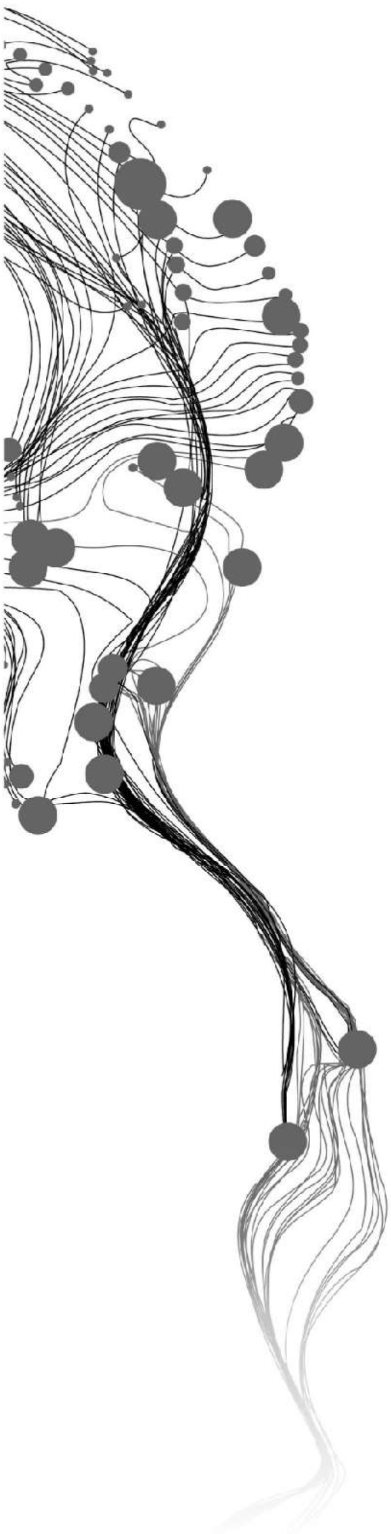
DATA COLLECTION TOOLS TO ANALYZE THE IMPACT OF STREETSCAPE DESIGN ON CYCLISTS' ROUTE CHOICE

ROBERTO NACXIT RAMIREZ JUAREZ
June 2022

SUPERVISORS:
Dr. A.B. Grigolon
Dr. A.M. Madureira



DATA COLLECTION TOOLS TO ANALYZE THE IMPACT OF STREETSCAPE DESIGN ON CYCLISTS' ROUTE CHOICE

ROBERTO NACXIT RAMIREZ JUAREZ
Enschede, The Netherlands, June 2022

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.

Specialization: Urban Planning & Management (UPM)

SUPERVISORS:
Dr. A.B. Grigolon
Dr. A.M. Madureira

THESIS ASSESSMENT BOARD:
Dr. J.A. Martinez (Chair)
Dr. L. M. Rabago Mayer (External examiner)

ABSTRACT

To encourage behavioral changes to reduce car use, understanding about the travel behavior is needed as well as interventions in infrastructure. Understanding the route choices of cyclists and their motivation based on their preferences regarding their trip attributes is important to improve cycling networks and therefore encourage the use of active travel modes such as cycling. This thesis had the aim to understand the influence of streetscape design features on cyclists' route choice, by developing a mixed-method approach to collect objective and subjective data. The proposed mixed-method involved the use of a survey using the Maptionnaire platform in combination with a VR experiment to simulate a bike ride in the city of Enschede, The Netherlands. Results showed the differences between the usual and ideal routes regarding streetscape design features and the combined methods allowed to improve understanding about cyclists' perceptions of such design features. Also from the results, the added value of the proposed methodology in terms of learning and usability as combining data from the methods seemed to improve understanding about the influence of streetscape design features in cyclists' route choices. Therefore, results from this study may encourage academics to develop and implement alternative mixed-methods approaches to increase understanding of cyclists' travel behaviour regarding route choice. Also from a practitioner perspective, implementation of such mixed-methods for data collection may increase the efficiency of the process and also help developing contextual data-driven interventions that encourage the use of bicycles.

Keywords: Route choice, Cycling, Streetscape, Mixed-methods, PPGIS, VR

ACKNOWLEDGEMENTS

Thank you

Family members that always keep me showing unconditional love and support.

Friends that helped me along the way, in person and at a distance.

ITC staff that provided such a wonderful learning environment.

Thank you Roberto, for not breaking along the way and face all the hiccups with a smile with the help and support of family, friends and professors.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. *Background*

Worldwide, the transport sector is one of the main sources of CO_2 emissions with the private car being the second highest contributor (Ritchie & Roser, 2020). Decisions about reducing car use and increase active means of transportation such as walking and cycling have been considered in transport-related policies and interventions (Banister, 2008). For such decisions, an analysis of the co-benefits of active means of transportation are considered; these co-benefits are mainly related to environmental and economic issues such as CO_2 emissions savings, increasing use of infrastructure, increasing property values and supporting long term behavioral changes to reduce car use (Mrkajic et al., 2015).

To encourage behavioral changes to reduce car use, understanding about the travel behavior from people is needed as well as interventions in infrastructure. In the case of provision of cycling infrastructure to improve the connectivity (and improve the cycling experience), Li et al., (2017) found out that understanding the route choices of cyclists and their motivation based on their preferences regarding their trip attributes and network factors is important to establish a better connected cycling network, to improve cycling networks and therefore encourage the use of active travel modes such as cycling.

1.1.1 Travel behavior and route choice

Studies about travel behavior have been developed to understand human behavior regarding choices such as transport mode and route (Ewing & Cervero, 2017). Travel behavior can be defined as "the complicated decision-making process of travelers during a trip, regarding travel mode choice, route choice, departure time choice, destination choice, and so on" (Li et al., 2018, p.113). As part of this complex decision-making process, a multi-disciplinary approach might help to better understand travel behavior. For example, Van Wee et. al., provide a conceptual framework based on the contributions from psychology, economics and geography to understand travel behavior, as choices are dependent on the needs, opportunities and abilities of individuals (Van Wee et al., 2013).

Understanding cyclists' behavior is important to allow interventions that encourage the use of non-motorized means of transport such as bicycles. In the case of cyclists behavior regarding their route choices, interaction with the built environment and attributes such as dedicated bike lanes, number of crossings, surface quality and presence of greenery have shown to be desirable and influential when choosing a route to move from one point to another (Hardinghaus & Papantoniou, 2020; S. Li et al., 2017). Therefore, identifying the elements of the built environment that influence the cycling experiences and understanding how they influence cyclists route choices may be beneficial for targeted interventions to improve the quality of bike infrastructure and thus encouraging the use of the bicycle.

1.1.2 Travel behavior and aesthetics of the built environment

Regarding travel behavior and its relationship with the built environment (BE), Cervero & Kockelman (1997) identify the main variables of the built environment that encourage active transportation such as density, diversity and design, also known as the 3 D's. Current research about the built environment and the impact on mode and route choice considers the dimensions proposed by Cervero and Kockelman (Liu et al., 2021; Ospina et al., 2020; Xiao et al., 2020). However, the majority of studies often focus on the density and diversity dimensions while design is relatively less discussed (Eom & Cho, 2015; Wang & Zhou, 2017).

The design dimension involves design features to reward pedestrians, cyclists or transit riders with amenities such as shade trees or civic squares as a way of 'leveling the playing field' with motorists (Cervero & Kockelman, 1997). In the case of cycling, provision of such aesthetical amenities are found to be a top motivator for the enjoyment of the cycling experience among different types of cyclists (Winters et al., 2010). In addition, the aesthetical attributes are mainly part of the leisure-related factors of the built environment that influence the route choice when cycling but some of those attributes (such as signalized intersections and pavement quality) are also related to convenience and safety factors (Chen et al., 2017).

Research has been conducted about which aesthetic elements of the urban environment - such as trees, illumination, window apparels, etc. - affect travel choices for non-motorized means of transport e.g. Cole-Hunter et al., 2015; Desjardins, Apatu, et al., 2021; Sun et al., 2017; Verhoeven et al., 2018. Also, studies focusing specifically on route choice of cyclists and the relationship with the built environment remark the importance of the design dimension (aesthetics); an example is the research of Desjardins et al., (2021), where they found that cycling is influenced in a large part by the quality, design and connectivity aspects of the infrastructure as participants discussed the perceptions of street-level features more than land use or urban form. However, their study did not address what are the specific street-level features that impact the route decision.

1.1.3 Perception of built environment

To understand the influence of the built environment in travel choices when cycling, psychological factors such as the individual's perceptions have shown a large influence in these decisions (Willis et al., 2015). Perception can be defined as "the way sensory information is organized, interpreted and consciously experienced" (Spielman et al., 2020, p.157). To better understand perceptions, considering different data collection methods is required. Both, objective and subjective measurements of the built environment must be considered together, as it may help explaining some inconsistent findings from studies that link the built environment with cycling behaviour based either only on subjective or objective measurements of perception of design attributes (Ma & Dill, 2015).

1.2. Research problem

1.2.1 Quantitative and qualitative data collection

During the last decade, the association between built environment (such as street design, provision of infrastructure or, land-use mix) and cycling behaviour has been greatly explored. In their research, Yang et al. (2019) reviewed 39 empirical studies between 2007 and 2017 to determine associations between cycling and built environment, and found that the most frequent qualitative data collection methods were standardized questionnaires and in few other cases collaborative mapping methods were used.

Quantitative (or objective) attributes of the built environment are often obtained from existing spatial data or field audits while qualitative (or perceived) information comes from personal interviews or other alternative methods such as simulated photos of proposed changes. One reason to focus on different methods to collect quantitative and qualitative information about the built environment is that objective attributes are considered more reliable than the perceived, more subjective ones (Yang et al., 2019). Thus, differences in measured attributes are expected depending on the methodology and the characteristics of the implemented data collection approach.

In travel behaviour studies that consider the application of qualitative data collection methods, travel surveys and personal interviews are dominant and, to a lesser extent, focus groups (Mars et al., 2016). However, a combination of qualitative and quantitative methods to collect and analyze data may improve the quality of the information. For example, using qualitative methods to complement quantitative findings as in first collecting quantitative data from field audits and then creating follow up interviews or focus groups for the qualitative aspects (Mars et al., 2016).

In the case of cycling behaviour, the impact of both objective and perceived built environment has been studied. Objective attributes of the built environment such as street design, traffic speeds, volumes, density of businesses, etc, have shown a strong influence on travel behaviour as they directly influence the perceptions of the built environment (Ma et al., 2014). Data about objective attributes of the built environment can be captured by simple field audits however, capturing data about perception of the built environment is often difficult.

1.2.2 Capturing perception data

The difficulty to capture perception lies in the interpretation process of reality. This interpretation of reality can be analysed from two main perception approaches, Top-Down and Bottom-Up (Spielman et al., 2020). On one hand, a Top-Down approach refers to the direct influence of the physical environment in perception; in other words, how design features such as trees, pavement, facades, etc and other sensory information like smell or sound influence the perception of the environment. On the other hand, a Bottom-Up approach refers to the interpretation of the receiving information based on prior knowledge, experiences and expectations; this means that, in a Bottom-Up approach, reality is processed based on individual preferences and backgrounds. Therefore, differentiation between these two approaches would allow the development of tools to measure specific types of perception; for example, the use of surveys may help to understand perception from the Bottom-Up approach while a ride-along interview is more of a Top-Down approach.

Even though traditional surveys about perception of the built environment help understanding some contextual parameters that influence route choices (such as preferences, socioeconomic status or attributes), respondents may not report all relevant information due to misinterpretation or survey fatigue (Lee et al., 2016). This reporting issues, in combination with the subjective nature of individual perception, have a direct impact of the quality of the retrieved information.

1.3. Research objectives

The aim of this research is to understand the influence of streetscape design features on cyclists' route choice, by developing a mixed-method approach to collect objective and subjective data. For this, the sub-objectives and guiding research questions are the following:

1. To explore current methods for collecting data regarding streetscape design features influencing cyclists' route choices.
    a. What are the methods that are being used to collect data on streetscape design features influencing cyclists' route choice?
    b. What are the features of the streetscape that affect route choice of cyclists according to literature?

2. To develop a methodology that allows collecting data on cyclists' perception of streetscape design features and its influence on route choice.
    a. How can information about cyclists' perception (from both top-down and bottom-up approaches) of streetscape design features be collected and represented for a given context?
    b. How can the added value of the proposed methods from a user and a developer perspective be evaluated?
    c. To what extent does the proposed mixed-method approach helps researchers to increase understanding about the impact of streetscape design features on cyclists' route choices?

3. To evaluate the added value of the proposed methodology.
    a. What are the differences, regarding perception of streetscape design features, between the chosen and the ideal routes for cyclists when travelling from home to work?
    b. To what extent does the implementation of the mix-method approach influences participants' perception of the streetscape regarding their cycling experiences?

1.4. Scientific and societal relevance

In terms of societal relevance, increased understanding about how the influence of streetscape design features on cyclists' route choices may be beneficial for decision-makers to develop contextualized and data-driven interventions and thus encouraging active transportation in urban areas. Regarding the scientific relevance, this research emphasizes the integration of alternative tools and technologies to improve data collection regarding perception of the streetscape design features. The aim is to increase understanding about the influence of the streetscape design features (such as presence of trees or vegetation, diversity in buildings' facades, quality of pavement, etc.) on cyclists' route choices.

1.5. Thesis structure

Chapter 1 of this thesis provides an overview of the background of the study and presents the aim and objectives to address the identified research problem. In chapter 2, information about how data about cycling route choices is collected and data collection technologies are presented. Chapter 3 presents the methodology from the development of the proposed mixed-method approach and the data collection process. In chapter 4, the results from the data collection are reported and then discussed in chapter 5. At last, chapter 6 presents the conclusions of this thesis, the ethical considerations, and the recommendations for future studies.

2. LITERATURE REVIEW

To answer the question 1a '*What are the methods that are being used to collect data on streetscape design features influencing cyclists' route choice?*' a systematic literature review was conducted. To constrain the search for current tools and methodologies for data collection regarding cyclists' route choices, the following criteria was considered:

- First, to filter the current methodologies and tools, a time-frame of the latest 10 years was contemplated. This means that only studies published in peer-reviewed journals from January 2011 until December 2021 were considered for analysis. This consideration was done to filter out the most recent technologies that are being used regarding data collection however, older key studies on the field were also included.

- Second, to search for relevant literature, a search matrix was developed considering the key concepts of this research (Streetscape, Cycling & Route choice) and their relationship with more narrow and broader terms as well as related synonyms for the key concepts resulting in two search queries; one, the 'complete', query using Boolean operators and wildcards and another, the 'refined', without wildcards as some databases do not support such elements of the query.

- Third, to ensure consideration of the most amount of information, three different databases were considered: Scopus, Web of Science and Science Direct.

From this criteria, a search query was created where a total of 930 results were retrieved. An example of the search log registering the filters regarding publishing dates, database, implemented search query and number of results can be found in Annex 1. After scanning the 930 papers, 57 articles were selected for further analysis and allowed to choose the methods to be implemented for the proposed methodology on this research.

Additionally, a review scheme was created to have an overview of the characteristics of the selected literature. This scheme consider aspects such as year of publication, country of study, data collection method, sample size, unit of analysis and type of trip (recreational or commuting cycling trips). This overview allows further discussion in the results section about current data collection tools and common characteristics and settles a starting point for comparison with the implemented methods from this research.

2.1. Cycling route choice data collection

To better understand the relationship between streetscape design features and cycling route choice behaviour, acquisition of geographical data is important. For this purpose, some studies use datasets from GPS-tracking apps such as STRAVA (McArthur & Hong, 2019) or Hamilton Bike Share (Scott et al., 2021). The way these data collection tools are implemented for research is that participants use the GPS app during the cycling activity to record their routes and then, these GPS routes are used in combination with secondary data to find the relationships between the built environment and the recorded routes. The use of such apps allows researchers to obtain large amounts of data about cycling trips. However, the retrieved data from these apps is potentially biased regarding representativeness of the sample as users of such apps are often cyclists that ride more for leisure purposes (Garber et al., 2019).

To mitigate biases in Volunteered Geographic Information (VGI) datasets such as STRAVA, Alattar et al., (2021) proposed a method based on the data fusion technique which combines multiple datasets to produce a more accurate dataset through implementation of Public Participation Geographic Information Systems (PPGIS). The sample collected using STRAVA was not representative of the study area so, to compensate for that, data from non-users was acquired using a PPGIS application. In this case, implementation of PPGIS demonstrates the feasibility to use the tool as rather a primary or complementary data collection method to compensate for representativeness in cycling routes datasets.

One example of a PPGIS is the digital web-based tool Maptionnaire. As a PPGIS, this tool allows researchers to reach out to a broad public to collect place-specific data with a customized survey that is designed to fit the specific purposes of the research in a given context and allows participants not to only contribute with the routes but also mark and comment on location-based attributes (Maptionnaire, 2020). The possibility of using a tailor-made survey design allows to compensate for representation biases in the dataset as well as considering other possible factors such as gender, age or trip purpose regarding an specific study case to improve the quality of the data.

2.2. Technology and individual's perception

2.2.1 Virtual reality

Development of new technologies generate alternatives for researchers to explore individual's perception. In the case of the built environment, Virtual Reality (VR) has been used to replace physical streetscape audits reducing the time taken to complete a visual audit in comparison with a physical audit. This process increases the level of agreement between the virtual and the physical formats to measure contextual features of the built environment (Badland et al., 2010). Having a high level of agreement between virtual and physical audits means that using virtual environments would be a reliable and resource-efficient option to assess streetscape features within a controlled environment for a specific purpose. However, in virtual environments, people can experience distorted perceptions of the space due to, for instance, estimation of distance or speed and restrictions from the field of view in a virtual environment (Wąsowicz, 2021).

VR has been used in travel behaviour studies for instance, to evaluate pedestrians' behaviour (Bhagavathula et al., 2018; Maghelal et al., 2011) or to evaluate cyclists' perception of safety (Nazemi et al., 2021). In these studies, different set-ups such as single or multiple screens, projectors or headsets are used to simulate the virtual environment. For example, in the case of Nazemi et al. (2021), a stationary bike and a 360-degree VR headset were implemented to explore five different cycling scenarios with different bike path characteristics. Even if they do not use the same set-up for the VR experience, these studies highlight the advantages of using VR as a reliable tool to capture perception in a safe and controlled environment. This method is found to compensate for contextual physical differences such as time of the day, weather conditions, road and traffic characteristics, etc. that may introduce variances in the data.

2.2.2 Eye-tracking

Another technology used to understand perception is eye-tracking. This technology measures the eye(pupil) movements to collect information about subjects' perception by capturing the main movements of the pupil, measured by fixations and saccades. A fixation can be defined as "the state when the eye remains still during a period of time" (Holmqvist et al., 2011, p.24) and it is used to measure the attention to a particular position. Saccades are "the rapid motion of the eye from one fixation to another" (Holmqvist et al., 2011, p.26) and are related to exploration of the space. These types of eye movements are reported in milliseconds in the case of fixation to determine time of attention in a particular point and in the case of saccades the total count is used to measure the degree of exploration in a particular area of interest.

Related to cycling behaviour, some studies use eye-tracking technology to understand cyclists' perception of risk (Kovácsová et al., 2018; von Stülpnagel, 2020) and identification of obstacles during a bike ride (Brazil et al., 2018; Mantuano et al., 2017). The use of eye-tracking technology helps increasing understanding about how elements of the built environment interact in real time while cycling and the impact that they have in perceptions in a controlled environment. Regarding the reliability of eye movements measurements in laboratory-based studies in comparison to real-life scenarios when cycling, Zeuwts et al. (2016) identified strong similarities between both scenarios (real life and video recordings) under certain constrains such as similar fields of view and sensation of speed.

Also in the study, Zeuwts et al. (2016) assume that as cycling in real life is more demanding than in a simulated environment since steering and navigating is present, participants in a lab condition could allocate more their visual attention towards other attractive regions of their visual fields besides the immediate road. These findings suggest that in a lab environment, participants can focus more in the contextual elements during the bike ride allowing researchers to measure the attention to, for example, aesthetical elements of the built environment.

2.3. *Participatory tools for data collection*

Besides the quality of retrieved data, the assessment of data collection tools involving public participation in terms of their added value and usability is difficult. To assess the added value of participatory tools, Pelzer et al, (2014) developed a framework to evaluate participatory tools on the individual, group and outcome level. The individual level focuses on the learning effects for the participants involved, the group level involves exchange of information, collaboration and efficiency of the tool and the outcome level considers the extent to which the tool influences the decision resulting from a participatory planning process. In the case of tools intended for data collection, evaluating certain variables from the individual, group and outcome levels may provide insight about the added value of the tool, allowing the identification of potential uses and limitations of such tool for decision-making processes. An overview of the evaluation of participatory tools based on Peltzer et al, (2014) framework is illustrated in Figure 1.

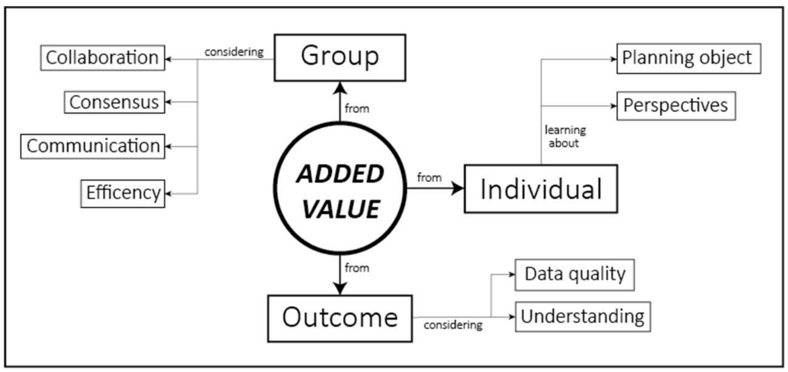


Figure 1. Illustration about added value of tools involving public participation based on framework developed by Pelzer et al, (2014).

2.3.1 Evaluation of individual level

Learning, both as an outcome and as a mean to achieve other goals, is important in tools that encourage public participation as it generates awareness about existing perceptions regarding the topic being discussed (Beukers et al., 2014). This learning can be discerned in two types such as single or double loop learning; single loop learning involves retrieving insights but does not increase insight in the way which other stakeholders perceive or address the topic in discussion as the case with double loop learning (Pelzer & Geertman, 2014). For evaluating learning from participatory tools, these types of learning can be translated into learning about the planning object (in the case of single-loop) and learning from the perspective of others (double-loop).

On one hand, learning about the planning object provides insight about what the problem is and what its causes may be as well as what possible effects this would contribute to planning interventions (Pelzer et al., 2014). This means that evaluating the data collection tool regarding its potential to increase understanding about the planning object (i.e. influence of aesthetics in cyclists' route choice) may be helpful to identify the strengths and address the limitations of a given method. Different methods can provide different insights about the planning object depending on their characteristics and how participants interact with the tool.

On the other hand, learning about the perspective of others provides insight into how involved stakeholders act and think based on the exchange of experiences (Pelzer et al., 2014). This means that evaluating learning from multiple individual perspectives may be helpful to understand the role of the tool and its impact as part of a decision-making process i.e. how the implementation of an specific tool influences the decision for targeted interventions, in this case, involving streetscape design features of the built environment to improve cyclists' riding experience to encourage the use of the bicycle.

2.3.2 Evaluation of group level

When evaluating the added value of tools involving public participation at the group level, four main potential added values can be recognized regarding collaboration, communication, consensus and efficiency (Pelzer et al., 2014). Regarding the assessment about the added value of tools for data collection, different criteria may be considered based on the main four categories as follows:

I. The *collaboration* value is about the potential of the implemented tool to promote interaction, sharing different perspectives and allow for revising arguments made by all participants involved in the process.
II. The *communication* added value is about the characteristics of a given tool to facilitate communication and discussion between participants allowing exchange of information.
III. The added value regarding the *consensus* category is about the combination of collaboration and communication to, depending on the type of problem addressed, reach common agreement about identification of problems and the criteria to evaluate them.
IV. The *efficiency* added value refers to the potential of the tool to reduce time or money for the data collection process through usability features of the tool.

2.3.3 Evaluation of outcome level

Measuring the added value of a tool involving public participation at this level is complicated as this level assesses weather a plan or decision would have been different without the application of the tool (Pelzer et al., 2014). However, for the case of a method intended for data collection, the outcome level can be assessed by reflecting on the potential of the collected data for a better-informed decision in comparison with other alternatives. In other words, for the case of a data collection tool the outcome level can be used to evaluate the potential of the retrieved information, and the way data is collected, to increase understanding of the problem in comparison with other methods.

3. METHODOLOGY

The methodology of this research is summarized in Figure 2. The dotted boxes contain the processes of each of the three objectives, and specific processes will be further explained in this section. The top box (objective 1) follows the process to identify the design features of the streetscape influencing cyclists' route choice from the literature review. The box in the middle (objective 2) involves the data collection process about cyclists' perception from both top-down and bottom-up approaches. Lastly, the bottom box (objective 3) regards the process for assessing the added value of the implemented methods and the quality of the output information.

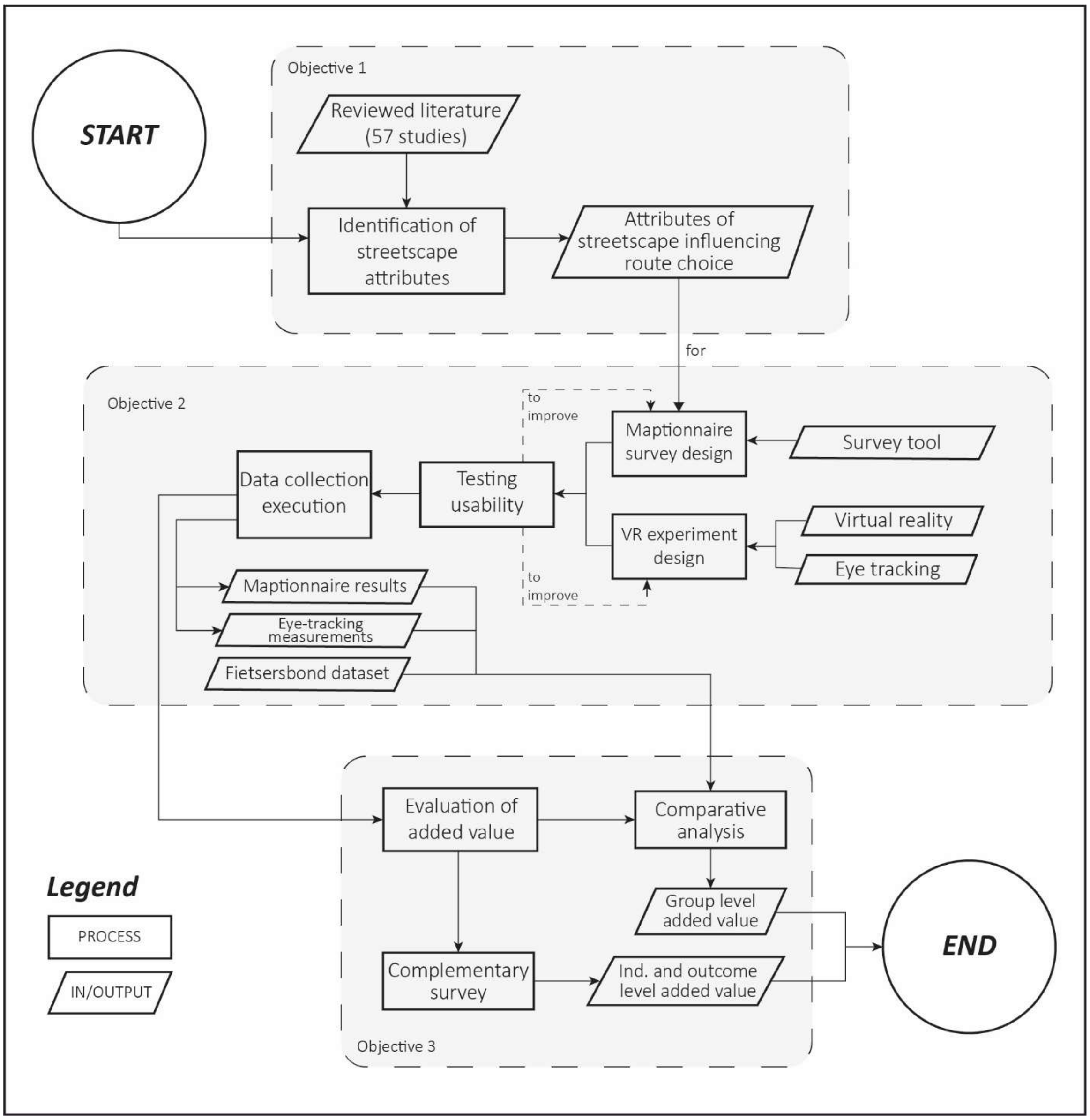


Figure 2. Methodological flowchart where highlighted blocks belong to the objectives of the research.

3.1. *Identification of streetscape design features*

To identify the features of the streetscape that influence cyclists' route choice from the reviewed 57 articles in the literature review section, a feature selection process was carried out. A feature selection process helps to analyse data that contains features that are rather redundant or irrelevant, and can thus be removed without much information loss (Guyon & Elisseeff, 2003). Therefore for this research, a feature selection process was chosen to allow simplification of the retrieved attributes of the built environment to make them easier to interpret and use for the research purpose.

The simplification process for the retrieved attributes considered the elements that are related to design features (aesthetics) of the built environment such as trees/plants, store fronts, benches, litter bins, bike racks, balconies, windows, terraces, etc and characteristics of the infrastructure related to the riding experience such as pavement quality, cycling lane width, road intersections, etc.

After selecting these attributes of the built environment, clusters were created. The resulting clusters (table 1) help to categorize all the attributes into three main groups of factors that are related to an active cycling experience:

1. Looking to the front. This category considers elements that cyclists look in advance (more than 10 meters ahead) to anticipate obstacles in the short term and that are more related towards safety.
2. Looking to the context. In this category, elements related to design features and provision of amenities that influence the enjoyability of the cycling experience are clustered. Often, these elements are located more to the side of the path rather than to the front.
3. Looking to the foreground. This category bundles elements that cyclists look in the immediate distance (around 1 to 10 meters ahead) for any sudden obstacles that they may face during the ride.

Also, for the identification of attributes of the built environment the type of travel plays a role in perception. Cycling for transport or cycling for recreation are associated with different environmental attributes (Heesch et al., 2015). Therefore, attributes that influence both behaviours were considered in the clusters as they both are part of a cycling experience.

Table 1. Clusters of design elements from literature that influence cyclists' route choices.

Active cycling experience, looking to:	
FRONT	Type of cycling lane Stop lights Amount of intersections
FOREGROUND	Pavement quality Surface material Bicycle lane width
CONTEXT	Parking availability for bikes along the way Diversity in buildings' facades Diversity of land use Presence of street-level windows Presence of tall buildings Presence of trees Presence of grass/vegetation Presence of landmarks Presence of water bodies

3.2. *Study area*

Enschede is a medium-size municipality located in the Overijssel region in the eastern part of The Netherlands with approximately 160 thousand inhabitants (Central Bureau of Statistics, 2021). In 2012, the city council adopted the cycling vision for Enschede 2020 where non-recreational bicycle movements were emphasized in the proposed package of measures with a budget of around eight million euros (Enschede, 2012). This measurements package involved five main intervention categories:

I. *Disentangling routes*. Involves management and design of alternative routes through residential areas to make clear that cyclists are dominant in those routes.

II. *Bundling routes.* Involves the improvement in connectivity between shared-traffic main roads lines and independent cycling lines.

III. *Bicycle sheds.* This category aims to provide more efficient bike stalling throughout the city and to make interventions to improve the functionality of current infrastructure.

IV. *Communication.* Involves measurements to promote cycling in the city and to encourage residents to participate in the decision-making process for interventions.

V. *Bottlenecks & safety.* Measures are divided into objective, subjective and social safety. Objective safety measurements are meant to reduce accidents in places that registered six or more bike accidents in a three-year period. Subjective safety measures relate to interventions to make cyclists feel safer in the road. Lastly, social safety measurements such as provision of lights and routes along concurred parts are meant to make cyclists feel safe from attacks or harassment.

In 2020, Enschede ranked among the top five bicycle cities in The Netherlands from the Fietsstad awards by Fietsersbond (Fietsersbond, 2020). These awards were granted based on objective and subjective factors from a national survey conducted by the association with about 45 thousand respondents from 340 different municipalities. The objective factors considered in this survey were detour factor (time taken navigating the network from a central point to another within a 1km radius in a straight line), urban density, roundabout design and number of separate cycling paths along 50km/h roads; in the case of the subjective scores, the survey considers a rating system (1 to 5) for riding experience, maintenance of infrastructure, logic of the network and provision of infrastructure (Fietsersbond, 2020).

3.3. *Data collection tools for cyclists' perception*

To analyse how perception of the design elements of the built environment influence cyclists' route choices from a bottom-up approach and to explore differences between the usual and the ideal commuting routes for cyclists, a survey was developed. Given the spatial information required for the actual and ideal commuting route and its relationship with perception of participants, Maptionnaire software was considered as a good fit for the task as it allows to mix survey questions with an interactive map that enables the possibility to collect and visualize spatial information with the surveyed subject's responses.

3.3.1 Selection of participants

For the survey and experiment phase of this research, participants were convened based on the following criteria:

I. Familiarity. This criterion involves both, familiarity with the activity of using the bicycle as a commuting transport mode and familiarity with the study area. Having participants that regularly use the bicycle as a common transport mode, allow to focus on the experiences and perceptions of the cyclists regarding the scenery (Desjardins, Higgins, et al., 2021). Also related to improving the focus on the scenery while cycling, participants that are familiar with the study area are more likely to have more experiences (bottom-up perception) which may increase the feedback of information for the aim of this study.

II. Common destination. As this study intends to reveal differences in usual and ideal commuting routes, gathering origin and destination information about random participants from the study area may be more difficult and may not reveal as detailed information as having a common destination from diverse origins. Therefore for the scope of this study, participants cycling to a common destination were considered, i.e. the Faculty of Geo-Information Science and Earth Information (ITC) from the University of Twente (Enschede, The Netherlands) which is located within the study area in a relatively central location. Also by choosing a common destination among participants, the process to gather participants was more efficient in comparison to reach out to the whole study area by different communication channels.

III. Excluded origin. As the survey aims to reveal preferences regarding a diverse sample of usual and ideal commuting routes, variety in these routes was considered to be important. Therefore, an exclusion for participants coming the main housing facility of the ITC was considered as having many participants from the same origin to the same destination would have not provided enough variances in the distribution of the routes within the study area.

IV. Demographic diversity. Variability among the subjects' backgrounds was considered positive to have a more general overview about perception of cyclists with different ages and education levels. Therefore, the call for participants within the ITC considered staff and students from different nationalities and age groups.

V. Language. A diversity of nationalities was considered to select participants for this study, however the English language was chosen as the standard language of communication. Thus, participants with a proficiency to communicate in English were considered in the final sample.

VI. Physical conditions. As the experiment phase involves participants to use Virtual Reality (VR) technology, people that had a known history regarding suffering from motion sickness were excluded from the sample for safety reasons.

To reach out for participants, the institutional e-mail and WhatsApp social network were used among ITC staff and students for a period of two weeks resulting in a total of 22 participants for the study. This sample size was considered enough to reveal secure variety of information throughout the study area without saturating the dataset due to the size of the study area and the common destination.

3.3.2 Content of the survey

To explore the preferences and perception of participants, a survey was developed. This survey is divided in five main question categories which are screening, preferences for commuting route, preferences for ideal route, attitudes, and demographics. The survey required participants to answer multi-choice questions about their routes and digitize in an interactive map their preferences and comments about what they liked and disliked about sections of roads or specific points. The survey was composed of 20 questions and took about 20 to 25 minutes to complete. A summary of the questions is shown in Table 2 and the complete design with the coding for questions and possible answers can be consulted in Annex 2.

Table 2. Summary of survey instrument questions.

Section	Question
Screening	How often do you commute by bicycle per week? How long have you been living in Enschede?
Commuting	In the map, draw your most common route for commuting to ITC by bike.
Ideal	Imagine you do not have any time or distance constrain. Draw your ideal route fo commuting to ITC by bike.
Commuting/Ideal	From your route, indicate which sections you like the most (and why). From your route, indicate which sections you dislike the most (and why). Add a marker of the thing you like about this route. Add a marker of the thing you dislike about this route. From the following list, which design attributes do you consider important for chosing this route? From the following factors, which ones do you consider for chosing this route?
Attitudes	In terms of safety, to which of the following typologies you relate your cycling behavior?
Demographics	What is your age? Which of these categories applies to you?

The questions in the screening section are intended to identify the degree of familiarity of participants of both cycling as an activity and cycling around the study area that allows to explore the possible influence of familiarity in cyclists' perceptions. The questions for the preferences of both usual and ideal commuting routes are the same and are intended to reveal the differences in perception and patterns among both types of routes while the stated preference questions are based on the design elements identified in the literature review. The digitizing part allow participants to also comment on specific sections and places they like or dislike, to gain additional insight about the reasoning to choose a specific route to reach the destination.

The question regarding the cycling attitudes is based on the study carried out by Dill & McNeil, (2013) where they examined Roger Geller's cyclist typologies (Geller, 2006) to better understand cycling behaviour and the potential of considering these typologies for interventions aimed at improving cycling infrastructure. They found significant differences between perceptions of the physical environment among the different types of cyclists regarding their safety (confidence) when cycling in an urban environment. Therefore, considering such categories the study aims to identify differences and similarities of perception of aesthetical elements to better understand how it may influence cyclists' route choices. Also, to compliment the insight from different types of cyclists, the last section about demographics has questions to explore variability in perceptions regarding age groups and education levels.

3.3.3 Survey implementation

Before the final version of the survey, a pilot version was tested by a couple of voluntaries on the functionality of the mapping tasks and to receive feedback about the clarity of the questions and possible usability complications. One of the main limitations of the Maptionnaire software was that for the mapping sections, the platform just works on desktop devices (Laptop/PC) and not on mobile phones. Therefore, to compensate for possible complications during the survey process regarding usability and to clarify some concepts (because of language) the set-up of the survey was carried out in face-to-face group sessions with some participants and one-on-one meetings for those who could not join the group sessions. Snapshots of the user interface for the survey can be found in figure 3.

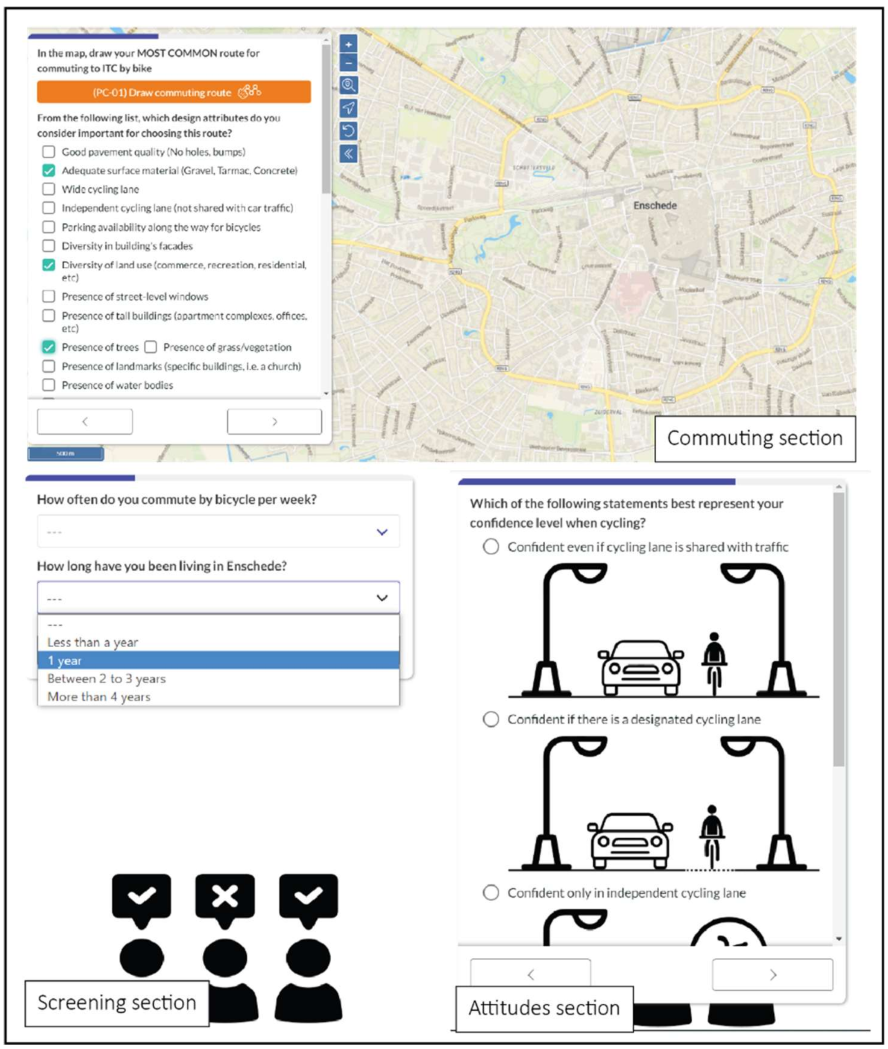


Figure 3. Snapshots of the survey's sections in Maptionnaire.

3.4. VR Experiment design

A complementary experiment was developed after the Maptionnaire survey with all participants, to assess perception of the aesthetical elements during cycling. This experiment used a combination of Virtual Reality (VR) and Eye-tracking technology to simulate a bike ride, to retrieve information about the cycling experience within the study area, and how participants interact with the environment in real time in the routes indicated in the survey phase. Combining the results from the survey phase allowed comparison between stated preferences of participants from a bottom-up approach (Maptionnaire survey) against their reactions to a real-time cycling experience using a top-down approach (VR experiment).

3.4.1 Hardware and software

To retrieve more consistent data from participants regarding their perceptions while cycling, a simulated bike ride was carried out using a Tobii VIVE Pro Eye headset, which is a 360-degree visualization hardware with integrated eye-tracking technology. Also, in order to run the simulation of the bike ride, the software used to run the experiment was the TobiiProLab (Tobii Pro AB, 2014) in combination with the STEAMVR plugin. Regarding the scenario of the simulations, the camera used for the recordings was a INSTA360 ONE X2 mounted in a helmet to make the recordings while riding a bicycle.

This set-up was considered as a good alternative to avoid external factors such as variability in weather, motorized traffic volume, and speed conditions that may affect the comparison of the eye-tracking measurements among participants. Also, to provide an immersive experience for participants for a simulated bike ride, several technical factors were taken into consideration. These considerations can be divided into two overall groups:

I. *Processing capabilities*. Due to the resource demand for VR to run stimuli a laptop running Windows 10 Home edition with a 11th generation Intel Core i9 processor, 32GB of RAM and a dedicated NVIDIA GeForce RTX 3070 graphics card was used. Regarding the quality of the recorded videos, a trade-off between resolution and bitrate had to be considered for improved stability of the recordings; the recorded videos had a 5.7K resolution with a set bit-rate of 45Bits per second. Also, as the TobiiProLab software showed some stability issues, the stimuli had to be partitioned into four separated stages resulting in four stimuli iterations instead of a single one. However, these iterations only affected the duration of the experiment as a calibration process for the eye-tracking had to be executed for each of the stimuli.

II. *Perspective and riding experience*. To provide participants with an immersive experience that resembles the most to a real life cycling experience several mounting positions were tested being the helmet mount which provided the most natural point of view while wearing the VR headset. The choice of recording a 360-degree video over a wide-angle one was to provide users the option to turn their heads around to explore the full environment as they would to in a real life situation. Also, for the several recordings presented to participants an average speed of 12Km/h was considered while recording the videoclips; this speed gives users enough time to be able to focus on different elements of their surroundings without feeling they go very fast. Additionally, to avoid participants getting motion sickness as they did not have control over the bike nor the directions of turns, verbal indications before turning were involved during the experiment so they would expect the turn and be prepared for the sudden changes.

3.4.2 Stimuli selection

In the survey phase, participants were asked to digitize their usual and ideal routes as well as to state the specific sections of their journey that they liked and disliked and the aesthetical features they considered for making those choices from. From this input, the most common sections that participants mentioned in the survey within the study area were considered for the simulated bike ride experiment resulting in four different route segments. Each of these resulting segments represent a different scenario related to the bike ride experience and the aesthetical elements present on each of these segments that made most participants rate these sections as Good, Bad, Scenic or Average regarding their preferences during their cycling experiences. These categories were chosen from the secondary dataset by Fietsersbond. Description of the categories can be found in section 3.5.

Having four different scenarios that have a different perception in quality according to participants allow to compare their responses with their eye movements during those specific sections, to explore how their behavior changes and where do participants place their attention. The analysis of the different sections of road they focus the attention was useful to understand how the design of the built environment influences their reasoning to rate a section of road as Good, bad, Scenic or Average in this case.

3.4.3 Experiment set-up

To measure participant's perceptions by tracking their eye movements, four main Areas of Interest (AOIs) were created to have an overall understanding about where participants focus their attention. This AOIs are based on the clusters of design elements from literature that influence cyclists' route choices (Table 1) that, translated to a virtual environment, cover the frontal and side field of view of people. Even though the recording allows participants to explore a 360-degree environment, for the purpose of cycling the part that involves looking behind is less likely to be explored in reality. Therefore, for the measurements of the eye movements a 190-degree field of view is considered as would measure the focus from participants to the front, the foreground and to the context in both sides (left & right). Figure 4 exemplifies the AOIs and the considered field of view used in the measurements.

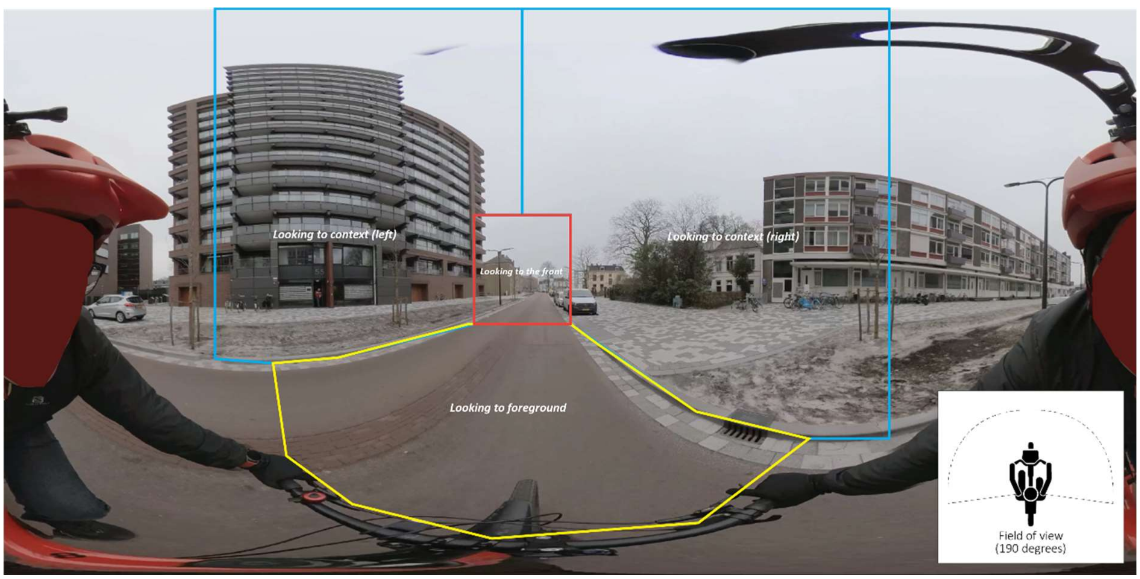


Figure 4. Virtual Reality environment with AOIs and field of view.

3.5. Secondary data on attributes of the cycling network

As complementary data regarding perception of cyclists about the built environment features and their influence in the riding experience within the study area, data from the Fietsersbond Route planner was used (Fietsersbond, 2021). The route planer dataset 2021 contains the vector layer of the bike infrastructure for the whole Netherlands with attributes such as road type, length, name of road, province and also other descriptive attributes for every section such as surface material, inclination, obstacles, illumination and, beauty collected by around 1,800 cyclist volunteers from the Fietsersbond.

For this research, the 'beauty' (from 'Schoonheid' in Dutch) attribute of the dataset was the main focus. This attribute provides a subjective evaluation of each section of road of the study area divided on five categories: picturesque, beautiful, average, ugly/boring and very ugly. These categories are assigned to every segment of road based on existing aesthetical elements such as monumental buildings, presence of picturesque nature, specific architectonical modern design or a clear horizon without obstructions. For the evaluation of this attribute volunteers were encouraged to base their grading in the aesthetical factors neglecting personal preferences or particular feelings during their ride regarding the infrastructure itself (even surfaces or lane wideness).

The beauty assessment from the dataset was used to complement the findings from both the survey and the experiment as comparing the perceptions and evaluation of trained volunteers (Fietsersbond) against regular cyclists (participants of the survey and experiment) allowed the identification of discrepancies between perceptions and behaviours among cyclists.

3.6. Added value from a user and developer pespectives

To answer question 2b '*How can the added value of the proposed methods from a user and a developer perspective be evaluated?*', the evaluation criteria for each of the methods considered the three levels from Pelzer et al. (2014) framework where the group level was evaluated by a comparative analysis and the individual and outcome levels were evaluated by a survey design.

3.6.1 Evaluation of group level

In order to estimate the added value from a developer perspective of the proposed mixed-method to collect information, a comparative analysis between individual components was carried out. This comparative analysis was meant to reflect on the added value of the tools in terms of potential for learning about the object (single-loop), collaboration, communication, consensus and efficiency. For this purpose, a matrix (Table 3) was created to compare the survey, the VR experiment and the secondary dataset where they were ranked in terms of potential per category in comparison with the other tools from the methodology. As the type of perception approach (top-down and bottom-up) is important to consider when it comes to collect data about perceptions, for the case of learning and efficiency two different rankings were considered.

Table 3. Comparison of added value of data collection tools based on Pelzer et al (2014) framework. Blue symbols belong to bottom-up approach and orange symbols belong to top-down approach.

	Potential regarding:				
Tool	*Learning*	*Collaboration*	*Communication*	*Consensus*	*Efficency*
Survey (Maptionnaire)	∧ ∨	∧	∧	∧	∧ –
Experiment (VR+Eye tracking)	∨ ∧	–	∨	∨	– ∧
Secondary data (Fietsersbond dataset)	– –	∨	–	–	∨ ∨

This comparison was intended to highlight the individual strengths of each of the data collection tools to address the importance of combining different methods to improve collection of data regarding route choices and perception of the built environment of cyclists.

3.6.2 Evaluation of individual and outcome levels

As part of the identification of added values of the methods from a user perspective, a complementary survey was carried out among a random subset of participants (10 respondents) to get insight regarding learning about the perspective of others (double-loop) and about the usability of the implemented tools using a Likert scale of 1 to 5 to allow comparison between tools. A summary of the survey is presented in Table 4, and the same questions were asked for both the survey and the VR experiment. The content of the survey is divided in two main categories: learning and usability. The questions in the learning category are intended to gain insight about the degree of reflection and awareness that participants gained after participating in both the survey and the experiment and how this experience may have influenced their route choices or what they focus their attention while cycling.

In the case of the questions in the usability category, the interrogates are based in Pelzer et al., (2016) usability variables to assess tools involving public participation. For the case of data collection tools, the considered variables are transparency, communicative value, user friendliness, level of detail, and integrality as these can be assessed by users' experiences. Definition of these categories can be found in Table 5.

Table 4. Learning and usability survey for assessment of added value of tools.

Section	Question
Learning	My attention to my surroundings increased when cycling. I think more about the reasons for chosing my commuting route. My preferences and criteria to chose my commuting route changed.
Usability	The information and variables presented (definitions/videoclips) were understandable for me. The visual (video/pictures/icons) and spatial (maps/landmarks) information was accordingly represented. I was able to use the tool without any inconveniences. The level of detail of the tool allowed me to provide a real answer to the questions. The tool allowed me to share my opinions about what I find interesting (attention) about a route when cycling.

Table 5. Definition of usability variables based on Pelzer et al (2016) framework to evaluate tools involving public participation.

Variable	Definition
Transparency	The extent to which the underlying information and variables used in the tool are accessible and understandable to users.
Communicative value	The extent to which spatial/visual information is aptly presented.
User friendliness	The extent to which participants are able to use the tool themselves.
Level of detail	The extent to which the level of detail of the tool matches the perspective of participants.
Integrality	The extent to which the tool takes all the relevant dimensions into account.

4. RESULTS

To summarize the findings of the research, this chapter is divided in three main sections that belong to the principal blocks from the methodology flowchart (Figure 2). The first section (4.1) presents the findings from the systematic literature review about the current methods for collecting data about cyclists' perception of streetscape design features when choosing a route. The second section (4.2, 4.3) displays the outputs of the data collection phase from both the Maptionnaire survey and the VR experiment. Lastly, the third section (4.4 and 4.5) shows the findings regarding the evaluation of the added value of the proposed methodology and from the comparative analysis of results from different methods.

4.1. Current methods for data collection about perception of streetscape design features

From the systematic literature review two main outputs were retrieved. First to answer the question 1b '*What are the features of the streetscape that affect route choice of cyclists according to literature?*', the feature selection process (section 3.1) allowed the identification of such attributes and the classification in three main clusters (Table 1). These clusters may be used in future research to improve the way information about perception of design features is collected. Also, the use of clusters of streetscape design features may be an asset for decision-makers to use these categories to address specific interventions regarding the design features of the streetscape to encourage the use of bicycles.

Second, the review of the 57 articles that collect information about cyclists' perception of streetscape design features and their route choices allowed to answer the question 1a '*What are the methods that are being used to collect data on streetscape design features influencing cyclists' route choice?*'. A vast majority of these studies (42) were published within the last five years. This increasing tendency in the number of published articles every year suggests a growing interest regarding understanding the influence of the built environment in cyclists' route choices. From the implemented methodologies in these studies, four categories could be identified: analytical models, literature review, surveys, and interviews.

From the studies that used *analytical models* (15), data from existing literature, secondary datasets, and GPS routes were used to identify the degree of influence that certain features of the streetscape design have over the route choices of cyclists from a sample size that was on average superior to 800 data points. In the case of the studies using a *literature review* methodology (7), the identification of meaningful design features of the streetscape that influence cyclists' route choices was based on the use of statistical analysis (i.e. principal component analysis) to find which were the most common elements of the built environment and the extend that such elements influenced route choices. What these two methodological approaches (analytical models and literature review) have in common is that they identify cyclists' perception of streetscape design features from a theoretical point of view.

Regarding the studies that implemented *surveys* (30) three main types of surveys were implemented: Remote surveys, field surveys, and photo surveys. In the case of studies implementing remote surveys (14), the average sample size was 2500 with a median of 1100, which allowed more insights about the preferences from a more diverse set of participants in comparison with the other type of surveys and for a larger (country/region/city) spatial extent. Regarding studies using field surveys (10), the average sample size was 16 and, even though is much smaller in comparison with the remote survey sample size, it allowed researchers to collect high-level detail information from a small (neighbourhood/street) spatial extent about specific design features of streetscape and their influence in cyclists' route choices. In the case of studies using photo surveys (6), the average sample size was 1700 with a median of 950; this method combined the reach in terms of sample size of the remote survey for a small spatial extent (as in field surveys) due to the use of pictures of a given study area, allowing researchers to identify specific elements of the built environment with a high-level of confidence. What these studies have in common is that they collect information about the revealed preferences and cyclists' perceptions of design features of the streetscape from a bottom-up point of view meaning that they are helpful to explore the perception of cyclists based on previous experiences.

From studies that used a methodological approach based on *interviews* (5), the average sample size was 30 and the set up was rather a bike-along or video interview. These set-ups allowed researchers to gain a deeper insight about the perceptions of cyclists' regarding the influence of design features of the streetscape in their route choices. As these perceptions were based on in-situ or video stimuli of participants, information regarding their perceptions from a top-down approach was collected. In contrast to the surveys, these approaches are effective to reveal information regarding how the design features of the streetscape influence perceptions in real time while cycling.

4.2. Maptionnaire survey: Revealed behavior and streetscape design features in usual and ideal commuting routes

The survey developed on Maptionnaire retrieved information about participants' perceptions regarding the influence of streetscape design features for both their usual and ideal commuting routes. The retrieved information from this tool provided insight from a bottom-up approach about different cycling behaviours, perceptions of the streetscape design features along their route, as well as their stated preferences for different types of routes as responses were based on participants' previous experiences. Additional to the insight gained about participants' perception from a bottom-up approach, reporting their routes in a map allowed the selection of four different scenarios for the Virtual Reality (VR) experiment, which allowed further comparison with perceptions from a top-down approach.

4.2.1 Participants revealed behaviour

A summary of the responses regarding participants' demographics and characteristics is found in Figure 5. Regarding demographics, half of participants were students and from the other half a few participants were staff members that are also studying. About the behavioural characteristics of the sample (n=22), 14 participants reported to commute by bicycle more than four days a week, six participants cycle to work two to three times a week and only two participants commuted only once a week by bike. This suggests that most participants show a strong preference to use the bicycle as a commuting transport mode. Also, from participants that stated living for a year in the city (n=9), more than half of them (5) use the bicycle more than four times a week in comparison with participants that have been living for more than four years (n=6) in the city where five people reported to use the bike more than four times a week with none of them reporting commuting once a week by bike. However, these findings are strongly affected by the sample size, context and the recruitment strategy.

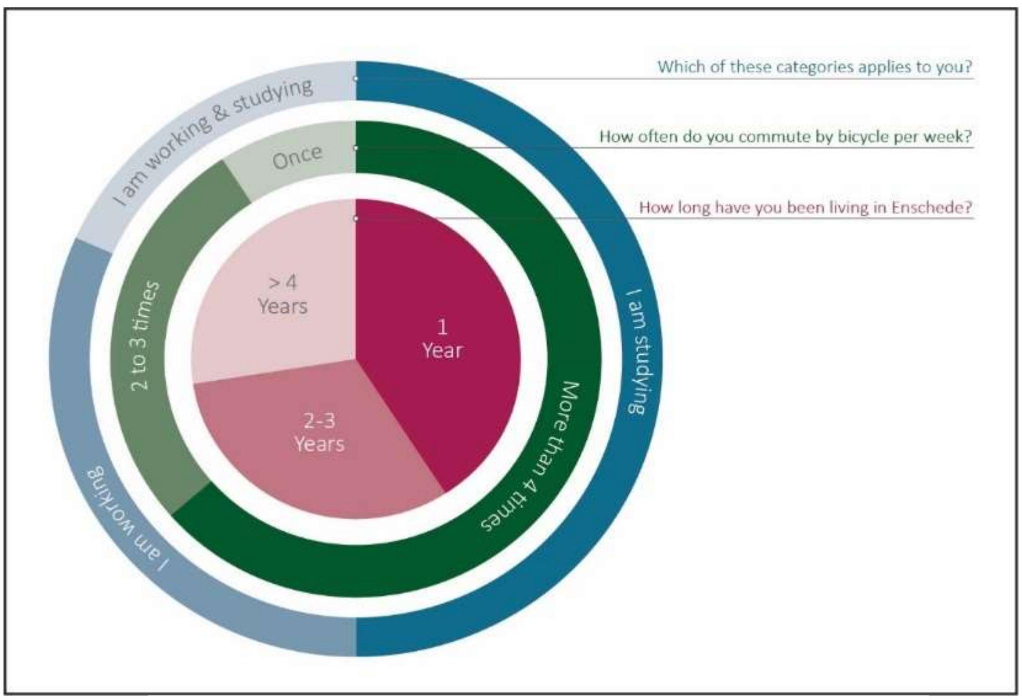


Figure 5. Summary of participants' characteristics and demographics.

4.2.2 Preferences in usual and ideal commuting routes

Regarding the research question 3a '*What are the differences, regarding perception of streetscape design features, between the chosen and the ideal routes for cyclists when travelling from home to work?*', the retrieved data provided insight about such differences, which are summarized in figure 6. For both routes, around 60% of participants reported preference for a good pavement quality, adequate surface materials and wide cycle lanes. Only about 20% of the participants indicated that parking availability along the way for bicycles, and presence of street-level windows or tall buildings influenced their route choices. These common preferences regarding the infrastructure quality are in line with the findings from other authors (Cole-Hunter et al., 2015; Desjardins, Apatu, et al., 2021; Verhoeven et al., 2018) that suggest that even though aesthetical elements have an impact on the enjoyability of the ride, the provision of infrastructure and its quality are preferred when cyclists choose a route.

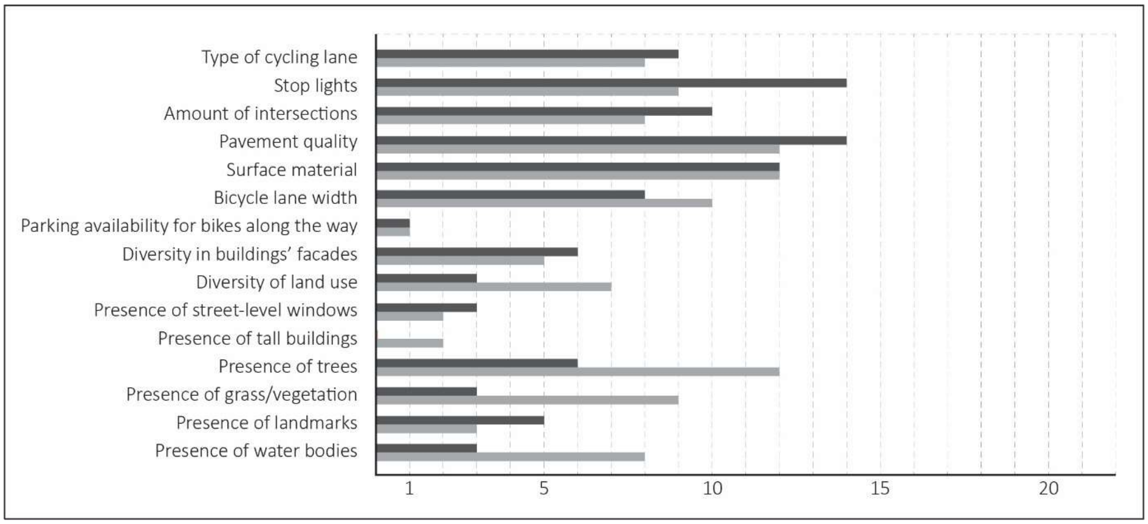


Figure 6. Tabulation of preferences for both usual (dark gray) and ideal (light gray) commuting routes.

The main differences between the usual and the ideal route were found regarding the presence of road intersections, vegetation or water bodies and avoidance of stop lights. From the usual commuting route 14 participants reported 'stop lights avoidance' as an influencing factor to choose their route against nine respondents that considered the same factor for choosing their ideal commuting route. A similar result was found for the consideration of 'least amount of road intersections' where 10 participants reported this factor to be influential for their usual commute in comparison with eight respondents considering the amount of intersections for their ideal commuting route. These results suggest that participants tend to be more time-efficient when it comes to choosing their usual commuting route. This tendency is also supported by the stated preference in the survey, showing that 17 participants considered the 'fastest route' factor on their usual commuting route against three respondents considering the 'fastest route' factor on their ideal route.

Regarding the presence of aesthetic features such as vegetation and trees, participants considered the presence of trees (6) and vegetation (3) as an influential factor for their usual commute whereas in their ideal route choice, participants reported a higher consideration for both trees (12) and vegetation (8). Also, the consideration of the 'diversity of land use' factor was higher in the case of the ideal route (7 respondents) than for the usual commuting route (3). These findings suggest that participants are more likely to reflect on the value aesthetical factors when certain constraints (such as time or distance to destination) are not present meaning that even though aesthetical factors are not the highest priority, in a scenario where the time and distance to the destination are the same within two routes the one that provides the most vegetation and diversity is more likely to be chosen. This result is in line with Winters et al., (2010) who found aesthetical amenities to be a top motivator for the enjoyment of the cycling experience.

4.2.3 Route sections' preferences and stated criteria

The comments from respondents when digitizing their usual and ideal routes regarding what they liked and disliked about sections of their routes helped to gain more insight from a more qualitative perspective about the influential aspects on route choices. From a spatial perspective, Figure 7 illustrates all routes combined (usual and ideal) in magenta, the sections that were reported as 'liked' in green, and the ones reported as 'disliked' in red; also, the number in the bubble represents the amount of respondents that reported the same section.

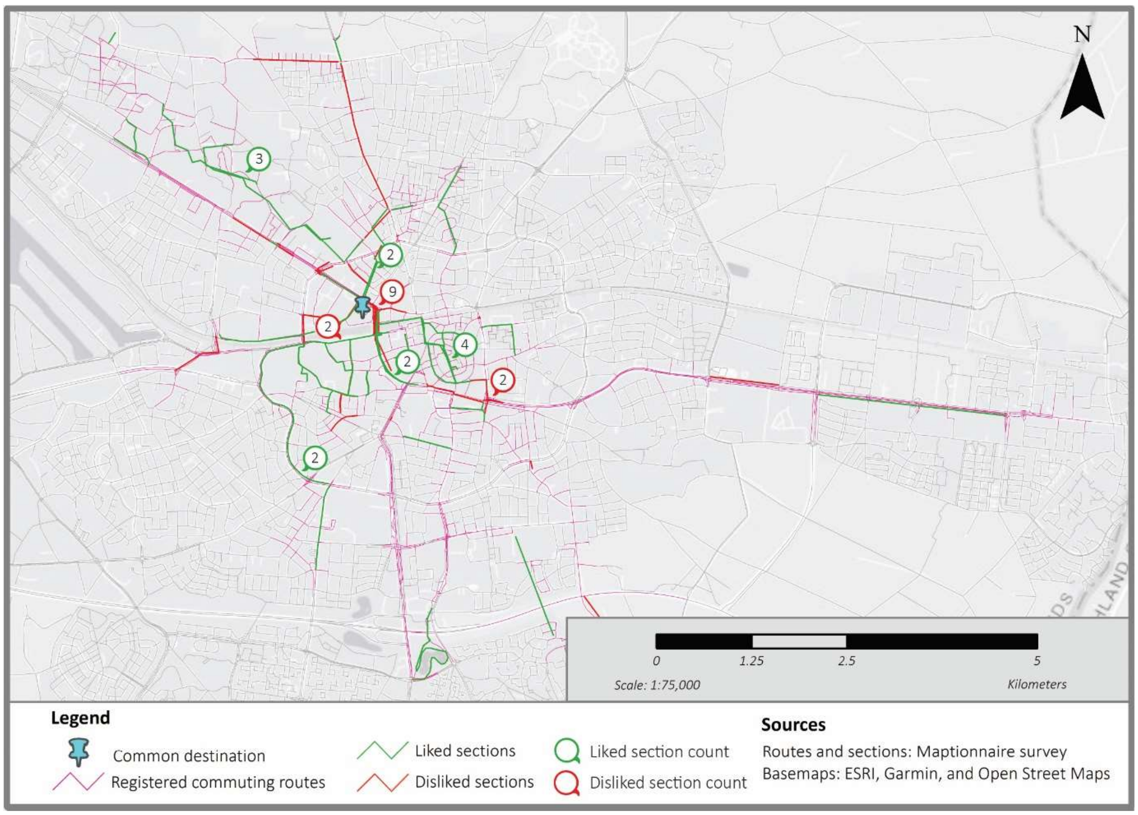


Figure 7. Registered usual and ideal routes and section counts from Maptionnaire survey.

From the sections of their routes that participants reported to like in both the usual and the ideal commutes, similar comments such as "*buildings look neat, trees on the way*", "*I love the newly built neighbourhood!*", "*Bike priority, road low traffic and to skip traffic lights*" and "*the view of buildings in the surrounding, the air quality from the trees and the park, low traffic noise*" suggest that the criteria they use to report a section of their route as 'liked' involves more aesthetical features of the built environment as well as characteristics of the infrastructure regarding traffic nuisance and safety.

Regarding the disliked sections, as part of their usual or ideal commuting routes, comments such as "*somewhat lifeless main road, architecture not interesting*", "*this is a 30 Km/h area where cars frequently drive faster than that. It is also a straight line with few features*", or "*boring straight line through housing area*" suggest that participants disregard sections that are not aesthetically pleasing for them. Monotonous sections of road were considered as "boring" or "not interesting", which may suggest that participants prefer contexts with more design variety when cycling. Also, comments regarding traffic safety such as "*busy, presence of cars, and crossings*", "*blind exits from the neighbourhood alarm the bikers*" prevailed.

4.2.4 Study case: usual vs Ideal route

To further analyse the differences between the usual and ideal routes, one example from the dataset was chosen and it is illustrated in figure 8. This example was chosen as it represents a large amount of differences in the streetscape design features preferences between the usual (blue) and the ideal (orange) route of one of the participants. The first difference is in the distance, where the registered usual route had a length of 4.68 km in comparison with the ideal route of 7.66 km. This difference in distance is in line with the findings from other studies that reported an average of 7 to 13 percent differences between the shortest and the usual cycling routes where the main motivators for cyclists to travel a longer distance were related to streetscape design features such as avoidance of busy road intersections, presence of vegetation and the slope (Krenn et al., 2014; Sarjala, 2019; Winters et al., 2010). In the example, these preferences were also revealed by the responses of the participant which indicated a preference for the shortest and fastest route for its usual route. In the case of the ideal route, the difference in distance (3 km) is supported by the stated preferences for presence of trees and vegetation and low motorized volumes as the route avoids main roads and goes through parks. However, the preference for an adequate surface material may not have been as important as some sections of the route are gravel or dirt paths (dashed line).

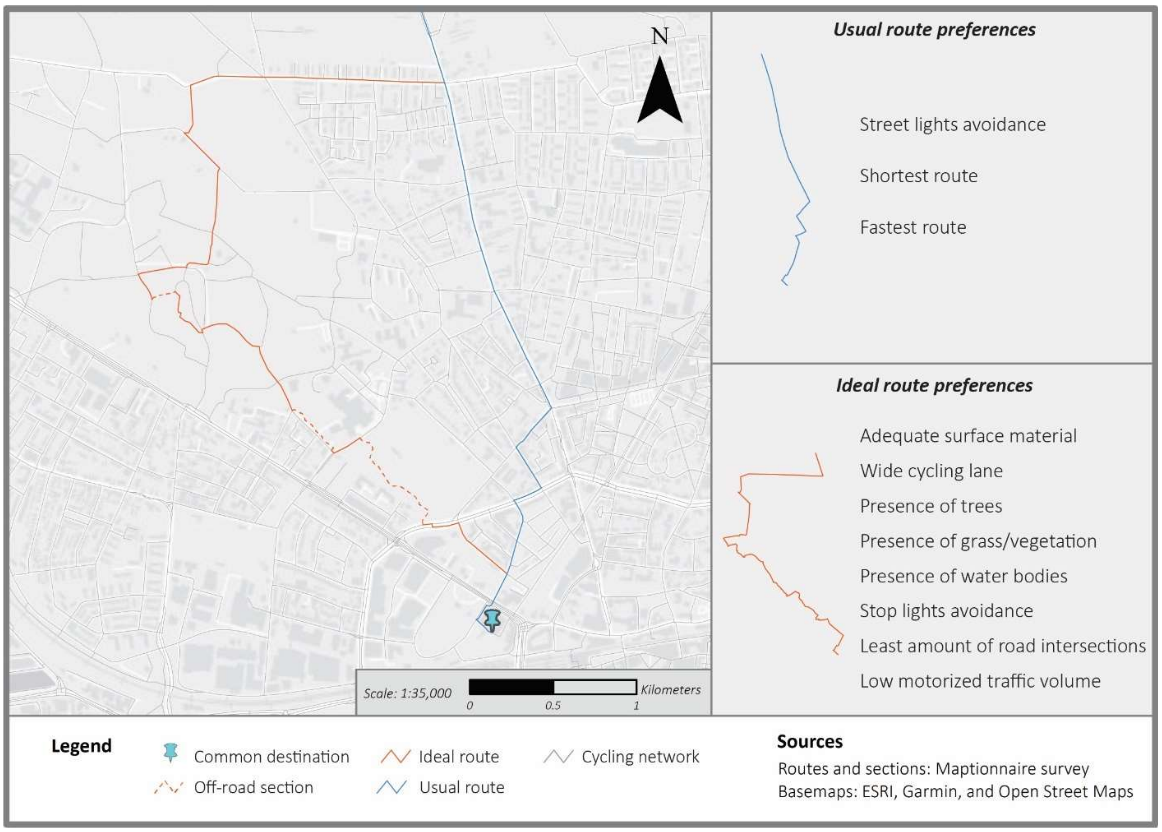


Figure 8. Case study: Usual vs Ideal routes

4.3. *VR experiment: Influence in cyclists' perception of design features*

The results from the VR experiment, which simulates a bicycle ride and recorded the eye movements of participants in different scenarios (section 3.4) allowed collecting perception data from a top-down approach to understand how streetscape design features influence cyclists' perception while cycling. Four different scenarios were considered, which relates to the categories from the responses of participants in the Maptionnaire survey (bad, average, good and scenic) and will be discussed in this section. Also, to allow comparison within AOIs (Figure 4) and between different scenarios, the measurements for both fixation times and number of saccades were standardized (U_v) ranging from 0 to 1 using a min-max interval formula. This resulting score follows a benefit criterion, meaning that the highest the value (closer to 1) the highest the time of fixation or number of saccades were registered. The formula is as follows:

$$U_v = \frac{Value\ -\ lowest\ value}{Highest\ value\ -\ lowest\ value}$$

A summary of the resulting values is found in tables 6 and 7. Table 6 values allowed for an horizontal comparison between AOIs to reveal where the attention of participants within each scenario was whereas the values from Table 7 allowed comparison between AOIs across different scenarios to reveal the differences in behaviour of participants.

Table 6. Standardized values for fixations and saccades where the min and max values for each of the scenarios are in brackets. Note: Standardized values are based in the average value for each of the measurements registered by participants (n=22)

Scenario	Front		Foreground		Context R		Context L	
	Fixation	Saccades	Fixation	Saccades	Fixation	Saccades	Fixation	Saccades
Bad (0-77,608/0-101)	0.62	0.29	0.06	0.04	0.38	0.26	0.46	0.35
Average (350-68,960/0-169)	0.70	0.55	0.04	0.04	0.38	0.46	0.25	0.28
Good (0-58,743/0-86)	0.64	0.46	0.05	0.05	0.46	0.55	0.34	0.37
Scenic (0-52,505/0-113)	0.55	0.24	0.03	0.02	0.67	0.57	0.56	0.49

Table 7. Standardized values for fixations and saccades based on the min (0/0) and max (77,608/169) values across scenarios. Note: Standardized values are based in the average value for each of the measurements registered by participants (n=22)

Scenario	Front		Foreground		Context R		Context L	
	Fixation	Saccades	Fixation	Saccades	Fixation	Saccades	Fixation	Saccades
Bad	0.55	0.29	0.06	0.04	0.34	0.26	0.41	0.35
Average	0.70	0.33	0.04	0.02	0.38	0.27	0.25	0.17
Good	0.48	0.23	0.04	0.02	0.34	0.28	0.25	0.19
Scenic	0.37	0.16	0.02	0.01	0.45	0.38	0.38	0.33

4.3.1 Results within scenarios

This section reports on the differences between AOIs for each of the four scenarios presented to participants based on the resulting scores from Table 6. First from results across all four scenarios, similar scores for fixation times and number of saccades revealed a very low interaction from participants with the foreground. This means that regardless of the type of scenario, participants barely focused their attention looking for immediate features of the infrastructure such as bumps or pavement type while riding. These low scores may suggest that participants place their attention much more on aesthetical and safety-related elements such as crossings, greenery or buildings (front and context AOIs) but also may indicate that the provision of well-maintained infrastructure allows cyclists to focus in other areas rather than the foreground. These findings are also in line with results from Mantuano et al., (2017) where attention to intersections, crosswalks, and other pedestrians were the elements reporting the most fixations in comparison to the infrastructure characteristics such as type of terrain during a bicycle ride.

Regarding the scenario rated as ‘bad or boring’ (figure 9) in the Maptionnaire survey, participants registered the most part of their attention looking to the foreground (0.62) and in a lesser extent to the context (0.38 and 0.46). However, according to the scores related to saccades, participants had the tendency to explore the context than looking to the front. These findings suggest that, in this scenario, even though participants place their attention looking to a few specific points to the front, they still explore the contextual elements (i.e. buildings and pedestrians) in a similar extent. A similar behaviour from participants was revealed for the ‘average’ scenario (figure 10), where participants also focused the most of their attention looking to the front (0.70). However different from the ‘bad or boring scenario’, participants in this scenario also registered the highest saccades factor when looking to the front (0.55) meaning that they found things such as other cyclists, crossings, and possible obstacles located to the front more important than looking to the sides in this section.

Figure 9. Snapshot of the 'bad/boring' scenario.

Figure 10. Snapshot of the 'Average' scenario.

From the ‘good’ scenario (figure 11), scores suggest that even though participants place most of their attention to the front (as in the ‘bad or boring’ scenario), similar scores regarding the saccades from the context suggest that participants evenly explore the features of the built environment in an ‘horizontal’ way. In other words, similar saccade scores between the context and looking to the front may suggest that participants transition their point of focus from the front to the context by spotting features ahead and then keeping their attention as they get closer while cycling. This transition may be explained in the scenario of spotting a landmark ahead and look for more details as cycling closer by (turning head to the side).

Figure 11. Snapshot of the 'good' scenario.

Regarding the ‘scenic or picturesque’ scenario (figure 12), fixation scores from contextual AOIs and the front were high. However, saccades scores regarding the context (0.67 and 0.56) compared against the one from the front side (0.24) are considerably higher. This difference in saccade scores suggest that participants spend a vast majority of the bike ride looking and exploring the context. These discrepancies in saccade scores between AOIs may be explained due to the presence of constantly changing vegetation to both sides of the path in the scenario, which encouraged participants to focus their attention to the context and explore the details. This behaviour is consistent with findings from B. Chen et al. (2022), where they found a higher positive correlation value of people looking at trees in comparison to other built environment elements such as buildings.

Figure 12. Snapshot of the 'scenic/picturesque' scenario.

4.3.2 Comparison between scenarios

To complement the results from table 7 and enhance the comparison between scenarios, Figure 13 illustrates the heat maps regarding fixations of each of the scenarios. These heat maps represent the concentration, in time length, of fixations for each of the scenarios where the red areas mean fixations of more than five seconds along the whole bike ride (two minutes per scenario).

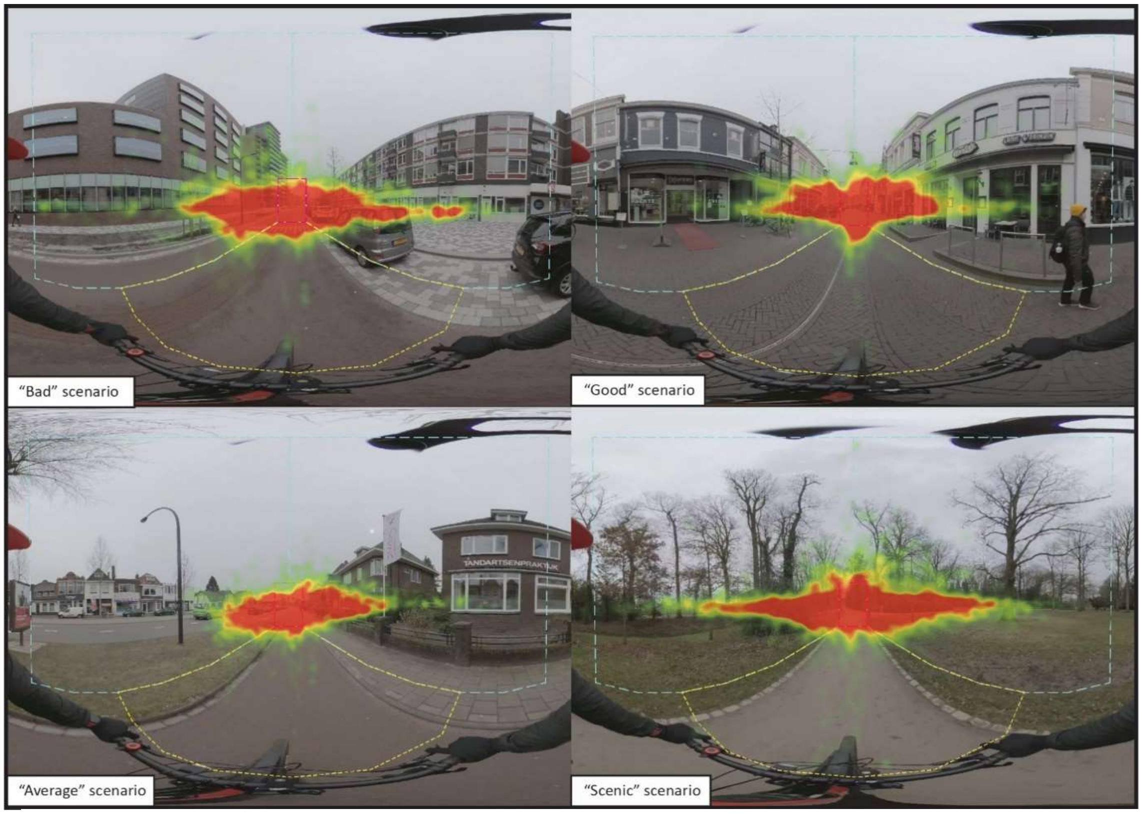


Figure 13. Heatmaps of the bike ride scenarios with respective AOIs.

The shape of the heat maps reveal the patterns of participants' behaviour during the whole simulation for each scenario. Similarities between the 'bad' and the 'scenic' shapes suggest that participants focused their attention to the front most of the time but also explored the context to both sides as the horizontal shape of the heat map suggests. However, differences are spotted in the fixation scores where in the case of the 'bad' scenario fixations to the front scored 0.55 against 0.37 in the 'scenic', meaning that participants placed more attention to the front in the 'bad' than the 'scenic' scenario. Also in both bad and scenic scenarios, participants spent about the same amount of number of saccades. This similarities in behaviour between a 'bad' and an 'scenic' scenario suggest that diversity of the scenery is not as influential as the specific features that a route has for specific sections to be categorized as boring or picturesque. This may happen as an environment with multiple buildings can be categorized as "boring" while a diverse path with different trees along the way may be categorized as "picturesque" even though both scenarios provide diversity.

Regarding the distribution of fixations represented for the 'average' scenario, the compact shape suggests that participants spent most time looking to the front in comparison with other scenarios. This is also supported by the fixation score of the 'good' scenario as it was the one scoring the highest (0.70) in comparison with the other scenarios. This focus in the centre suggests that participants were not as interested in the context on average scenarios. Even though the 'average' scenario results regarding the context AOIs are very similar to the 'good' scenario regarding fixation (0.38, 0.25/0.34, 0.25) and saccades (0.27, 0.17/0.28, 0.19), differences are more understandable when comparing the fixation scores to the front AOI as the fixation score of the 'good' scenario (0.48) was smaller. This suggests that the motivation to rate between an average and good scenario for participants may be presence of ephemeral distractors such as presence of pedestrians along the way.

4.4. *The added value of the proposed methods*

Regarding the research question 2b '*How can the added value of the proposed methods from a user and a developer perspective be evaluated?*', results from the post-data collection survey give insight about the evaluation of the added value of both the Maptionnaire survey and the VR experiment in terms of learning and usability. Results from these two main categories are presented in figures 14 and 15, where the top bar belongs to the Maptionnaire tool (MP) and the lower one to the VR experiment, to allow for comparison.

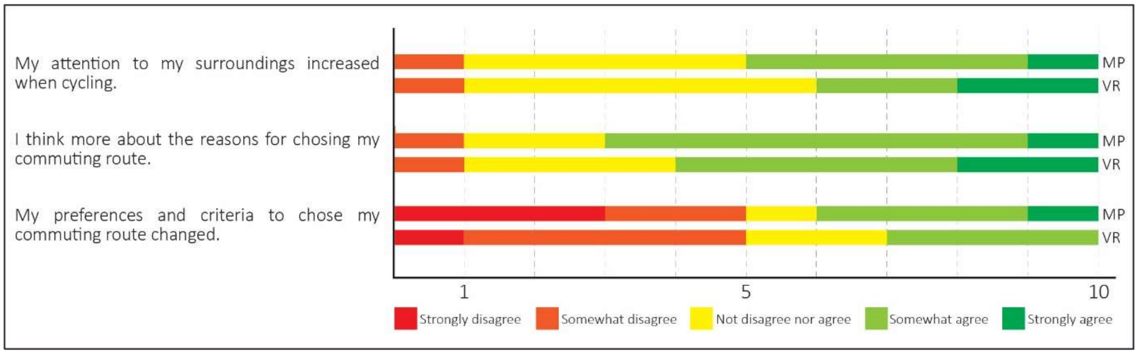


Figure 14. Distribution of responses about learning of participants after the use of the data collection tools.

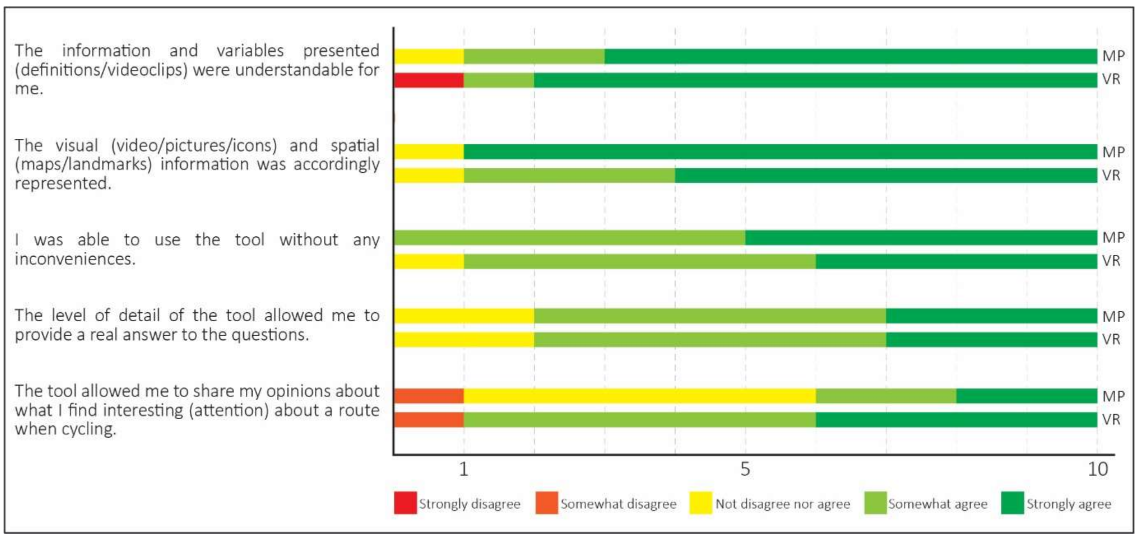


Figure 15. Distribution of responses about usability of the data collection tools.

In terms of learning, participants reported similar evaluations for both the Maptionnaire survey and the VR experiment, suggesting that both tools have a similar potential to increase awareness of its users about the understanding of the learning object. Even though the distribution of responses for both tools suggest a tendency for participants to be more aware of their reasons for choosing their commuting routes after using the tool, the use of the tool does not seem to have influenced as much the behaviour of participants while cycling. This means that after using any of the implemented tools, participants may present an increased awareness about how the design features of the streetscape influence their route choices but, according to the responses regarding the change in their attention while cycling, it would probably not change the aspects they focus their attention while cycling.

Results regarding the change in criteria when choosing their commuting routes suggest that even though they may be more aware about how the streetscape design features play a role, there is a high chance for participants to keep their usual routes, which suggest that other factors such as distance or travel times may have a larger influence in their route choices. For example, this higher hierarchy in the influence of distance or travel time over the streetscape design features is supported by studies that assessed the influence of travel distances in cyclists' route choice (Lu et al., 2018; Ospina et al., 2020). Despite this fact, increasing awareness and understanding of the influence of streetscape design features on cyclists' routes may be helpful to increase the feedback quality for future interventions as participants that are more aware of how these design features influence their cycling routes may be more encouraged to share more specific information regarding the topic.

As to the usability of the implemented data collection tools, the majority of participants reported very positive feedback about the easiness to use both tools. This positive feedback suggests that both tools may increase the efficiency for collecting data considering larger samples. The representation of information for both tools was perceived positively, with a slight difference in the degree of understanding of variables involved where the Maptionnaire tool seems to have been more successful to represent the variables over the VR environment, even though both tools were reported to have the same level of detail. However, the VR tool seems to be better at capturing the opinions about what participants find interesting about a route when cycling. This output may be due to the eye-tracking capabilities involved in the VR experiment, that allow to answer the question 'what I find interesting while cycling?' in a more dynamic way for participants and without much effort.

4.5. Similarities and discrepancies in perception

To answer the question 2c '*To what extent does the proposed mixed-method approach helps researchers to increase understanding about the impact of streetscape design on cyclists' route choices?*', a comparison between the results from the Maptionnaire survey, the VR experiment, and the Fietsersbond dataset allowed to identify the differences regarding cyclists' perceptions of the streetscape design features. Also, this comparison allowed reflection on how the combination of the proposed methods could be used to explain the reason for such discrepancies and similarities in cyclists' perception.

Figure 16 illustrates the differences in perception of the same sections of road from a bottom-up approach from the Fiertsersbond dataset (left) and the stated preferences from participants in this study (right). The four sections of road that were presented to participants in the VR experiment are indicated with comparison markers.

Figure 16. Comparison between Fietsersbond (2021) dataset and responses from survey.

The main difference between the Fietsersbond dataset and the reported sections from participants in the Maptionnaire survey is that most of the road sections that were reported by the volunteers for the study area are categorized as 'average' (yellow), with the exception of a few sections rated as 'good or beautiful' (green), which match with the stated ranking from participants in the survey. Even though participants from the Maptionnaire survey did not state their evaluation for each of the road sections as in the Fietsersbond dataset, the discrepancies in areas that were rated as 'average' on the dataset but as 'good' in the other may be due to generalization and differences in scale as the dataset from Fietsersbond is a subset from the whole country, whereas the results showed in the dataset from the Maptionnaire survey are from a very specific sector within the study area. Therefore, considering data collection from participants that are more 'local' to the study area may increase the variation in the rating of the sections and thus reveal a deeper insight about the study area for further analysis.

Also, discrepancies and similarities between the Fietsersbond ratings and the survey responses can be explained with further analysis from the retrieved participants' comments and complementary data from the eye-tracking measurements from the VR experiment. For example, in the case of *comparison markers 1 and 4*, the similar ranking in both datasets is supported by the retrieved participants' eye movements measurements as in both scenarios ('scenic' and 'good') participants registered high saccades values when looking to the AOIs located in the context (table 6). This relation suggests that in both cases (Fietsersbond and Maptionnaire) participants and volunteers may have been encouraged to explore more diverse surroundings while cycling, leading them to rate the road sections as more 'scenic' or 'beautiful' than others.

Regarding the mismatch in categorization from 'average' to 'bad' in *comparison marker 3*, the additional information collected from the VR experiment and participants' comments from the survey suggests that the reason for participants to rate the section as 'bad' was due to the presence of a stop light and the lack of diverse surroundings (as stated in comments from participants). These statements were also supported by participants' fixation time as in this section of road they reported a larger fixation value looking to the front in comparison with looking to the context. These differences may explain why in the Fietsersbond dataset the section is rated as 'average' as volunteers may have relied just in aesthetical features of the section without contemplating additional factors as the ones from the Maptionnaire survey. A similar case can be also found in the mismatch in *comparison marker 2* as participants from the survey categorized both as 'good' and 'bad' depending on personal preferences, even though their fixation measurements were very high as well as their saccades when looking to the front in that section.

Chapter summary

Different methods to collect information about the influence of streetscape design features in cyclists' route choices allow researchers to gain insight about the topic from different approaches. On the one hand, methods such as literature review, analytical models, and surveys allow understanding of individuals' perceptions from a bottom-up approach, revealing preferences based on prior experiences. On the other hand, interview methods such as bike-along and video interviews reveal information about perception from a top-down approach, which means that information about the interaction of cyclists' senses with the context influences perception.

From the results of the proposed mixed-method, participants reported differences regarding the influence of design elements in their usual and ideal commuting routes as well as different behavior (fixations and saccades) when interacting with their surroundings in multiple scenarios which are also discussed in the following chapter. Extrapolation of results from different methods also allowed to identify discrepancies in perception of cyclists along their routes suggesting the importance of mixing different tools to collect information that may be more accurately represented for a given context.

Regarding the comparison of the added value of the proposed methods, results suggest that participants increased their understanding about how streetscape design features may influence their route choices but this did not seem to have influenced their choices when choosing their usual commuting routes. In terms of usability, feedback from participants allowed to identify the strengths (such as efficiency to collect data and better understanding of variables from the Maptionnaire survey or the easiness to capture attention from the VR experiment) and flaws (i.e. the level of detail in the VR experiment or limitations to report the attention to the context on the Maptionnaire survey) of each of the implemented tools to collect data about perceptions of streetscape design features regarding to cyclists' route choices.

5. DISCUSSION

The aim of this study *was to understand the influence of streetscape design features on cyclists' route choice, by developing a mixed-method approach to collect objective and subjective data*. This study explored the influence of streetscape design features in cyclists' route choices using two different approaches regarding perception: bottom-up and top-down. Also, an evaluation of the mixed-method's added value provided insight about the strengths of each of the methods to retrieve information about perception regarding learning, usability, and output of information.

5.1. Influence of streetscape design on cyclists' route choices

After the identification of the streetscape design features that influenced cyclists' route choices (3.1), a mixed-method data collection process was carried out to explore how such elements influence cyclists' choices in the form of a survey (3.3) and a VR experiment (3.4). From the results, participants reported considerable differences between their usual and ideal commuting routes (4.2.2) where preferences towards avoidance of stop lights and good pavement quality were predominant in the usual routes against the preference for the presence of trees, vegetation, water bodies, and diversity of land uses in the ideal commuting routes. These preferences were also supported by the results from the eye-tracking measurements (4.3). For example, participants reported larger fixation times and saccades looking at the context in the 'scenic' scenario, meaning that they spent most of their time looking and exploring their surroundings that involved vegetation and trees along the way. In contrast, for the average scenario participants registered a larger fixation time looking to the front to elements such as crossings and stop lights.

These findings are in line with Winters et al. (2010), who also found that aesthetical amenities were influential for the enjoyment of the cycling experience. However, when it comes to the degree of influence that these elements may have when choosing a route, avoidance of stop lights and the quality of pavement may have the largest impact. This influence is supported by the findings of Lu et al., (2018) or Ospina et al., (2020) where despite the fact that cyclists consider factors such as vegetation and water bodies as a positive attribute, more weight is given to distance and travel times when choosing their commuting routes.

5.2. Perception of streetscape design features using two approaches

Comparison between results from different methodological approaches (4.5) allows to reflect on the question 2a '*How can information about cyclists' perception (from both top-down and bottom-up approaches) of streetscape design features be collected and represented for a given context?*'. Due to the different nature of these two approaches, using a mixed-method approach was considered appropriate as the combination of results from both perspectives allowed to further understand how the streetscape design features influence the cycling experience.

On the one hand, the survey allowed to explore the reasoning of participants to choose their routes and explore the rationale to consider sections of their routes as 'bad or boring' or 'beautiful' (4.2.3). This type of comments provide subjective data on perception from a bottom-up approach and allows to understand the influence of the design features based on their personal experiences, which may be useful to further understand the reasoning behind route selection. On the other hand, a simulated bike ride and the measurement of participants' eye movements allow to understand how streetscape design features influence the perception in real time (top-down approach) when cycling. These measurements allow to analyse the attention of participants to design features and how these may influence the overall riding experience in a given context (4.3.2).

The combination of these two methods that collected data about perception of streetscape design features allowed to contextualize the retrieved information as data from sections within the study area was collected from participants that were familiar with the environment. This familiarity aspect also allowed to focus the attention to the enjoyability of ride when participating in the VR experiment and consequently, after mixing results from both methods, gain detailed information about how participants perceive streetscape design features and how they interact with them when cycling. This information may be valuable for decision-makers to address targeted interventions or to receive feedback from participants about a specific context from both their previous experiences and their interaction in real time with the environment.

5.3. Added value of the mixed-method approach

Regarding the added value of the implemented mixed-method approach, Pelzer et al (2014)'s framework for the individual, group and outcome level was used. From the evaluation of the individual level, results from the survey allowed to reflect on the question 3b '*To what extent does the implementation of the mix-method approach influences participants' perception of the streetscape regarding their cycling experiences?*' as participants showed an increase in the level of awareness about the reasons to choose their commuting routes. However, this increased awareness seemed not to influence the preferences and criteria of the participants to change their commuting routes after being involved in the study. These results suggest that, after participating in the study participants reflected on their responses and the way they interact with their surroundings when cycling. This can be translated as a single-loop learning about the study object, as they increased the understanding about the learning object. Therefore, this potential for increasing understanding may be useful for decision-makers and researchers when implementing this mixed-method approach to gain insight about specific interventions regarding streetscape design features or to improve the cycling infrastructure from a data-driven perspective.

From the group level, the main advantage of using a mixed-method approach is that combination of different methods allows for compensation in performance from each other in terms of learning, collaboration, communication, consensus and efficiency. This can be better visualized in table 3 where even though the Maptionnaire survey seems to be the most useful method as seems to have the most potential when it comes to collaboration, communication and consensus. As for efficiency and learning potential, the VR experiment provided more insightful results from a top-down approach. This means that using these two methods together may improve the efficiency to capture data about cyclists' perceptions of streetscape design features, without missing the capabilities for communication or consensus that the VR experiment misses.

Regarding the added value from the output level, the advantages of the proposed mixed-method approach can be explained in terms of the potential of the collected data for an improved understanding about the influence of streetscape design features in cyclists' route choices. For this, comparing the results from each of the developed methods (4.5) allowed to support the added value of complementing information. The combination of eye-tracking measurements from certain sections with the responses from the survey allowed to reflect upon the reason for the differences in rating from the Fietsersbond dataset, like liked/disliked sections from the Maptionnaire survey. This means that, by merging the results from different tools, there is an increasing chance to better understand how cyclists interact with the streetscape design features and how these influence their perception and choices when cycling.

5.4. Limitations

The limitations of this research can be categorized in terms of theoretical, technical capabilities, and methodological considerations. First, in the case of the theoretical limitations for this study the main constraint was how the notion of perception is applied in different studies as studies often explore perceptions from rather a bottom-up or a top-down approach. This differences are expected as the concept of perception may have different meanings depending on the field of study. For example, to improve data collection of perception from a bottom-up approach, consideration of more variables regarding the background preferences from participants such as country of origin, or the assessment of cognitive functions related to way-finding (when reading maps), and other ethnographic characteristics would potentially improve the reliability of the collected data as this additional information may reveal participants' biases that influence their preferences.

Second, regarding technical limitations in this study several trade-offs had to be considered when developing the VR experiment that may have influenced the behaviour and eye movements of participants. Considerations about processing power, a more stable software and quality of videoclips (higher resolution, frames per second and bit rates) would impact the experience of participants as the stimuli would feel more natural and immersive, allowing for better measurements of their attention to AOIs during the simulation of a bike ride.

Lastly, the limitations in the case of the methodology involve consideration of a larger and more diverse sample size for both the survey and the experiment. This diversity may be introduced by not considering a single common destination but an area such as the city centre to retrieve more information about the bicycle infrastructure of the whole study area from inhabitants and visitors. Another methodological consideration would be to assess the usability of the tools in an iterative manner, to address problems regarding understanding of concepts and variables. Also, introducing more possibilities to comment on specific streetscape design features that may have been left out from the literature that were used in this study, as these missing elements may have and influence when choosing a route.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

To encourage behavioral changes to reduce car use, understanding travel behavior is needed. Understanding the route choices of cyclists and their motivation based on their preferences is important to improve cycling networks and therefore encourage the use of active travel modes such as cycling. In this study, a mixed-method approach was developed to understand the influence of streetscape design features on cyclists' route choices and for this, three sub-objectives were identified.

The first sub-objective *was to explore current methods for collecting data regarding streetscape design features influencing cyclists' route choices*. Even though several studies address perceptions using similar tools to identify the design elements, they often focus on one type of perception rather bottom-up or top-down with the use of surveys, interviews, or analytical models. However, findings from this study suggest that the combination of different methods may improve the understating about how cyclists interact and are influenced by the already identified streetscape design features.

The second sub-objective was *to develop a methodology that allows collecting data on cyclists' perception of streetscape design features and its influence on route choice*. From the results of the data collection, information regarding the perception from two different approaches was retrieved and the findings suggest cyclists have the tendency to focus their attention to diverse and changing environments while cycling. This means that participants reported a preference for design features that enhanced the aesthetics of their routes such as trees, diverse facades, presence of vegetation and water bodies. However, these preferences may just influence the enjoyability of the ride but would not have more importance over shorter travel times when it comes to commuting. These revealed preferences may be useful for decision-makers to develop interventions of infrastructure to reward cyclists and therefore encouraging more the use of the bicycle in specific urban environments.

Lastly, the third sub-objective was to evaluate the added value of the proposed methodology to understand the impact in the perception of streetscape design features in cyclists' route choice behaviour. From the findings, combination of the results from the implemented data collection methods revealed the advantages that mixing different types of tools to collect data about perception can provide as these tools complement each other. As part of the added value, based on results from the post-study survey, participants showed learning from the study object, meaning that there was an increase in awareness about the influence of the streetscape design features in their commuting cycling routes.

This research addressed the identified research gaps regarding the influence of streetscape design features in cyclists' route choices. The proposed mixed-method approach addressed the need to combine collection of quantitative and qualitative data to improve the understanding of the influence that streetscape design features have on cyclists' route choices and also addresses the difficulty to capture perceptions by considering both the bottom-up and top-down approaches to improve interpretation of the retrieved information. Therefore, results from this study may encourage academics to develop and implement alternative mixed-methods approaches to increase understanding of cyclists' travel behaviour regarding route choice. Also from a practitioner perspective, implementation of such mixed-methods for data collection may increase the efficiency of the process and also help to develop contextual data-driven interventions that aim to encourage the use of bicycles.

6.2. *Recommendations for further studies*

The main focus of this study was to showcase the importance of a mixed-method approach for collecting data about perception of streetscape design features and its influence on cyclists' route choices. From the findings of this study, some recommendations for future research can be considered:

- From the collected data in this study, the possibility for further analysis could be comparing the individual preferences of participants and their eye movements, which may give insight about the discrepancies between the stated preferences from a bottom-up approach (Maptionnaire survey) the results from the VR experiment (top-down approach). These possible discrepancies may be used to improve collection of data regarding perception of streetscape design features influencing route choices.

- The implementation of this mixed-method approach may be helpful if embedded in a participatory process for targeted interventions as participants (stakeholders) may address sections of roads that they would like to intervene and, with the use of a simulated VR environment with the changes, give feedback about different alternatives for intervention. This way, public participation may be positively increased as well as the quality and feasibility of the interventions to existing cycling infrastructure.

6.3. *Ethical considerations*

For the development of this study, personal information about participants was collected in the Maptionnaire survey. To address possible concerns, participants were made aware of the aim of the research, the implications of taking part in the study and informed about the possible risks involved in an information sheet . Also, on the back of this information sheet, a consent form was also shared and signed by each of the participants. An example of both the consent form and the information sheet that was handed in to participants can be found in Annexes 3 and 4.

To protect the identity of each of the participants and to keep the responses anonymous, a participant ID was assigned to every consent form and participants used their IDs for the whole process. Also, to maintain anonymity from the shared location of their homes when digitizing their commuting route, the reported lines were used to compute a spatial overlay selection using the Fietsersbond network in a GIS environment. This selection considered a buffer of 100m around the original lines so the exact starting point of the lines would be disguised.

7. LIST OF REFERENCES

Alattar, M. A., Cottrill, C., & Beecroft, M. (2021). Public participation geographic information system (PPGIS) as a method for active travel data acquisition. *Journal of Transport Geography*, *96*, 103180. https://doi.org/10.1016/J.JTRANGEO.2021.103180

Badland, H. M., Opit, S., Witten, K., Kearns, R. A., & Mavoa, S. (2010). Can virtual streetscape audits reliably replace physical streetscape audits? *Journal of Urban Health*, *87*(6), 1007–1016. https://doi.org/10.1007/S11524-010-9505-X

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, *15*(2), 73–80. https://doi.org/10.1016/J.TRANPOL.2007.10.005

Beukers, E., Bertolini, L., & Te Brömmelstroet, M. (2014). Using cost benefit analysis as a learning process: identifying interventions for improving communication and trust. *Transport Policy*, *31*, 61–72. https://doi.org/10.1016/J.TRANPOL.2013.12.002

Bhagavathula, R., Williams, B., Owens, J., & Gibbons, R. (2018). The reality of virtual reality: A comparison of pedestrian behavior in real and virtual environments. *Proceedings of the Human Factors and Ergonomics Society*, *3*, 2056–2060. https://doi.org/10.1177/1541931218621464

Brazil, W., O'Dowd, A., & Caulfield, B. (2018). Using eye-tracking technology and Google street view to understand cyclists' perceptions. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *2018-March*, 1–6. https://doi.org/10.1109/ITSC.2017.8317619

Central Bureau of Statistics. (2021). *Regional key figures The Netherlands*. Regional Key Figures. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70072ned/table?ts=1646037305581

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Chen, B., Gong, C., & Li, S. (2022). Looking at buildings or trees? Association of human nature relatedness with eye movements in outdoor space. *Journal of Environmental Psychology*, *80*. https://doi.org/10.1016/J.JENVP.2022.101756

Chen, P., Shen, Q., & Childress, S. (2017). A GPS data-based analysis of built environment influences on bicyclist route preferences. *International Journal of Sustainable Transportation*, *12*(3), 218–231. https://doi.org/10.1080/15568318.2017.1349222

Cole-Hunter, T., Donaire-Gonzalez, D., Curto, A., Ambros, A., Valentin, A., Garcia-Aymerich, J., Martínez, D., Braun, L. M., Mendez, M., Jerrett, M., Rodriguez, D., de Nazelle, A., & Nieuwenhuijsen, M. (2015). Objective correlates and determinants of bicycle commuting propensity in an urban environment. *Transportation Research Part D: Transport and Environment*, *40*, 132–143. https://doi.org/10.1016/j.trd.2015.07.004

Desjardins, E., Apatu, E., Razavi, S. D., Higgins, C. D., Scott, D. M., & Páez, A. (2021). "Going through a little bit of growing pains": A qualitative study of the factors that influence the route choice of regular bicyclists in a developing cycling city. *Transportation Research Part F: Traffic Psychology and Behaviour*, *81*, 431–444. https://doi.org/10.1016/J.TRF.2021.06.005

Desjardins, E., Higgins, C. D., Scott, D. M., Apatu, E., & Páez, A. (2021). Using environmental audits and photo-journeys to compare objective attributes and bicyclists' perceptions of bicycle routes. *Journal of Transport & Health*, *22*, 101092. https://doi.org/10.1016/J.JTH.2021.101092

Dill, J., & McNeil, N. (2013). Four Types of Cyclists?: Examination of Typology for Better Understanding of Bicycling Behavior and Potential. *Transportation Research Record: Journal of the Transportation Research Board*, *2387*(2387), 129–138. https://doi.org/10.3141/2387-15

Enschede, M. of. (2012). *Enschede Fietsstad 2020*. https://www.enschede.nl/sites/default/files/fietsvisie-enschede-fietsstad-2020.pdf

Eom, H. J., & Cho, G. H. (2015). Exploring thresholds of built environment characteristics for walkable communities: Empirical evidence from the Seoul Metropolitan area. *Transportation Research Part D: Transport and Environment*, *40*, 76–86. https://doi.org/10.1016/j.trd.2015.07.005

Ewing, R., & Cervero, R. (2017). Does Compact Development Make People Drive Less? The Answer Is Yes. *Journal of the American Planning Association*, *83*(1), 19–25. https://doi.org/10.1080/01944363.2016.1245112

Fietsersbond. (2020a). *Fietsersbond Survey 2020*. https://www.fietsersbond.nl/fietsstad2020/enquete/

Fietsersbond. (2020b). *Fietsstad 2020: dit is de top 5*. Nieuws. https://www.fietsersbond.nl/nieuws/fietsstad-2020-dit-is-de-top-5/

Fietsersbond. (2021). *Fietsersbond Routeplanner*. Fietsersbond Routeplanner App. https://routeplanner.fietsersbond.nl/?#?gclid=Cj0KCQjw4uaUBhC8ARIsANUuDjXHDX5S3okYP2XjSD54l9ogMEXsopGzzc81x2C6laFC5rufsflaNWQaAlYEEALw_wcB

Garber, M. D., Watkins, K. E., & Kramer, M. R. (2019). Comparing bicyclists who use smartphone apps to record rides with those who do not: Implications for representativeness and selection bias. *Journal of Transport & Health*, *15*, 100661. https://doi.org/10.1016/J.JTH.2019.100661

Geller, R. (2006). *Four Types of Transportation Cyclists*. Portland Bureau of Transportation. https://www.portland.gov/transportation/walking-biking-transit-safety/bicycle-counts

Guyon, I., & Elisseeff, A. (2003). An Introduction to Variable and Feature Selection André Elisseeff. *Journal of Machine Learning Research*, *3*, 1157–1182. https://jmlr.csail.mit.edu/papers/v3/guyon03a.html

Hardinghaus, M., & Papantoniou, P. (2020). Evaluating Cyclists' Route Preferences with Respect to Infrastructure. *Sustainability 2020, Vol. 12, Page 3375*, *12*(8), 3375. https://doi.org/10.3390/SU12083375

Heesch, K. C., Giles-Corti, B., & Turrell, G. (2015). Cycling for transport and recreation: Associations with the socio-economic, natural and built environment. *Health & Place*, *36*, 152–161. https://doi.org/10.1016/J.HEALTHPLACE.2015.10.004

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer, J. (2011). *Eye Tracking: A comprehensive guide to methods and measures*. Oxford University Press.

Kovácsová, N., Cabrall, C. D. D., Antonisse, S. J., de Haan, T., van Namen, R., Nooren, J. L., Schreurs, R., Hagenzieker, M. P., & de Winter, J. C. F. (2018). Cyclists' eye movements and crossing judgments at uncontrolled intersections: An eye-tracking study using animated video clips. *Accident Analysis and Prevention*, *120*, 270–280. https://doi.org/10.1016/J.AAP.2018.08.024

Krenn, P. J., Oja, P., & Titze, S. (2014). Route choices of transport bicyclists: A comparison of actually used and shortest routes. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 1–7. https://doi.org/10.1186/1479-5868-11-31/TABLES/3

Lee, R. J., Sener, I. N., & III, J. A. M. (2016). An evaluation of emerging data collection technologies for travel demand modeling: from research to practice. *The International Journal of Transportation Research*, *8*(4), 181–193. https://doi.org/10.1080/19427867.2015.1106787

Li, M., Zou, M., & Li, H. (2018). Urban travel behavior study based on data fusion model. In *Data-Driven Solutions to Transportation Problems* (1st ed., Vol. 1, pp. 111–135). Elsevier. https://doi.org/10.1016/B978-0-12-817026-7.00005-9

Li, S., Muresan, M., & Fu, L. (2017). Cycling in Toronto, Ontario, Canada: Route Choice Behavior and Implications for Infrastructure Planning: *Transportation Research Record: Journal of the Transportation Research Board*, *2662*(1), 41–49. https://doi.org/10.3141/2662-05

Liu, J., Wang, B., & Xiao, L. (2021). Non-linear associations between built environment and active travel for working and shopping: An extreme gradient boosting approach. *Journal of Transport Geography*, *92*. https://doi.org/10.1016/J.JTRANGEO.2021.103034

Lu, W., Scott, D. M., & Dalumpines, R. (2018). Understanding bike share cyclist route choice using GPS data: Comparing dominant routes and shortest paths. *Journal of Transport Geography*, *71*, 172–181. https://doi.org/10.1016/J.JTRANGEO.2018.07.012

Ma, L., & Dill, J. (2015). Associations between the objective and perceived built environment and bicycling for transportation. *Journal of Transport & Health*, *2*(2), 248–255. https://doi.org/10.1016/J.JTH.2015.03.002

Ma, L., Dill, J., & Mohr, C. (2014). The objective versus the perceived environment: what matters for bicycling? *Transportation 2014 41:6*, *41*(6), 1135–1152. https://doi.org/10.1007/S11116-014-9520-Y

Maghelal, P., Natesan, P., Naderi, J. R., & Kweon, B. S. (2011). Investigating the use of virtual reality for pedestrian environments. *Journal of Architectural and Planning Research*, *28*(2), 104–117.

Mantuano, A., Bernardi, S., & Rupi, F. (2017). Cyclist gaze behavior in urban space: An eye-tracking experiment on the bicycle network of Bologna. *Case Studies on Transport Policy*, *5*(2), 408–416. https://doi.org/10.1016/J.CSTP.2016.06.001

Maptionnaire. (2020, January 28). *4 Benefits of PPGIS for Transportation and Mobility Planning*. Maptionnarie Blog. https://maptionnaire.com/blog-list/4-benefits-ppgis-transportation-mobility-planning

Mars, L., Arroyo, R., & Ruiz, T. (2016a). Qualitative Research in Travel Behavior Studies. *Transportation Research Procedia*, *18*, 434–445. https://doi.org/10.1016/J.TRPRO.2016.12.057

Mars, L., Arroyo, R., & Ruiz, T. (2016b). Qualitative Research in Travel Behavior Studies. *Transportation Research Procedia*, *18*, 434–445. https://doi.org/10.1016/j.trpro.2016.12.057

McArthur, D. P., & Hong, J. (2019). Visualising where commuting cyclists travel using crowdsourced data. *Journal of Transport Geography*, *74*, 233–241. https://doi.org/10.1016/J.JTRANGEO.2018.11.018

Mrkajic, V., Vukelic, D., & Mihajlov, A. (2015). Reduction of CO2 emission and non-environmental co-benefits of bicycle infrastructure provision: the case of the University of Novi Sad, Serbia. *Renewable and Sustainable Energy Reviews*, *49*, 232–242. https://doi.org/10.1016/J.RSER.2015.04.100

Nazemi, M., van Eggermond, M. A. B., Erath, A., Schaffner, D., Joos, M., & Axhausen, K. W. (2021). Studying bicyclists' perceived level of safety using a bicycle simulator combined with immersive virtual reality. *Accident Analysis & Prevention*, *151*, 105943. https://doi.org/10.1016/J.AAP.2020.105943

Ospina, J. P., Botero-Fernández, V., Duque, J. C., Brussel, M., & Grigolon, A. (2020). Understanding cycling travel distance: The case of Medellin city (Colombia). *Transportation Research Part D: Transport and Environment*, *86*. https://doi.org/10.1016/J.TRD.2020.102423

Pelzer, P., & Geertman, S. (2014). Planning support systems and interdisciplinary learning. *Planning Theory & Practice*, *15*(4), 527–542. https://doi.org/10.1080/14649357.2014.963653

Pelzer, P., Geertman, S., Heijden, R. van der, & Rouwette, E. (2014). The added value of Planning Support Systems: A practitioner's perspective. *Computers, Environment and Urban Systems*, *48*, 16–27. https://doi.org/10.1016/J.COMPENVURBSYS.2014.05.002

Pelzer, P., Geertman, S., & van der Heijden, R. (2016). A comparison of the perceived added value of PSS applications in group settings. *Computers, Environment and Urban Systems*, *56*, 25–35. https://doi.org/10.1016/J.COMPENVURBSYS.2015.10.008

Ritchie, H., & Roser, M. (2020). CO_2 and Greenhouse Gas Emissions. *Our World in Data*. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Sarjala, S. (2019). Built environment determinants of pedestrians' and bicyclists' route choices on commute trips: Applying a new grid-based method for measuring the built environment along the route. *Journal of Transport Geography*, *78*, 56–69. https://doi.org/10.1016/J.JTRANGEO.2019.05.004

Scott, D. M., Lu, W., & Brown, M. J. (2021). Route choice of bike share users: Leveraging GPS data to derive choice sets. *Journal of Transport Geography*, *90*, 102903. https://doi.org/10.1016/J.JTRANGEO.2020.102903

Spielman, R. M., Jenkins, W. J., & Lovett, M. D. (2020). *Psychology 2e* (1st ed., Vol. 1). OpenStax. https://openstax.org/books/psychology-2e/pages/1-introduction

Sun, Y., Du, Y., Wang, Y., & Zhuang, L. (2017). Examining Associations of Environmental Characteristics with Recreational Cycling Behaviour by Street-Level Strava Data. *International Journal of Environmental Research and Public Health 2017, Vol. 14, Page 644*, *14*(6), 644. https://doi.org/10.3390/IJERPH14060644

Tobii Pro AB. (2014). *Tobii Pro Lab* (1.152.30002). Tobii Pro AB. https://www.tobiipro.com/

Van Wee, B., Annema, J. A., & Banister, D. (2013). *The transport system and transport policy: an introduction* (B. van Wee & J. A. Annema (eds.); 1st ed.). Edward Elgar Publishing.

Verhoeven, H., Van Hecke, L., Van Dyck, D., Baert, T., Van de Weghe, N., Clarys, P., Deforche, B., & Van Cauwenberg, J. (2018). Differences in physical environmental characteristics between adolescents' actual and shortest cycling routes: A study using a Google Street View-based audit. *International Journal of Health Geographics*, *17*(1), 1–15. https://doi.org/10.1186/S12942-018-0136-X/TABLES/5

von Stülpnagel, R. (2020). Gaze behavior during urban cycling: Effects of subjective risk perception and vista space properties. *Transportation Research Part F: Traffic Psychology and Behaviour*, *75*, 222–238. https://doi.org/10.1016/J.TRF.2020.10.007

Wang, D., & Zhou, M. (2017). The built environment and travel behavior in urban China: A literature review. *Transportation Research Part D: Transport and Environment*, *52*, 574–585. https://doi.org/10.1016/j.trd.2016.10.031

Wąsowicz, M. (2021). Representing Built Environments with Digital Tools: Problems with Human Perception. *Lecture Notes in Civil Engineering*, *122*, 167–179. https://doi.org/10.1007/978-3-030-63879-5_13

Willis, D. P., Manaugh, K., & El-Geneidy, A. (2015). Cycling Under Influence: Summarizing the Influence of Perceptions, Attitudes, Habits, and Social Environments on Cycling for Transportation. *International Journal of Sustainable Transportation*, *9*(8), 565–579. https://doi.org/10.1080/15568318.2013.827285

Winters, M., Teschke, K., Grant, M., Setton, E. M., & Brauer, M. (2010). How Far Out of the Way Will We Travel?: Built Environment Influences on Route Selection for Bicycle and Car Travel. *Transportation Research Record: Journal of the Transportation Research Board*, *2190*(2190), 1–10. https://doi.org/10.3141/2190-01

Xiao, L., Yang, L., Liu, J., & Yang, H. (2020). Built environment correlates of the propensity of walking and cycling. *Sustainability (Switzerland)*, *12*(20), 1–16. https://doi.org/10.3390/SU12208752

Yang, Y., Wu, X., Zhou, P., Gou, Z., & Lu, Y. (2019). Towards a cycling-friendly city: An updated review of the associations between built environment and cycling behaviors (2007–2017). *Journal of Transport & Health*, *14*, 100613. https://doi.org/10.1016/J.JTH.2019.100613

Zeuwts, L., Vansteenkiste, P., Deconinck, F., van Maarseveen, M., Savelsbergh, G., Cardon, G., & Lenoir, M. (2016). Is gaze behaviour in a laboratory context similar to that in real-life? A study in bicyclists. *Transportation Research Part F: Traffic Psychology and Behaviour*, *43*, 131–140. https://doi.org/10.1016/J.TRF.2016.10.010

8. APPENDIX

Annex 1: Search matrix & search log

Search matrix			
Key concept	**Narrower term**	**Broader term**	**Related term**
Street scape	Aesthetics	Street design	Street scape
Cycling	Cycling	Non-motorized	Active transport
Route Choice	Route choice	Travel behavior	Path choice

Search queries	
Complete	(“Aesthetic*” OR “Street design” OR “Street scap*”) AND (“Cycl*” OR “Non-motor*” OR “Active transport*”) AND (“Route choice*” OR “Travel behav*” OR “Path choice*”)
Refined	(“Aesthetics” OR “Built environment” OR “Street scape”) AND (“Cycling”) AND (“Route choice” OR “Path choice”)

Search log					
Date	**Database**	**Query**	**Setting**	**# Results**	**Notes**
12-Jan-21	Scopus	Complete version	Limit from 2011-2021	528	26 selected results.
	Web of Science	Complete version	Limit from 2011-2021	10	3 selected results
13-Jan-21	Science direct	Refined	Limit from 2011-2021	366	32 Selected
	Web of science	Refined	Limit from 2011-2021	28	9 selected

Annex 2: Survey instrument and coding of answers

Section	Code	Sub_code	Question & Answer code	Type
Screening	S-	01	How often do you commute by bicycle per week?	Choose category
			_01 Never	
			_02 1	
			_03 2 to 3	
			_04 More than 4	
		02	How long have you been living in Enschede?	Choose category
			_01 Less than a year	
			_02 1 year	
			_03 Between 2 to 3 years	
			_04 More than 4 years	
Preferences Commute	PC-	01	In the map, draw your most common route for commuting to ITC by bike	Polyline
		04	From your route, please indicate which sections you like the most	Line
		05	From your route, please indicate which sections you dislike the most	Line
		06	Please add a marker of the things that you LIKE about this route	Point
		07	Please add a marker of the things that you DO NOT LIKE about this route	Point
		02	From the following list, which design attributes do you consider important for choosing this route?	Multi choice
			_01 Good pavement quality (No holes, bumps)	
			_02 Adequate surface material (Gravel, Tarmac, Concrete)	
			_03 Wide cycling lane	
			_04 Independent cycling lane (not shared with car traffic)	
			_05 Parking availability along the way for bicycles	
			_06 Diversity in building's facades	
			_07 Diversity of land use (commerce, recreation, residential, etc)	
			_08 Presence of street-level windows	
			_09 Presence of tall buildings (apartment complexes, offices, etc)	
			_10 Presence of trees	
			_11 Presence of grass/vegetation	
			_12 Presence of landmarks (specific buildings, i.e. a church)	
			_13 Presence of water bodies	
			_14 Street stop lights avoidance	
			_15 Least amount of road intersections	
		03	From the following factors, which ones you do you consider for this route?	Multi choice
			_01 Shortest route	
			_02 Fastest route	
			_03 Low motorized traffic volume	
			_04 High pedestrian traffic volume	
			_05 Slope (inclination)	
			_06 Traffic safety	
Preferences Ideal	PI-	01	Imagine you do not have any time or distance constraint. Draw your ideal route for commuting to ITC by bike	Polyline
		02	From your route, please indicate which sections you like the most	Line
		03	From your route, please indicate which sections you dislike the most	Line
		04	Please add a marker of the things that you LIKE about this route	Point
		05	Please add a marker of the things that you DO NOT LIKE about this route	Point
		06	From the following list, which design attributes do you consider important for choosing this route?	Multi choice
			_01 Good pavement quality (No holes, bumps)	
			_02 Adequate surface material (Gravel, Tarmac, Concrete)	
			_03 Wide cycling lane	
			_04 Independent cycling lane (not shared with car traffic)	
			_05 Parking availability along the way for bicycles	
			_06 Diversity in building's facades	
			_07 Diversity of land use (commerce, recreation, residential, etc)	
			_08 Presence of street-level windows	
			_09 Presence of tall buildings (apartment complexes, offices, etc)	
			_10 Presence of trees	
			_11 Presence of grass/vegetation	
			_12 Presence of landmarks (specific buildings, i.e. a church)	
			_13 Presence of water bodies	
			_14 Street stop lights avoidance	
			_15 Least amount of road intersections	
		07	From the following factors, which ones you do you consider for this route?	Multi choice
			_01 Shortest route	
			_02 Fastest route	
			_03 Low motorized traffic volume	
			_04 High pedestrian traffic volume	
			_05 Slope (inclination)	
			_06 Traffic safety	
Attitudes	A-	01	In terms of safety, to which of the following typologies you relate your cycling behavior?	Choose category
			_01 Very comfortable even without bike lanes	
			_02 Somewhat comfortable while in bike lanes	
			_03 Not very comfortable while in bike lanes	
			_04 Very uncomfortable even in bike lanes	
Demographics	D-	01	What is your age?	Open question
		02	Which of these categories applies to you?	Choose category
			_01 I am working	
			_02 I am studying	
			_03 I am working & studying	
			_04 None of the above	
	P-ID		What is your participant ID?	Text

Annex 3: Information sheet

INFORMATION SHEET FOR PARTICIPANTS

INFLUENCE OF THE BUILT ENVIRONMENT ON CYCLISTS' ROUTE CHOICES

We would like to invite you to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Your participation is anonymous.

Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Information about the survey:

Aim of the research: *To understand how the built environment influences cyclists' route choices on commuting and leisure trips.*

Target respondents: *Regular cyclists*

If you take part: *The survey will take around 20 to 25 minutes and your responses will be stored for further analysis. Provided information and responses will be used only for the purpose of this research. You may withdraw any data/information you have already provided up until is processed and analysed for final results of the project.*

Possible risks: *The survey may require more time than expected depending of the drawing section. Responses will be anonymous meaning that no one will be able to match your responses to you. Your responses will be stored in a cloud data repository owned and protected by Maptionnaire as well as a local copy in the researchers' computer for analysis.*

Possible benefits: *We will be happy to send you a copy of the final report upon publication. Please contact the person in the contact details to receive a PDF version of the report via email.*

Thank you for taking the time to read and consider this information.

If you have any questions or require more information about this study, please contact the researcher using the following contact details:

Roberto N. Ramirez
University of Twente, ITC Faculty
r.n.ramirezjuarez@student.utwente.nl

Annex 4: Consent form

INFORMED CONSENT

INFLUENCE OF THE BUILT ENVIRONMENT ON CYCLISTS' ROUTE CHOICES

Please carefully read & sign this form for consent.

1. I confirm that I have read and understand the provided information sheet for this study. I may keep this information sheet for my records and I have had the opportunity to ask questions to the researcher directly.

2. I understand that my participation is voluntary and I am free to withdraw from the study at any point without giving any reason and without being penalized or disadvantaged in any way.

3. I understand that my answers may be looked at by responsible individuals from the University of Twente. I give permission for these individuals to access to this data as relevant to his research project.

4. I understand that this consent file will be considered by researchers to maintain my anonymity throughout the project, including publication.

5. I agree to take part in this study.