may enhance the explanatory power of the model.

The first and one of the most common categorizations is based on the cyclist’s ability to cycle. Using this categorization, Wilkinson et al. (1994) broadly divided cyclists into two classes: advanced cyclists class and a joint class of basic and child cyclists. Advanced cyclists are described as riders who are comfortable riding their bicycles on most traffic conditions, while members of the latter group are less confident to cycle in situations where adequate cycling facility is not provided. Due to their confidence on their ability to cycle, the first group can usually be found cycling on arterial or primary roads which have the most direct routes, while the second might be more hesitant to do so (Caulfield et al., 2012; Wilkinson et al., 1994). A similar approach of categorization can be made by classifying the cyclists based on their frequency to travel. Cyclists who cycle more regularly have been shown to have traits comparable to those of advanced cyclists. In general, they are less sensitive to factors which may hinder other travelers to cycle, such as moderate-to-high adjacent traffic speed or conflicts with traffic (Sener et al., 2009; Stinson & Bhat, 2003). Additionally, both increases in cycling experience and cycling frequency have been found to be correlated with more value placed on travel time, respectively (Hunt & Abraham, 2007; Sener et al., 2009).

The second categorization is done by identifying the cyclist's trip purpose. Previous literature in the field of travel behavior research have often used a general grouping of utilitarian or recreational trips (Saelens, Sallis, & Frank, 2003), and some literature which specifically address cycling behavior have also done so (Abraham et al., 2002; Dill & Voros, 2007; Sener et al., 2009). Nevertheless, a number of other studies segmented the trip purposes in a more detailed manner, for instance by classifying them into work, shopping, social, personal business, and school (Winters, Teschke, Grant, Setton, & Brauer, 2010). Regarding the differences of behavior between the two main groups mentioned previously, utilitarian cyclists tend to be more sensitive to travel time (Aultman-hall, 1996; Stinson & Bhat, 2003) and thus prefer direct routes more than recreational cyclists.

Personal attributes such as age and gender cyclists have also been used by previous literatures when examining differences in cycling behavior. Numerous studies found that females are more likely to have greater preference toward more separated cycling infrastructure (Caulfield et al., 2012; Garrard et al., 2008; Tilahun et al., 2007; Winters & Teschke, 2010). Related to the age of cyclists, a study (Stinson & Bhat, 2003) examined the interactions between said variable and link- and network-level factors of cycling infrastructure. Older individuals are shown to place more value on wider lanes situated on the right-hand side of a road and smooth riding surface, have less concern on travel time, and avoid major streets more than younger groups. However, another study obtained a different result: it was indicated that the group of older cyclists were less concerned by having to share the road with traffic, although this finding was not statistically significant (Hunt & Abraham, 2007).

3.2 Design principles of cycling infrastructure

The positive association between provision of cycling infrastructure and cycling level has been put forth in the previous subsection. However, the decision to cycle is not only affected by the presence of cycling infrastructure but also the quality of it. The design of cycling infrastructure is thus becomes the "key facilitator or potential barrier to encouraging cycling" (Hull & O'Holleran, 2014 p. 370).

3.2.1 Key design principles

Perception of safety has been identified as one of the most important factors which influence people's willingness to cycle (Dill, 2009). The apparent association between provision of cycling infrastructure and cycling level arguably correlates to the general preference of cyclists on dedicated bicycle infrastructure such as bicycle paths or physically separated lanes (Buehler & Dill, 2016; Heinen et al., 2010; Tilahun et al., 2007) since separation from traffic introduces a sense of safety. Findings from the study by Mertens et al. (2016) further indicated the positive effect improved perception of safety has on a road's appeal for cycling, although the actual safety of the path itself remained the same. Taking the notion further, a Danish cycling report (Andersen et al., 2012) and a study (Hull & O'Holleran, 2014) state that it is the travelers' subjective perception of safety, instead of the actual road safety measured objectively from accident statistics, which actually encourages them to adopt bicycle as their mode of choice. The preference towards bicycle facilities which can provide a stronger sense of safety is even greater in the groups of women, older and younger people, and inexperienced cyclists (Aldred et al., 2017; Buehler & Dill, 2016; Garrard et al., 2008).

In addition to safety, speed, comfort, and continuity are also identified as the strong influencers of cycling adoption among travelers (Hull & O'Holleran, 2014). Building upon those factors and the design aspects which are used to assess the level of service of bicycle facilities from a number of design manuals such as the Dutch (CROW, 2009) and American (FHWA, 1998) guides, the study highlights five cycling infrastructure design principles which are coherence, directness, attractiveness, road safety, and comfort. Similar design principles are also suggested in City of London's cycling design manual (Transport for London, 2014) derived from international best practices. Those principles of good design, which include the five design principles by Hull & O'Holleran (2014) with an addition of adaptability, can be used to assess the quality or level of service (LoS) of cycling infrastructure (Transport for London, 2014). Moreover, construction and maintenance costs, as well as ease of implementation are also cited to be considered when designing cycling infrastructure (Wilkinson et al., 1994).

The mentioned design principles and their subsequent design outcomes are shown in Table 1 below. The first five principles are the main requirements for a cycling-friendly environment, ordered based on a requirement priorities of utilitarian cycle network design by Dufour (2010). The prioritization is made since there may sometimes be trade-offs between the principles, for instance when the most direct route is the one along a busy main road hence being less safe. Since safety is the utmost priority, appropriate separators might be needed to segregate the cyclists from the motorists on that route to increase the level of safety. Another option is to design a cycling route on slightly less direct, but has less traffic, roads. The other principles, while do not directly influence the quality of a cycling infrastructure itself, are suggested to be considered to ensure the feasibility of construction and sustainability of the facility in the long-term (Transport for London, 2014; Wilkinson et al., 1994).

Table 1 Design principles for cycling infrastructure
(Hull & O'Holleran, 2014; Transport for London, 2014; Wilkinson et al., 1994)

Design principle	Design outcomes
Road safety	Safe segregation with motorized traffic, sufficient infrastructure upkeep
Directness	Logical, continuous routes which consider the costs of travel time, without unnecessary obstacles or delays
Coherence	Consistent and continuous cycling infrastructure which connects destinations, easily understandable by all users
Comfort	Comfortable surface (e.g. surface material and incline) and sufficient space to cycle, ease to navigate through the network
Attractiveness	Well-designed cycling infrastructure (e.g. width and surface material), street furniture, and illumination considering cyclists' personal safety
Adaptability	Able to accommodate all types of bicycles and the increasing number of users
Costs	Feasible and efficient construction and maintenance costs
Ease of implementation	Implementable design considering the existing available space and traffic operations

3.2.2 Addressing the urban environment contexts

According to the Oxford English Dictionary (2018) context is defined as "*the circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood*". Design, at its essence, is an effort to achieve a good fit between a designed form, as a solution, and its context, which defines the problem (Alexander, 1964). While scientific studies specifically addressing the influence of physical context in designing cycling infrastructure are still limited, the practice of understanding contexts and using the information in a design process is one of the standard approaches in urban design.

Pucher et al. (2010) highlights the importance of contexts to be considered in providing successful cycling infrastructure, or other cycling-promoting measures in general. Reviewing a number of journal articles as well as design manuals about cycling infrastructure design, it is generally agreed that a copy-and-paste approach of a cycling infrastructure design which works in a place may not be adequate for the design to be as impactful in another place.

In a built environment, a “contextual design” means that the individual form draws relation to its surrounding social, cultural, historical, as well as physical and other conditions (Komez-Daglioglu, 2017). We will focus, however, on the physical conditions when referring to “urban environment contexts” from this section and beyond.

3.3 CHARACTERIZING THE INFRASTRUCTURE

The literatures discussed in the previous subsection have shown the influence of cycling infrastructure provision on the level of cycling. There are, however, many types of cycling infrastructures which can be installed in an urban area and the discussion is still ongoing on the effective design which could increase a street’s attractiveness to cycle on.

The design of cycling infrastructure, as with the infrastructure for motorized vehicles or railways, can be categorized into two general levels, which are network- and link-level designs. The network- or route-level designs include features such as the continuity of the routes, how good the paths connect destinations, the density of the cycling infrastructure network, the directness of the available paths, and other factors which are only admissible when the network of links, including intersections or junctions, is concerned as a whole. Travel time, although is a component of travel which has been shown to be significant in the determination of mode choice, is related to those network-level indicators and is thus not included as a variable in this research.

Meanwhile, link-level designs concerns the features of cycling infrastructure segment between two intersections (Stinson & Bhat, 2003). The table below shows the attributes which have been used to characterize link-level cycling infrastructure and its urban environment by previous studies.

Table 2 Attributes of cycling and road infrastructure in previous studies

Link-level attribute	Association with cycling preferences	Reference
	Cycling infrastructure design features	
Separation with motorized traffic		
Separation in general	In general, cyclists prefer separation from motorized traffic	Stinson & Bhat (2003); Mertens et al. (2014); Sanders (2003)
	Lack of dedicated cycling infrastructure hinders people to cycle	Akar & Clifton (2009)
Off-road cycle lane	Physically separated path adjacent to the street is less preferred than on-road bicycle lane	Stinson & Bhat (2003)
	Off-street facilities are preferred over on-road bike lanes	Abraham et al. (2002); Broach et al. (2012)
	Mixed results of before-and-after studies on cycling levels and introduction of new off-road cycle lane facilities	Burbidge & Goulias (2009); Cohen et al. (2008)
On-road cycle lane	Positive association between the cycle lanes and cycling activities	Abraham et al. (2002); Stinson & Bhat (2003); Tilahun et al. (2007); Dill & Carr (2003)
	Cyclists are willing to make detours to cycle on streets with designated cycle lanes	Dill (2009); Krizek et al. (2007); Tilahun et al. (2007)

	Commuter cyclists mostly use the most direct routes, which are often on-road cycle lanes	Aultmann-Hall et al. (1997); Stinson & Bhat (2003)
	No significant correlation is found between on-road cycle lanes and cycling activities	De Geus et al. (2007); Dill & Voros (2006)
Shared cycle & bus lane	Shared cycle & bus lanes are popular among cyclists in the UK	Ruth & Guthrie (2004)
	Shared cycle & bus lanes are less favored than other types of facility by both experienced and inexperienced cyclists	Caulfield et al. (2014)
Bike path	Travelers are willing to cycle longer on bike paths on parks	Abraham et al. (2002)
	Cyclists diverted very slightly from the most direct paths, except when the off-street bike path is of the highest quality (wide, good surface, extends to long distances)	Tilahun et al. (2007)
Separation with pedestrian	People dislike separation between cycle lane and sidewalks using bollards	Mertens et al. (2014)
Type of lane separation		
Physical separation in general	Agreement of preference is found in both cyclists and drivers on physical separation between their spaces, which relates to their perceived comfort	Sanders (2003)
	Mere visual separation (e.g. stripes) is not effective to attract new cyclists	Sanders (2003)
Specific type of separation (bollards, vegetation/hedge, curb, colorized pavement, stripes)	Bollards might be seen as "evasive" when used as separators	Mertens et al. (2014)
	Separation from traffic with hedge is preferred compared to with curb	Mertens et al. (2015)
	People still prefer low-traffic streets to cycle on than striped bike lanes on higher traffic streets	
Width of cycling infrastructure	Wider cycling lane increase cyclists' comfort since it reduces collision risk	Li et al. (2012)
	People prefer wider cycle lane, but it is not a priority	Mertens et al. (2014)
	No preference on wider or narrower cycle lanes	Sener et al. (2009)
Roadway surface material	Preference for smooth and even paths	Stinson & Bhat (2003); Mertens et al. (2014); Mertens et al. (2016)

Urban environment characteristics		
Geometric configuration		
Motorized vehicle lane width / Number of lanes	Roads with more lanes are less preferred to cycle on	Evans-Cowley & Akar (2014); Petritsch et al. (2006)
Adjacent traffic		
Motorized vehicle speed	There is a general dislike toward roads with higher adjacent motorized vehicle speed	Stinson & Bhat (2003); Evans-Cowley & Akar (2014); Caulfield (2014); Heinen et al. (2010); Sener et al. (2009); Broach et al. (2012); Mertens et al. (2016)
Motorized vehicle traffic density	There is a general dislike toward roads with higher level of traffic	Stinson & Bhat (2003); Evans-Cowley & Akar (2014); Caulfield (2014); Heinen et al. (2010); Sener et al. (2009); Broach et al. (2012); Dill & Voros (2007)
Presence of buses/trucks	Presence of trucks increases likelihood of serious injuries on cyclists and reduce the comfort of cyclists, hence less preferred	Allen-Munley & Daniel (2006); Wilkinson et al. (1994); Hurtubia, Guevara, & Donoso, (2015)

Presence of on-street parking	The presence of on-street parking reduces the street's attractiveness for cycling	Stinson & Bhat (2003); Evans-Cowley & Akar (2014); Broach et al. (2012)
	The presence of on-street parking increases the street's attractiveness for cycling	Harket et al. (1998)
Presence of vegetation	Vegetation which is too dense reduces the sense of safety of cyclists	Evans-Cowley & Akar (2014); Mertens et al. (2014)
Adjacent land-use density	Streets in a low density, residential area is preferred over medium and high-density area	Mertens et al. (2015)
Roadway class		
Arterial	Minor arterials are preferred to major arterials	Stinson & Bhat (2003)
Residential	Residential roads are preferred due to their lower traffic level	Stinson & Bhat (2003); Abraham et al. (2007); Broach et al. (2012)
Hilliness	Preference for moderately hilly terrain compared to flat terrain	Stinson & Bhat (2003); Sener et al. (2009)
	Cyclists avoid hilly terrains	Broach et al. (2012)

3.4 Conclusion

To summarize, a number of empirical findings have indicated that the provision of cycling infrastructure is significantly associated to improvement in the level of cycling trips. Ogilvie et al. (2011) suggests a model which indicates the influence of having infrastructure interventions on cycling behavior. Indeed, other factors for instance socio-demographic and household characteristics, natural environment factors such as climate and weather, and psychological factors such as attitudes and habits are also part of the equation. Nevertheless, those factors are more difficult to be altered by government authorities. Cycling infrastructure development and improvement continues to be one of the commonly chosen measure to improve the share of active mode usage in cities hence the relevance of this research to support cycling in urban areas.

As a part of answering the first research sub-question "*What link-level design features are relevant to be used to characterize cycling infrastructure?*" many attributes have been used in previous researches and in general they address five aspects: separation with motorized traffic, separation with pedestrians, type of lane separation, width of cycling infrastructure, and roadway surface material. Travel time, although has been shown to be an important determinant of cycling, is classified as a network-level feature and thus not included as an attribute in this research. The literature review shows that findings concerning the influence of some of the identified link-level attributes still have mixed results, and that acts as an input for the estimated attributes selection process which is elaborated in Chapter 5.

For the second research sub-question "*What are the relevant urban environment variables used to characterize road segments?*" a number of road segment characteristics which have been used in previous researches have been identified, which are the geometric configuration of the road segment, adjacent traffic speed and density, presence of heavy vehicles, on-street parking, and vegetation, adjacent land-use density, roadway class, and hilliness. Those identified elements act as candidates in the context attribute selection process in Chapter 5.

In addition to answering the two research sub-questions, the literature review done in this chapter also shows the possible effects travelers' personal characteristics have to their cycling behavior. Therefore, a number of personal characteristic variables such as gender, cycling ability, and cycling frequency are included as part of the survey.

CHAPTER 4.

THE CASE STUDY: TIRANA

This research of link-level cycling infrastructure design covers the Municipality of Tirana, Albania, as its case study. The main aims of this chapter are firstly to provide answer the third research sub-question: *"What are the main types of road commonly present in an urban area?"*, which will be addressed in the overview of the city's road hierarchy structure in Section 4.3. The second aim is to identify design choices made in the city's current and planned cycling infrastructure and also to identify elements of the actual road segments which can be used to characterize them, which are needed to answer the first and second research sub-questions regarding the relevant attributes and context attributes in the following chapter. A brief discussion regarding the city's current actions and visions to encourage urban cycling will also be presented to highlight the practical relevance of this study for the city.

4.1 OVERVIEW OF TIRANA

The Municipality of Tirana is the capital city of Albania, a country located in the western part of Balkan Peninsula in southeastern Europe. The city is part of the Tirana Metropolitan Area, one of the 12 prefectures of Albania.

Figure 4 Geographic location of Tirana (Google Maps, 2018)

Tirana is experiencing an explosion in population due to urbanization, especially since the communist regime which restricted population migration was brought down (Pojani, 2011a). Based on the latest survey done by the country's Institute of Statistics (INSTAT), in 2011 Tirana was inhabited by 622.575 people. Although indeed the number is rather small compared to other European capitals, given the city's small area Tirana's population density was already among the highest at the time (Pojani, 2011b). A study (JICA, 2012) projected the future population of Tirana to reach almost 900.000 in 2027.

Although the small area of the city and its flat terrain are favorable for non-motorized transport, car usage has been rapidly increasing since the communist-era's ban of automobile usage was lifted. Based on a 2007 survey, around two-thirds of the Tiranian households own at least a car (Pojani, 2011b). The heavy use of cars as the mode of choice by many Tiranians causes traffic jams throughout the city during the day (Pojani, 2011b). The effect is also amplified by presence of on-street parking, both legal or illegal (JICA, 2012). The high level of car traffic does not only affect the car users themselves due to the congestions but also the pedestrians who comprise around 30% of travelers in Tirana (JICA, 2012), exposing them to higher risk of safety and higher rate of air pollution. Assuming the growth rate of car ownership of 13.1% per year between the year 2000 to 2007 continues its pace and also taking the region's GDP growth rate into account, it was predicted that the number of cars owned by Tirana citizens would be more than tripled from 2007 to 2021 (ECAT Tirana, 2007).

4.2 Cycling in Tirana

As mentioned in the previous section, the compactness of the city and its terrain accommodate people to walk or cycle, and are further supported by the generally friendly climate (Van Veen, Nout, & van der Kloof, 2016). Nevertheless, the share of bicycle as the chosen mode of transport is declining over the years (Pojani, 2011a). Therefore, the municipality of Tirana is putting effort to increase the cycling level of the citizens as a more sustainable form of transport.

4.2.1 Cycling as mode of transport

Some research has been undertaken to investigate how cycling is seen by the citizens of Tirana as a mode as transport. In general, the studies agreed that most movements within the urban area can be conducted on foot or by cycling (Pojani, 2011a, 2011b; Van Veen et al., 2016). The compactness of the city is indeed beneficial since cyclists can travel from one side of the city to another in less than one hour (Pojani, 2011b). However, as can be seen from one of the studies (Pojani, 2011b), the share of people who use bicycle to commute fell from 15% of Tiranian men and 3% of Tiranian women in 2003 to 6% and 1% in 2007, respectively. A more recent modal split survey by the Municipality of Tirana in 2009 showed that the total modal split of cycling for both gender was 4% (Sotja & Lako, 2013).

The numbers are subjects to concerns because in the communist era, cycling was widely used by most as the citizens in Tirana to travel throughout the city (Pojani, 2011a). Based on an interview with an expert from Tirana municipality and also cited on two studies (Pojani, 2011a, 2011b), the hesitation to use bicycle to travel is partly caused by the stigma local people have toward it, which they see as "a mode of transport for poor people". Meanwhile, the use of car is popular since it can be shown as a status symbol. However, one study which was done recently by a Dutch consultant firm to investigate about the cycling conditions in Tirana (Van Veen et al., 2016) stated differently. Although indeed they confirmed that cars are perceived to be a symbol of wealth, based on the conversations they had in the city they did not found a significantly negative attitude toward cycling. Conversely, they presented their findings of the presence of many cyclists on the city's streets, indicating a thriving bicycle culture in Tirana that is potential to be reinforced further.

Interviews made for this research with young local citizens of Tirana also in general showed analogous results with the one by the Dutch consultant. They are aware of the positive impacts cycling can bring for the city's traffic conditions and most of them also stated that indeed the use of bicycle is feasible for travelling between most destinations in Tirana. Although not all of them actually cycle on the daily basis, the findings supported the positive attitudes many citizens, at the very least the young generation, have toward cycling. Nevertheless, many of them also complained about the price of bicycles in Tirana which is considered expensive for university students. The high risk of the bicycles being stolen also is also stated by a number of young local citizens as a factor hesitating them to own a bike.

4.2.2 Current cycling infrastructure

Based on observations made in the city and conversations with local citizens, there is indeed a momentum moving on about making cycling great again in Tirana. Community movements such as Critical Mass, a community of young cyclists who organize monthly event of mass cycling around the city, and also bike-sharing program by EcoVolis, a bicycle advocacy organization, are also actively promoting cycling. The municipality also shows their support and actions to increase the modal share of cycling by having educational programs to familiarize children with cycling and installing cycling infrastructure. Although indeed the network has yet to be fully developed, new cycling lanes are built in the recent years mostly on the main roads, and the existing ones are getting refurbished gradually (Pojani, 2011c).

Since many of the cycling infrastructure were just developed in the past two years or are currently under development, no official data on the use of those lanes, i.e. the number of cyclists, has been published. However, some general findings are apparent during a five-day observation period in summer 2018. Firstly, cyclists generally ride on the designated facility wherever it is available. Secondly, since the number of cyclists is not very large, no issue of congestion or dense bicycle flow was found on the bicycle lanes throughout the city. Thirdly, there is a problem of conflicts with pedestrians. Based on the observation and interviews with experts and local citizens, pedestrians often misuse cycling infrastructure as their own although level separations have been made, prompting the cyclists to make maneuvers to avoid collisions with pedestrians. Statements from the interviewees further confirm that conflicts with pedestrians are indeed troublesome for the cyclists. Nevertheless, while there are fences to further separate the pedestrian area from the cycling lane on certain roads, the separator is omitted at the newly developed cycling lanes.

There are a variety of designs regarding the cycling infrastructure in Tirana, in particular in the street- or link-level, as can be seen in a collection of images below.

Figure 5 Various designs of link-level cycling infrastructure in Tirana (Retrieved 15 June 2018 from https://www.facebook.com/ecovolis/)

In addition to the above images, a newer cycling lane was also recently installed on the streets of Bllokku area, which is a popular area close to the city center for young people to gather. The lanes are two-directional and painted green, with bollards separating the lanes from the motorized traffic. However, the bollards are said to be removed once the car users are used to not drive on the cycling facility and vice versa for the cyclists. Based on the observations, link-level design features of cycling infrastructure especially cycle lanes in Tirana that vary are the width, surface material and color, and separators from motorized traffic and also pedestrians. A question on how the designs were decided was included in the interview with an expert from the municipality. It is then apparent that the design processes were somewhat pragmatic in a way that the designs were confined with the spaces available and no fixed design guide was used to determine specific features. There was no clear statement on, for instance, why bollards were used in a specific roads and curbs on the others.

4.3 Structure of motorized transport network in Tirana

Around 250 kilometers of roads stretch throughout the Municipality of Tirana (Sotja & Lako, 2013). The main structure is made of three ring roads and a number of radial roads connecting the rings. Five of the radial rings are primary roads extending to the neighboring built areas. To cope with the increasing transport demand, the municipality devised plans to develop new roads, with the most prominent one being the outer ring road which has yet to be completed (JICA, 2012). Below is the structure of the future road network in Tirana, based on the so-called General Local Plan Tirana2030, which is an urban plan of Tirana for the year 2030.

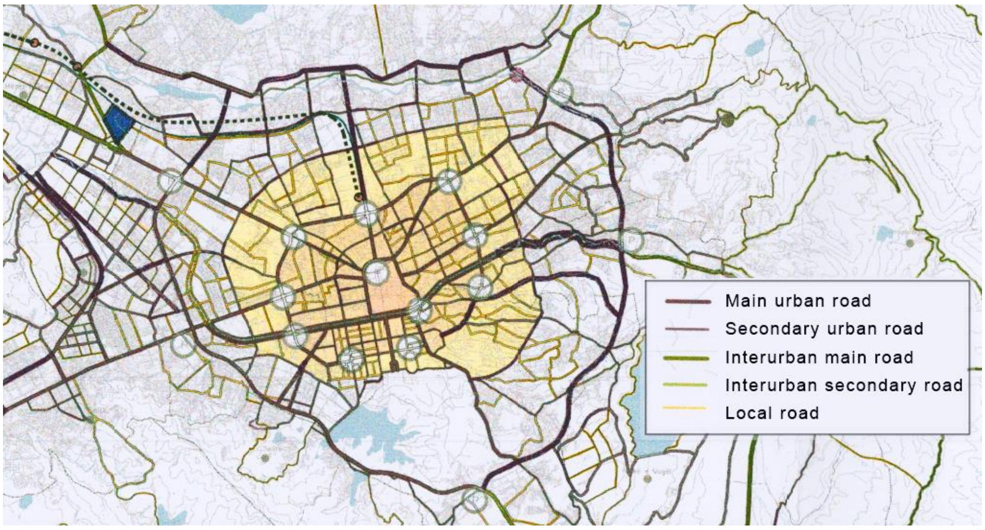

Figure 6 Future road network of Tirana
(adapted from Harta e rrjetir rrugor te propozuar*, retrieved 8 May 2018 from http://www.tirana.al/publikimepdf/Harta_e_rrjetir_rrugor_te_propozuar.pdf)*

As can be seen from the map in Figure 6 above, the roads in Tirana are classified into several categories. Based on Road Code of the Republic of Albania, the characteristics of the three main road types present in Tirana, which are primary, secondary, and local roads, are as follows (JICA, 2012).

Table 3 Road types in Tirana

Road type	Description	Functions	Speed limit*
Primary	High capacity road (5.300 pcu/hour) with separate carriageway for each direction, each with two moving lanes	• Connects city center to interurban roads • Bypasses city center • Links sub-centers in the city	60 km/h or above

Secondary	Medium to high capacity road (3.500 pcu/hour) with a minimum of two moving lanes	• Collects or disperses traffic from or between primary roads and other roads • Interconnects urban blocks	45 – 60 km/h
Local	All other roads with low capacity (2.200 pcu/hour)	Local entrances of blocks	30 – 45 km/h

*Source: ECAT Tirana (2007)

A number of typical road sections are also listed in the General Local Plan document. The sections show the link-level differences of roads which exist or are planned to be constructed in Tirana. As can be seen in Figure 7, other than the presence of cycling lane, the main variations which exist between the road sections include presence of busses, roadway width, number of lanes, and presence of on-street parking.

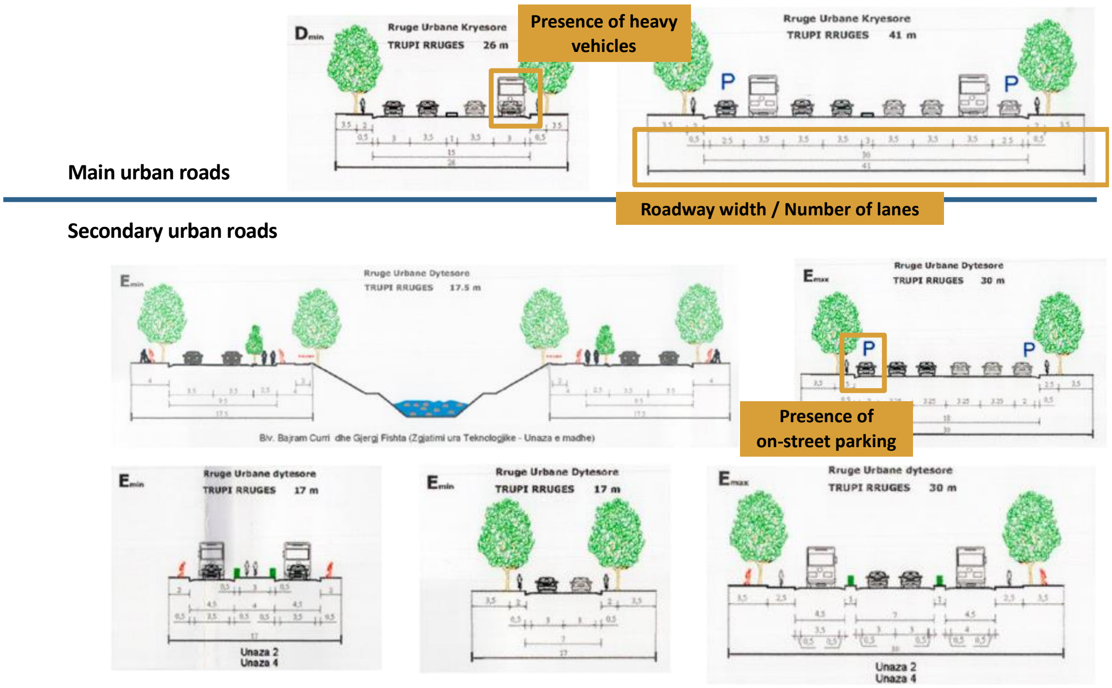

Figure 7 Variations of road section
(adapted from Harta e rrjetir rrugor te propozuar*, retrieved 8 May 2018 from http://www.tirana.al/publikimepdf/Harta_e_rrjetir_rrugor_te_propozuar.pdf)*

4.4 Conclusion

Answering the third research sub-question *"What are the main types of road commonly present in an urban area, and to what extent they can act as a proxy for urban environment characteristics?"*, in Tirana roads are classified into three main types: primary, secondary, and local. The types are distinguished by their functions in the urban road network, density of traffic flow, and maximum traffic speeds and therefore can act as a proxy for those attributes.

The overview made on this chapter also identify a number of cycling infrastructure design variables and urban road elements in Tirana which can be taken into consideration when answering the first and second research sub-questions of relevant attributes and context attributes further in Chapter 5. For the bicycle lanes, the designs vary in terms of lane width, surface material, and type of separators from motorized traffic and pedestrians. Meanwhile, apart from the distinguishing factors between road types which were mentioned in previous paragraph, the road segments can be differentiated by observing their widths, presence of heavy vehicles, and presence of on-street parking. The identified different designs and characteristics in addition are also used to be considered as the “levels” of estimated attributes, which selection process will be elaborated in the next chapter.

CHAPTER 5.

SURVEY DESIGN AND ADMINISTRATION

The research is conducted on an individual-level, and a stated preference experiment eliciting the choices made individually by travelers is used as the method to collect the data for the discrete choice models. As stated by Ryan, Bate, Eastmond, & Ludbrook (2001), experiments with discrete choice approach "allow estimation of the relative importance of different aspects …", or in this particular research, the relative importance of different bicycle infrastructure design elements.

In this chapter, firstly the process of constructing the stated preference is elaborated in Section 5.1. The beginning of the section covers the selection process of attributes and context attributes, which also derives answer the first and second research sub-questions: "*What link-level design features are relevant to be used to characterize cycling infrastructure?*" and "*What are the relevant urban environment variables used to characterize road segments?*". After the design has been finalized, the alternatives are translated into visual presentations in Section 5.2.

5.1 DESIGNING THE CONTEXT-DEPENDENT STATED PREFERENCE EXPERIMENT

People's valuations of attributes are conditional on the circumstances in which the choices are made (Oppewal & Timmermans, 1991). In other words, people might make different choices when different contexts are presented as backgrounds along with the choice sets. Inclusion of those context effects into a choice model may increase the performance of the model (Bos, Van der Heijden, Molin, & Timmermans, 2004; Molin & Timmermans, 2010; Tinch, Colombo, & Hanley, 2015).

As mentioned in Chapter 1 and 2, the possible effects of road characteristics contexts are subject to the investigation in this study. To enable observation of context effects, the "regular" choice sets with varying attributes and attribute levels are nested under the set of context descriptions, following the work by Oppewal & Timmermans (1991) as illustrated in Figure 8. The approach ensures each choice set is represented under each context and no correlation between the context descriptions and choice sets. Such larger experiment is needed to estimate the interactions between context variables and selected attributes. The context effects are included as interaction effects, since specifying them as generic variables will cause them to appear on both alternative in a choice set and hence their effects on choices cannot be observed. The context descriptions themselves are constructed by systematically vary the context variables using an experimental design (Molin & Timmermans, 2010).

Each of the choice tasks given to the respondents in a stated preference survey consists of alternatives, which are defined by a number of attributes with different attribute levels. An experimental design is used to specify the attributes and attribute levels of each alternative in each choice task. The selected experimental design also determines the number of choice situations required to be undertaken by respondents, which ultimately leads to the number of choice tasks given to each respondent (Choice Metrics, 2018).

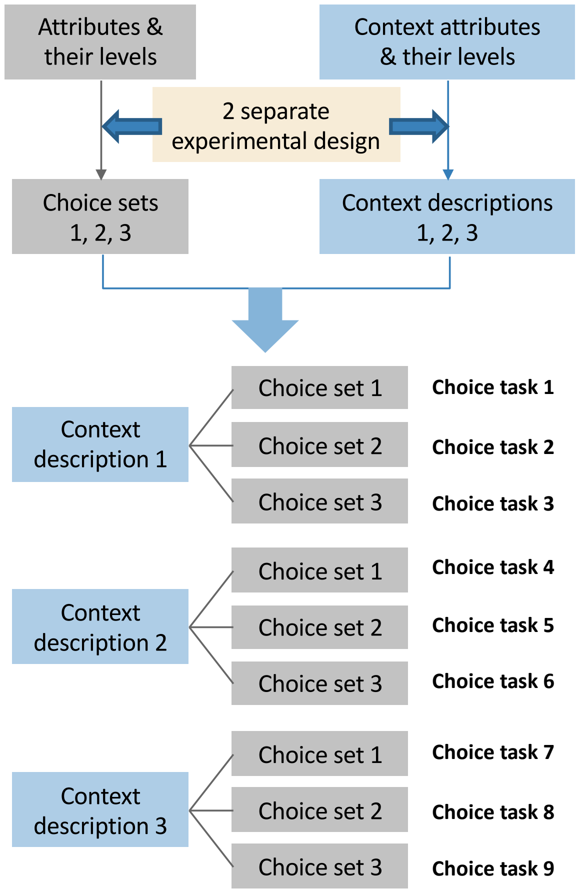

Figure 8 Construction of a context-dependent stated preference experiment

These are the three general steps in designing stated preference experiments, which descriptions are drawn from the design manual of Ngene software (Choice Metrics, 2018).

1. *Model specification*

   This first step covers alternatives, estimated attributes, and model type selection, as well as deciding whether an attribute is generic or only applies to certain alternative(s) and inclusion of interaction effects and nonlinear effects to the model.
2. *Generating experimental design*

   The choice situations and the number of choice tasks given to the respondents are determined in the second step. Ngene software (Choice Metrics, 2018) can be used to generate experimental designs for stated preference experiments.
3. *Constructing questionnaire*

   In the last step, the experimental design matrix is translated into choice situations which will be given to the respondents. The questionnaire can be either paper-based or web-based.

The application of those steps in constructing the stated preference experiment for this research is elaborated below.

5.1.1 Attributes, contexts, and levels selection

From the literature review done in the previous chapters it is apparent that there are many attributes, each with varying levels, which can be used to investigate cycling infrastructure design preferences. However, not all of them are relevant to the study in terms of its scope and its case study. Furthermore, having too many attributes to test in a single experiment would result in too many choice tasks for the respondents and therefore are prone to respondents' fatigue and unwillingness to participate. Therefore, selections have to be made on the most relevant attributes.

The experiment in this research aims to also estimate the effect of contexts to the preferences travelers made hence the use of context-dependent stated preference experiment to collect the needed data. Therefore, selections have to be made not only to filter relevant regular attributes and levels, but also to identify suitable context descriptions.

A. Selection of attributes and their levels

Four considerations are made in selecting the attributes for this research. *Firstly,* a priority is given to attributes which still have mixed results between studies. Therefore, this research can add more nuance and insights to the field. *Secondly*, it is preferred to have attributes which have been tested several times in prior studies. The notion is considered to increase the comparability of this study to other works in the literatures (Aldred et al., 2017) by strengthening or countering the results identified on previous studies. Those first two considerations are related to the scientific purposes of this research. *Thirdly*, the attributes preferably can be conveyed visually to be suitable for an image-using stated preference experiment. *Fourthly*, the attributes are considered based on their relevance for design manuals and the conditions in Tirana as the case study. The last two considerations lend to the practical aspects of this research.

For the first two considerations, analysis on the attributes used in previous literature which are listed in Chapter 3 is done by using three variables: 1) significance of the attribute; 2) the number of literatures using them in their experiment, and 3) the attribute's estimates across the literature. The results of the analysis are as follows.

Table 4 Analysis of attributes in literature

Attribute	Found to be significant?	Has been used in SP experiments? *	Still has mixed results?
Level of separation with motorized traffic	Yes	Yes (+++)	Yes
Level of separation with pedestrians	Yes	Yes (+++)	Yes
Type of lane separator	Yes	Yes (++)	Yes
Width of lane	Yes	Yes (++)	No
Surface material	Yes	Yes (++)	No

* Note: (+) = used once, (++) = 2-3 experiments, (+++) = more than 4 experiments

Three most potential attributes are identified from the analysis of used attributes in scientific literature done above, which are level of separation with motorized traffic, level of separation with pedestrians, and type of lane separators. All three of those attributes are found to be significant in previous works, nevertheless still have mixed results. Two of the attributes were tested in more than four experiments (Caulfield et al., 2012; Ghekiere et al., 2018; Mertens et al., 2015; Stinson & Bhat, 2003; Tilahun et al., 2007), while the other one was used in three experiments (Caulfield et al., 2012; Mertens et al., 2016; Stinson & Bhat, 2003).

For the practical relevance consideration, firstly an analysis on design guides of cycling infrastructure is also done to obtain attributes by listing the design features which are varied in the guides. From reviewing the design guides two design variables which are present on multiple guides are the width of bicycle lane and type of lane separator (Andersen et al., 2012; Dufour, 2010; Ove Arup & Partners Ltd., 2013). Secondly, the various design features in Tiranian cycling infrastructure identified in Chapter 3 are revisited.

The attributes mined from those three approaches (scientific literature review, grey literature review, and observation) are then compared. Selection of final attributes are made by identifying the attributes which are present on the three lists, illustrated in Figure 9 below.

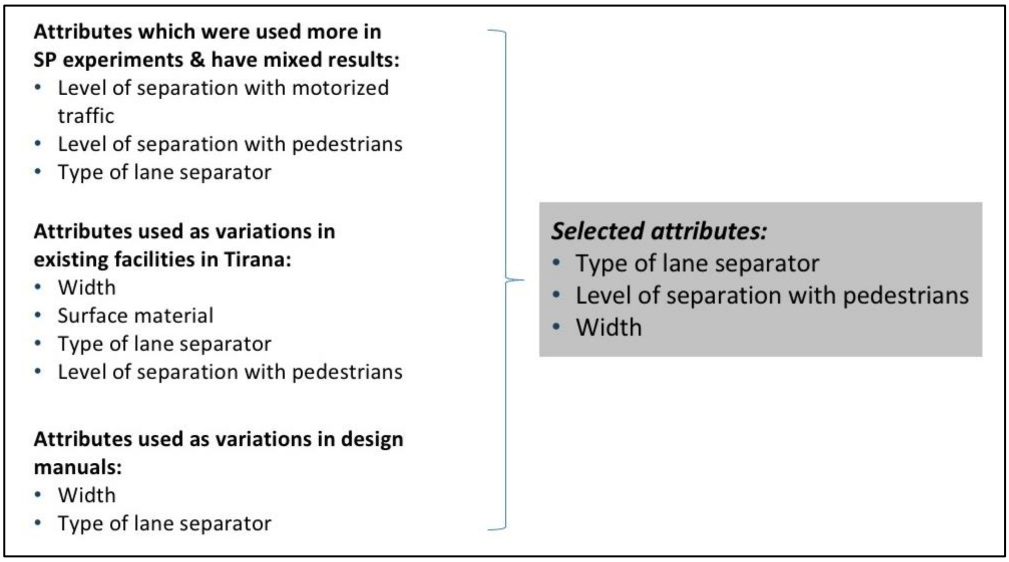

Figure 9 Final selection of attributes

The selection process results in three attributes: *type of lane separator with motorized traffic, level of separation with pedestrians*, and *the width of bicycle lane*. The level of separation with motorized traffic, which for instance concerns whether the cycling infrastructure is situated on or off the road, or whether the lane is shared with buses, is not included as an estimated attribute. Instead, it is decided to have the separation level fixed as regular bicycle lane which is situated on the same level with the traffic, since the type is the one relevant with the actual conditions in the urban streets of Tirana.

Having chosen the attributes to be tested in the experiment, the next step is to determine the levels of each attribute. In addition to the levels used in scientific literature, the levels are also selected considering the actual variations of design features in Tirana to ensure that the alternative conveyed are deemed realistic by the respondents and feasible to be implemented in the city. The analysis can be seen in the Table 5, with the levels written in bold are the ones shared between multiple studies.

Table 5 Levels of attributes

Attribute	Previous study	Levels in the study	Proposed levels for this study
Type of separation with motorized traffic	Mertens et al (2016); Ghekiere et al (2018)	1. **No facility** 2. **Marked lane** 3. **Curb** shared with pedestrian 4. Hedge shared with pedestrian 5. **Curb+color** shared with pedestrian 6. Hedge+color shared with pedestrian	1. Marked lane + color 2. Curb-separated + color 3. Color + bollards (design from actual cycling infrastructure in Tirana)
	Caulfield et al (2012)	1. **No facility** 2. Shared bus-bike lane 3. **Only marked lane (on-road)**	

		4. **Curb**+vegetation (off-road)	
	Hurtubia et al (2015)	1. **No facility on roadway** 2. **Marked lane on roadway** 3. No facility shared with pedestrian 4. Marked lane on pedestrian path	
	Stinson & Bhat (2003)	1. **No facility** 2. **Marked lane** 3. Separated path (separator not specified)	
	Tilahun et al (2007)	1. **No facility** 2. **Marked lane** 3. Completely off-road (at park)	
	Sener et al (2009)	1. **No facility** 2. **Marked lane**	
	Wardman et al (2007)	1. **No facility** 2. **Marked lane** 3. **Curb-separated** 4. Completely off-road	
	Mertens et al (2014)	1. **Color+curb** 2. Color+curb+hedge	
Type of separation with pedestrian	Mertens et al (2016); Ghekiere et al (2018	1. **Curb-separated** 2. **Painted line** 3. **Painted line + color**	1. Level separation 2. Level separation + vertical separators (fence)
	Caulfield et al (2012)	1. No separation 2. **Painted line**	
	Rosetti et al (2017)	1. No separation 2. **Painted line** 3. **Curb-separated**	
	Mertens et al (2014)	1. **Color** 2. **Color + bollards**	
Cycle lane width	Sener et al (2009)	1. 1,5 bicycle width (3,75ft) 2. 2,5 bicycle width (6,75ft)	1. Narrow 2. Wide
	Mertens et al (2014)	1. **Narrow** 2. **Wide**	
	Rosetti et al (2017)	1. **Narrow** 2. **Wide**	

It is to be noted that although "no separation" level was present in two out of four studies investigating the "level of separation with pedestrian" attribute, the level is not included in the estimation. This is done because facility sharing with pedestrians has been found to be not desirable from both cyclists' and pedestrians' points of view (Rosetti et al, 2017; Heydon & Lucas-Smith, 2014) and to cause safety issues from cyclist-pedestrian conflicts (Parkin & Koorey, 2012; Aultmann-Hall & Hall, 1998). The final selection results in one 3-level attribute and two 2-level attributes to be tested in the experiment.

B. Selection of context attributes

Similar analysis is also done on the identified context attributes from the published literature. The previously mentioned three variables are also used to consider the relevant contexts to be used in this study, with the addition of the use of the context attributes in design manuals to increase the practical relevance of the results. The results are given as follows.

Table 6 Analysis of context attributes in literature

Context attribute	Found to be significant?	Has been used in SP experiments?*	Still has mixed results?	Used in design manuals?
Width of roadway / # lanes	Yes	Yes (+)	No	**Yes**
Adjacent traffic speed	Yes	**Yes (+++)**	No	**Yes**

Adjacent traffic volume	Yes	Yes (++)	No	**Yes**
Presence of buses/trucks	Yes	Yes (+)	No	**Yes**
Pedestrian volume	Yes	Yes (++)	**Yes**	**Yes**
Cyclist volume	Yes	Yes (++)	No	**Yes**
Presence of on-street parking	No	Yes (++)	No	**Yes**
Presence of vegetation	Yes	**Yes (+++)**	**Yes**	No
Presence of traffic calming devices	Yes	Yes (+)	No	No
Adjacent land-use density **	Yes	Yes (++)	No	
Adjacent land-use function **	Yes	Yes (++)	No	No
Road type	Yes	Yes (++)	No	**Yes**
Hilliness	Yes	Yes (++)	**Yes**	**Yes**

* Note: (+) = used once, (++) = 2-3 experiments, (+++) = more than 4 experiments
** Often combined with road type

Based on the analysis above, the five context attributes selected for the experiment are *roadway width, traffic speed, traffic volume, pedestrian volume,* and *presence of heavy traffic.* However, as will be elaborated in the next section, these context attributes are still subject for further iterations.

5.1.2 Generating experimental design

After the attributes, their levels, and the context chosen to be examined have been chosen, they are used to construct the stated preference experiment. In this chapters, the process of experiment construction will be elaborated. For context-dependent stated preference experiment, two separate experimental designs have to be generated, one for varying the levels of attributes to obtain choice sets and the other for constructing the context descriptions. As mentioned previously, the choice sets are then nested under each context description (Oppewal & Timmermans, 1991).

A. First experimental design: Choice sets

The first experimental design to obtain choice sets was done in Ngene. If a full-factorial design is applied, an experiment with one 3-level attribute and two 2-level attributes will need 16 choice sets. However, 16 choice sets are deemed too many since the choice sets will be nested under choice descriptions, further multiplying the number. Therefore, an orthogonal design was specified to be generated in Ngene. Using sequential construction and specifying attribute level balance, 12 choice sets are generated and the design is used for the experiment.

By definition, in an orthogonal design no correlation is present between the main attributes in an alternative (Choice Metrics, 2018). It does not guarantee that there will be no correlation between interaction effects. However, there might be interaction effects between “width” and “type of separation” attributes. For example, curb or bollards may not be as attractive when the space available is limited (narrow cycle lane). If it is indeed happening, the other parameter estimates will be confounded, or on the other words there will be a possibility of bias on main effect estimates. Possible procedures searching for a design which eliminates correlation between the main effects and the interaction effects are to apply foldover design or to specify the interaction in Ngene. If a foldover design is specified, the two-way correlation will be eliminated on the cost of having twice the number of choice sets. That will result in 24 choice sets which has been stated to be too many. In the second alternative, by specifying the predicted interaction in the Ngene syntax the software will search for a design “which minimize the correlation between the specified interaction and other parameters” (Choice Metrics, 2018).

Nevertheless, when the correlation matrix from the generated orthogonal experimental design was checked, already no correlation was present between interaction effects and other parameters. Therefore, the 12-choice set design is still suitable for the experiment. The syntax used to generate the experimental design in Ngene is presented in Appendix A.

B. Second experimental design: Context descriptions

A second experimental design was generated to obtain context descriptions. However, several approaches were considered in developing the context descriptions and the process was not as straightforward as the first experimental design.

The first possible approach was to have a number of road types as the context descriptions, each with pre-specified width, speed, traffic volume, pedestrian volume, and presence of heavy traffic. The road types would be based on the categorization of roads in Albania as mentioned in Chapter 4, which are primary, secondary, and local roads. Given this approach, three context descriptions would be obtained. In terms of limiting the burden of respondents, the low number was acceptable. Nevertheless, this approach has a number of drawbacks. By pre-specifying the road types' characteristics solely based on the road specifications in Albania, the findings might not be generalizable to road types in other countries. In addition, two roads within the same type might not even have the same characteristics. For instance, there might be a secondary road which is also used by heavy vehicles, while another secondary road is exclusively used by regular vehicles.

The second option was to specify two levels for each five context attributes and use Ngene software to generate an experimental design from them. Five 2-level context attributes result in 64 context descriptions if all effects are to be estimated, and 8 context descriptions for an orthogonal design. The approach would result in a complete estimation of context effects. However, there is an issue of the resulting combinations of levels. Some combinations are not possible or not realistic, e.g. higher traffic volume is usually only permissible on wider roadway, and speed limit is also associated with roadway width. This is not favorable since unrealistic alternatives might make the respondents question the experiment's credibility.

The third approach was to group the often-correlated context attributes, which are the traffic speed, traffic volume, and lane width. "Road type" is then used as a proxy attribute for those three, which can be seen in the table below.

Table 7 "Road type" context attribute levels

Level	Road type	Width	Average traffic speed	Traffic volume
2	Primary	Wide	High	High
1	Secondary	Medium	Medium	Medium
0	Local	Narrow	Low	Low

Adding "Road type" context attribute to represent traffic speed, traffic volume, and lane width altogether, the resulting set of context attributes and their levels to be estimated are as follows.

Table 8 Context attributes and levels

Context attributes	Levels
Road types	1. Primary

	2. Secondary 3. Local
Pedestrian volume	1. Low 2. High
Presence of heavy vehicles	1. Yes 2. No

Since in this step we only needed to obtain context descriptions and not choice sets, a design from a basic plan was used. The basic plan chosen was the one able to accommodate one 3-level attribute and two 2-level attributes. From the basic plan it was apparent that 8 context descriptions are needed. However, two context descriptions had to be crossed out since they contained a combination of heavy vehicles in a local road, which is not possible in reality. The consequence is the orthogonality of the context descriptions cannot be preserved. Using SPSS software, a 0.433 correlation between "Road type" and "Presence of heavy vehicles" is found.

The resulting context descriptions are:

1. Local road, less pedestrians, no heavy vehicle
2. Local road, many pedestrians, no heavy vehicle
3. Secondary road, less pedestrians, no heavy vehicle
4. Secondary road, many pedestrians, heavy vehicles
5. Primary road, many pedestrians, no heavy vehicle
6. Primary road, less pedestrians, heavy vehicles

The 12 choice tasks obtained from the first experimental design of main attributes are then nested under the six context descriptions above, resulting in 72 choice situations in total. To limit the burden of the respondents, each respondent is only presented with three choice tasks per context description. The set of three tasks per context description is selected randomly, with the consequence of introducing correlations between estimated parameters. In the end, each respondent is given 18 choice tasks to complete in the stated preference experiment section of the survey.

5.2. Developing the Visual Alternatives

The stated preference experiment used images to convey the choices in the questionnaire. To make the visual representation as realistic as possible, the images were developed by manipulating photos from Google Street View using Photoshop instead of rendered completely from a 3D modelling software. A similar approach has been done previously on a number of published works (Ghekiere et al., 2018; Hurtubia et al., 2015; Mertens et al., 2017). The workflow done to develop the visual choice sets is illustrated as follows.

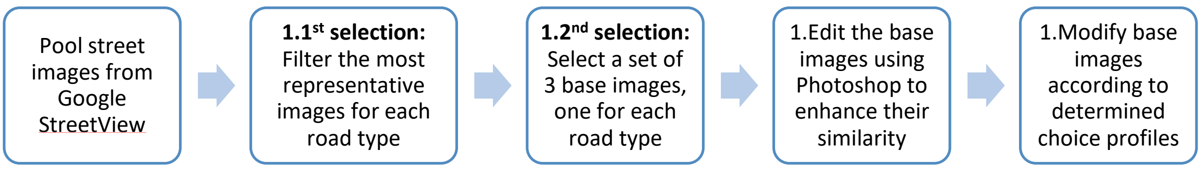

Figure 10 Workflow of visual choice set development

A thorough selection was done to obtain the images that are deemed to be best represent the typical scenery primary, secondary, and local roads would have in Tirana. Additionally, the set of three base images should be of similar quality in terms of the light, angle, shadow, color tone, and other elements other than the examined attributes for instance the function of the buildings along the road. This is done to reduce It was challenging to find images with the expected similarity, thus further modification was made in Photoshop to make the images look similar and to reduce distracting details, such as derelict details in buildings and electric cables. It is important to achieve the highest possible level of similarity to reduce the risk of respondents being focused on accidental variations in details (Jansen, Boumeester, Coolen, Goetgeluk, & Molin, 2009). Afterwards, it was to modify the images accordingly to the characteristics defined in Table 7. The results of that step can be seen in the figure below.

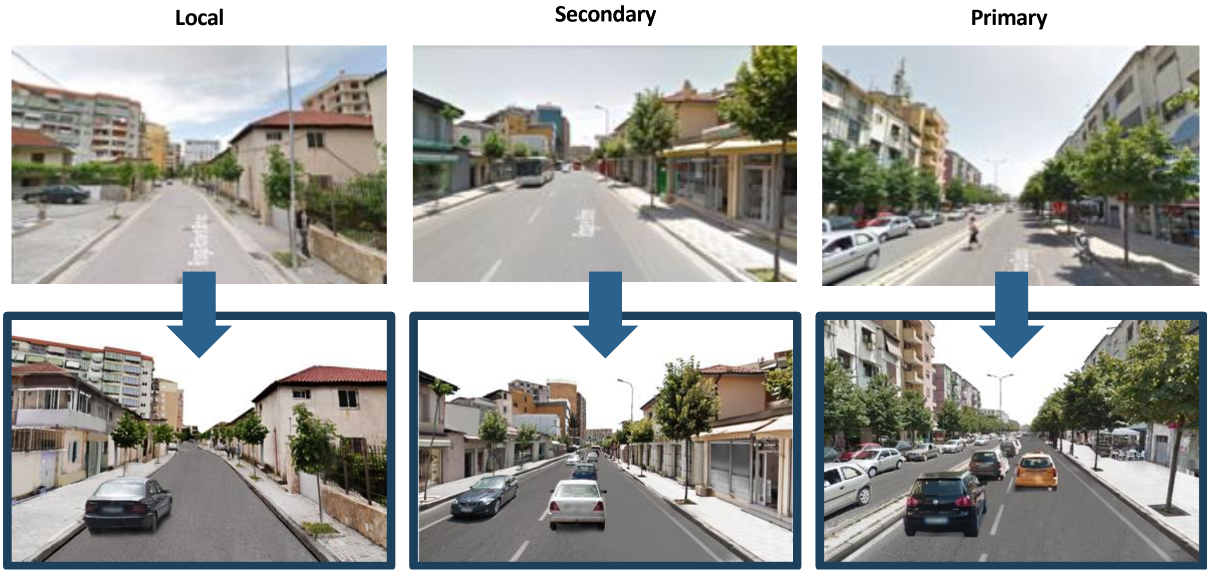

Figure 11 Base images modification

The final step of developing the visual choice set was to modify the base images according to determined choice profiles. Some example of the final images which were used in the questionnaire are illustrated in Figure 12. As can be observed, the two images are based on the same base image which is the secondary road. However, the base image was modified by adding a bus to represent the presence of heavy vehicle on the road and changing the number of pedestrians, and the attribute levels were changed to match their specified profiles. An image of a cyclist was also added, firstly as a subject for the respondents to relate to ("*imagine you are the cyclist in the picture*") and secondly as a human-scale so that the respondents can benchmark the scale of the other objects in the image.

At the preliminary survey, the options were conveyed exclusively by images. However, some of the respondent pointed out the necessity to further clarify the bicycle lane width and the average traffic speed. Therefore, in the actual survey some texts were added to clarify the levels.

The average adjacent speeds specified in the choices are based on average traffic speed data on a number of roads in Tirana (Drejtoria e Transportit e Trafikut Rrugor, 2017). The data was collected on the 4th quarter of 2017, and the measurements were done on peak and off-peak hours. The average speed data used in the questionnaire are the peak hour speeds, which are 35 km/h, 25 km/h, and 15 km/h for primary, secondary, and local road contexts, respectively.

The width for "narrow" bicycle lane is based on the absolute minimum bicycle lane width specified in PRESTO Cycling Policy Guide (Dufour, 2010). As for the "wide" lane, the value is based on the recommended comfortable width for low flow, i.e. under 1000 cyclists per day, suggested by the same guidebook and also by Transport for London (2014).

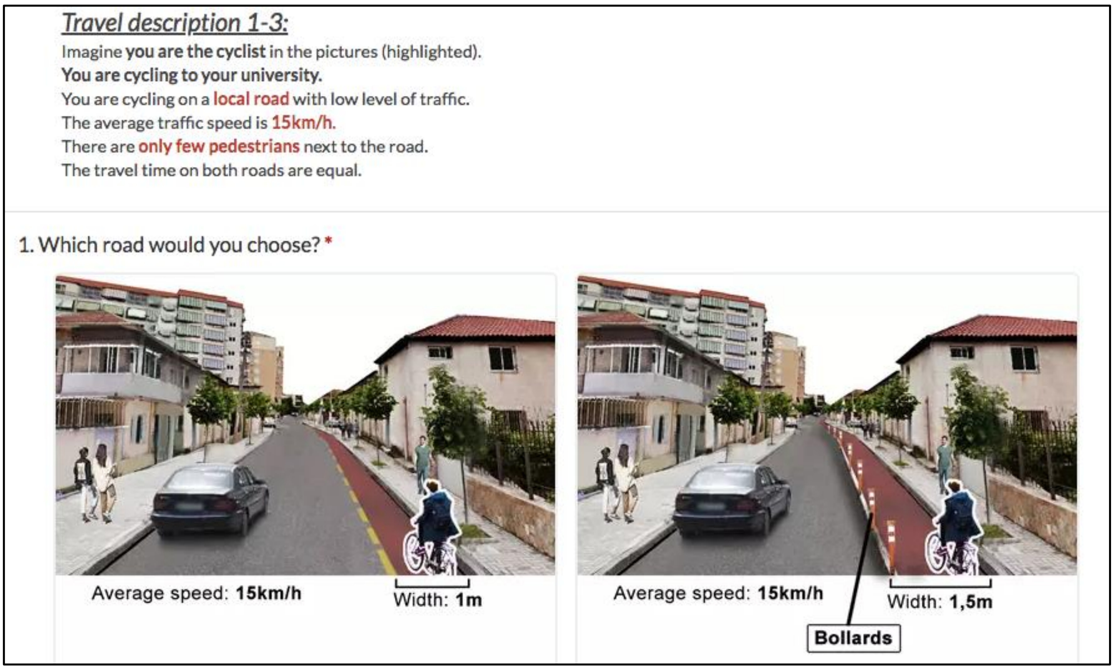

Figure 12 Example of a choice task in the final survey

5.3 DATA COLLECTION PLAN

The experiment data is collected through a web-based survey. The questionnaire is put online via a survey hosting website and the link is spread through social media platforms. The online survey was made available for two weeks in the summer of 2018. To be able to reach the target audience, a number of local young people in Tirana were willing to help posting the link to their communities. Some of the communities which shared the survey link on their social media pages were Critical Mass Tirana, TedX Tirana, and EcoVolis. The link was also shared multiple times by individuals. In addition of sharing the link via social media, the distribution of the survey was also done manually by asking people on a face-to-face basis to fill in the survey.

5.4 CONCLUSION

To provide answers for the first research sub-question, "*What link-level design features are relevant to be used to characterize cycling infrastructure?*" and second research sub-question "*What are the relevant urban environment variables used to characterize road segments?*", a list of selected attributes, context attributes, and their levels is presented in Table 9 below.

Table 9 Tested link-level main attributes, context attributes, and their levels

Main attributes	Levels
Type of separation with motorized traffic	1. Colored lane with painted stripes only 2. Colored lane with concrete curb 3. Colored lane with bollards
Type of separation with pedestrians	1. Level separation only 2. Level separation and fence
Bicycle lane width	1. Wide (1,5 m)

	2. Narrow (1 m)
Context attributes	**Levels**
Road types	1. Primary 2. Secondary 3. Local
Pedestrian volume	1. Low 2. High
Presence of heavy vehicles	1. Yes 2. No

The road type attribute is intended to act as a proxy for width, average traffic speed, and traffic volume. Given the three context attributes and their corresponding levels, eight context descriptions are generated from a basic plan. Two of the descriptions are excluded as they are not possible to be present in reality with a consequence of sacrificing the orthogonality of the design. Nesting the choice sets of main attributes under the six context descriptions, in total 72 choice tasks are generated. However, to limit the respondent's burden, each individual is only given 18 choice tasks to complete.

A number of iterations were made in the process of developing the images to convey alternatives in the survey. Potentially distracting details were removed, and to clarify level specifications which were stated to be "vague" in the pilot survey text descriptions are added for some of the variables to the main survey.

In addition to the stated preference experiments, questions to identify the personal characteristic and travel habits of the respondents are included in the survey following the results of literature review in Chapter 3, which highlights the possible influence those variables might have on the choice behavior. A survey verification test, which has been described in Chapter 2, is made available for the respondents to participate in the final part of the survey should they opt to do so. To summarize, the structure of the main survey can be seen in Table 10.

Table 10 Structure of the survey

Section	Number of questions	Presentation method
I: Stated preference experiment	18	Visual choice experiment, with additional text descriptions for some variables
II: Personal characteristic	6	Questionnaire with multiple choice options
III: Travel habits	3	Questionnaire with multiple choice options
IV: Survey verification test (optional)	2	Questionnaire with multiple choice options
V: Ideas for cycling infrastructure in Tirana	1	Open question

CHAPTER 6.

MODEL ESTIMATIONS AND RESULTS

The main objective of this chapter is to answer the fourth research sub-question of this study: "*To what extent the values perceived by Tiranian travellers from the design attributes of bicycle lane vary under different contexts of urban environment?*" Discrete choice models are estimated from the pool of collected data to derive the values, and a discussion is made on the outcomes of the analysis. Preceding the discussion, firstly a quantitative description covering the personal characteristics and cycling habits distribution among the respondents is presented, followed by the outcomes of the survey verification test. Following that, the steps taken to analyze the data are elaborated to provide clarity of the assumptions and decisions made along the model estimation process.

6.1 DESCRIPTIVE STATISTICS

The administered web-based survey gathered a total of 205 responses. Among those, 120 respondents provided complete responses on the stated choice questions. Filtering out the responses from non-targeted audience, i.e. those who are not familiar with the typical road situations in Tirana or not university students, 108 valid responses were collected and led to a total of 1.944 observations. The assumption of respondents' familiarity of Tirana was based on the data of the geographical area from which they filled in the survey.

6.1.1 RESPONDENTS' CHARACTERISTICS AND CYCLING HABITS

A quantitative analysis will be made on the socio-demographic characteristics and the cycling habits of the respondents who gave valid responses in the main survey, to see how the sample represents the population in Tirana. Table 11 below shows the distribution of respondents' characteristics.

Table 11 Respondents' characteristics distribution

Variable	Absolute (N = 108)	Relative (%)
Age group		
< 18 years old	1	1%
18 – 25 years old	56	52%
> 25 years old	51	47%
Gender		
Male	56	52%
Female	52	48%
Bicycle ownership		
Own a bicycle	91	84%
Do not own a bicycle	16	15%
Missing values	1	1%
Distance from residence to campus		
< 1 km	23	21%

1 – 5 km	50	46%
5 – 10 km	23	21%
> 10 km	12	11%
Cycling ability		
Beginner	9	8%
Intermediate	38	35%
Advanced	61	56%

Considering practical reasons such as the timeframe of the study, it was decided on the early phase of the research to conduct the survey via online platforms and to use English as the language of choice in the survey. Those decisions brought several consequences, for instance limiting the groups of audience to be reached by the survey. It was predicted that if no target audience group was set, the respondents would nonetheless be biased toward the younger age groups due to the language- and digital-barriers which are still present in the country's older generations. Therefore, the survey was further designed to specifically target the group of university students, which is most probably not prone to those barriers. Although it might be argued that the needs and preferences of the group are not necessarily similar to the general population, studies investigating the travel behavior of university students, especially regarding active modes, are emerging in recent years (see, for instance, Akar & Clifton, 2009; Motoaki & Daziano, 2015; Whalen, Páez, & Carrasco, 2013). Three of the reasons why the insights gained from university environment are deemed valuable include: 1) high number of commuting trips are generated due to the presence of universities, hence the need to promote active and more sustainable modes within the community (Whalen et al., 2013), 2) habits formed in the youth are likely to be adopted in the long term (Balsas, 2002), and 3) since the present-day students will become the ones occupying "influential roles" in the community (Tolley, 1996) it is important to develop environmentally-concious mentality among students (Balsas, 2002). In addition, there are 91.737 enrolled university students in Tirana (INSTAT, 2018b), therefore comprising more than 1/10 of the city's population.

Several deviations from the university student population statistics are apparent. Both genders are represented almost equally in the sample, while there are considerably more females within the university students group in Tirana (INSTAT, 2018b). However, if the whole population of Tirana is considered, the almost equal number of people of the two genders is indeed representative (INSTAT, 2018a). The most notable deviation is observable on the cycling ability variable, which shows a clear bias toward the groups of intermediate to advanced cyclists. The deviation could be attributable to the snowball sampling distribution method of the survey. People who already cycle are more supportive towards cycling infrastucture advocacies, thus the survey was spread mostly by cycling communities or cyclists who are interested in the cause.

In accordance to the observed tendency in the sample towards groups who have more confidence in their cycling ability, bicycle is also shown to be the mode of choice to commute by half of the respondents, as illustrated in Figure 13. More than three-quarter of the respondents also stated that they last rode their bicycles within a week, further showing that many of the respondents are already regular cyclists. The consequences of the observed deviations from the population statistics on the findings will be discussed further in this section.

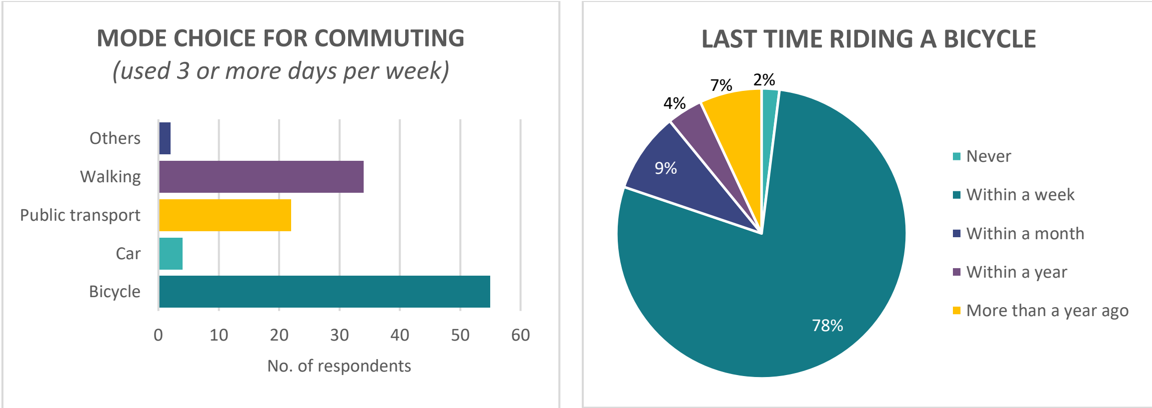

Figure 13 Respondents' travel habits

A Pearson's correlation matrix is derived using SPSS software to investigate the correlations between the socio-economics and travel habits variables, as can be seen in Appendix B. In general, the significant correlations with the highest values are as expected, which could be interpreted as a sign of reliability of the data. Owning a bicycle is positively correlated to frequency of commuter cycling and cycling confidence to a lesser extent. Respondents who are more confident in their cycling ability also cycle more. Other strong correlations are present between gender with cycling ability, and gender with cycling frequency. As shown in Figure 14, females are less confident in their cycling ability, suggesting that there are more male cyclists in the city. This finding supports previous literatures which suggested the presence of gender bias to cycling in Balkan areas (Pojani et al., 2017) and the lesser cycling rates females have due to, for instance, perceived risk of safety especially in countries with low utilitarian cycling trips (Garrard et al., 2008; Tilahun et al., 2007).

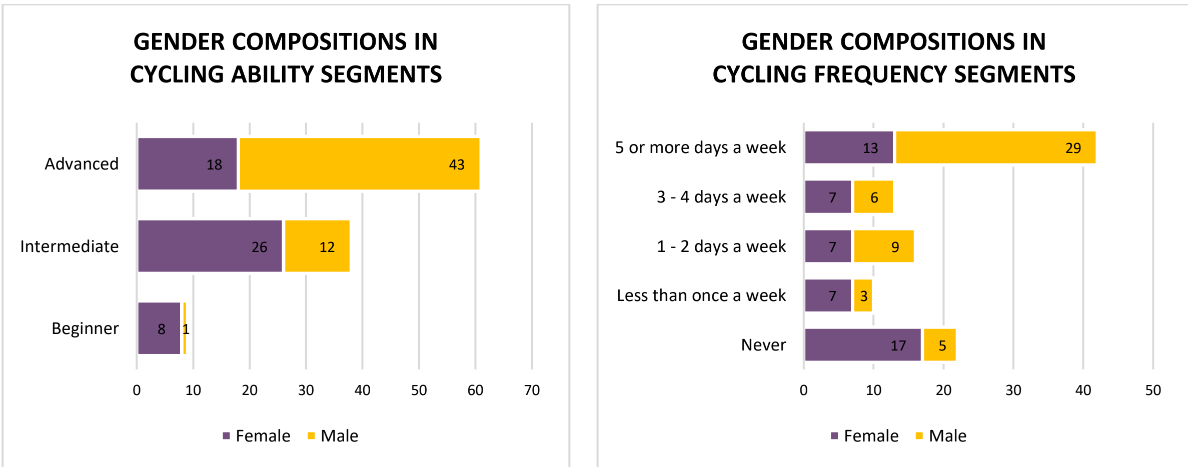

Figure 14 Gender compositions in cyclist segments

Considering the representativeness of the sample group, the data does not represent the population of Tirana in the following ways: firstly, the sample taken consists of university students and secondly, a large share of the respondents already cycle on a relatively regular basis. However, given the distribution of other socio-demographic attributes such as gender, age group, trip distance to campus, and ability to cycle, the sample is rather heterogeneous and represent the group of Tiranian university students well. The fact that more cyclists are represented in the group brings a consequence on how the results should be interpreted as the group has been shown in previous researches to have differences in their preferences compared to people who do not cycle regularly. Therefore, conservatively, this implies that the results might be not suitable to derive design recommendations which straightforwardly could encourage non-cyclists to cycle more, but rather to accommodate people who already cycle to have better experiences in cycling.

In addition to questions identifying personal characteristics and cycling habits, the respondents were asked to choose the factors which hinder them to cycle more. The answers obtained are shown in Figure 15.

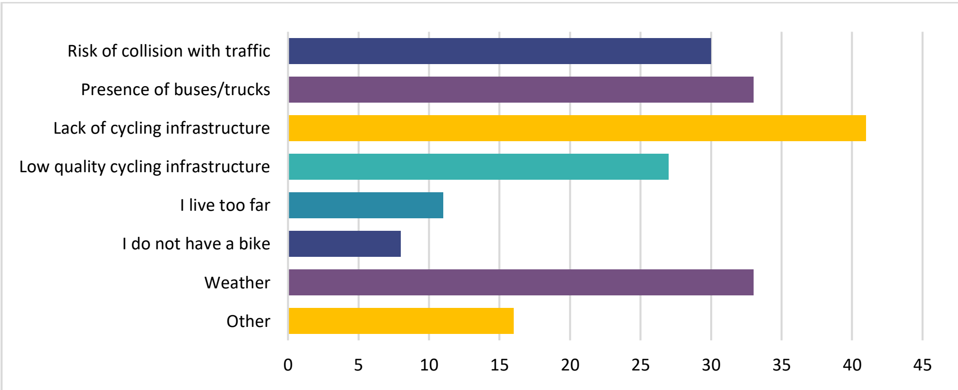

Figure 15 Hindrance to cycle more

It is apparent that the most chosen factors are the lack of cycling infrastructure, followed by the presence of buses/truck on the cycling route and weather, risk of collision with motorized traffic, and low-quality cycling infrastructure. The first factor is expected since the cycling network in Tirana have not been fully developed yet. The bicycle infrastructure has been only installed on the major roads as explained in Chapter 5. High level of traffic and frequent buses also prompts the concern of colliding with motorized traffic and heavy vehicles. The data furthermore imply the inclination of the Tiranian respondents to have a segregated cycling infrastructure, to reduce perceived collision risk with the traffic. These qualitative data serve as one measure to check the validity of the quantitative model's outputs.

6.1.2 Survey verification test results

In Chapter 2.2 it has been discussed that one possible issue of using images to convey alternatives in a survey instead of explicitly specifying them in texts is misestimation of attribute levels by the respondents. To detect if the issue is indeed taking place in the survey, a set of questions were included to check whether the respondents' actual perception on the attribute levels matches the intended levels depicted by the images. In the preliminary survey, the variables which distinctions were still vague according to the respondents are "*traffic speed*" and "*bicycle lane width*". As mentioned in Chapter 5.2, verbal descriptions of them were then added to the main survey. To check if the added texts improve the clarity of the conveyed alternatives, questions about how the respondents perceive the magnitude of the two variables were asked in the main survey. Presented in Figure 16 are the results of the test.

Some perception distortions do occur to some extent on both variables. 23,5% of the respondent under-estimate the width of lane. A significant share of the respondents also under-estimate the traffic speed, especially in the primary road context. The misperception of bicycle lane width level might be due to the chosen value of width, which difference with the narrower counterpart might not be large enough. On the other hand, the "*speed*" variable is indeed relatively difficult to be conveyed by a static image and the under-estimation might be caused by several reasons. The first one, similar to the possible cause of "*width*" under-estimation, relates to the chosen value. Although a written value of the average speed has been provided and the average speed of the primary road is the highest among contexts, the respondents do not base their magnitude perception on comparability basis and thus means that the sole value of 35 km/h is not sufficient to be considered as a "high" speed. The second possible reason might be distractions from other variables. In this case, it is possible that since there are more cars depicted in the primary roads, the respondents intuitively associate it with a lower traffic speed.

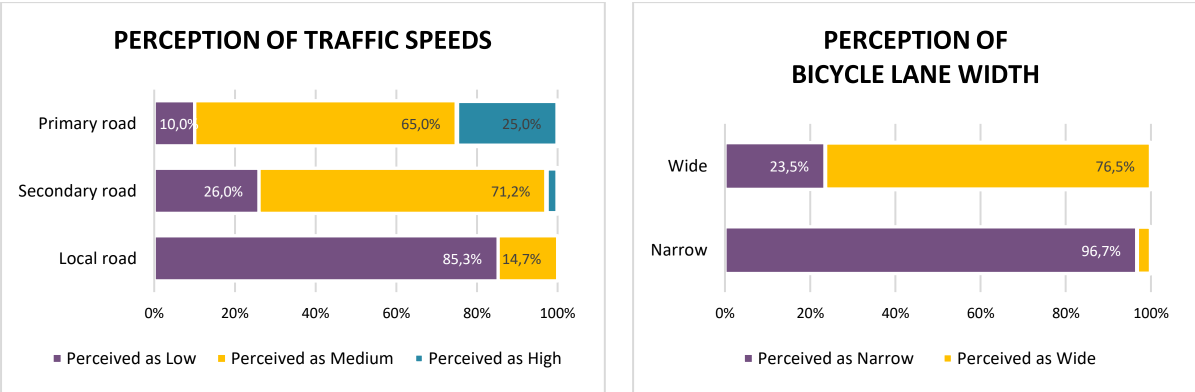

Figure 16 Survey verification test results

It is important to note the presence of those perception distortions since they may affect the outcomes of estimated models. One consequence of it is the use of "*road type*" attribute levels as proxy for traffic speed levels should be regarded cautiously, especially for the "primary road" level. Given that a huge share of respondents perceives the speed levels on primary and secondary road similarly, i.e. as "medium" speed, the difference between preferences on the two contexts may be underestimated in this research.

Therefore, it should be checked whether the responses made by respondents who misestimate the levels differs significantly with the ones who do not. A possible measure, similar to the one proposed by Hurtubia, Guevara, & Donoso (2015), is to add the misperceptions as socio-demographic characteristic variables and to include them as interaction terms with other variables in the model. The measure, however, is subject to further research.

6.1.3 Exploration of Given Answers

The distribution of given answers for each context description is shown in the Figure 17. A question is regarded to have a dominant alternative when the answers are distributed more than 85% to one of the choices. Meanwhile, if the given answers of a question are distributed almost equally, i.e between the range of 35% to 65%, it is labelled as "balanced".

Controlling the presence of heavy vehicles, the percentages of questions with balanced choices get lower from the local road context to secondary and primary road contexts. They, as a group, show more tendency to choose a particular alternative in a given choice task under the contexts of roads with higher hierarchy. This suggests that the contexts indeed influence the sample population's decisions.

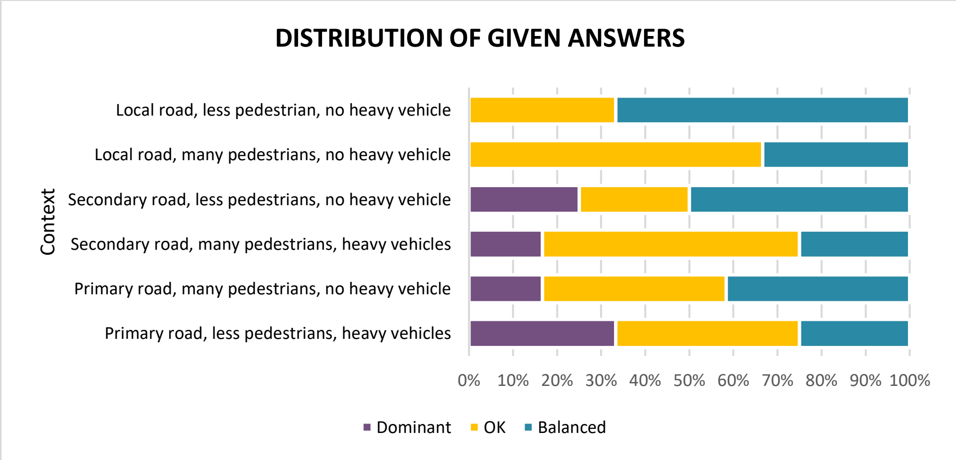

Figure 17 Distribution of given answers

6.2 MODEL ESTIMATION

Multiple discrete choice models were estimated using BIOGEME (Bierlaire, 2009) software on the retrieved survey data. Although the tested variables have been filtered through a literature- and practical-based selection process elaborated in Section 5.1, a number of iterations are again done on the model specifications to arrive on a model which is able explain the choice behavior of travelers in a parsimonious way. Multinomial logit (MNL) model is firstly estimated to obtain the base parameter values as reference. However, the model cannot capture the taste heterogeneity and panel effect which may occur due to the multiple choices made by each of the respondents. A panel mixed logit (ML) model is then estimated to take those into account.

Since there are categorical attributes and context attributes, for instance the type of separation with motorized traffic and road types, the attribute levels are recoded using dummy coding scheme. A number of literatures suggested that another coding scheme, i.e. effects coding, is superior in terms of dealing with utility identification problem between the base level of attributes with alternative-specific constants or ASCs (Bech & Gyrd-Hansen, 2005). However, the argument for the superiority of effects coding is rebutted by a recent study (Daly, Dekker, & Hess, 2016) since only differences in utility matter. In addition, the use of effects coding without normalization of the utility values may also introduce interpretation problems since there is no clear reference level (Daly et al., 2016). Therefore, dummy coding scheme is used due to its simpler set-up and its well-defined base levels for a clearer interpretation of the results.

In dummy coding, one level of an attribute is constrained to have zero utility contribution to act as the base reference level. Therefore, only $K-1$ number of indicator variables are estimated for an attribute with K levels. The indicator variable is coded as 1 when the level is present and 0 otherwise. The application of the coding scheme is given in the Table 12.

Table 12 Applied dummy coding scheme

Attributes & levels		Indicator variables	
Main attributes			
Separation with motorized traffic		BOL	CURB
	Bollards	1	0
	Curb	0	1
	Only stripes	0	0

Separation with pedestrians		SPED	
	Fence	1	
	No fence	0	
Bicycle lane width		WID	
	Wide	1	
	Narrow	0	
Context attributes			
Road type		PRI	SEC
	Primary	1	0
	Secondary	0	1
	Local	0	0
Volume of pedestrian		VPED	
	Many	1	
	Few	0	
Presence of heavy vehicles		HVEH	
	Present	1	
	None	0	

6.2.1 MULTINOMIAL LOGIT (MNL) MODEL ESTIMATION

To get first insights in how significant each main attribute impacts the choice behavior, initially the attributes are estimated individually on separate models. An example of the equations used to estimate the utility of an alternative in an individual attribute model is shown below.

$$U_i = \beta_{Bol} \cdot BOL_i + \beta_{Curb} \cdot CURB_i + \varepsilon_i$$

Where:

U_i : Utility of alternative i

β_{Bol} : Coefficient value of dummy variable BOL (bollards as separators from motorized traffic)

β_{Curb} : Coefficient value of dummy variable CURB (curbs as separators from motorized traffic)

BOL_i : Dummy variable for existence of bollards (1) and no bollard (0)

$CURB_i$: Dummy variable for existence of curb (1) and no curb (0)

ε_i : Random error component with zero mean

No ASC is estimated since the alternatives have generic attributes, and we also assume that the respondents are indifferent to the order the alternative is presented (on the left-hand side or on the right-hand side). The resulting coefficient values and their corresponding significance of the individual MNL models are presented in Appendix D.

The individual main attribute models have low adjusted rho-squared values which indicate low model fit. This is expected since each model only have an attribute to describe the choices. Nevertheless, the models are able to show that all main attributes are significant on a 95% confidence interval, implying that they indeed affect the preferences to some extent although the values are not discussed further since there is omitted variable bias, which is discussed in the subsequent paragraphs. Therefore, all of them are included in the combined MNL model.

In addition to the main attributes, context effects are included to the model by interacting context attributes with main attributes. Furthermore, the interaction effects between the main attributes are also tested to explore additional effects the main attributes might have when combined, as put forth in Section 5.1.2. With 4 indicator variables for the main attributes, 16 context effect variables, and 5 main interaction effects, initially a total of 21 parameters are estimated.

The utility function used in the combined MNL model is shown below, and the BIOGEME syntax of the initial combined model is shown in Appendix C.

$$U_i = \beta X_i + \gamma Y_i + \delta Z_i + \varepsilon_i$$

Where:

U_i : Utility of alternative i

β, γ, δ : Vector of parameters to be estimated

X_i : Vector of indicator variables of main attributes in alternative i

Y_i : Vector of context effect variables in alternative i

Z_i : Vector of main interaction effect variables in alternative i

ε_i : Random error component

However, after the model is estimated it is apparent that not all the tested parameters are significant at the 95% confidence interval. Considering model parsimony, the none significant parameters are then excluded with some exceptions. The context effects of presence of heavy vehicles on type of separation with motorized vehicles are retained since a number of literatures (Allen-Munley & Daniel, 2006; Hurtubia et al., 2015; Wilkinson et al., 1994) and the qualitative data shown in Section 6.1.1 have shown the effect of their presence on cycling behavior. The model is then re-estimated and afterwards checked for multicollinearity, since it will be difficult to determine precise effects of the parameters individually when they are highly correlated. The issue is crucial to be addressed when formulating an explanatory model (Shmueli, 2010). Nevertheless, none of the parameters in the model is highly correlated based on the correlation matrix.

The resulting MNL model has 14 estimated parameters, 13 of which are significant at the 95% confidence interval. The estimation produces sensible results in terms of the significant parameters and their respective signs. The values are presented in Table 13. All of the indicator variables for the main attributes are significant with positive signs for the separation with motorized traffic attribute width attributes, concurring with previous literature (Buehler & Dill, 2016; Heinen et al., 2010; Tilahun et al., 2007) and the qualitative data which suggest the preference toward a more segregated cycling infrastructure. On the other hand, the separation with pedestrian attribute has a negative sign which replicates the finding from an empirical study (Mertens et al., 2014) done in Belgium. The change of sign direction from the result of the individual MNL model with no interaction effect indicate that the preference toward having fence as separator with pedestrian is actually conditional to other variables. Omitting the interactions is therefore shown to bias the parameter estimate. Regarding the context effects, one would expect that contexts related with motorized traffic such as the type of road and presence of heavy vehicles will affect the preferences related to separation with motorized traffic such as the separator type and bicycle lane width while not affecting preferences on separation with pedestrians, and vice versa for the context attribute related to pedestrians i.e. the volume of pedestrians. The model estimation produces results in line with the hypothesis, as shown from the significance of the expected context effects.

The logical results, in addition with the significant improvement of log-likelihood of the final MNL model with the 14 parameters from the null model (final loglikelihood = -1127.02, χ^2= 431.11, degree of freedom = 14, p-value = 0,00), suggest that appropriate selection of variables to be estimated in the discrete choice model has been made.

6.2.2 Mixed logit (ML) model estimation

To gain better insights on the preferences of the respondents, a more advanced model i.e. mixed logit model which allow for taste heterogeneity and panel effect is estimated. The panel nature of the data is taken into account by changing the unit of observation into the sequence of choices made by an individual, hence acknowledging that the tastes of an individual respondent are the same across his or her choices. The taste heterogeneity limitation of MNL model is overcome by allowing the estimation of different attribute coefficient values among individuals, following an assumed distribution.

The procedure for the mixed logit model estimations is as follows. Firstly, a mixed logit model containing only the main attributes is estimated to identify the random parameters using t-statistic tests. Then, the model is re-estimated by including the context effects.

T-statistic tests are conducted on the standard deviations to select random parameters. A parameter is considered random if its standard deviation is statistically significant. An initial estimation with normal distribution shows that all of the main attributes are randomly distributed. Models with other mixing distributions are also tested. Indeed, new developments suggest the use of flexible mixing distribution with no *a priori* assumption of the shape of distribution (Train, 2016), however for computational reasons it is not tested. A model with Johnson S_B distribution which allows for flexible bounds with no strict symmetry assumption (Hess, 2010) was tested but could not reach convergence. In another model, a lognormal distribution is assumed for the width parameter which is reasonably expected to always have positive value, while the other are normally distributed given no strong justification for the attributes to be exclusively valued on certain sign. In this model, however, the means of all the random parameters become insignificant and hence rejected. The other model assumes symmetrical triangular distribution for the random parameters. While the use of the distribution does not alleviate the potential biased mean problem due to its symmetrical assumption, the bounds on its sides eliminate the problem of having extreme values of coefficients being estimated for some share of individuals (Train, 2003), which is evident in the initial ML model with normal distribution. However, the model is rejected due to the insignificance of most parameters and unreasonable result of the one which is significant, i.e. a negative value of the width parameter.

Compared to the other mixing distributions, the normal distribution results in more sensible results and hence used. The model is then expanded to include the context effects and estimated using 500 Hess-Train draws. The results of the final ML model are presented in Table 13.

6.3 Analysis of results

Table 13 below shows the results of estimated models, with values written in italics indicate that they are not significant at the 95% confidence interval. The values in main effects section show the utility of the main attributes when all context effects are at their base levels, hence contributing zero utility. Insignificant context effect means the utility value of the subjected main attribute does not differ across contexts within the context group.

The following discussion is based largely on the final ML model which used normal distribution, for the reasons of rejecting the other distributions stated in the previous section. The MNL model results are presented in the table to act as reference. One first thing to note is that two of the indicator variables for the main attributes become insignificant in the final ML model. This is possible since the MNL model does not take into account the panel nature of the data, hence underestimating the standard errors. Another thing to be noted is that although two dummy indicators are used for some of the attributes, they should be interpreted relative to each other since both are related to a single attribute.

Table 13 Model estimation results

Estimated variable	**MNL**			**ML**		
	Coeff. value	**Rob. p-value**		**Coeff. value**	**Rob. p-value**	
Main attributes coefficients						
Separation with motorized traffic						
With bollards (BOL)	0.390	0.02	**	*0.454*	*0.12*	
With curbs (CURB)	0.500	0.02	**	0.583	0.05	**
Fence as separator with pedestrians (SPED)	-0.291	0.02	**	*-0.244*	*0.25*	
Bicycle lane width (WID)	0.557	0.00	**	1.02	0.00	**
Interactions of main attributes						
CURB * WID	-0.674	0.00	**	-0.627	0.02	**
SPED * WID	0.482	0.00	**	0.522	0.02	**
Context effects						
Road type						
PRI * BOL	1.300	0.00	**	2.480	0.00	**
PRI * CURB	0.979	0.00	**	1.700	0.00	**
PRI * WID	*0.331*	*0.07*	*	*0.408*	*0.08*	*
SEC * BOL	0.990	0.00	**	1.940	0.00	**
SEC * CURB	0.782	0.00	**	1.230	0.00	**
SEC * WID	0.405	0.00	**	*0.419*	*0.07*	*
Volume of pedestrian						
VPED * SPED	0.377	0.00	**	0.585	0.00	**
Presence of heavy vehicles						
HVEH * BOL	0.353	0.04	**	*0.575*	*0.07*	*
Standard deviation of random coefficients						
BOL				-2.40	0.00	**
CURB				1.62	0.00	**
SPED				1.26	0.00	**
WID				1.15	0.00	**
Final loglikelihood	-1131.923			-939.004		
Adj. Rho-squared	0.149			0.289		

* and ** significant on 90% and 95% confidence interval, respectively

6.3.1 TYPE OF SEPARATION WITH MOTORIZED TRAFFIC

Based on the obtained large standard deviations of the parameters compared to the means, it is evident that there are widely different views regarding the preference toward the type of separations, even after several interaction effect with the context attributes have been shown to be significant. The notion is more evident in the view regarding bollards. Its p-value suggests that the mean utility value of having bollards is not significantly different from zero, while its standard deviation is large. This implies that while many people appreciate the separator, about as many are also averse to it. A similar finding is also revealed for curb, where about 35% of the sample assign negative value to the type of separator.

The urban environment contexts are shown to affect the values. It is evident that only the road type contexts have influence on the preference on the type of separation with motorized traffic on the 95% confidence interval. While there is a relatively large positive effect of heavy vehicles on the preference towards bollards, the value is only significant at the 90% confidence interval and hence the possibility of it only be due to chance cannot be ignored.

Compared to having physical separators in a local road (the base level), the preference towards having bollards or curbs are stronger in roads with higher hierarchy. The context effects values indicate that, while on local roads there is a strong preference toward having curb over bollards, the notion does not hold on higher road hierarchies. Holding other attributes constant, based on the mean values the total utility of having bollards on primary and secondary roads are greater than that of curbs on the same road types respectively, although to a lesser extent on secondary road. The results are not surprising as roads with higher hierarchy and/or their associated elements such as higher traffic speed, higher traffic volume, and more number of lanes have been shown to be less attractive to cycle on (Caulfield et al., 2012; Evans-Cowley & Akar, 2014; Mertens et al., 2014).

The findings above suggest that we indeed cannot generalize the type of separators between the bicycle lane and motorized traffic on every road type. Even in Tirana, where the cycling is not the norm and thus the people are expected to be much more precautious about cycling safety (Pojani et al., 2017), bollards only become more preferable on higher hierarchy roads.

6.3.2 Separation with pedestrians

Although the MNL model estimates indicate the dislike towards having fence separating the bicycle lane with the pedestrian area, the ML model shows that the respondents hold opposing views regarding the attribute. This is rather unexpected given the apparent issue of pedestrians using the cycling facility in Tirana, which in Chapter 4 has been identified to be troublesome for cyclists. The finding, nevertheless, concurs to some extent with Mertens et al. (2015) who found that people did not like having bollards separating bicycle lane and footpath. One possible reasoning behind this share of respondents who disfavor fence is that the separator might block the cyclists' effort to evacuate to the "safer" pedestrian area should there be any potentially harmful conflict with motorized traffic, however this speculation has yet to be confirmed with the local citizens.

Nevertheless, the results of "volume of pedestrians" context variable shows that crowded pedestrian area makes having fence to separate the bicycle lane and pedestrian path become more preferable than only having a level separation. This arguably stems from the increasing concern of conflicts with the presence of more pedestrians, therefore cyclists are more willing to have a more prominent barrier between them and the pedestrians.

6.3.3 Bicycle lane width

A relatively bigger positive value of this main attribute estimate's mean compared to other main effects indicates that the width of bicycle lane is considered important for the travelers. More specifically, the attribute is shown to have the biggest influence on bicycle lane choice, especially when the road type context is on its base level, i.e. local road. Given the insignificance of the context effects related to this attribute, it can be concluded that the preference of having wider lanes do not vary across the contexts. Nevertheless, based on the probability density function of the effect, evidently there is a 18% probability of observing negative utility for having wider cycling lane. The finding is rather counter-intuitive since we generally expect for cyclists to always prefer wider lanes. However, this might be due to measurement error. It has been discussed previously in Section 6.1.2 that almost a quarter of the respondents wrongly perceive the “wide lane” depicted in the questionnaire images as narrow. Therefore, it is possible that they could not sufficiently grasp the difference between the wide and narrow lanes in the alternatives, and thus the utility values of having wider lane becomes biased for the share of respondents.

6.3.4 Interactions between main effects

Two significant interactions between the main attributes are evident based on the model estimations. The first significant main effect interaction is between the indicator variables of fence as separator with pedestrians and wide lane, which has a positive utility value of 0.522. This implies the preference of having fence with pedestrians when the bicycle lane is wide. The association might firstly seem illogical. However, when we consider the speculation of cyclists not liking the fence due to its restrictive nature, as in limiting their maneuvering space when dodging motorized vehicles which drive too close, the interaction make sense: wider lane provides more space which is considered sufficient for cyclists for them to dodge from potential traffic conflicts. Therefore, speculatively, this imply that cyclists are actually inclined toward having fences separating them from pedestrian, given sufficiently wide cycling lane.

The second interaction effect is between the indicator variables of having curbs as separator with motorized traffic and wide lane, valued negatively at -0.627. Controlling the context variables to be at their base levels and also the separation with pedestrian attribute level, the negative interaction effect causes wide lane with curbs less favored than simply having wide lane with painted stripes on local roads. This implies that in local road cyclists are already content with having wide lane and do not feel the need for physical separators. Meanwhile, on secondary and primary roads, this significant interaction effect makes bollards become even more preferred when coupled with wider lanes.

6.4 Effects of personal characteristics

Significant random coefficient values found from the mixed logit model estimation also suggest that there are still unobserved factors which introduce variance in tastes across respondents. In Chapter 3, we discuss that personal characteristics such as socio-demographic variables and travel habits may influence the preferences of an individual. This section explores if the taste heterogeneity can be partly explained by differences in personal characteristics. The insights will be beneficial for policy makers when they are planning policies targeted to certain segments of the population.

An analysis conducted on the descriptive statistics using cross tabulation, presented in Appendix B, show that there are differences in the share of choices made between segments of socio-demographic variables, with some more prominent than the other. The notable ones are for instance the shares of choices on type of separator with motorized traffic between genders, between age groups, between segments of bike ownership, and between segments of trip distance to campus. In addition, the shares of choices on lane width also differ between segments of trip distance and biking frequency. Therefore, those differences are expected to have effects in the discrete choice model.

Age, gender, bike ownership, distance from home to campus, ability to cycle, and cycling frequency are the personal characteristic variables tested in the models. In the questionnaire, the respondents’ frequency of using other modes such as car, public transport, and walking were also inquired but are not included as estimated variables since the sample sizes are very small. Small sample size consideration also underlies the decision to combine some of the segments in a personal characteristic variable. The “under 18 years” and “18 to 25 years” age groups are combined into “under 25 years”. The distance to campus segments are integrated into “near” (5 km or less) and “far” (more than 5 km). Lastly, the weekly cycling frequency are grouped into “never/rarely” (2 days or less per week) and “often” (3 or more days per week).

It has been put forth that the ML model performs better to represent the true behavior of population since it is able to take the panel effect into account. However, estimating mixed logit models with the addition of many personal characteristic variables is very time-consuming. Therefore, the possible taste variations between the mentioned segment groups is captured by specifying the personal characteristic segment variables as interaction effects using MNL models instead, with the expense of not knowing to what extent the previously observed taste heterogeneity can be explained by the segmentations in personal characteristics. Nevertheless, the effects which are found to be significant can be straightforwardly incorporated to the ML model by specifying them also as interaction effects and subsequently the portion of standard deviations which are “taken away” can be observed.

6.4.1 Personal characteristic influence on main attributes

Personal characteristic attributes are interacted with the main attributes to check if some portion of the variance in tastes is due to differences in personal characteristics. The summary of the model estimations results is given in Table 14, and the complete results are listed in Appendix E. The significant values are written in bold typeface. The most notable differences between segments is discussed.

Table 14 Interactions of main attributes with personal characteristics

Main attribute	BOL	CURB	SPED	WID
Base value	**0.390**	**0.500**	**-0.291**	**0.557**
Age				
< 25 years	0.170	**0.371**	**-0.473**	**0.728**
25 years or older	**0.631**	**0.651**	-0.093	**0.375**
Gender				
Female	**0.484**	**0.391**	-0.167	**0.538**
Male	**0.288**	**0.591**	**-0.414**	**0.575**
Bike ownership				
Own a bike	**0.471**	**0.593**	**-0.253**	**0.544**
Do not own a bike*	-0.007	0.034	**-0.510**	**0.639**
Cycling frequency				
Often (3 days or more/week)	**0.313**	**0.458**	**-0.404**	**0.671**
Never/rarely (< 3 days/week)	**0.467**	**0.555**	**-0.175**	**0.438**
Cycling ability				
Advanced	**0.342**	**0.539**	**-0.322**	**0.537**
Intermediate	**0.492**	**0.495**	-0.218	**0.972**
Beginner*	0.324	0.089	-0.378	**0.485**
Distance to campus				
Far (> 5 km)	**0.763**	**0.575**	-0.029	**0.514**
Near (5 km or less)	0.215	**0.463**	**-0.412**	**0.580**

* small sample (less than 20 respondents)

Although older cyclists are more inclined to have physical separation with motorized traffic, the type of separator itself is shown to be not very important given the similar values attached to bollards and curb. Meanwhile, younger cyclists put less importance on the separation with motorized traffic while appreciate wider lanes more. The younger group also has relatively strong disfavor toward having fence separating them from pedestrian, compared with the older group who are indifferent on the attribute.

Several differences in tastes are apparent between genders. Females prefer to have bollards as physical separator rather than having curb, while the opposite holds for males. This is as expected since females are found to be more perceptive toward safety risks and thus prefer greater preference toward more separated cycling infrastructure (Caulfield et al., 2012; Garrard et al., 2008; Tilahun et al., 2007; Winters & Teschke, 2010). The dislike toward having fence to separate the bike and pedestrian lanes is moreover only significant within the male group.

Interestingly, people who do not own a bicycle do not put any value on physical separation with motorized traffic. This indeed could be the by-product of having small sample for the segment, but if indeed this reflect the reality this shows that protecting the bicycle evidently is a huge motivation for people in Tirana to put more importance on separation with motorized traffic. The finding may relate to the fact that bicycles, at least which are used by many university students according to the interviews, are expensive in Tirana since they are more of a lifestyle product instead of everyday necessities such as in Netherlands. However, the speculation needs further confirmation with the locals.

The dislike toward having fence as separator with pedestrians is stronger for frequent cyclists and they also put slightly less importance to the presence of physical separation with motorized traffic, while preferring wider lanes more than less frequent cyclists. This suggests that the more people cycle, the less they are bothered by the surroundings, analogous with previous studies (Sener et al., 2009; Stinson & Bhat, 2003). Moreover, the observed tendencies of preferring no obstruction and more cycling space imply that frequent cyclists prefer to have more room to maneuver, for instance to take over other cyclists.

Regarding the cycling ability, while intermediate cyclists are evidently do not put importance on the type of separator as long as they are physically segregated from motorized traffic, advanced cyclists prefer to have curb rather than bollards. They also care relatively less about wider lanes compared to intermediate cyclists. The findings explicitly show their comfort to cycle.

Interestingly, notable preference differences are found between cyclists who have to travel far and those who cycle on shorter distances. The group of cyclists who have to travel further is one of the only two groups, along with females, who prefer bollards over curbs. They are also not bothered with fences separating them from pedestrian area. Acknowledging that the further cyclists have to cycle to the universities, which are mostly located in the central or southern part of Tirana, the more they are exposed to higher traffic conditions, the results are logical. The finding is discussed further on the next section, which take the context effects into account.

6.4.2 Personal characteristic influence on context effects

The process to investigate the influence of different personal characteristics on having variety of tastes can also be applied to check if they also have different sensitivities to context effects. Indeed, in the mixed logit model the context effects are not specified as random since having too many random parameters will not benefit the interpretability of the findings, as "*There is a natural limit on how much one can learn about things that are not seen"* (Train, 2003, p. 147). However, we could get a more fine-grained understanding on what motivates the differences in tastes from this investigation.

Table 15 Interactions of context effects with personal characteristics

Context effect	PRI * BOL	PRI * CURB	SEC * BOL	SEC * CURB	PRI* WID	SEC * WID	VPED * SPED	HVEH * BOL
	1,300	0,979	0,990	0,782	0,331	0,406	0,377	0,347
Age								
< 25 years	**1,100**	**0,946**	**0,831**	**0,612**	**0,610**	0,649	**0,647**	0,179
25 years or older	**1,570**	**1,040**	**1,190**	**1,000**	0,045	0,169	0,137	**0,560**
Gender								
Female	**1,500**	**0,896**	**1,170**	**0,811**	**0,381**	0,366	**0,473**	**0,539**
Male	**1,130**	**1,070**	**0,848**	**0,788**	0,285	0,443	0,289	0,181
Bike ownership								
Own a bike	**1,490**	**1,120**	**1,080**	**0,954**	0,326	**0,397**	-0,111	0,390
Do not own a bike*	0,447	0,435	0,601	-0,231	0,358	0,467	**0,471**	0,110
Cycling frequency								
Often (3 days or more/week)	**1,420**	**1,110**	**1,010**	**0,832**	**0,399**	**0,473**	**0,372**	**0,490**
Never/rarely (< 3 days/week)	**1,200**	**0,874**	**0,973**	**0,738**	0,262	0,332	0,381	0,217
Cycling ability								
Advanced	**1,400**	**1,170**	**0,923**	**0,749**	0,285	**0,399**	**0,405**	0,431
Intermediate	**1,290**	**0,840**	**1,070**	**0,922**	0,336	0,230	**0,368**	0,334
Beginner*	**1,050**	0,522	**1,300**	0,594	0,628	**1,330**	0,233	-0,071
Distance to campus								
Far (> 5 km)	**1,830**	**1,050**	**1,220**	**0,669**	0,155	0,322	**0,714**	**1,000**
Near (5 km or less)	**1,110**	**0,967**	**0,897**	**0,853**	**0,415**	**0,446**	0,218	0,129

* small sample (less than 20 respondents)

From the outcomes it can be observed the context effects of road types on the type of separation with motorized traffic are stronger for older travelers. They also have more preference toward having bollards to separate them with traffic when they have to cycle alongside heavy vehicles. Those imply that older travelers are more concerned to road traffic conditions, while the younger group is more sensitive to pedestrians as can be seen from the significant positive utility they attach to the interaction between pedestrian volume context variable and type of separation with pedestrians. The finding contradicts Hunt and Abraham (2007), which suggests that older individials are less averse to traffic.

As expected, females are more sensitive to context effects than males. In general, the higher the risk of having conflicts with traffic or pedestrians, i.e. on roads with higher hierarchy, when heavy vehicles are present, or when there are many pedestrians, the more they prefer greater physical segregation than males do. Females also have stronger preference of having fence separating them from pedestrians when high volume of pedestrians is apparent and to have bollards separating them from traffic when there are heavy vehicles on the road, two context effects which are insignificant in the male group. Those findings related to female's preference toward more separated cycling infrastructure are in line with a number of previous studies studying gender preferences mentioned in Chapter 3 (Caulfield et al., 2012; Garrard et al., 2008; Tilahun et al., 2007; Winters & Teschke, 2010).

Observing the segments based on bike ownership, owning a bicycle makes an average individual more sensitive to context effects related, especially the ones related to separation with motorized traffic. The non-owners, on the other hand, are indifferent to all context effects except the positive interaction between pedestrian volume and having physical separation between bicycle lanes and pedestrian area. A speculation that this might relate to the motivation of protecting the bicycles themselves is mentioned in the previous section. Another possible reasoning also can be made related to the positive correlation with cycling frequency to some extent as shown in Appendix B. Many of the bike owners are frequent cyclists and hence are more aware to the actual street conditions than the non-owners, which prompts them to be more separated with traffic. The non-bike owners, on the other hand, can be said to cycle less to some extent. Therefore, they cannot imagine the actual cycling conditions thus their indifference to many context effects. Same line of reasoning is argued to be applicable to explain the differences of preference in the cycling frequency segments, in which non-frequent cyclists are less sensitive to context effects.

There is a remarkably stronger inclination of beginner cyclists toward bollards compared to curbs on the higher hierarchy roads. They are also indifferent to the effect of higher pedestrian volume, which is not the case with advanced and intermediate cyclists who become inclined to have fence separating them from pedestrian. From the results it is also apparent that beginner cyclists have stronger preference toward wider lanes, especially in the secondary roads.

Travelers who have to take further trips are in general more inclined to have more physical separation on both sides, i.e. having bollards to separate them from traffic and fence from pedestrians, on primary and secondary roads, when there are heavy vehicles present, and when the pedestrian volume is high. On the other hand, shorter-distance travelers put more importance on having wider lanes on higher hierarchy roads. As mentioned in the previous section, the findings can be related to the exposure cyclists have to the actual conditions of roads with higher hierarchy when they have to travel further from the city center. Tirana, as explained in Chapter 4, has ring roads on the outskirts of the city which are classified as primary roads with higher speed and more heavy vehicles. The far-distanced cyclists who have to cycle on these roads then have the first-hand experience of cycling in primary roads, giving them more perspective on the need of more segregated cycling infrastructure.

6.5 Conclusion

The outcomes of the models can be used to answer the fourth research sub-question: "*To what extent the values perceived by Tiranian travellers from the design attributes of bicycle lane vary under different contexts of urban environment?*" The significant results of a number of the context effects give evidence on the difference preferences people have on bicycle lane design on different settings of urban environment.

The preferences on the type of separation with motorized traffic are influenced by the road types. Although in general having physical separation with traffic is preferable for Tiranian travelers than only having stripes marking the bicycle lanes, on local roads curbs are more favorable while on roads with higher hierarchies the inclination travelers are more inclined toward having bollards. The presence of heavy vehicle on a road also improves the utility of having bollards, although only significant in the 90% confidence level. Meanwhile, the situation on the pedestrian area affects the cyclists' preference on the type of separators with pedestrians. While in the reference case people dislike having fence separating the cycle and pedestrian lanes, when the number of pedestrians is increased they become inclined to have fences as an additional separator system.

"Tiranian travelers" by no means have the exact same characteristics. By segmenting the data, it is found that some parts of the taste heterogeneity are caused by differences in personal characteristics. Women are shown to be more inclined towards having more segregated bicycle lane from both motorized traffic and pedestrian area. Different preferences on bicycle lane design features are also evident between people with different cycling ability and frequency.

However, these findings need to be treated with caution since the sample are from the group of university students which have certain differences with the statistics of the general population, and the sample furthermore are biased toward groups with better cycling ability. Nevertheless, the values obtained are in general make sense and further research with a more heterogenous sample can be done to increase their reliability.

CHAPTER 7.
CONCLUSION, DISCUSSION, AND RECOMMENDATION

Updated studies concerning traveler's preferences on specific link-level design features of cycling infrastructure are scarce, let alone investigating how the preferences might vary upon different contexts of urban environments. Moreover, a major share of cycling infrastructure-related studies is done in developed countries or countries which already have a prominent cycling culture. In the European context, there are still limited studies done in the south- or eastern-part of the continent, while the countries on the area are the ones who are striving to grow (or in some countries: revive) cycling habits among their citizens.

Therefore, a research question is formulated for this study to fill the gap, and this study is conducted in a city where the cycling culture is only starting to emerge as a response. A conclusion on the research is made in Section 7.1, followed by a discussion including the limitations of this study along with recommendations for practice and further research in Section 7.2.

7.1 CONCLUSION

In this study a context-dependent discrete choice model to investigate traveler's preferences on cycling infrastructure design features is developed. The objective to **investigate the extent the preferences on cycling infrastructure design is affected by the characteristics of a road segment** is related to the theoretical framework by Ogilvie et al. (2011) which listed physical environment as one of the factors which could intervene traveler behavior on slow mode usage. This study corroborates the framework by confirming that *a)* dedicated cycling infrastructure is preferred and *b)* a number of urban settings, in terms of road infrastructure and its related elements, do influence people's preferences of cycling infrastructure design. Therefore, we believe that the term "physical environment" is not only bounded to the quality or quantity of the cycling infrastructure, but also to the appropriateness of the design to the roads where the facility is installed upon.

In this research, the design features and road characteristic contexts tested are scoped based on literature study on the scientific domain as well as grey literature such as bicycle infrastructure design guidebooks and city planning documents. Interviews with urban planning expert and practitioners are also conducted to affirm the realism of the alternatives conveyed. The inclusion of grey literature is crucial to increase the research's relevance to the current practice of bicycle lane design, since from the study we conclude that not all the attributes tested in scientific literature are suitable to the contexts in the area of study. For instance, in a city where the urban fabric has been built densely such as in Tirana, development of cycling infrastructure is mostly limited to bicycle lanes installed along the existing roads (Transport for London, 2014; Wilkinson et al., 1994). It is impractical, and often not feasible due to space and budget constraints, to develop a totally segregated cycling path network. Consequently, when studying the preferences on cycling infrastructure design where the facility has to be retrofitted to existing roads, it is more important to put emphasis on the micro-scale design features. Three design features are thus considered relevant to be investigated: *type of separation with motorized traffic, width of cycling infrastructure, and type of separation with pedestrians.*

The "contexts" in this research are the given characteristics of the roads, which are not altered by the installation of the cycling infrastructure. Since the practical objective of this research is to aid practitioners in designing link-level cycling infrastructure design, the contexts are chosen on the basis of how practitioners categorize urban roads and also to allow for the generalizability of the research findings. A review on city planning documents including the Road Code of the Republic of Albania and design guidebooks show that many of them nest the characteristics of traffic speed, traffic volume, and roadway width under "road types". Therefore, the general categorization of *primary, secondary,* and *local* road types is used in this research as context attributes representing roads with highest, moderate, and lowest traffic speed, traffic volume, and roadway width respectively. However, as a side note, for future researches the suitability of road types being used as the proxy attribute for traffic speed is debatable based on the verification test conducted within this research. Other characteristics of the road which are not nested under *road types* are *presence of heavy vehicle* and *volume of pedestrians*, which vary between urban settings.

The discrete choice model estimation shows that **people attach different values on certain design features of a cycling infrastructure under different urban contexts**, which answers the main research question of this study. To illustrate, Figure 18 summarizes the changes of mean utility values of the tested design attributes under the six roads with distinct characteristics.

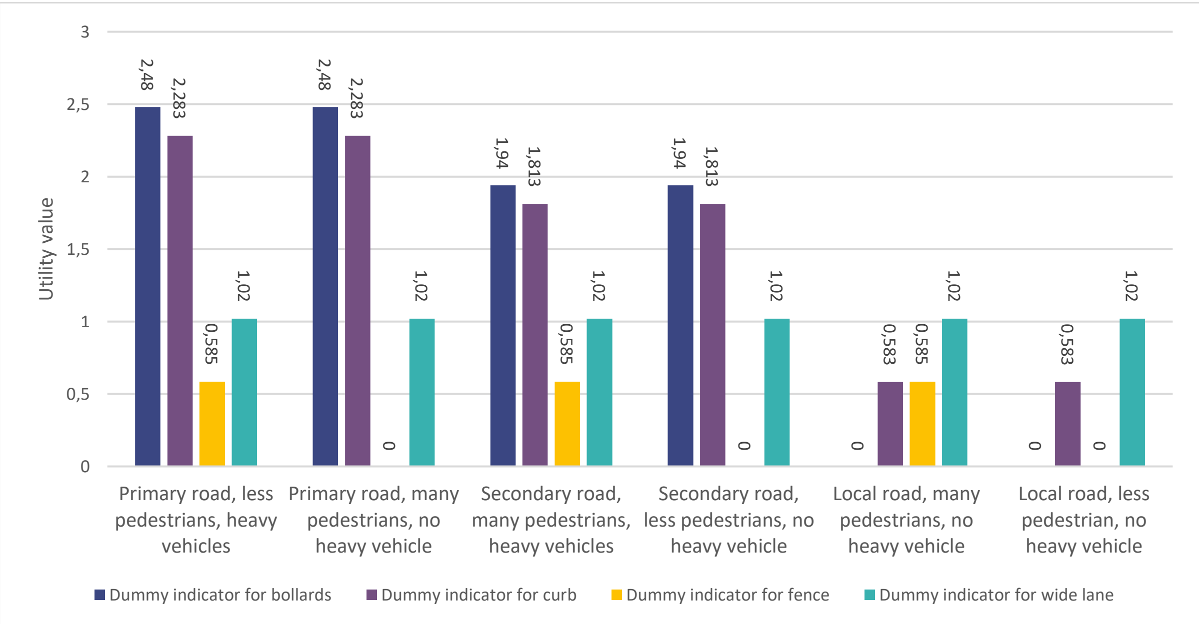

Figure 18 Changes in utility values on different roads

We can conclude that people preferences on link-level design features of cycling infrastructure vary across roads with different characteristics. The preferences of design features which are sensitive to the contexts are of the type of separation with motorized traffic and type of separation with pedestrians, and the extent of the changes is dependent upon the road type and volume of pedestrians on the road, respectively. Curbs are on average more preferred than bollards in local roads. However, the context effect of being in secondary or primary road changes the mean utility value of bollards to be greater than of curbs and therefore bollards become more preferable on the higher hierarchy roads. Secondly, cyclists hold opposing views on having fences to introduce physical segregation between cycling and pedestrian lanes or just having grade separation. Nevertheless, when the context changes i.e. when there is a higher volume of pedestrians, travelers are more inclined to have the fence as an additional separator system.

The findings that bollards, which arguably contribute to most sense of separation and thus safety to the cyclists compared to other tested types of separator, are chosen as the preferred type of separation on primary and secondary roads show that the respondents value higher separation greatly. Given the group of respondents are biased toward people who already cycle more, which by some studies (Sener et al., 2009; Stinson & Bhat, 2003) are shown to be less sensitive to safety risks, studies with more non-cyclists are not expected to produce results with less preference on greater separations.

Having wide lane, on the other hand, is valued the same across contexts. In other words, cyclist's appreciation on having wider lane do not increase even on roads with higher hierarchy. Meanwhile, although the model result indicates that the heavy vehicle presence on the road prompts people to be more inclined towards having bollards, it is not statistically significant at the 95% level cutoff. A discussion regarding the rather counter-intuitive result is presented on the next section.

We should also note that there is significant heterogeneity on the preferences across respondents which still cannot be explained by the variation of contexts. Segmenting the data based on personal characteristic attributes, we found that differences in traveler's personal characteristics are associated with certain differences in valuation of design features and also in sensitivity toward context effects.

7.2 Discussion

To the best of our knowledge there has been no research which simultaneously examined the set of link-level design features attributes and the context effects of road characteristics. Updated studies investigating how people value the micro-scale design features using the same method of discrete choice modelling are also scarce. The comparisons in Table 16 are therefore made with a number of recent literatures which examine similar attributes, without making strict limitations on the research method or the tested features. Locations where the studies were conducted are mentioned for additional background information.

Table 16 Comparison of findings with existing literature

Variable	Previous literature	Findings	Findings of this research
Type of separation with motorized traffic	Sanders (2013) *Location: California, USA*	Barrier-separation between motorized traffic and non-motorized traffic is preferred over visual demarcation	Physical separators (bollards or curbs) are consistently valued higher than only having stripes to mark the bicycle lane
Type of separation with pedestrians	Mertens et al. (2014) *Location: Flanders, Belgium*	People dislike separation between cycle lane and sidewalks using bollards	There are mixed views on having fence separating the lane and pedestrian area. The mean value is negative, nevertheless is not significant

Bicycle lane width	Sener et al. (2009) *Location: Texas, USA*	No preference on wider or narrower cycle lanes	Wider cycling lane is more preferred
	Li et al. (2012) *Location: Nanjing, China*	Wider cycling lane increase cyclists' comfort and thus preferred	
	Mertens et al., (2014) *Location: Flanders, Belgium*	People prefer wider cycle lane, but it is not a priority compared to the type of separation with motorized traffic	The utility value of having wider lanes is only greater than having any type of physical separation with motorized traffic on local roads
Interaction between type of separation with motorized traffic and with pedestrians	Mertens et al., (2014) *Location: Flanders, Belgium*	People dislike having physical separators on both sides of the lanes	Separation with pedestrian using fence becomes attractive when placed on wider lanes
Context effect of urban settings on type of motorized traffic	Mertens et al., (2015) *Location: Flanders, Belgium*	Although constantly preferred over curb and no separation, the inclination towards having hedge to separate the lane from motorized traffic gets stronger on residential areas with higher densities	Curb is preferred on local roads, however in primary and secondary roads bollards become more appealing

The findings of this research largely corroborate previous empirical studies, with few minor differences. Nevertheless, the differences found can be related to the fact that we also examined the effect of road characteristics on the preferences and taste heterogeneity. For instance, while Mertens et al. (2014) stated the dislike of physical separation between bicycle lane and pedestrian path and we also obtained a similar result in our MNL model, after allowing for taste heterogeneity the effect becomes insignificant. Therefore, we can argue that the negative value observed in our MNL model is biased and actually the respondents hold mixed views regarding the attribute. Since the study by Mertens et al. (2014) assumed fixed value for the coefficient, no clarification can be obtained regarding the value’s reliability.

The study (Mertens et al., 2014) furthermore asserted the less importance people attach on having wider lanes compared to having physical separation with traffic and dislike of having physical separators on both sides of the lanes. Other study (Mertens et al., 2015) showed that hedge, which could be perceived similarly to bollards due to the more prominent separation they provide, is consistently preferred over curb. In our study we observed that the preferences on the mentioned attributes are conditional upon the road contexts or the presence of another attribute.

Having discussed the significant parameters, the following discussion highlights the notable finding of insignificant parameter from the model estimation.

Since two studies (Caulfield et al., 2012; Hurtubia et al., 2015) suggested the negative effect of buses for a road alternative to be chosen to cycle on, it was expected that the presence of heavy vehicles on the road would be associated with choices conveying greater separation, even more so in Tirana where cycling is not the norm yet. Nevertheless, in this study no context effect related to the presence of heavy vehicles is significant on the 95% confidence level. The most notable effect of the attribute is to increase the preference of having bollards to separate the lane from motorized traffic, which is only significant at the 90% confidence level. Hence, the result might be due to coincidence. The insignificance of the effects of this context variable is rather unexpected, since as described in Section 6.1.1 a substantial number of respondents stated their discomfort of cycling along buses or trucks as one of the reasons hindering them to cycle more. However, the estimated standard deviation for the random coefficient is significant, indicating taste heterogeneity. One explanation for the insignificance and heterogeneity might be related to the presentation of alternative in the survey. Although the presence of heavy vehicle has been presented both visually and verbally, the given description might not be sufficient for all respondents to render the effect which may be present when an individual actually cycle alongside heavy vehicle.

7.3 Recommendation

Based on the findings and also acknowledging the limitations of this study, recommendations are made in this section for further research and practice.

7.3.1 Recommendations for further research

A number of recommendations for further research are made below following the findings of this study, as well as to address the limitations in this study.

Investigate the effects of other urban characteristic attributes

In the research, the context attributes tested are limited to only three attributes related to the road characteristics. Perhaps, there are still other attributes which left out. Future research can investigate the context effects of urban elements beyond those related to the road e.g. adjacent building functions, building density, surface material of the road, or even presence of vegetations.

Examine other road user's preferences

The respondents are only asked to answer the stated preference survey from the viewpoint of cyclist. However, a road is shared between multiple users such as car drivers and also pedestrians on the adjacent pedestrian path. It is possible that there are differences of view between the user groups and a design compromise should be made, rather than only implementing the ideal design according to cyclists. Therefore, for more comprehensive insights and implementable policy advices, we suggest future research to also examine the preferences of other road users.

Improved presentation method for the survey

The use of images to convey the alternatives in the stated preference survey have also been noted to have several limitations. While it is useful in presenting physical design features which may be difficult to be described verbally, leaving less room for respondents' own interpretations of the alternative, and making the survey less fatiguing, there are also issues of potential bias due to accidental details in the images and possible difference of perception of attribute levels when presented only visually. Although precautions such as accompanying the visual choices with text descriptions when needed and processing the images digitally to minimize accidental details, from the verification test it is apparent that some perception distortions still occur to some extent on the "speed" and "width of bicycle lane" variables. Undoubtedly, it is important to note the presence of those perception distortions since they may affect the outcomes of estimated models, in ways which has been discussed in the previous chapters.

Future researches which find similar distortions may explicitly take that into account by, for instance, estimating them as interaction variables in their model to get insight on how those distortions influence the observed choice behavior. Nevertheless, other alternative methods of visual presentations may also be done in future researches to better convey the alternatives. For example, since it is evident here that speed attribute levels are rather difficult to be conveyed by static images, motion pictures can be used instead. Although more complicated, the use of video will also increase the realism of the choices which in turn expectedly will contribute to a more reliable data. Given the rapid development of virtual reality (VR) devices in the recent years, it is also interesting to explore the possibility of using them to present the choice situations in a much more realistic manner.

Use visual stated choice experiment for other domains

Albeit having several limitations as addressed in the previous paragraph, we note that the use of visual representation of alternatives in a survey is beneficial in multiple ways. Firstly, the images reduce the need for verbal description. This is can largely aid researchers who are faced with language barrier in their area of study, since minimum texts are needed to describe the alternatives. Secondly, images can describe certain attributes better than verbal description. Therefore, studies which investigate preferences on physical designs can largely benefit from it, both from or outside the transport domain such as urban design or architecture studies. We have elaborated the process of developing the images for stated preference survey in this report, which can be used as a guide for future researches following the same approach.

Calibrate the results with revealed preference data

The choice to use stated preference data is mainly related to the method’s ability to examine choices made on hypothetical situations. Currently, there are still limited cycling infrastructure and number of cyclists to be observed and therefore some combinations of design features cannot be observed properly. However, one prominent drawback of this type of choice data is the researcher cannot state surely if the choices stated by the respondents will illustrate their actual behavior. One possibility to respond to this issue is to compare the results of the research with revealed preference data from for example GPS trackings or travel diary to check to what extent the observed preference convey the actual behavior of travelers when the data is available in the future.

Better data sampling

Due to concerns of time constraint and language barrier, the respondents are scoped to university students instead of having more heterogenous sample of the population. Moreover, given the sampling method which is snowball sampling the survey was distributed more often among cyclist communities which therefore further reducing the heterogeneity of the sample. It is then possible that some bias is introduced to the estimation values. Future researches can use a more heterogenous sample to validate the findings of this study or to check if the results can be generalized to the other segments of the population.

Investigate the latent classes of respondents

The investigation of personal characteristics attribute by merely specifying them as interaction variables in separate models makes the insights and recommendation for practical purposes which can be made are rather limited. A latent class model, which identifies segments of respondents which have similar tastes in a parsimonious way, is more suitable to derive more nuanced policy recommendations.

7.3.2 RECOMMENDATIONS FOR PRACTICE

The practical objective of this research is to provide practical recommendations on the design of bicycle infrastructure for policy makers and urban designers, especially in the city of case study, and therefore the practical relevance is always kept in mind when throughout the process of the survey design. Although the sample for this research are from university student group, which may have different preference compared with other groups, in Tirana the university students comprise approximately 1/10 of the population. Hence, the findings can still be at relevance for policy making. Nevertheless, the fact that more cyclists are represented in the group brings a consequence on how the results should be interpreted as the group has been shown in previous researches to have differences in their preferences compared to people who do not cycle regularly. Therefore, conservatively, this implies that the design recommendations below may not straightforwardly could encourage non-cyclists to cycle more, but rather to accommodate people who already cycle to have better experiences in cycling.

Bicycle lane design recommendation based on the results

The utility values estimated can be used as one aspect to consider when designing bicycle lanes in different roads. In the light of the relatively large and significant context effect of primary road on bollards, the finding supports the installments of bollards-separated bicycle lanes along the primary roads in Tirana, such as the latest development of cycling infrastructure on the city's main boulevard. We also suggest for bollards to be the separator system of choice on the ring roads of Tirana, since the roads display similar characteristics to the boulevard, even having busier traffic in the peak hour. The ring roads are also part of the route of the people who have to cycle further from their campus, and from the examination of personal characteristics effect we have observed that they are more inclined on having bollards.

Meanwhile, in secondary roads a lesser separation such as curbs more appealing to more cyclists. Although bollards have slightly more mean utility value, it also has larger standard deviation which imply the widely varied view cyclists hold against them. The large context effect of primary road on bollards arguably offsets the probability of bollards having negative views on the road, however in secondary roads the effect is less pronounced. Therefore, choosing curb to separate the bicycle lanes in secondary roads, such as in Blokku area, might cater the preferences of more cyclists.

In local roads, the space restrictions need to be acknowledged. The design recommended should take the other road users' need for space into account. Although from purely utility point of view having both physical separation and wider lanes is superior, having both attributes might be not possible since the average dimension of existing local roads is limited compared to the other two types of road. Given the higher appreciation cyclists attach to wider lanes on local roads compared to improvement in physical separation, and also the smaller standard deviation the attribute has hence indicating less diverse views, we suggest the installment of wide painted lanes without physical separators on local roads.

Other recommendations

The recommendations derived above are the ones stemming directly from the values cyclists attach to each of the design features, conditional upon the road characteristics. Nevertheless, we would also like to suggest other inputs for Tiranian municipality based on our observations to the actual conditions of bicycle lanes in the city and interviews with local citizens.

One first notable observation is that there is lack of continuity and sense of consistency in the bicycle lane designs in Tirana, which therefore contradicts the key design principles of cycling infrastructure identified in the literature study. Often, there are sudden discontinuity of bicycle lanes after intersections, which may disorient some cyclists. We also miss the sense of coherent bicycle network throughout the city, since the designs are remarkably different from one place to the other. For example, the new bicycle lanes on the boulevard are painted red, while in Blokku area they are painted green. The older cycling lanes do not even have any color differences with the adjacent road. This may confuse people who are not yet familiar with the concept of having cycling lanes. Although the designs of separators or the width can be varied across roads, as suggested from our findings, the sense of coherence can be introduced from the having the same color painted on the lane surface and uniform signage system.

The second recommendation relates to the treatment of cycling infrastructure in intersections. As far as the observation goes there has been no specific design on the part of lanes at road intersections, while as suggested by a study (Buehler & Dill, 2016) the number of potential conflicts with other road users increases at those nodes. A variety of intersection treatments, such as bike boxes which serve as waiting area for cyclists during red signals, can be installed in the intersections to reduce the conflicts with traffic as well as pedestrians crossing the roads.

Thirdly, we would also suggest interventions related to the attitude and habits of travelers in addition to improvements in the infrastructure. We should state beforehand that the recommendations below are more speculative, since we have done no thorough study confirming the findings. Although some previous studies (Pojani, 2011a, 2011b) suggested the hesitation to cycle due to the stigma local people have toward it, which they see as "a mode of transport for poor people", the interviews done with local young citizens show their generally positive attitude toward cycling. The finding is important since young people comprise a large share of population in Tirana. One interesting finding from the interviews is that the positive perception young people have towards cycling, in addition to its sustainability, is also related to them viewing the mode as "trendy" and as a life-style product. Therefore, promotional campaigns directed to young people might benefit from having public figures set as examples by portraying them using bicycle as their mode of transport.

From the interviews, many also complained about the price of bicycles in Tirana which is considered expensive for university students. The high risk of the bicycles being stolen also is also stated by a number of young local citizens as a factor hesitating them to own a bike. Therefore, support from the municipality to make bicycle more accessible for wider population is needed. Bike sharing program which has evidently started recently is a positive step, nevertheless other measures such as giving access to more affordable yet "stylish" looking bicycles (which relates to the mode viewed as a lifestyle product) for young citizens may also have positive impacts on the cycling level in Tirana.

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Appendix A. Experimental design

A.1 Ngene syntax (main attributes)

```
design
;alts = alt1, alt2
;rows = 8
;orth = seq
;model:
U(alt1) = b1 * SMOT[0,1,2] + b2 * SPED[0,1] + b3 * WID[0,1]/
U(alt2) = b1 * SMOT        + b2 * SPED      + b3 * WID
$
```

A.2 Ngene design (main attributes)

Choice set	Alt 1			Alt 2		
	SMOT	SPED	WID	SMOT	SPED	WID
1	0	0	0	2	0	1
2	1	1	1	0	1	0
3	2	1	1	1	0	0
4	2	0	0	1	0	1
5	0	0	1	2	1	0
6	1	1	0	0	0	1
7	1	0	0	0	1	1
8	2	0	1	2	1	1
9	0	1	0	2	0	0
10	1	0	1	1	1	0
11	2	1	0	0	0	0
12	0	1	1	1	1	1

A.3 Pearson product moment correlation matrix (main attributes)

Attribute	alt1.SMOT	alt1.SPED	alt1.WID	alt2.SMOT	alt2.SPED	alt2.WID	alt1.SMOT *alt1.SPED	alt1.SMOT *alt1.WID	alt1.SPED *alt1.WID	alt2.SMOT *alt2.SPED	alt2.SMOT *alt2.WID	alt2.SPED *alt2.WID
alt1.SMOT	1	,	,	,	,	,	,	,	,	,	,	,
alt1.SPED	0	1	,	,	,	,	,	,	,	,	,	,
alt1.WID	0	0	1	,	,	,	,	,	,	,	,	,
alt2.SMOT	-0,375	-0,40825	0,20412	1	,	,	,	,	,	,	,	,
alt2.SPED	-0,20412	-0,33333	0,66667	0	1	,	,	,	,	,	,	,
alt2.WID	0	-0,33333	-0,33333	0	0	1	,	,	,	,	,	,
alt1.SMOT*alt1.SPED	0	0	0	-0,125	-0,20412	-0,40825	1	,	,	,	,	,
alt1.SMOT*alt1.WID	0	0	0	0,375	-0,20412	0	0	1	,	,	,	,
alt1.SPED*alt1.WID	0	0	0	-0,20412	0	0,33333	0	0	1	,	,	,
alt2.SMOT*alt2.SPED	0,375	0	0,20412	0	0	0	0,125	-0,375	-0,61237	1	,	,
alt2.SMOT*alt2.WID	0,375	0	0,20412	0	0	0	0,125	0,125	0,20412	0	1	,
alt2.SPED*alt2.WID	0,20412	0,33333	0	0	0	0	-0,20412	0,20412	0	0	0	1

APPENDIX B. DESCRIPTIVE STATISTICS

B.1 CORRELATIONS BETWEEN SOCIO-DEMOGRAPHIC ATTRIBUTES

Correlations

Correlations		AgeGroup	Gender	Bike Ownership	Distance Campus	Cycling Ability	FreqBike	FreqCar	FreqPT	FreqWalk
AgeGroup	Pearson Corr.	1	,110**	-,125**	,235**	0,026	,099**	0,043	-0,042	-,100**
	N	1944	1944	1926	1944	1944	1854	1782	1782	1782
Gender	Pearson Corr.		1	-,064**	-0,009	,432**	,357**	-0,03	-,115**	-,194**
	N		1944	1926	1944	1944	1854	1782	1782	1782
Bike Ownership	Pearson Corr.			1	0,012	,309**	,448**	,257**	,169**	,090**
	N			1926	1926	1926	1836	1764	1764	1764
Distance Campus	Pearson Corr.				1	,118**	,124**	,262**	,145**	-,143**
	N				1944	1944	1854	1782	1782	1782
Cycling Ability	Pearson Corr.					1	,469**	0,029	-,171**	-,228**
	N					1944	1854	1782	1782	1782
FreqBike	Pearson Corr.						1	-,197**	-,399**	-,448**
	N						1854	1782	1782	1764
FreqCar	Pearson Corr.							1	,127**	-0,001
	N							1782	1746	1746
FreqPT	Pearson Corr.								1	,154**
	N								1782	1728
FreqWalk	Pearson Corr.									1
	N									1782

** Correlation is significant at the 0.01 level (2-tailed).

B.2 CROSS-TABLE OF CHOICES AND PERSONAL CHARACTERISTICS

Characteristic variables	Total	SMOT			SPED		WID	
		Stripes	Curbs	Bollards	None	Fence	Narrow	Wide
Bike Ownership								
No	288	28%	27%	45%	49%	51%	43%	57%
Yes	1638	20%	35%	45%	47%	53%	44%	56%
Cycling Ability								
Beginner	162	28%	28%	44%	49%	51%	41%	59%
Intermediate	684	20%	32%	48%	46%	54%	45%	55%
Advanced	1098	21%	35%	44%	48%	52%	44%	56%
Distance to Campus								
< 1 km	414	25%	31%	44%	54%	46%	43%	57%
1 - 5 km	900	21%	35%	44%	46%	54%	45%	55%
5 - 10 km	414	21%	33%	46%	46%	54%	46%	54%
> 10 km	216	16%	33%	50%	44%	56%	39%	61%
Freq Bike								
Never	396	19%	32%	49%	50%	50%	43%	57%
Less than once a week	180	26%	31%	43%	49%	51%	51%	49%
1 - 2 days per week	288	18%	36%	47%	39%	61%	53%	47%
3 - 4 days per week	234	23%	35%	42%	48%	52%	37%	63%
5 or more days per week	756	21%	35%	44%	48%	52%	44%	56%
Gender								
Female	936	21%	31%	48%	46%	54%	45%	55%
Male	1008	21%	36%	43%	49%	51%	43%	57%

C.1 MNL MODEL SYNTAX

```
[ModelDescription]
"MNL with all contexts and all interactions"

[Choice]
CHOICE

[Beta]
BETA_BOL        0       -10000      10000       0
BETA_CURB       0       -10000      10000       0
BETA_SPED       0       -10000      10000       0
BETA_WID        0       -10000      10000       0

//interactions
BETA_BOL_SPED   0       -10000      10000       0
BETA_BOL_WID    0       -10000      10000       0
BETA_CURB_SPED  0       -10000      10000       0
BETA_CURB_WID   0       -10000      10000       0
BETA_SPED_WID   0       -10000      10000       0

//contexts
BETA_PRI_BOL    0       -10000      10000       0
BETA_PRI_CURB   0       -10000      10000       0
BETA_PRI_SPED   0       -10000      10000       0
BETA_PRI_WID    0       -10000      10000       0
BETA_SEC_BOL    0       -10000      10000       0
BETA_SEC_CURB   0       -10000      10000       0
BETA_SEC_SPED   0       -10000      10000       0
BETA_SEC_WID    0       -10000      10000       0
BETA_VPED_BOL   0       -10000      10000       0
BETA_VPED_CURB  0       -10000      10000       0
BETA_VPED_SPED  0       -10000      10000       0
BETA_VPED_WID   0       -10000      10000       0
BETA_HVEH_BOL   0       -10000      10000       0
BETA_HVEH_CURB  0       -10000      10000       0
BETA_HVEH_SPED  0       -10000      10000       0
BETA_HVEH_WID   0       -10000      10000       0

[Utilities]
1   Alt1  av1    $NONE
2   Alt2  av2    $NONE

[GeneralizedUtilities]
1 BETA_BOL * BOLLARD1 + BETA_CURB * CURB1 + BETA_SPED * SPED1 + BETA_WID * WID1
  + BETA_BOL_SPED * BOLLARD1 * SPED1 + BETA_BOL_WID * BOLLARD1 * WID1 + BETA_CURB_SPED * CURB1
    * SPED1 + BETA_CURB_WID * CURB1 * WID1 + BETA_SPED_WID * SPED1 * WID1
  + BETA_PRI_BOL * PRI * BOLLARD1 + BETA_PRI_CURB * PRI * CURB1 + BETA_PRI_SPED * PRI * SPED1
  + BETA_PRI_WID * PRI * WID1 + BETA_SEC_BOL * SEC * BOLLARD1 + BETA_SEC_CURB * SEC * CURB1
  + BETA_SEC_SPED * SEC * SPED1 + BETA_SEC_WID * SEC * WID1 + BETA_VPED_BOL * VPED * BOLLARD1
  + BETA_VPED_CURB * VPED * CURB1 + BETA_VPED_SPED * VPED * SPED1 + BETA_VPED_WID * VPED * WID1
  + BETA_HVEH_BOL * HVEH * BOLLARD1 + BETA_HVEH_CURB * HVEH * CURB1 + BETA_HVEH_SPED * HVEH *
    SPED1 + BETA_HVEH_WID * HVEH * WID1

2 BETA_BOL * BOLLARD2 + BETA_CURB * CURB2 + BETA_SPED * SPED2 + BETA_WID * WID2
  + BETA_BOL_SPED * BOLLARD2 * SPED2 + BETA_BOL_WID * BOLLARD2 * WID2 + BETA_CURB_SPED * CURB2
    * SPED2 + BETA_CURB_WID * CURB2 * WID2 + BETA_SPED_WID * SPED2 * WID2
  + BETA_PRI_BOL * PRI * BOLLARD2 + BETA_PRI_CURB * PRI * CURB2 + BETA_PRI_SPED * PRI * SPED2
  + BETA_PRI_WID * PRI * WID2 + BETA_SEC_BOL * SEC * BOLLARD2 + BETA_SEC_CURB * SEC * CURB2
  + BETA_SEC_SPED * SEC * SPED2 + BETA_SEC_WID * SEC * WID2 + BETA_VPED_BOL * VPED * BOLLARD2
  + BETA_VPED_CURB * VPED * CURB2 + BETA_VPED_SPED * VPED * SPED2 + BETA_VPED_WID * VPED * WID2
  + BETA_HVEH_BOL * HVEH * BOLLARD2 + BETA_HVEH_CURB * HVEH * CURB2 + BETA_HVEH_SPED * HVEH *
    SPED2 + BETA_HVEH_WID * HVEH * WID2

[Expressions]
av1 = 1
av2 = 1

[Model]
$MNL
```

C.2 ML MODEL SYNTAX

```
[ModelDescription]

[Choice]
CHOICE

[Beta]
BETA_BOL        0          -10000          10000          0
BETA_CURB       0          -10000          10000          0
BETA_SPED       0          -10000          10000          0
BETA_WID        0          -10000          10000          0

//interactions
BETA_BOL_SPED   0          -10000          10000          1
BETA_BOL_WID    0          -10000          10000          1
BETA_CURB_SPED  0          -10000          10000          1
BETA_CURB_WID   0          -10000          10000          0
BETA_SPED_WID   0          -10000          10000          0

//contexts
BETA_PRI_BOL    0          -10000          10000          0
BETA_PRI_CURB   0          -10000          10000          0
BETA_PRI_SPED   0          -10000          10000          1
BETA_PRI_WID    0          -10000          10000          0
BETA_SEC_BOL    0          -10000          10000          0
BETA_SEC_CURB   0          -10000          10000          0
BETA_SEC_SPED   0          -10000          10000          1
BETA_SEC_WID    0          -10000          10000          0
BETA_VPED_BOL   0          -10000          10000          1
BETA_VPED_CURB  0          -10000          10000          1
BETA_VPED_SPED  0          -10000          10000          0
BETA_VPED_WID   0          -10000          10000          1
BETA_HVEH_BOL   0          -10000          10000          0
BETA_HVEH_CURB  0          -10000          10000          1
BETA_HVEH_SPED  0          -10000          10000          1
BETA_HVEH_WID   0          -10000          10000          1

//ML parameters
SIGMA_BOL       0          -10000          10000          0
SIGMA_CURB      0          -10000          10000          0
SIGMA_SPED      0          -10000          10000          0
SIGMA_WID       0          -10000          10000          0

[Utilities]
1   Alt1  av1    $NONE
2   Alt2  av2    $NONE


[GeneralizedUtilities]
1 BETA_BOL [ SIGMA_BOL ] * BOLLARD1 + BETA_CURB [ SIGMA_CURB ] * CURB1 + BETA_SPED [ SIGMA_SPED ]
  * SPED1 + BETA_WID [ SIGMA_WID ] * WID1
  + BETA_BOL_SPED * BOLLARD1 * SPED1 + BETA_BOL_WID * BOLLARD1 * WID1 + BETA_CURB_SPED * CURB1
    * SPED1 + BETA_CURB_WID * CURB1 * WID1 + BETA_SPED_WID * SPED1 * WID1 + BETA_PRI_BOL * PRI
    * BOLLARD1 + BETA_PRI_CURB * PRI * CURB1 + BETA_PRI_SPED * PRI * SPED1 + BETA_PRI_WID * PRI
    * WID1 + BETA_SEC_BOL * SEC * BOLLARD1 + BETA_SEC_CURB * SEC * CURB1 + BETA_SEC_SPED * SEC
    * SPED1 + BETA_SEC_WID * SEC * WID1 + BETA_VPED_BOL * VPED * BOLLARD1 + BETA_VPED_CURB
    * VPED * CURB1 + BETA_VPED_SPED * VPED * SPED1 + BETA_VPED_WID * VPED * WID1 + BETA_HVEH_BOL
    * HVEH * BOLLARD1 + BETA_HVEH_CURB * HVEH * CURB1 + BETA_HVEH_SPED * HVEH * SPED1
   + BETA_HVEH_WID * HVEH * WID1


2 BETA_BOL [ SIGMA_BOL ] * BOLLARD2 + BETA_CURB [ SIGMA_CURB ] * CURB2 + BETA_SPED [ SIGMA_SPED ]
  * SPED2 + BETA_WID [ SIGMA_WID ] * WID2
  + BETA_BOL_SPED * BOLLARD2 * SPED2 + BETA_BOL_WID * BOLLARD2 * WID2 + BETA_CURB_SPED * CURB2
    * SPED2 + BETA_CURB_WID * CURB2 * WID2 + BETA_SPED_WID * SPED2 * WID2 + BETA_PRI_BOL * PRI
    * BOLLARD2 + BETA_PRI_CURB * PRI * CURB2 + BETA_PRI_SPED * PRI * SPED2 + BETA_PRI_WID * PRI
    * WID2 + BETA_SEC_BOL * SEC * BOLLARD2 + BETA_SEC_CURB * SEC * CURB2 + BETA_SEC_SPED * SEC
    * SPED2 + BETA_SEC_WID * SEC * WID2 + BETA_VPED_BOL * VPED * BOLLARD2 + BETA_VPED_CURB
    * VPED * CURB2 + BETA_VPED_SPED * VPED * SPED2 + BETA_VPED_WID * VPED * WID2 + BETA_HVEH_BOL
    * HVEH * BOLLARD2 + BETA_HVEH_CURB * HVEH * CURB2 + BETA_HVEH_SPED * HVEH * SPED2
   + BETA_HVEH_WID * HVEH * WID2

[PanelData]
ID
BETA_BOL_SIGMA_BOL
```

```
BETA_CURB_SIGMA_CURB
BETA_SPED_SIGMA_SPED
BETA_WID_SIGMA_WID

[Expressions]
av1 = 1
av2 = 1

[Draws]
500

[Model]
$MNL
```

APPENDIX D. DISCRETE CHOICE MODEL RESULTS

D.1 INDIVIDUAL MNL MODEL

No	Attribute	Coefficient			Final LL	Adj. Rho-squared
		Value	t-test	p-value		
1	Separation with motorized traffic				-1.233	0.083
	Bollards	1.050	14.26	0.00		
	Curb	0.445	6.08	0.00		
2	Separation with pedestrians (SPED)	0.224	4.04	0.00	-1.339	0.005
3	Bicycle lane width	0.457	7.99	0.00	-1.315	0.024

D.2 ML MODEL OF MAIN ATTRIBUTES

No	Attribute	Coefficient			Final LL	Adj. Rho-squared
		Value	t-test	p-value		
1	Separation with motorized traffic				-1.009	0.244
	Bollards	0.794	6.45	0.00		
	Curb	0.565	4.60	0.00		
2	Separation with pedestrians (SPED)	-0.0264	-0.29	0.77		
3	Bicycle lane width	0.502	4.83	0.00		
4	Interaction Curb * Width	-0.337	-1.35	0.18		
5	Interaction SPED * Width	0.522	2.62	0.01		
	Standard deviations					
	Bollards	1.51	9.91	0.00		
	Curb	1.11	9.02	0.00		
	SPED	-1.00	-8.47	0.00		
	Width	-0.801	-7.00	0.00		

APPENDIX E. INTERACTION EFFECTS WITH PERSONAL CHARACTERISTICS

Estimated variable		Value	Std err	t-test	p-value	Final LL	Adj. Rho sq
Main attributes (from MNL model)						-1131.926	0.149
Separation with motorized traffic							
BOL		0.390	0.166	2.36	0.02		
CURB		0.500	0.195	2.57	0.01		
Separation with pedestrian							
SPED		-0.291	0.120	-2.43	0.02		
Bicycle lane width		0.557	0.152	3.66	0.00		
WID							
A. Type of separation with motorized traffic							
BOL		0.390	0.166	2.36	0.02	-1131.926	0.149
CURB		0.500	0.195	2.57	0.01		
Age						-1127.398	0.151
BOL	Young (< 25 years)	0.170	0.144	1.18	0.24		
	Old (25 years or older)	0.631	0.150	4.21	0.00		
CURB	Young (< 25 years)	0.371	0.183	2.03	0.04		
	Old (25 years or older)	0.651	0.190	3.42	0.00		
Gender						-1129.422	0.151
BOL	Female	0.484	0.145	3.33	0.00		
	Male	0.288	0.146	1.97	0.05		
CURB	Female	0.391	0.188	2.08	0.04		
	Male	0.591	0.184	3.21	0.00		
Bike ownership						-1127.450	0.151
BOL	Own a bike	0.471	0.128	3.69	0.00		
	Do not own a bike	-0.007	0.215	-0.03	0.98		
CURB	Own a bike	0.593	0.173	3.43	0.00		
	Do not own a bike	0.034	0.250	0.14	0.89		
Cycling frequency						-1131.410	0.148
BOL	Often (3 days or more/week)	0.313	0.146	2.15	0.03		
	Never/rarely (< 3 days/week)	0.467	0.146	3.21	0.00		
CURB	Often (3 days or more/week)	0.458	0.182	2.51	0.01		
	Never/rarely (< 3 days/week)	0.555	0.190	2.92	0.00		
Cycling ability						-1130.131	0.148
BOL	Advanced	0.342	0.143	2.40	0.02		
	Intermediate	0.492	0.163	3.02	0.00		
	Beginner	0.324	0.267	1.21	0.23		
CURB	Advanced	0.539	0.180	2.99	0.00		
	Intermediate	0.495	0.201	2.46	0.01		
	Beginner	0.089	0.315	0.28	0.78		
Distance to campus						-1126.909	0.152
BOL	Far (> 5 km)	0.763	0.174	4.39	0.00		
	Near (5 km or less)	0.215	0.135	1.60	0.11		
CURB	Far (> 5 km)	0.575	0.204	2.82	0.00		
	Near (5 km or less)	0.463	0.177	2.61	0.01		

B. Separation with pedestrian							
SPED		-0.291	0.120	-2.43	0.02	-1131.926	0.149
Age						-1126.992	0,152
SPED	Young (< 25 years)	-0.093	0.128	-0.73	0.47		
	Old (25 years or older)	-0.473	0.126	-3.75	0.00		
Gender						-1129.831	0.150
SPED	Female	-0.167	0.127	-1.32	0.19		
	Male	-0.414	0.127	-3.26	0.00		
Bike ownership						-1130.762	0.150
SPED	Own a bike	-0.253	0.114	-2.21	0.03		
	Do not own a bike	-0.510	0.182	-2.81	0.01		
Cycling frequency						-1130.134	0.150
SPED	Often (3 days or more/week)	-0.404	0.127	-3.19	0.00		
	Never/rarely (< 3 days/week)	-0.175	0.127	-1.38	0.17		
Cycling ability						-1131.503	0.148
SPED	Advanced	-0.322	0.124	-2.60	0.01		
	Intermediate	-0.218	0.139	-1.57	0.12		
	Beginner	-0.378	0.227	-1.67	0.10		
Distance to campus						-1127.572	0,149
SPED	Far (> 5 km)	-0.0292	0.143	-0.20	0.84		
	Near (5 km or less)	-0.412	0.119	-3.46	0.00		
C. Bicycle lane width							
WID		0.557	0.152	3.66	0.00	-1131.926	0.149
Age						-1127.919	0.152
Young (< 25 years)		0.728	0.156	4.67	0.00		
Old (25 years or older)		0.375	0.156	2.40	0.02		
Gender						-1131.882	0,149
Female		0.538	0.156	3.45	0.00		
Male		0.575	0.156	3.69	0.00		
Bike ownership						-1131.791	0.150
Own a bike		0.544	0.145	3.75	0.00		
Do not own a bike		0.639	0.213	3.00	0.00		
Cycling frequency						1130.184	0.150
Often (3 days or more/week)		0.671	0.156	4.30	0.00		
Never/rarely (< 3 days/week)		0.438	0.156	2.80	0.01		
Cycling ability						-1129.904	0.150
Advanced		0.537	0.153	3.50	0.00		
Intermediate		0.972	0.258	3.77	0.00		
Beginner		0.485	0.167	2.90	0.00		
Distance from campus						-1131.804	0.149
Live far from campus (>5 km)		0.514	0.167	3.07	0.00		
Live close to campus (5 km or less)		0.580	0.150	3.86	0.00		

Estimated variable		Value	Std err	t-test	p-value	Final LL	Adj. Rho sq
Context effects (from MNL model)						-1131,926	0,150
Road type							
PRI * BOL		1,300	0,225	5,79	0,00		
PRI * CURB		0,987	0,197	5,00	0,00		
PRI * WID		0,331	0,161	2,05	0,04		
SEC * BOL		0,993	0,217	4,58	0,00		
SEC * CURB		0,789	0,192	4,12	0,00		
SEC * WID		0,406	0,158	2,57	0,01		
Volume of pedestrian							
VPED * SPED		0,377	0,121	3,12	0,00		
Presence of heavy vehicles							
HVEH * BOL		0,347	0,196	1,77	0,08		
A. Road type * Type of separation with motorized traffic							
PRI * BOL		1,300	0,225	5,79	0,00	-1131,926	0,150
PRI * CURB		0,987	0,197	5,00	0,00		
SEC * BOL		0,993	0,217	4,58	0,00		
SEC * CURB		0,789	0,192	4,12	0,00		
Age						-1129,417	0,148
PRI * BOL	Young (< 25 years)	1,100	0,260	4,21	0,00		
	Old (25 years or older)	1,570	0,292	5,37	0,00		
PRI * CURB	Young (< 25 years)	0,946	0,241	3,92	0,00		
	Old (25 years or older)	1,040	0,244	4,25	0,00		
SEC * BOL	Young (< 25 years)	0,831	0,250	3,33	0,00		
	Old (25 years or older)	1,190	0,275	4,32	0,00		
SEC * CURB	Young (< 25 years)	0,612	0,228	2,68	0,01		
	Old (25 years or older)	1,000	0,245	4,08	0,00		
Gender						-1129,879	0,148
PRI * BOL	Female	1,500	0,283	5,28	0,00		
	Male	1,130	0,265	4,27	0,00		
PRI * CURB	Female	0,896	0,247	3,63	0,00		
	Male	1,070	0,239	4,48	0,00		
SEC * BOL	Female	1,170	0,274	4,27	0,00		
	Male	0,848	0,251	3,38	0,00		
SEC * CURB	Female	0,811	0,240	3,38	0,00		
	Male	0,788	0,232	3,40	0,00		
Bike ownership						-1123,637	0,153
PRI * BOL	Own a bike	1,490	0,241	6,20	0,00		
	Do not own a bike	0,447	0,381	1,17	0,24		
PRI * CURB	Own a bike	1,120	0,210	5,36	0,00		
	Do not own a bike	0,435	0,360	1,21	0,23		
SEC * BOL	Own a bike	1,080	0,229	4,72	0,00		
	Do not own a bike	0,601	0,374	1,61	0,11		
SEC * CURB	Own a bike	0,954	0,202	4,73	0,00		
	Do not own a bike	-0,231	0,406	-0,57	0,57		

Cycling frequency						-1131,433	0,147
PRI * BOL	Often (3 days or more/week)	1,420	0,276	5,13	0,00		
	Never/rarely (< 3 days/week)	1,200	0,270	4,44	0,00		
PRI * CURB	Often (3 days or more/week)	1,110	0,246	4,50	0,00		
	Never/rarely (< 3 days/week)	0,874	0,239	3,65	0,00		
SEC * BOL	Often (3 days or more/week)	1,010	0,262	3,86	0,00		
	Never/rarely (< 3 days/week)	0,973	0,259	3,75	0,00		
SEC * CURB	Often (3 days or more/week)	0,832	0,228	3,64	0,00		
	Never/rarely (< 3 days/week)	0,738	0,243	3,03	0,00		
Cycling ability						-1130,113	0,145
PRI * BOL	Advanced	1,400	0,268	5,22	0,00		
	Intermediate	1,290	0,309	4,17	0,00		
	Beginner	1,050	0,499	2,10	0,04		
PRI * CURB	Advanced	1,170	0,239	4,89	0,00		
	Intermediate	0,840	0,270	3,12	0,00		
	Beginner	0,522	0,468	1,12	0,26		
SEC * BOL	Advanced	0,923	0,253	3,65	0,00		
	Intermediate	1,070	0,289	3,71	0,00		
	Beginner	1,300	0,570	2,28	0,02		
SEC * CURB	Advanced	0,749	0,222	3,37	0,00		
	Intermediate	0,922	0,278	3,31	0,00		
	Beginner	0,594	0,465	1,28	0,20		
Distance to campus						-1128,588	0,149
PRI * BOL	Far (> 5 km)	1,830	0,360	5,09	0,00		
	Near (5 km or less)	1,110	0,241	4,60	0,00		
PRI * CURB	Far (> 5 km)	1,050	0,291	3,59	0,00		
	Near (5 km or less)	0,967	0,219	4,41	0,00		
SEC * BOL	Far (> 5 km)	1,220	0,318	3,85	0,00		
	Near (5 km or less)	0,897	0,236	3,81	0,00		
SEC * CURB	Far (> 5 km)	0,669	0,271	2,47	0,01		
	Near (5 km or less)	0,853	0,215	3,96	0,00		
B. Road type * Bicycle lane width							
PRI * WID		0,331	0,161	2,05	0,04	-1131,926	0,150
SEC * WID		0,406	0,158	2,57	0,01		
Age						-1126,476	0,152
PRI * WID	Young (< 25 years)	0,610	0,198	3,08	0,00		
	Old (25 years or older)	0,045	0,197	0,23	0,82		
SEC * WID	Young (< 25 years)	0,649	0,196	3,31	0,00		
	Old (25 years or older)	0,169	0,191	0,89	0,37		
Gender						-1131,777	0,148
PRI * WID	Female	0,381	0,200	1,90	0,06		
	Male	0,285	0,194	1,47	0,14		
SEC * WID	Female	0,366	0,194	1,89	0,06		
	Male	0,443	0,191	2,31	0,02		
Bike ownership						-1131,898	0,148
PRI * WID	Own a bike	0,326	0,168	1,94	0,05		
	Do not own a bike	0,358	0,313	1,14	0,25		
SEC * WID	Own a bike	0,397	0,163	2,43	0,02		
	Do not own a bike	0,467	0,331	1,41	0,16		

Cycling frequency						-1131,540	0,148
PRI * WID	Often (3 days or more/week)	0,399	0,196	2,03	0,04		
	Never/rarely (< 3 days/week)	0,262	0,198	1,32	0,19		
SEC * WID	Often (3 days or more/week)	0,473	0,190	2,49	0,01		
	Never/rarely (< 3 days/week)	0,332	0,195	1,70	0,09		
Cycling ability						-1131,540	0,148
PRI * WID	Advanced	0,285	0,188	1,51	0,13		
	Intermediate	0,336	0,226	1,49	0,14		
	Beginner	0,628	0,398	1,58	0,11		
SEC * WID	Advanced	0,399	0,184	2,17	0,03		
	Intermediate	0,230	0,217	1,06	0,29		
	Beginner	1,330	0,448	2,97	0,00		
Distance to campus						-1131,218	0,149
PRI * WID	Far (> 5 km)	0,155	0,230	0,67	0,50		
	Near (5 km or less)	0,415	0,180	2,31	0,02		
SEC * WID	Far (> 5 km)	0,322	0,224	1,44	0,15		
	Near (5 km or less)	0,446	0,175	2,54	0,01		
C. Volume of pedestrian * Type of separation with pedestrians							
VPED * SPED		0,377	0,121	3,12	0,00	-1131,926	0,150
Age						-1127,688	0,152
Young (< 25 years)		0,647	0,154	4,20	0,00		
Old (25 years or older)		0,137	0,146	0,94	0,35		
Gender						-1131,364	0,149
Female		0,473	0,152	3,12	0,00		
Male		0,289	0,146	1,97	0,05		
Bike ownership						-1128,878	0,151
Own a bike		-0,111	0,231	-0,48	0,63		
Do not own a bike		0,471	0,127	3,71	0,00		
Cycling frequency						-1131,925	0,149
Often (3 days or more/week)		0,372	0,149	2,50	0,01		
Never/rarely (< 3 days/week)		0,381	0,148	2,57	0,01		
Cycling ability						-1131,773	0,148
Advanced		0,405	0,143	2,83	0,00		
Intermediate		0,368	0,169	2,18	0,03		
Beginner		0,233	0,304	0,77	0,44		
Distance from campus						-1128,447	0,151
Live far from campus (>5 km)		0,714	0,178	4,01	0,00		
Live close to campus (5 km or less)		0,218	0,134	1,63	0,10		
D. Presence of heavy vehicles * Type of separation with motorized traffic (Bollards)							
HVEH * BOL		0,347	0,196	1,77	0,08	-1131,926	0,150
Age						-1131,029	0,150
Young (< 25 years)		0,179	0,230	0,78	0,44		
Old (25 years or older)		0,560	0,258	2,17	0,03		

Gender					-1131,128	0,149
Female	0,539	0,253	2,13	0,03		
Male	0,181	0,233	0,77	0,44		
Bike ownership					-1131,661	0,149
Own a bike	0,390	0,206	1,89	0,06		
Do not own a bike	0,110	0,373	0,30	0,77		
Cycling frequency					-1131,460	0,149
Often (3 days or more/week)	0,490	0,249	1,96	0,05		
Never/rarely (< 3 days/week)	0,217	0,235	0,92	0,36		
Cycling ability					-1131,354	0,149
Advanced	0,431	0,235	1,84	0,07		
Intermediate	0,334	0,278	1,20	0,23		
Beginner	-0,071	0,443	-0,16	0,87		
Distance from campus					-1128,536	0,151
Live far from campus (>5 km)	1,000	0,345	2,91	0,00		
Live close to campus (5 km or less)	0,129	0,210	0,61	0,54		

APPENDIX F. SURVEY QUESTIONS

Hello, welcome to Cycling Infrastructure in Tirana survey! The purpose of this survey is to gain insights about **your preferences on bicycle infrastructure designs**, especially from university students. The results hopefully can be used to help design better cycling environment in Tirana and other Balkan cities.

The survey should only take 5-10 minutes to finish. Please answer all the questions on each page. **All the information you provide will be kept confidential and only be used for this research.**

This survey is part of my graduation thesis project at Delft University of Technology in the Netherlands.
If you have any question about the survey, you can contact me at etsa.amanda@gmail.com.
Thank you for your participation, your thoughts will be very valuable for the research!

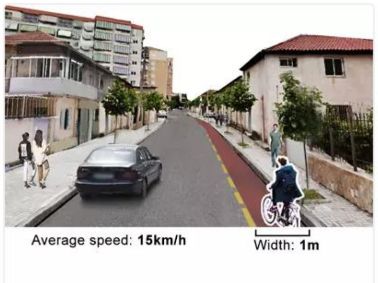
Etsa Amanda
Master's student
Delft University of Technology

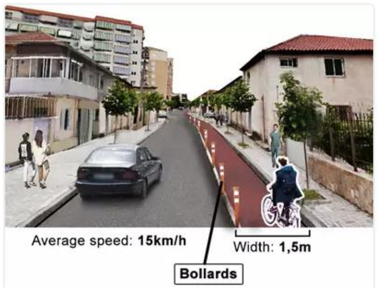
(Example of questions in) Part I. Bicycle infrastructure design preferences

This part consists of 20 questions. On <u>each page</u>, you will be given a description of your travel as a cyclist. You will be asked to choose between 2 images of road situations. Please choose the road you prefer to cycle on by clicking the image.

<u>Travel description 1-3:</u>
Imagine **you are the cyclist** in the pictures (highlighted).
You are cycling to your university.
You are cycling on a local road with low level of traffic.
The average traffic speed is 15km/h.
There are only few pedestrians next to the road.
The travel time on both roads are equal.

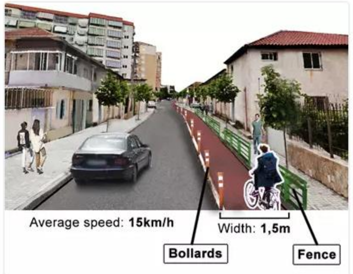
1. Which road would you choose? *

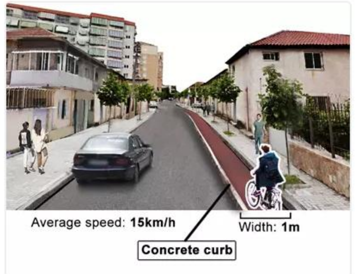




2. Which road would you choose? *

3. Which road would you choose? *





Part II. Personal characteristics

Please tell us a bit about yourself. As stated before, **all information will be kept confidential.**

79. Are you a university student?

- ◯ Yes
- ◯ No

80. What is your age?

- < 18 years old
- 18 - 25 years old
- > 25 years old

81. What is your gender?

- Male
- Female

82. Do you own a bicycle?

- Yes
- No

83. How far do you live from campus?

- < 1 km
- 1 - 5 km
- 5 - 10 km
- > 10 km

84. How would you rate your ability to cycle?

- Advanced, I am confident to cycle in most roads and traffic situations
- Intermediate, I am confident to cycle in some roads and traffic situations
- Beginner, I try to always cycle on cycle paths or lanes separated from traffic

Part III. Travel habits

85. On average, how many times do you commute to campus by these modes:

	Never	Less than once a week	1 - 2 days per week	3 - 4 days per week	5 or more days per week
Bicycle	○	○	○	○	○
Car	○	○	○	○	○
Public transport	○	○	○	○	○
Walking	○	○	○	○	○
Enter another option	○	○	○	○	○

86. When was the last time that you rode a bicycle?

- Within a week
- Within a month
- Within a year
- More than a year ago
- I never ride a bicycle

87. What keeps you from cycling more often to campus? You may pick **up to 3 main reasons.**

- I am worried about collision with traffic
- I am not comfortable to cycle alongside busses/trucks
- Lack of cycling infrastructure (bike lanes or paths) from my house to campus
- Low quality cycling infrastructure
- I live too far from campus
- I do not have a bike
- The weather is not comfortable for cycling
- Other - Write In ________ *

(Example of questions in) **Part IV. Survey verification test**

89. What do you think of the **traffic speed** and **bicycle lane width** in the picture below?

	Low	Medium	High
Traffic speed	○	○	○
Bicycle lane width	○	○	○

94. What do you think of the **traffic speed** and **bicycle lane width** in the picture below?

	Low	Medium	High
Traffic speed	○	○	○
Bicycle lane width	○	○	○