The effect of crowding on cyclists' route choice:

a visual stated choice experiment on the impact of crowding on the willingness to cycle of students

Thesis in the MSc program Spatial, Transport and Environmental Economics

School of Business and Economics

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Date:	June 29, 2023
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Abstract

A better understanding of the influences on the route choice decision of cyclists is essential to ensure a continuous increase in the number of cyclists. Yet, little attention has been paid to the issue of crowding on cycle paths which already occurs in countries with an established cycling infrastructure like the Netherlands. In this thesis, a visual stated preference survey is used to investigate the impact of crowding and infrastructure elements on the route choice decisions of students (n = 152) living in the Netherlands. In general, students express a higher willingness to cycle to avoid crowding compared to specific infrastructure types. They are willing to cycle 1.33 km to shift from a road with cycle tracks to green surroundings and 2.38 km to avoid the highest level of crowding which corresponds to a willingness to pay of €1.07 and €1.93 respectively. When including interaction terms, international and male students show a higher willingness to cycle up to 20% longer distances compared to female Dutch students, while other influences such as the place of residence or the level of experience reveal no significant impact. These findings emphasize the need to further investigate the effects of crowding along with the value of travel time for cyclists.

Key words

Bicycling, Visual stated preferences, Bicycle crowding, Willingness to cycle, Route preferences, Cycling infrastructure, Student

1 Introduction

Currently 73% of all European citizens live in urban areas; a number which is predicted to rise to over 80% in 2050 (United Nations 2019, p. 27). This increase in urban population, combined with the consequences of climate change, challenges cities to find solutions to sustain the livability of these areas. In addition, urban mobility and transport are directly linked to economic productivity and seen as one of the most important issues of European cities causing negative externalities through congestion, air pollution, traffic fatalities and noise (European Commission 2017, p. 5). Cycling as a clean and efficient means of transport, especially for short distance trips in urban areas, is touted as a solution to many of these challenges while also improving health, reducing obesity and creating jobs (Bruntlett and Bruntlett 2018, p. 127; Wang and Akar 2018, p. 67; Hardinghaus and Papantoniou 2020, p. 1; European Commission 2021; Government of the Netherlands 2022; Myhrmann et al. 2022, pp. 1–2). Moreover, cycling friendly cities are considered to increase the livability and overall quality of urban areas as bikes are space-efficient and thus reduce the demand for urban land (European Commission 2021).

According to the International Transport Forum (ITF 2021, p. 98) the modes of transport walking, cycling and micromobility are forecasted to increase more than 2.5-fold by 2050. This trend will influence urban infrastructure planning and impact metropolitan residents' relation to transport. However, the lack of cycling infrastructure, risk of injury and direct exposure to air pollution currently impede this development. To facilitate the modal shift towards the bike and to ensure a lasting change in mobility behavior, gaining a better understanding of the various influences of cyclists' route choice decisions is essential. While aspects such as infrastructure and safety perception have been studied in multiple papers, less attention has been drawn to the issue of the enlarging number of cyclists eventually resulting into crowding on cycle paths. First influences of crowding among cyclists on the perception of safety and route choice were investigated by Palao et al. (2019) and Vedel et al. (2017) at the example of Copenhagen in Denmark finding that respondents were willing to cycle different additional distances to avoid crowding depending on multiple factors. In this context, the Netherlands, which are considered an established cycling infrastructure in the literature (Pucher and Buehler 2008, p. 496; Chataway et al. 2014, p. 32; Hull and O'Holleran 2014, p. 369; Ton et al. 2017, p. 75), set a precedent as crowding and congestion among cyclists already occur but little research has been done on it (Groot-Mesken et al. 2015, p. 2; Bruntlett and Bruntlett 2018, p. 51; Wierbos et al. 2020, p. 1). According to forecasts by the Kennisinstituut voor Mobiliteitsbeleid (2022, p. 44) the bicycle use in the Netherlands will increase by 12% until 2027 compared to levels in 2019. In addition, the Dutch government aims to convince 100,000 people more to commute by bike in the next two years (Government of the Netherlands 2022). This sharp growth of the already high modal share of cyclists in the Netherlands could further reduce the positive effects of cycling due to possible negative impacts of crowding which may carry over to other emerging cycling cities. At the same time, the number of fatalities among cyclists is continuously higher than among car passengers since 2019, with latest figures from 2022 counting 291 and 201 fatalities respectively (Centraal Bureau voor de Statistiek 2023). Even though most of these fatalities are due to accidents with cars, the aspect of safety also plays a role in the perception of crowding.

In the context of the overall increasing number of cyclists, students represent the future adults who will shape the mobility behavior of tomorrow's society. According to Balsas (2003, p. 46) and Motoaki and Daziano (2015, p. 218) the young and physically active student community at universities is key to strengthen lasting sustainable transport habits as students tend to adopt the mobility behavior they acquired during their time at university after graduation. Nonetheless, this target group's cycling behavior is less examined in the literature. Simultaneously, studies conducted within a university environment aiming for a diverse participant pool often tend to overrepresent students and highly educated staff which reduces the overall transferability of results (Wang and Akar 2018, p. 70; Park and Akar 2019, p. 200; Wierbos et al. 2020, p. 4; Nazemi et al. 2021, p. 4; Fitch et al. 2022, p. 441). To avoid this potential selection bias and further explore the research gap for the specific cycling behavior of students, this thesis aims to answer the research question: What is the willingness to cycle to avoid crowded cycling routes for students living in the Netherlands? Using a visual stated preference survey, a main objective is to compare students' willingness for detours, expressed in route length, and willingness to pay to avoid crowding and specific infrastructure elements with recent results from the literature to determine the extent to which students engage in similar behavior living in an established cycling infrastructure. Moreover, the influence of cycling habits, socio-economic factors and place of residence will be investigated.

The analysis of the visual stated choice experiment with a logit regression shows that students living in the Netherlands are willing to realize longer detours to avoid higher levels of crowding than for specific infrastructure elements. In quantitative terms, the basic model without interaction terms reveals that students are willing to cycle an additional distance of 2.38 km to avoid the highest level of crowding and 1.33 km to shift from a road with a cycle track to green surroundings which translates to a willingness to pay of €1.93 and €1.07 respectively. When including interaction terms, female Dutch students prove to have a lower willingness to cycle with detours up to 20% shorter compared to male and international students. Further aspects such as the place of residence, the experience level or cycling behavior indicate no significant influence on the route choice. These outcomes contribute to the literature by confirming previous results about infrastructural preferences and by adding new findings to the emerging field of crowding among cyclists with a focus on the Netherlands from the perspective of students. The use of photos for the stated choice experiment was positively perceived by the respondents. This further encourages the advantages for visual components in stated preference surveys.

The remainder of the thesis is structured as follows: The literature review briefly addresses the Dutch cycling context as well as the research about influences on route choice of cyclists in relation to crowding and succinctly recapitulates the use of stated choice experiments in these circumstances. Afterwards the methodology part sets out the data collection, survey design and its development. Moreover, the econometric model and used formulas are introduced. Thereafter the section about the results summarizes characteristics of the participants and findings of the model estimation followed by the calculation of the willingness to cycle and the willingness to pay. Subsequently the discussion section examines these results and highlights limitations as well as further research potential before summarizing the overall findings in the conclusion.

2 Literature review

The route choice of cyclists represents a complex interaction of various influences. The literature in this context shifted from a focus on physical elements towards a more holistic approach including socio-economic factors and safety perception. The section hereinafter briefly points out the circumstances of Dutch cycling culture and its perception from the perspective of international students, followed by the most important literature on the factors affecting route choice decisions along with recent publications about crowding among cyclists. Lastly, the stated choice experiment techniques used in this context are presented with a focus on visual components.

2.1 Dutch cycling context

Cycling in the Netherlands slowly became a popular means of transport after a social movement in the 1970s, inspired by the desire to reduce cycling fatalities in combination with the political willingness to improve cycling infrastructure, setting the base for today's advanced urban design (Dekker 2022, p. 335). As Dekker (2022, p. 338) points out a lasting transformation of public space in favor of cyclists is a gradual process involving multiple factors such as cultural acceptance of bikes as well as financial efforts by the government. However, researchers do not only see the established cycling infrastructure and flat landscape as reasons for the high number of cyclists in the Netherlands, but especially focus on the cultural relation and social norms favoring cycling (Nello-Deakin and Nikolaeva 2021, p. 290). Kuipers (2013, pp. 18–20) classifies cycling in the Netherlands as "national habitus"[1] which she defines as "learned practices and standards that have become so much part of ourselves that they feel self-evident and natural". In contrast, immigrants often did not grow up in these circumstances and have a different perspective on cycling infrastructure and cycle less compared to people who grew up in the Netherlands (Kuipers 2013, p. 20; Harms et al. 2014, p. 240; Nello-Deakin and Nikolaeva 2021, p. 290). As depictured by Nello-Deakin and Nikolaeva (2021, pp. 299–300) cycling is often seen by immigrants

[1] The initial concept of "national habitus" was introduced by Elias et al. 1996.

as the “Dutch lifestyle” and a step towards integration into the local culture.[2] In this context, international students can be compared with immigrants according to Waard et al. (2020, p. 286) as students are staying at least for a year and often intend to commute by bike like local residents. In their study comparing the cycling behavior of Dutch and international students with a focus on safety aspects and maneuver performance, no significant difference in average speed or lane positioning was found, but international students tended to make more mistakes and reported a higher number of crashes prior to the study (Waard et al. 2020, p. 290). This insecurity in cycling behavior, which especially occurs in the beginning of the stay of international students, can lead to an interruption of the traffic flow, crashes or negative interactions with other cyclists. As a result, the thesis will also examine whether a significant difference in the willingness to cycle between international and Dutch students can be determined.

2.2 Influences on route choice

For infrastructure and land-use attributes the majority of studies empirically confirm that the more separated cycle lanes are from traffic, the higher the associated level of utility and perceived safety (Vedel et al. 2017, p. 61; Palao et al. 2019, p. 6; Park and Akar 2019, p. 197; Hardinghaus and Papantoniou 2020, p. 10; Clark et al. 2021, p. 143; Nazemi et al. 2021, p. 5). Cyclists favor lanes separated from the road to avoid interaction with motorized traffic (Buehler and Dill 2016, p. 21; Vedel et al. 2017, p. 61). In quantitative terms, Tilahun et al. (2007, p. 298) and Anowar et al. (2017, p. 75) find a willingness to cycle between 11 to 17 minutes longer to cycle on continuous and separated lanes. Moreover, green surroundings are preferred over cycle tracks on roads and cycle lanes as shown by Vedel et al. (2017, p. 61) and Palao et al. (2019, pp. 6–7) at the example of cyclists in Copenhagen. In addition, cyclists frequently associate green surroundings with a lower exposure to air pollution (Vedel et al. 2017, p. 60; Park and Akar 2019, p. 191). However, several studies point out that cyclists are often not aware that a detour through parks resulting in a longer overall trip can increase the absolute amount of inhaled pollutants (Anowar et al. 2017, p. 76; Broach and Bigazzi 2017, p. 156).

In addition to these infrastructural influences, the relation between socio-economic factors and attitudes towards cycling and the environment play a role. For instance, studies investigate to what extent participants like cycling, how important cycling facilities are to them or what their motivation is (Muñoz et al. 2016, p. 7; Wang and Akar 2018, p. 71; Fitch et al. 2022, p. 436). These attitudes become in particular important when transferring findings to other cultural and geographical contexts as several studies comparing different cities or countries emphasize the importance of a thorough analysis of local circumstances (Chataway et al. 2014, p. 33; Hardinghaus and Papantoniou 2020, p. 12; Nazemi et al. 2021, p. 10). Especially the mere transfer of Dutch cycling infrastructure is prone to fail if not adapted

[2] An example for the perspective of international newcomers in the city of Amsterdam on cycling and their key arguments for taking up cycling can be found in Nello-Deakin and Nikolaeva (2021). Moreover, Zaal (2021) presents multiple perspectives of international students at the example of cycling in Groningen.

to the regional conditions (Fleming 2012, p. 147; Nello-Deakin and Nikolaeva 2021, p. 308; Hoed and Jarvis 2022, p. 312).

Another factor influencing the route choice is the level of confidence, which is strongly related to the notion of comfort, the level of experience and associated with the perception of safety. Multiple studies have confirmed that a higher level of confidence can reduce insecurities when cycling (Hunt and Abraham 2007, p. 466; Misra and Watkins 2018, p. 145; Ravensbergen et al. 2020, p. 3; Nazemi et al. 2021, p. 8; Fitch et al. 2022, p. 445). Moreover, researcher argue that with an increase in experience, the willingness to realize detours decreases and cyclists care less about the type of infrastructure. For the classification of the level of experience multiple approaches are used such as asking for the years of cycling experience (e.g., Anowar et al. 2017, pp. 69–70) or a self-assessment of capabilities (e.g., Hunt and Abraham 2007, p. 459; Wang and Akar 2018, p. 72; Fitch et al. 2022, p. 436). At the example of revealed preference data from 318 cyclists in Copenhagen, Palao et al. (2019, p. 1) demonstrate how confidence in terms of speed is related to the safety perception and stress level. For instance, they find that fast and medium-speed cyclists express a preference for main roads which are assumed to be highly correlated with congestion (Palao et al. 2019, p. 7). As a result, they conclude that this group of cyclists is less affected by crowding compared to slower cyclists with an average speed lower than 15.5 km/hour who are willing to realize up to 20.5% longer detours to avoid these routes.

Regarding the relation between route choice and gender, studies confirm the conclusion of the meta-analysis on risk-taking tendencies by Byrnes et al. (1999, p. 377) stating that women tend to be more risk averse than men (Tilahun et al. 2007, p. 298; Anowar et al. 2017, pp. 74–75). As a result, several studies see the increase of the proportion of women in a cycling population as a potential indicator for the improvement of cycling infrastructure (AitBihiOuali and Klingen 2022, p. 8; Rupi et al. 2023, p. 10). In addition, researchers argue that in countries with established cycling infrastructure more women assess themselves as experienced cyclists and differences between genders become less important (Pucher and Buehler 2008, p. 496; Prati et al. 2019, p. 6). As a result, the relation between the willingness to cycle and the gender as well as the level of experience will be investigated through targeted questions in the survey.

The topic of crowding and congestion among cyclists has slowly emerged in the last years. Countries with an established cycling infrastructure and a high modal share of cyclist, such as Denmark and the Netherlands, encounter challenges with the growing number of cyclists. In general, crowding can lead to a longer travel time negatively impacting utility or forcing cyclists who want to avoid it to leave earlier or later than their preferred departure time (Small and Verhoef 2007, p. 70). Furthermore, other negative effects include the increased potential for negative interaction between cyclists as well as with other road users such as motorized vehicle drivers and pedestrians along with a higher risk for injuries and crashes negatively influencing the perception of safety (Hunt et al. 2017, p. 24; Vedel et al. 2017, p. 61). As a consequence, the bike might not be used anymore resulting into higher costs for taking another means of transport or a lower level of overall physical activity with negative health impacts. In quantitative terms no definition or threshold is given for the phenomenon of crowding among cyclists occurring before it comes to congestion. In contrast, the notion of congestion in transport is commonly defined when demand exceeds capacity (Wierbos et al. 2019, p. 693). Compared to congestion between cars, Wierbos et al. (2020, p. 2) emphasize that queues of cyclists tend to be less organized due to the size of bikes and the possibility for individual behavior, e.g., overtaking or bypassing maneuvers, which increases the feeling of insecurity. In the literature, crowding is seen as physical densification along with a subjective feeling defined by Stokols (1972, p. 275) as a state "in which the restrictive aspects of limited space are perceived by the individuals exposed to them" which is supported by other early studies focusing on psychological measures and the stressful effects of crowding on people (Walden and Forsyth 1981, p. 62).[3] A recent definition of overcrowding on pedestrian sidewalks is given by Autumn (2013, p. 6) as "the point beyond which movement is restricted and personal space invaded" which can be transferred to cycle lanes due to their similar structure. In this context, Vedel et al. (2017) represent a key paper investigating the route choice behavior of commuting cyclists in Copenhagen in relation to crowding. In their stated choice experiment among 3,891 participants, they find an average willingness to cycle of 1.03 km to prevent cycling on heavily crowded routes which increases during peak hours up to 1.2 km (Vedel et al. 2017, pp. 60–61).[4] Several findings of Vedel et al. (2017) were confirmed in the master thesis of Pax (2020, pp. 16–17) showing with a stated preference survey among 129 cyclists that they are willing to cycle an additional distance of 2.78 km and 0.99 km to avoid the highest level of congestion and crowding respectively.[5] In addition, Pax (2020, p. 16) verifies that female participants are willing to realize detours up to 30% longer to avoid crowding in contrast to men. These results and specific outcomes of the willingness to pay will be compared with findings of this thesis in the discussion of results section.

2.3 Stated choice experiments

Stated choice experiments, also referred to as stated preferences surveys, enable respondents to be exposed to a situation which they might not be familiar yet, such as crowding on cycle paths, and to include different perspectives from active cyclists as well as non-cyclists. In addition, the use of stated preferences allows for greater variation in attribute levels which is key to investigate the participants'

[3] These aspects demonstrate the relation between crowding and cyclists' perception of safety. Even though investigating this relation is not part of the thesis, the concepts of subjective safety and fear represent an important aspect to consider in the overall picture of route choice analysis (Chataway et al. 2014; Ravensbergen et al. 2020; Nazemi et al. 2021).

[4] For an example of concrete infrastructure measures to combat safety issues related to crowding, Hunt et al. (2017) published a report about congestion on cycle paths in Copenhagen and potential solutions.

[5] In her thesis, Pax (2020, p. 8) relates crowding to the number of cyclists on the route and how busy it is whereas congestion is associated to cycling speed forcing cyclists to often slow down at a high level.

hypothetical behavior (Train 2009, p. 153). Nonetheless, the reduction to a specific number of attributes is essential to concentrate on particular aspects ignoring other components (Vedel et al. 2017, p. 54). Moreover, researchers emphasize that respondents prefer short and clear descriptions to not be overwhelmed by the number of alternatives and attributes to consider for their decision (Hunt and Abraham 2007, p. 458; Anowar et al. 2017, p. 70). A pairwise comparison of two alternatives facilitates the understanding of the presented scenario (Evans-Cowley and Akar 2014, p. 20). Surveys using this technique often show around six choice situations to avoid tiring the respondents (Caulfield et al. 2012, p. 413; Vedel et al. 2017, p. 55; Clark et al. 2021, p. 131). Furthermore, setting respondents into a specific scenario helps to make a situation more relatable. For instance, Caulfield et al. (2012, p. 414), Vedel et al. (2017, p. 55) or Tilahun et al. (2007, p. 290) tell participants that they are cycling to work to create a realistic setting.

Surveys using visual footage either use virtually generated images (e.g., Caulfield et al. 2012, p. 415; Vedel et al. 2017, p. 56), photos taken by the researchers or from Google Street View (e.g., Evans-Cowley and Akar 2014, p. 20; Wang and Akar 2018, p. 70) or modified pictures (e.g., Clark et al. 2019, p. 91). The use of visual components for a stated choice experiment allows, on one hand, to reduce the potential bias compared to a scenario which is described in written form. Instead of imagining a "crowded cycle track next to a car", a photo shows an actual situation (Caulfield et al. 2012, pp. 413–414; Hurtubia et al. 2015, p. 461; Vedel et al. 2017, p. 54; Rossetti et al. 2019, p. 699; Nazemi et al. 2021, p. 2). On the other hand, the perception of photos remains subjective and leaves room for further interpretation such as the temperature or surroundings (Hurtubia et al. 2015, p. 461; Hardinghaus and Papantoniou 2020, p. 5; Nazemi et al. 2021, pp. 2–3). Moreover, Evans-Cowley and Akar (2014, p. 20) remark that the selection of the photos is already constrained by the researcher's subjective judgment whether a situation is suited to be presented to participants. In addition, variations in the photo quality, e.g., the lighting, saturation or time of the day, can impact the respondents' perception which is why photos of similar quality should be chosen (Evans-Cowley and Akar 2014, pp. 20–21). Further potential biases related to the use of stated choice experiments will be considered in the discussion of results section.

To conclude, crowding among cyclists is emerging in the literature about route choice decisions using stated choice experiments with a focus on established cycling cities. This thesis aims to add to this field by concentrating on the less researched group of students' cycling behavior in the Netherlands using a visual stated preference survey. The above review identified several important influences such as the role of gender, the level of experience, the place of residence, cycling behavior and nationality which will be included in the analysis.

3 Methodology

The following section briefly addresses the distribution of the survey and describes the process of its design. Afterwards the econometric part presents the statistical model, the transformation of the survey data and the formulas used for the calculation of the willingness to cycle and willingness to pay to avoid crowding and specific infrastructure elements.

3.1 Data collection

The survey was online during three weeks in May 2023 and distributed via messenger applications to student groups from various universities across the Netherlands[6] and Facebook groups for surveys. In addition, posters with the QR code[7] to access the survey were hung across the campus of Vrije Universiteit Amsterdam. The accompanying message clearly stated that only students living in the Netherlands are targeted no matter if they actively cycle or not. As an incentive the participants were given the chance to win one out of 10 vouchers in the amount of €10 for a shop of their choice independently of their answers.

3.2 Survey design

The survey consisted of three parts: choice scenarios, cycling habits and personal information. If a respondent indicated to not ride a bike, the block about cycling habits was replaced by a question about the reasons why they did not cycle to investigate whether this decision was due to the fear of injury or other reasons unrelated to infrastructure (e.g., no bike available, missing knowledge about how to ride a bike). Otherwise, the questions about cycling habits investigated the type of bike, how often respondents cycled and at what time of the day to get an impression how used someone is to crowded situations as most cycling traffic occurs during rush hours according to Kennisinstituut voor Mobiliteitsbeleid (2020, p. 7). Afterwards respondents had to assess their level of experience by choosing between the three statements “I can ride a bike, but I’m not very confident doing so”, “I am somewhat confident riding a bike” or “I am very confident riding a bike” adopted from the self-assessment question in the survey of Fitch et al. (2022, p. 436). As the literature review highlighted, the personal questions collected information about gender, age, monthly net income, place of residence and whether a student is international or not. Due to the decision to solely focus on students, further personal questions such as the civil status, household income, number of children and availability of a car were not asked because these aspects are considered to play a less important role in the lives of most students. Before publishing the survey, a pilot version was tested to assure an understandable design. The evaluation of the pilot survey, resulting changes as well as the exact order and all answer options of the final survey can be found in the sections Appendix A. Pilot survey results and Appendix B. Survey.

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[6] The survey link was distributed in WhatsApp groups of the following universities: Vrije Universiteit Amsterdam, Universiteit van Amsterdam, Groningen University, Hogeschool van Amsterdam, Tilburg University.
[7] In total, 12 out of 152 participants used the QR code to access the survey.

The choice situation exposed the respondents to two scenarios differing in at least one of the attributes between the type of infrastructure, the level of crowding and the travel distance. Table 1 describes the specific attribute levels. The three types of infrastructure are based on the most common cycling infrastructure elements in Amsterdam. Figure 1 shows these types at the lowest level of crowding. All photos were taken during the morning rush hour in Amsterdam in April 2023. It was important to show the characteristics of each infrastructure type such as the presence of cars for the cycle lane and the cycle track on the road. The photos for the highest level of crowding for the infrastructure type "green surroundings" and "road" were modified by inserting more cyclists than actually present in the original photo. This does not mean that these situations are not realistic, however, as the photos were taken in reality it was difficult to perfectly capture extremely crowded moments due to time limits. Consequently, respondents were only informed that the photos were taken in Amsterdam but not that some of them were modified. After several attempts to take the photos, a selection for each crowding category was discussed and led to the final choice of the photos presented in the section Appendix C. Final photos. For privacy reasons recognizable faces and license plates were blurred.

Figure 1: Types of infrastructure from left to right: green surroundings, cycle lane, painted cycle track on road

The trip length was expressed in kilometers rather than minutes because travel time does not differentiate between the type of bike as it is the same for all whereas travel distance is likely perceived differently by an electric compared to a conventional cyclist. To give the respondents a reference for the travel distance, a map in the explanation text showed the shortest and longest travel distance (3 km and 7 km) at the example of Amsterdam. These distances were among other things inspired by Vedel et al. (2017, p. 58). Furthermore, the average cycling distance for all trips realized by bike in the Netherlands lies at 4.22 km (Centraal Bureau voor de Statistiek 2022). Even though 7 km is significantly longer than this average distance, it was considered as a reasonable upper limit because trips within cities can easily reach this length. The presented choice scenarios in this survey had no restriction for the maximum difference in distance to test whether respondents would start to always choose the shorter distance no matter the level of crowding or type of infrastructure from a specific threshold on.

Consequently, the possible maximum distance between two alternatives was 4 km, in contrast to studies like Vedel et al. (2017, p. 55) limiting differences to 3 km. For the level of crowding no quantitative specification was used due to its subjective perception and the lack of definitions. Therefore, the crowding level in the chosen photos was subject to the author's perception.

Table 1: Attribute levels and description

Attribute	**Level (coding)**	**Levels**
Type of infrastructure	Green surroundings (1)	Wide cycle lanes going through a park or the countryside with cyclists coming from both directions.
	Cycle lane (2)	Detached cycle track from the street, visible with red paving, sharing the sidewalk with pedestrians. Cyclists can ride in both directions.
	Road (3)	Painted cycle track on the road sharing the road with cars and motorists. All cyclists are going in the same direction.
Crowding on cycling route	Crowding (1, 2, 3)	None, some, many
Travel distance	Kilometers	3.0 km – 7.0 km (in steps of 0.5 km)

Based on the before mentioned literature about influences on route choice, it was assumed that respondents always prefer the lowest level of crowding, the shortest distance, and green surroundings as well as separated cycle lanes on sidewalks over the painted cycle track on streets. After defining these characteristics of the dominant choice, the potential scenarios were clustered into four blocks:

1. Comparisons between the same type of infrastructure but different levels of crowding and travel distances
2. Comparisons between green surroundings and the cycle lane
3. Comparisons between green surroundings and the cycle track on the road
4. Comparisons between the cycle lane and the cycle track on the road

As Figure 2 illustrates the fractional factorial design led to a total of 1,701 choice scenarios with all possible non-dominant combinations. The respondents faced seven choice situations with one question from block one and two of each other block. The used survey tool Qualtrics allowed to randomize the order of blocks, answer options and which questions were picked from each block.[8] As a result, each respondents had a different survey and the randomization allowed to reduce potential bias due to the order of choice situations (e.g., boredom when answering the last scenario compared to the first one).

[8] To display all choice scenarios the same number of times, the function "evenly present questions" was used. Due to the low participant number, 155 out of the 459 possible choice situations for blocks two, three and four were not displayed.

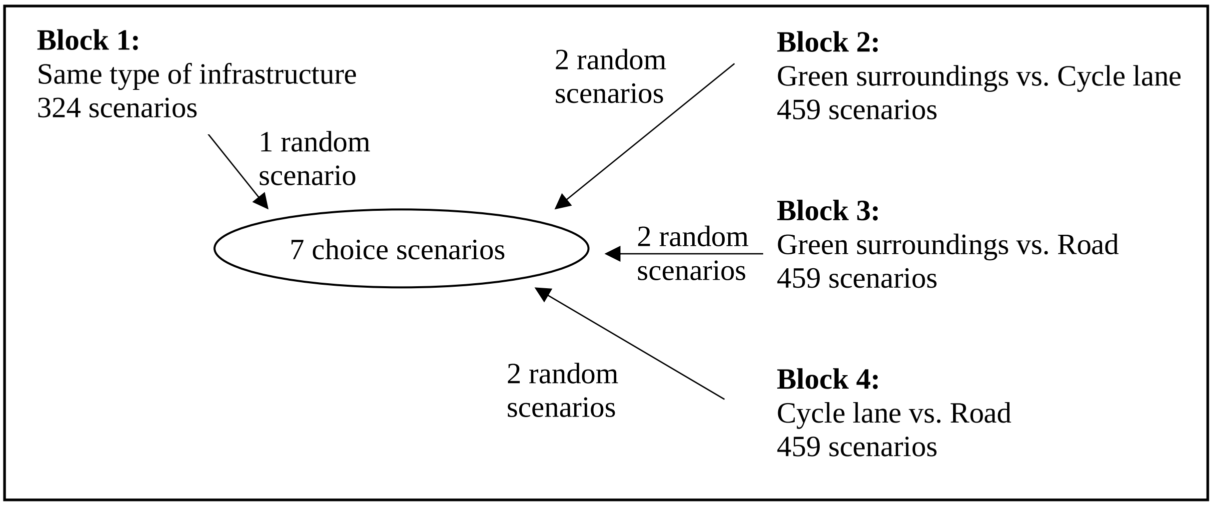

Figure 2: Composition of how choice scenarios were randomly selected for the respondent

To make the situation more relatable, the introduction text to the choice scenarios specified that the student was on the way to university to attend a lecture or to the train station to go to university to also include students who are not usually cycling due to long travel distances. These circumstances implied a clear and realistic trip purpose in combination with a time constraint set with the beginning of the lecture. To remind the respondents of this setting, each choice scenario was introduced with the statement "Imagine you are cycling to university/train station for a lecture. Which route would you choose out of these two options?". Moreover, respondents should assume that the pictured situation would hold for the entire ride. The explanation text did not contain any example pictures of the type of infrastructure or level of crowding to avoid influencing the participant before seeing the choice scenarios.

3.3 Econometric model

In the design of the survey two alternative routes**,** ***A*** and ***B***, are compared. Every option is associated with a utility function reflecting the attributes of the alternative, summarized by the vector ***x***, meaning the type of infrastructure, the level of crowding as well as the travel distance, and the socio-economic characteristics, summarized by the vector ***s***, of the decision maker ***i*** (McFadden 1973, p. 108).

$$U_{iA} = f(x_{iA}, s_i) \quad (1)$$
$$U_{iB} = f(x_{iB}, s_i)$$

According to the random utility framework of McFadden (1973), which was further developed by Train (2009), this individual ***i*** chooses between these two alternatives, ***A*** and ***B***, the one which maximizes his level of utility considering the presented attribute levels of all alternatives. The following equation shows the exemplary case that alternative ***A*** provides a greater utility than alternative route ***B***:

$$U_{iA} > U_{iB} \; \forall \; A \neq B \quad (2)$$

This utility of choosing route ***A*** can be decomposed into the deterministic part V_{iA}, which consists of the attributes observed by the researcher, and the unobserved error term ϵ_{iA} as shown in the equation below and explained by Train (2009, p. 15):

$$U_{iA} = V_{iA} + \epsilon_{iA} \tag{3}$$

Following McFadden (1973) this error term is independently and identically extreme value type 1 distributed. For the analysis of this thesis, several specifications for the deterministic utility of a respondent were tested and finally two specifications are used following the methodological application of Vedel et al. (2017, p. 57) where individual ***i*** has an exemplary deterministic utility V_{iA} for route ***A*** in the choice situation ***n***. The attributes of the alternative change with the choice situation while individual characteristics remain the same throughout the survey. The first deterministic utility presented in equation (4) is the sum of all attributes listed in Table 1 whereas the second specification in equation (5) adds multiple interaction terms with the difference in distance as it directly affects the willingness to cycle expressed in route length. The interaction terms include the gender (1 if male, 0 otherwise), the place of residence (1 if Amsterdam, 0 otherwise), the nationality (1 if international, 0 otherwise), being an active cyclist (1 if yes, 0 otherwise) and the level of experience (1 if very experienced cyclist, 0 otherwise).

$$\begin{aligned} V_{iA} = \alpha + \beta_1 Difference\ in\ distance_{An} + \beta_2 Difference\ in\ crowding_{An} + \\ \beta_3 Difference\ in\ infrastructure_{An} \end{aligned} \tag{4}$$

$$\begin{aligned} V_{iA} = \alpha + \beta_1 Difference\ in\ distance_{An} + \beta_2 Difference\ in\ crowding_{An} + \\ \beta_3 Difference\ in\ infrastructure_{An} + Difference\ in\ distance_{An} * (\beta_4 Male_i + \\ \beta_5 Amsterdam_i + \beta_6 International_i + \beta_7 Cyclist_i + \beta_8 Experience_i) \end{aligned} \tag{5}$$

A logit model is used to assess the probability that a utility maximizing individual chooses alternative route option ***A*** considering the presented attributes defined in the deterministic utility equations. The logistic regression is realized in the statistical software Stata using the “logit” command. For the calculation of the logit model, the decision between the alternatives and their respective attributes are transformed into categorical variables. Table 2 shows the description of the different values for these variables. A disadvantage of this transformation is that jumps between different types of infrastructure or levels of crowding, e.g., between level 1 and 2 or level 2 and 3, are assumed to be equally valued. Moreover, several scenarios happen to have either same distance, the same level of crowding or the same type of infrastructure which does not add information to the model. These issues are further reviewed in the discussion of results section.

Table 2: Transformation of variables into categorical variables

Variable	Description	Value
Difference in distance	Categorical variable in steps of 0.5 (Distance of option A – Distance of option B)	Min -4 Max 4
Difference in level of crowding	1 over 3 1 over 2 or 2 over 3 Same level of crowding 2 over 1 or 3 over 2 3 over 1	-2 -1 0 1 2
Difference in type of infrastructure	Green over Road Green over Cycle lane or Cycle lane over Road Same type of infrastructure Cycle lane over Green or Road over Cycle lane Road over Green	-2 -1 0 1 2

After the model estimation, the willingness to cycle (WTC) to avoid crowding or a specific type of infrastructure is calculated for the two model specifications. Based on the formula used by Vedel et al. (2017, p. 57) equation (6) presents the overall willingness to cycle with the coefficients of the first model at the example that route alternative ***A*** was chosen. To demonstrate differences in the willingness to cycle based on gender and nationality, equation (7) incorporates the respective coefficient of these interaction terms. The numerator is either the coefficient for difference in the level of crowding or the type of infrastructure whereas the denominator uses the coefficients of the difference in distance and respective interaction terms.

$$WTC_{attribute,A} = -\frac{\beta_{attribute}}{\beta_{1_{Difference\ in\ distance}}} \tag{6}$$

$$WTC_{attribute,A} = -\frac{\beta_{attribute}}{\beta_{1_{Difference\ in\ distance}} + \beta_{interaction\ term}} \tag{7}$$

The resulting values are expressed in kilometer per level, meaning that they have to be multiplied with the respective level of crowding or infrastructure as coded in Table 1. The willingness to pay (WTP) for taking detours will be calculated later in the section of the willingness to pay based on further assumptions about the value of travel time (VOTT) and the average speed of conventional cyclists. Combining these assumptions with the calculated willingness to cycle yields the following formula:

$$WTP = \frac{WTC\ in\ \frac{km}{level}}{Average\ speed\ in\ \frac{km}{h}} * level\ of\ crowding\ or\ infrastructure * VOTT\ in\ \frac{€}{h} \tag{8}$$

4 Results

The following section at first summarizes the socio-economic characteristics of the respondents along with their answering behavior and briefly addresses personal feedback received during the distribution of the survey. The section about the model estimation elaborates on the results of the logit model. Subsequently, the willingness to cycle as well as the willingness to pay to avoid specific levels of crowding and types of infrastructure are calculated and compared for the different model specifications.

4.1 Summary statistics

In total, 152 students participated in the survey resulting into 1,064 choice decisions. Table 3 shows the distribution of socio-demographic information. Female participants are overrepresented making up 66% of the studied population. One participant did not provide information about gender and chose the option "prefer not to say". Otherwise, the respondent pool is almost balanced in terms of students living in Amsterdam or other municipalities (51% vs. 49%) and between international and Dutch students (48% vs. 52%). The average age is roughly 24 years with the youngest participant being 18 and the oldest 46 years old.[9] Moreover, only 6 respondents used an electric bike which is why the survey category "bike type" was summarized into a general binary variable for cyclists and non-cyclists. Overall, 14 respondents indicated to not actively cycle. The most frequently mentioned reasons were that the respondents did not own a bike (64%), distances were too long (36%) and the fear of injuries or crowded situations (21%).[10] Out of the full respondent pool, the majority of active cyclists considered themselves as very confident (68%) and used the bike every day or multiple times a week (64%) flexibly according to their needs (56%).

In terms of choice decision behavior, a clear impact of the difference in distances can be observed for differences larger than 2 km. Although for each difference there exists at least one choice situation where a participant was willing to cycle up to 4 km further to avoid the other alternative, respondents clearly tend to choose the shorter option, regardless of the level of crowding or type of infrastructure from the threshold of 2 km on. Nonetheless, respondents were willing to cycle between 2.5 km and 4 km more to avoid the alternative in 12.31% of all cases, presenting 131 of the 1,064 choice situations.

With regard to feedback on the survey during its distribution via social media, some participants communicated that they enjoyed the survey design due to the use of photos instead of text. Moreover, some students expressed their interest in study outcomes due to the frequent occurrence of crowding

[9] The standard deviation lies at 3.95 years. In total, 5 participants were older than 30 years. The oldest participant with 46 years seems relatively old to be a student, however, there was no possibility to verify the active enrollment of the respondents. Due to their small number, the observations are nonetheless kept.

[10] Non-cyclists were allowed to mention multiple reasons which is why numbers do not add up to 100%. Further mentioned reasons were that participants did not want to sweat due to physical activity (21%), their bike got stolen too often (7%), their social environment did not bike (7%) or they did not know how to ride a bike (7%).

among cyclists during rush hour and an international student commented that she "stopped biking due to the fact that in rush hours it's super busy in the center [of Amsterdam] and becomes annoying" emphasizing the need to further investigate the consequences of crowding on cycle paths.

Table 3: Distribution of socio-demographic information of survey respondents

Attribute	Description	Responses	% of Respondents
Gender	Female	100	65.79%
	Male	51	33.55%
	Prefer not to say	1	0.66%
Income in €	< 1,000	96	63.16%
	1,000 - 3,000	39	25.66%
	> 3,000	4	2.63%
	Prefer not to say	13	8.55%
Residence location	Amsterdam	78	51.32%
	Other municipality	74	48.68%
International student	Yes	73	48.03%
	No	79	51.97%
Cyclist	Yes	138	90.79%
	No	14	9.21%
Bike confidence	Not confident	6	3.95%
	Somewhat confident	29	19.08%
	Very confident	103	67.76%
Bike frequency	Everyday/multiple times a week	97	63.82%
	1x week	25	16.45%
	1x month	11	7.24%
	Less often	5	3.29%
Time of the day	Mostly during peak hours	28	18.42%
	Mostly outside peak hours	25	16.45%
	Changes flexibly	85	55.92%

4.2 Model estimation

The specification based only on the difference in the attributes of distance, infrastructure and crowding is labeled as model (1). The specification including further interaction terms is labeled as model (2). In both model specifications, the variables for the difference in distance, the type of infrastructure and the level of crowding are significant at the 1% level as shown in the regression output in Table 4. Furthermore, the coefficients of these variables are all negative showing marginal utilities which indicate that an increase in the difference of the distance, the type of infrastructure or the level of crowding negatively affects utility. As specified in the section about the econometric model in Table 2, an increase of the difference in the level of crowding or the type of infrastructure, means for instance that crowding level 2 was chosen over level 1 compared to choosing level 1 over level 2 or road was chosen over green surroundings in contrast to choosing green surroundings over road. The coefficient for the level of crowding is larger in absolute terms than the one for the type of infrastructure indicating that the level of crowding impacts utility stronger than the type of infrastructure.

For model (2), which includes interaction terms about gender, place of residence, nationality, a dummy for active cyclists, and whether they consider themselves as very experienced, only the interaction terms for being male and an international student are significant at the 5% level. The other interaction terms for living in Amsterdam, being an active cyclist and considering oneself as very experienced are not significant. The interaction term for international students shows a positive sign, indicating that they are willing to cycle longer to avoid higher levels of crowding or other infrastructure types compared to green surroundings in contrast to Dutch students. Moreover, the interaction term for male participants has a positive sign, suggesting that male students are also willing to cycle a longer distance to avoid higher levels of crowding or other infrastructure types compared to green surroundings in contrast to female students. Possible explanations for this sign and further robustness checks are presented in the discussion of results section.

In terms of goodness of fit, the second model performs slightly better with a log-likelihood of -501.9 compared to -508.5 for the model without interaction terms. The intercept shows the logarithm of the odds for choosing alternative ***A*** if the difference in the type of infrastructure, the level of crowding and the distance would equal zero. In this case, the probability of choosing route alternative ***A*** is 51.77% for both model specifications revealing a balanced answering behavior meaning that respondents did not have a tendency to always choose the same alternative independently from the attribute values. This conclusion is supported by the intercept value not being significantly different from zero.

Table 4: Regression output of the logit model

	Model (1) without interaction terms	Robust S.E.	Model (2) with interaction terms	Robust S.E.
Difference in distance	-1.185***	0.0829	-1.483***	0.211
Difference in level of crowding	-0.939***	0.0894	-0.958***	0.0905
Difference in type of infrastructure	-0.524***	0.0739	-0.516***	0.0732
Distance_Male			0.230**	0.114
Distance_Amsterdam			-0.0847	0.119
Distance_International			0.260**	0.121
Distance_Cyclist			0.230	0.234
Distance_Experience			-0.142	0.137
Constant	0.0708	0.0765	0.0709	0.0788
Observations	1,064		1,064	
Log-Likelihood	-508.5		-501.9	
AIC	0.963		0.960	
McFadden R^2	0.309		0.318	

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

4.3 Willingness to cycle

For model (1) without interaction terms, students are willing to cycle 0.88 km to avoid cycle lanes which are detached from the road and 1.33 km to avoid cycle tracks on roads compared to cycling in green surroundings. For the level of crowding, participants expressed a willingness to cycle 1.58 km to avoid “some” crowding and 2.38 km for the highest level compared to no crowding on the route. These results show that in general students are willing to realize a longer detour to avoid higher levels of crowding rather than a specific type of infrastructure. Table 5 reveals the change in results when including the interaction term for international or male students from model (2). Female international students are willing to cycle 0.84 km and 1.27 km to avoid cycle lanes and cycle tracks respectively compared to green surroundings in contrast to slightly lower values of 0.83 km and 1.24 km for male Dutch students for the same infrastructure types. For the highest level of crowding, the detours amount to 2.35 km for female international students and 2.29 km for male Dutch students. Regarding the base reference group of female Dutch students in model (2) when the significant interaction terms are excluded, the last row in Table 5 indicates that female Dutch students are willing to cycle in average a 20% shorter route compared to female international and male Dutch students.

Table 5: Willingness to cycle in kilometers with respect to the reference scenario of green surroundings for the type of infrastructure and no crowding for the level of crowding for the different model specifications

Level of infrastructure/crowding / **Model specification**	**Cycle lane**	**Road**	**Moderate crowding**	**High crowding**
Model (1) without interaction terms	-0.88	-1.33	-1.58	-2.38
Model (2) with interaction term for international students	-0.84	-1.27	-1.57	-2.35
Model (2) with interaction term for male students	-0.83	-1.24	-1.53	-2.29
Model (2) for female Dutch students	-0.70	-1.04	-1.29	-1.94

4.4 Willingness to pay

To calculate the willingness to pay, additional distances expressed in kilometers are converted into time assuming an average cycling speed of 12.1 km/hour for conventional cyclists of the age group 12 to 34 years as indicated by the statistic investigation of Kennisinstituut voor Mobiliteitsbeleid (2017).

Based on the findings of Basu and Hunt (2014, p. 297) trips of college students realized by bike reveal to have a lower value of travel time (VOTT) compared to trips by cars. In contrast, van Ginkel (2014, pp. 47–48) argues in his master thesis that cycling is more physically exhausting compared to a car ride and time cannot be used productively compared to public transport which leads to an increase in the VOTT. Latest figures of the VOTT for traveling in the Netherlands were calculated by Kouwenhoven et al. (2014, p. 47) with a stated preference survey differentiating between commuting, business and other trips with a focus on car, train and public transport (bus, metro or tram) rides. For commuting trips van Ginkel (2014, p. 48) finds the same values as Kouwenhoven et al. (2014, p. 46) of 9.25 €/hour, 11.50 €/hour and 7.75 €/hour for the respective categories. For cycling van Ginkel (2014, p. 18) reasons that the VOTT is lower when cyclists are using a more comfortable route which is supported by further research (Björklund and Mortazavi 2013; Pourhashem et al. 2023). van Ginkel (2014, p. 48) finds a VOTT of 9.80 €/hour for cycling on a comfortable route compared to 13.43 €/hour for a standard cycling route. These numbers are based on a stated preference survey with a diverse respondent pool (n = 532) representing people with higher values of time in contrast to students who have lower incomes (van Ginkel 2014, p. 37). Due to the lack of specific numbers for the VOTT of students and cyclists, the following calculations use a VOTT of 9.80 €/hour assuming that the majority of the presented pictures for cycling infrastructure (i.e., green surroundings and cycle lane) are perceived as a comfortable cycling route.

With these assumptions the first model specification translates into a willingness to pay of €0.72 and €1.07 to avoid cycling on cycle lanes and roads compared to green surroundings. For the level of crowding this willingness is higher with €1.28 and €1.93 to avoid moderate and high levels of crowding compared to no crowding. For model (2) Table 6 shows that female international and male Dutch students express a similar but slightly lower willingness to pay compared to model (1). When excluding the significant interaction terms of model (2), female Dutch students are willing to pay €0.85 to switch from a road to green surroundings and €1.57 to avoid the highest level of crowding compared to no crowding at all. In general, the willingness to pay is higher to avoid crowding rather than a specific type of infrastructure for all specifications.

Table 6: Willingness to pay in € with respect to the reference scenario of green surroundings for the type of infrastructure and no crowding for the level of crowding of the different model specifications

Level of infrastructure/crowding **Model specification**	**Cycle lane**	**Road**	**Moderate crowding**	**High crowding**
Model (1) without interaction terms	-0.72	-1.07	-1.28	-1.93
Model (2) with interaction term for international students	-0.68	-1.02	-1.27	-1.90
Model (2) with interaction term for male students	-0.67	-1.00	-1.24	-1.86
Model (2) for female Dutch students	-0.56	-0.85	-1.05	-1.57

5 Discussion

This section starts with a discussion of the findings from the model estimation and the values for the willingness to cycle and pay. Moreover, the suitability of the econometric model as well as potential biases related to the use of stated preference surveys are considered. Afterwards limitations and further research potential are briefly highlighted.

5.1 Discussion of results

In the initial conception of this thesis, the idea was to compare the cycling behavior of electric versus conventional cyclists. However, this could not be realized due to the small sample size of 152 respondents and only 6 electric cyclists taking part in the survey. Anticipating this issue, trip length could have been expressed in minutes rather than kilometers which is often more plausible for respondents. The overall findings of this thesis show that students are generally willing to realize a detour to avoid higher levels of crowding and prefer green surroundings over cycle lanes and cycle tracks on roads. Vedel et al. (2017, p. 61) and Pax (2020, p. 13) find a willingness to cycle of 1.03 km and 2.78 km to avoid the highest level of crowding or congestion respectively. The willingness to cycle calculated for model (1) with 2.38 km to avoid the highest level of crowding fits in between those values. Furthermore, the results of both model specifications in this thesis support the finding of Pax (2020, p. 13) that congestion has the biggest impact on the route choice, besides the difference in distance, assuming that the understanding of crowding in this thesis equates the concept of congestion from Pax (2020, p. 8). For the type of infrastructure, Vedel et al. (2017, pp. 58–60) find that respondents are willing to cycle 0.8 km more for green surroundings instead of a route on a main traffic road without cycling track compared to the value of 1.33 km calculated in this thesis to switch from a cycle track on the road to green surroundings. The higher values for the willingness to cycle compared to Vedel et al. (2017) could indicate that students either have a lower VOTT and thus mind less taking a longer detour to cycle in green surroundings or that students care more strongly about the type of infrastructure and are thus willing to cycle longer. In general, students are also physically more fit due to their age which might let them perceive an additional distance as less onerous compared to older age groups.

In terms of willingness to pay, Pax (2020, p. 15) demonstrates that men and women are willing to pay €0.96 and €1.25 respectively to shift from a route with heavy congestion to light congestion whereas the values to switch from heavy to light crowding are lower with €0.33 and €0.43 for men and women respectively. For both model specifications of this thesis the calculated willingness to pay, laying between €1.57 and €1.93 to avoid cycling in highly crowded situations, is higher compared to these values. On one hand, the values are higher because Pax (2020, p. 15) assumes a lower VOTT of 9 €/hour and a higher average speed of 15.8 km/hour. On the other hand, no differentiation between the phenomena of crowding and congestion is made in this thesis assuming that crowding leads eventually to congestion whereas Pax (2020, p. 8) differentiates between these notions. Moreover, Pax (2020) does not specifically focus on students and has a more heterogenous participant pool which could further explain differences in the willingness to pay.

Overall, the findings of this thesis in terms of willingness to cycle and pay suggest that students living in the Netherlands care less about the type of infrastructure and more about the level of crowding. The willingness to realize longer detours for the level of crowding could further be due to the advanced cycling infrastructure in the Netherlands allowing for the majority of cycle routes to be separated from interaction with other motorized vehicles. As a result, respondents mind less about the type of infrastructure compared to the level of crowding which emphasizes the need to address crowding among cyclists more in transport policy.

The significance and positive sign of the interaction term for international students confirms that immigrants, who did not grow up in a “national habitus” which is as strongly related to cycling as the Dutch culture, express a higher willingness to cycle to avoid crowded situations and prefer infrastructure separated from interaction with other motorists. These findings partially support the idea of Waard et al. (2020, p. 290) showing that international students are more cautious because of a higher potential for crashes or severe mistakes. Due to the limited number of questions, the survey was not able to ask for the length of the stay as Waard et al. (2020, p. 291) and Nello-Deakin and Nikolaeva (2021, p. 303) argue that differences in cycling behavior would vanish over time. However, since only students were inquired, it can be assumed that most international participants have lived in the Netherlands for a few years at most. Nonetheless, it could be helpful to inform international students better about Dutch cycling culture and rules to avoid an increase in conflict potential.

In contrast, the positive sign for the significant interaction term for male participants is opposite to the expectation that men are either more risk-taking as shown by the literature or that no significant difference between genders within an established cycling infrastructure can be found. Vedel et al. (2017, p. 62) and Pax (2020, p. 14) both find that women are willing to cycle longer distances to avoid high levels of crowding. Different approaches were tested to explain this contradictory finding. First, it was checked whether the information on gender was correctly transferred from the raw data to the cleaned table. Moreover, Table D1 in the section Appendix D. Robustness checks includes further interaction terms to investigate whether there are differences in the answering behavior of international versus Dutch students and those living in Amsterdam versus other municipalities. The interaction term for male international participants from Amsterdam shows a negative sign and a higher value in absolute terms compared to male Dutch students living in Amsterdam and other municipalities. A segmented model analysis excluding observations from different groups of male participants suggests that when only male international students from Amsterdam are included, the sign for the male interaction term becomes negative. However, when dividing the already small population of male participants into categories for nationality and place of residence, each group only has between 10 to 16 respondents which weakens the validity of these findings. Other potential explanations could be a self-selection of study participants meaning that especially male respondents who, for instance, wanted to express their dislike for a higher level of crowding participated in the survey. In addition, male participants might also have tended to choose the longer route if it is less crowded because it gives the impression that they could speed up more easily compared to a shorter but more crowded route. In this context, crowding could be perceived as a slowdown of cycling speed rather than a direct relation to safety issues. However, the survey was not able to account for this potential perception bias as no questions regarding the perception of crowding were asked.

Regarding the other interaction terms in Table 4 for the place of residence, being a cyclist and the level of experience no significant relation was found which indicates that these factors are less important to consider. Nonetheless, the negative sign for living in Amsterdam and assessing oneself as a very experienced cyclist make sense assuming that students living in Amsterdam are used to crowding on cycle paths like experienced cyclist and mind those situations less. However, the positive sign of being an active cyclist indicating a willingness to realize a longer detour seems counterintuitive as it is expected that cycling students are less afraid of crowded cycle paths compared to non-cyclists. At the same time this could also suggest that active cyclists who have experienced crowding can better judge the stress related to such a situation rather than non-cyclists. After all, the number of 14 non-cyclists in the survey is too small to derive meaningful interpretations from these values. Further interaction terms regarding the cycling habits (time of the day, frequency of the ride, other level of experience) were not included in the model specifications because they showed no statistical significance as can be seen in Table D2 in the section Appendix D. Robustness checks.

Despite the significant coefficients of the difference in distance, type of infrastructure and level of crowding, these results should be interpreted carefully due to the unrealistic assumption that jumps between differences are valued equally. Moreover, several choice situations (in total 420 observations) had the same attribute level for a category which does not add information to the logistic regression and represents a flaw in the survey design. If all these observations were dropped, the regression output in Table D3 of section Appendix D. Robustness checks reveals that coefficient values and the respective willingness to cycle (see Table D4) only slightly change. When using a multinominal logit model with the reference categories "no crowding" and "green surroundings" Table D5 in section Appendix D. Robustness checks shows the regression output. The subsequent Table D6 compares the willingness to cycle and reveals lower values compared to the logit model, especially for the level of moderate crowding with an insignificant coefficient indicating the students might care about the highest level of crowding but do not strongly differentiate between some and no crowding. In addition, the large number of scenarios compared to the small sample size has resulted in not all scenarios being answered at least once. Concentrating on a reduced number of specific situations rather than generating a high number of potential scenarios could have avoided this issue. For the calculation of the willingness to pay, the assumptions about the average speed and VOTT strongly influence the numerical outcome which thus has to be interpreted carefully. The specific value for the VOTT is subject to uncertainty due to the small number of papers examining this value and the heterogeneity of participants; some might really enjoy cycling whereas others have a strong preference for cars, for example. The VOTT used in this thesis is based on a stated preference survey from 2014 not accounting for different age as well as income groups or the change in purchasing power of the monetary value over time.

Lastly, the hypothetical setting of the stated choice experiment can result into different biases which are shortly discussed in the following paragraph. In the specific case of route choices of cyclists, the respondents might indicate a longer willingness for detours than they would actually be ready to take when confronted to the situation in real life (Bovy and Bradley 1985, p. 19; Train 2009, p. 153). Moreover, the used photos were taken during a cloudy season in Amsterdam with different light conditions which might be perceived differently by the respondents (e.g., one photo showed a puddle which could subconsciously provoke the impression that it would rain soon and is therefore selected less often). Furthermore, the display of photos affected the user friendliness on mobile devices as the photos were shown one after another if the phone was not used in landscape mode. The survey tool Qualtrics was not able to show how many surveys were answered on mobile devices, however, this issue could have led to an increase of biased responses due to idleness to scroll between the photos. Additionally, incentivizing participants with the possibility to win a voucher, could have led to a higher number of participants filling out the survey inattentively or always choosing the same option to finish faster. However, only 59% of all respondents left contact information to participate in the lottery and the insignificant intercept of the regression output shows that no general tendency for selecting the same alternative was found. Conducting a pilot version with multiple participants in advance allowed to check for the comprehensiveness of the explanations and realistic attributes. However, assuming the conditions of the photos would hold for the entire ride is unrealistic as crowding is not a static phenomenon but changes throughout the trip. Respondents might have underestimated how a highly crowded route for several kilometers influences their perception compared to the snapshot of a situation presented in the photo. In terms of selection bias, it could be possible that students who are especially interested in the topic of crowding among cyclists answered the survey even though no strategic outcome could be achieved by doing so. Nonetheless, this cannot be refuted as no questions regarding attitudes towards cycling and the motivation to fill out the survey were asked. Finally, in spite of a thorough study design and trying to make the survey as realistic as possible, errors due to boredom or misunderstanding of the task constitute another source of potential bias.

5.2 Limitations

The focus on students living in the Netherlands who are used to the Dutch established cycling infrastructure along with the generally small size of the studied population reduces the overall transferability of results to other age groups and differing local circumstances. The participant pool itself was very homogenous in terms of age, income and education because of the prior decision to focus on students, however, women were overrepresented. Concentrating on the typical cycling infrastructure of Amsterdam further reduces transferability as the presented types of infrastructure were not as comprehensive as in other studies which differentiate more in detail between the road environment and other elements. Furthermore, no numeric definition of crowding was given and the lowest level of crowding with no other cyclist in the photo might be seen as unrealistic. Consequently, the levels of crowding could have been reduced to moderate and heavy crowding to have a more authentic reproduction of realistic circumstances.

As pointed out by Vedel et al. (2017, p. 62), the differences in distance and overall route length are strongly influenced by the elasticity for distance which differs in relation to a participant's usual cycling distance. The survey did not ask for specific information about the habitual cycling route length and thus could not capture the impact of this relation. Moreover, the use of distance instead of travel time was motivated by the speed difference between electric and conventional cyclists. However, if these groups are not directly targeted by a survey, travel time in minutes is better conceivable for respondents.

Due to the limit in time and capacity to find suitable survey participants, only a pilot version could be tested but no prior interaction with focus groups was possible. Furthermore, in order to achieve a high completion rate and avoid mistakes due to boredom, only a limited number of questions could be asked and further aspects, for instance the role of comfort and perceived safety, had to be neglected. Finally, results of this stated choice experiment could not be confirmed by revealed preference data.

5.3 Further research potential

The use of photos did not allow to differentiate between the types of bike shown in crowded situations. Further research could examine whether new emerging types of bikes such as cargo or electric bikes are perceived differently compared to conventional cyclists due to their size and speed difference. Moreover, investigations about how crowding is perceived among different age groups with respect to other circumstances (e.g., role of accompanying children, the influence of car ownership, attitudes towards cycling and the environment) in relation to the used bike type represent further research gaps. Especially the cycling behavior of young cyclists using electric bikes and their perception of crowding is less studied and becoming more important due to the increase in electric bike ownership among young people. Regarding the measurement of the willingness to cycle and the related willingness to pay, another approach could include the shift of the preferred arrival or departure time and to further investigate the value of time of cyclists among different age and income groups for different purposes.

6 Conclusion

In general, the results of the visual stated preference survey with 152 participants showed that students living in the Netherlands are willing to realize a longer detour to avoid crowding compared to specific infrastructure types. In quantitative terms, students are willing to cycle 0.88 km to avoid cycle lanes which are detached from the road and 1.33 km to avoid cycle tracks on roads compared to cycling in green surroundings which translates into a willingness to pay of €0.72 and €1.07 respectively. For the level of crowding, the participants are willing to cycle 1.58 km to avoid moderate crowding and 2.38 km for the highest level compared to no crowding which converts into a willingness to pay €1.28 and €1.93 to avoid the respective level of crowding. When including interaction terms, international and male students express a higher willingness to cycle up to 20% longer distances compared to female Dutch students. Further interaction terms for active cyclists, the level of experience or living in Amsterdam compared to other municipalities showed no statistical significance. In comparison to the literature about crowding among cyclists, these values for the willingness to cycle are slightly higher which can be due to a lower value of time among students, the fact that they mind detours less due to comfortable cycling infrastructure and a generally higher fitness level compared to older age groups. Even though the calculated values of this thesis have to be interpreted carefully, the overall outcome shows that crowding among cyclists has to be further researched and addressed in transport policy. Including the occurrence of crowding in cost benefit analyses of infrastructure planning is important to acknowledge the impacts on the well-being of cyclists and potential reduction of positive effects of cycling. However, the specific values to consider for cost benefit analysis need further research.

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Appendices

Appendix A. Pilot survey results

Before publishing the survey, a pilot version was conducted to test the comprehensibility of the survey. For this purpose, students from the master program Spatial, Transport and Environmental Economics as well as from other study programs were asked to provide feedback. In each group, at least one cyclist and one non-cyclist participated to make sure that both groups understand the differing questions. In total, six people responded and gave valuable feedback. As a result, the following aspects of the survey were changed:

1. The explanation of the choice scenarios was repeatedly perceived as too long and more complicated than the actual task. Consequently, the text was shortened and adapted to a simpler version focusing on the main aspects (level of crowding, type of infrastructure, distance) and the setting.
2. For the question "What type of bike do you ride?" the option "Prefer not to say" was deleted as it does not represent confidential information.
3. For the list of reasons why a respondent does not cycle, the option "Physical health condition" was added.
4. The answer options for the question "When do you cycle in most cases? (time of the day)" were formulated more clearly focusing on the fact whether respondents mostly cycle outside or during rush hours.

Moreover, the pilot showed that the number of seven choice scenarios was acceptable to answer as the display of images enabled to easily understand the situation instead of reading a written description. The images were perceived as well visible and the level of crowding as clearly differentiable.

Appendix B. Survey

Start of Block: Introduction

Introduction

Survey about cycling & crowding

Thank you for taking the time to answer this survey which is realized for a master thesis within the program "Spatial, Transport and Environmental Economics" of Vrije Universiteit Amsterdam. This survey focusses on **students in the Netherlands** and will take about **5 minutes to complete**.

Your **responses are anonymous.** In the end, you can **win 1 out of 10 vouchers** in the **amount of 10 €** for a shop of your choice by indicating your e-mail address.

By checking this box to continue, you give **informed consent for the data within this survey to be used.**

- o I have read and understood the provided information, and consent to participate in this survey.

End of Block: Default Question Block

Start of Block: Explanation

Explanation

You will answer **7 different choice scenarios**. Imagine you are **cycling** with **your bike to university to attend a lecture or to get to the train station to go to university**. You have to **choose between two scenarios** that differ in the following attributes:

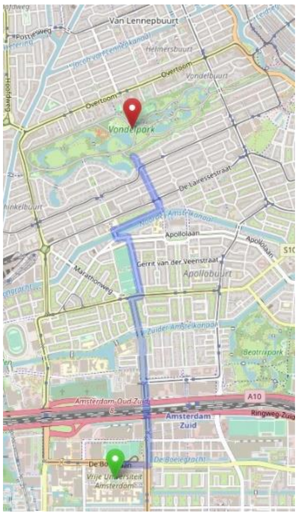
There are three stages for the level of **crowding** in the picture: **none**, **some** and **many**.

There are three types of **infrastructure** in the picture: **parks**, **cycle lanes** and **cycle tracks on a road**.

The travel **distance** is written out and ranges from **3 to 7 km**.

Assume that the **scenario would hold for your entire ride**.

To easier relate to the travel distances, here are two examples:

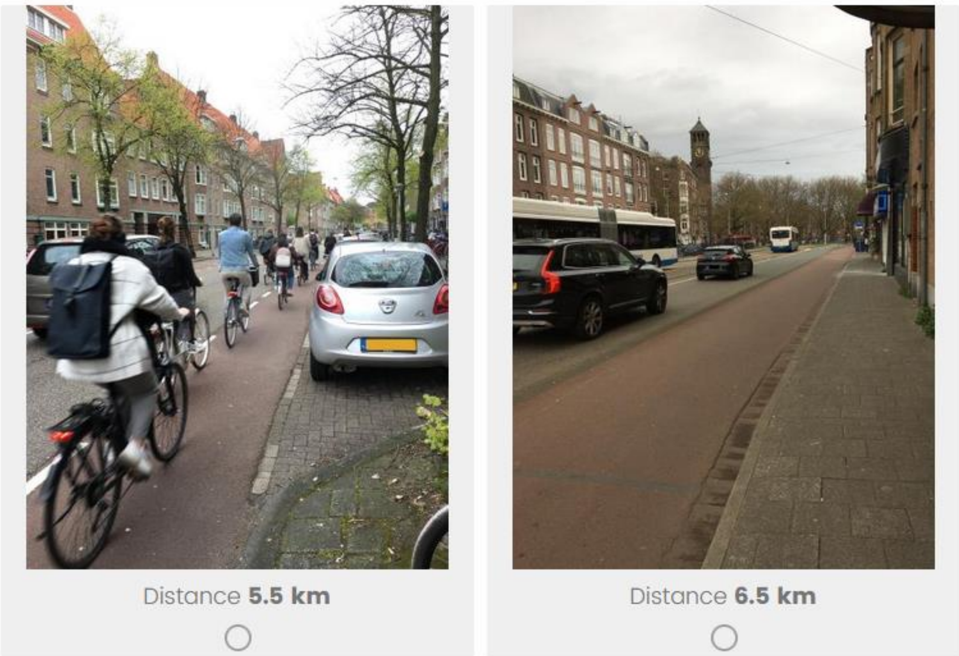
3 km: from VU to Vondelpark	**7 km**: from VU to Centraal
	

End of Block: Explanation

Start of Block: Randomization of choice situations

Exemplary choice situation (7 in total):

Imagine you are cycling to university/train station for a lecture. Which route would you choose out of these two options?



End of Block: Randomization of choice situations

Start of Block: Bike type

Bike type

Which type of bike do you ride?

- I do not ride a bike
- Bike (NOT electrified)
- E-Bike / Pedelec / other electric bike

End of Block: Bike type

Start of Block (if option “I do not ride a bike” was selected: Non-cyclist

If option “I do not ride a bike” was chosen, the following question was displayed:

Non-cyclists

Why do you not ride a bike? [multiple answers possible]

- I do not own a bike
- I do not know how to ride a bike
- Physical health condition
- Fear of injury/crash
- Fear/discomfort in crowded situations
- Distances are too long
- My social environment does not bike either
- Fashion/I do not want to sweat

- Other:
- Prefer not to say

Otherwise, the respondent was led to the following questions about cycling habits:

End of Block: Non-cyclist

Start of Block if option “I do not ride a bike” was not selected: Cycling habits

Cycling habits

How often do you cycle?

- Everyday/multiple times a week
- 1x per week
- 1x per month
- Less often

When do you cycle in most cases? (time of the day)

- Mostly **during peak hours** (6h30-9h00 and 16h00-18h30)
- Mostly **outside of peak hours**
- Changes **flexibly according to my trips**

End of Block: Cycling habits

Start of Block if option “I do not ride a bike” was not selected: Level of experience

Please select between statements regarding your level of confidence when cycling:

- I can ride a bike, but I'm **not very confident** doing so
- I am **somewhat confident** riding a bike
- I am **very confident** riding a bike

End of Block: Level of experience

Start of Block: Personal information

Personal information

How do you identify?

- Male
- Female
- Non-binary / third gender
- Prefer not to say

How old are you in years?

What is your monthly net income?

- < 1,000 €
- 1,000 € - 3,000 €
- 3,000 €
- Prefer not to say/I don’t know

Where do you live?

- Amsterdam
- Other municipality
- Prefer not to say

Are you an international student?

- Yes
- No
- Prefer not to say

End of Block: Personal information

Start of Block: Lottery

Lottery

If you **want to participate in the lottery** for 1 out of 10 vouchers, please **indicate your e-mail address below**. All contact information will be handled regardless of responses and will be deleted after the end of the survey. **Winners will be notified in mid-June**. Otherwise you can skip this question.

End of Block: Lottery

We thank you for your time spent taking this survey.

Your response has been recorded.

End of Survey

Appendix C. Final photos

Photos for the categories green surroundings, cycle lane and cycle track on road (first to third row) and the levels of crowding none, some and many (from left to right)

Appendix D. Robustness checks

Table D1**:** Regression output of logit model adding further interaction terms to investigate the sign of male interaction term and segmented model analysis

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Difference in distance	-1.483***	-1.876***	-1.589***	-1.493***	-1.559***	-1.943***	-1.806***	-1.901***	-1.839***	-1.757***
	(0.211)	(0.247)	(0.224)	(0.215)	(0.214)	(0.246)	(0.270)	(0.278)	(0.252)	(0.249)
Difference in level of crowding	-0.958***	-1.009***	-0.965***	-0.957***	-0.971***	-1.019***	-1.056***	-1.032***	-1.022***	-0.946***
	(0.0905)	(0.0955)	(0.0919)	(0.0907)	(0.0903)	(0.0951)	(0.114)	(0.110)	(0.109)	(0.106)
Difference in type of	-0.516***	-0.552***	-0.533***	-0.516***	-0.520***	-0.561***	-0.596***	-0.600***	-0.615***	-0.557***
infrastructure	(0.0732)	(0.0751)	(0.0735)	(0.0730)	(0.0738)	(0.0755)	(0.0898)	(0.0908)	(0.0897)	(0.0861)
Distance_Male	0.230**	0.550***	0.0371	0.186	0.138	0.665***	-0.655***	0.907***	0.165	0.649***
	(0.114)	(0.127)	(0.134)	(0.125)	(0.136)	(0.203)	(0.243)	(0.230)	(0.226)	(0.198)
Distance_Amsterdam	-0.0847	0.142	-0.286**	-0.0278	-0.0334	-0.0391	-0.0370	-0.0421	-0.0349	-0.0423
	(0.119)	(0.124)	(0.128)	(0.143)	(0.128)	(0.165)	(0.167)	(0.165)	(0.166)	(0.160)
Distance_International	0.260**	0.480***	0.504***	0.208	0.336**	0.730***	0.690***	0.697***	0.709***	0.651***
	(0.121)	(0.114)	(0.144)	(0.134)	(0.136)	(0.166)	(0.169)	(0.168)	(0.168)	(0.163)
Distance_Cyclist	0.230	0.266	0.271	0.236	0.215	0.261	0.166	0.281	0.177	0.228
	(0.234)	(0.239)	(0.237)	(0.236)	(0.233)	(0.236)	(0.262)	(0.270)	(0.239)	(0.251)
Distance_Experience	-0.142	-0.0360	-0.0929	-0.142	-0.126	-0.00855	-0.111	-0.105	-0.0637	-0.130
	(0.137)	(0.140)	(0.135)	(0.137)	(0.138)	(0.137)	(0.152)	(0.153)	(0.150)	(0.155)
Dist_Male_AMS_Inter		-1.209***				-1.353***				
		(0.263)				(0.320)				
Dist_Male_AMS_Dutch			0.850***			0.235				
			(0.245)			(0.271)				
Dist_Male_Muni_Inter				0.195		-0.498*				
				(0.237)		(0.273)				
Dist_Male_Muni_Dutch					0.328	-				
					(0.220)					
Constant	0.0709	0.0600	0.0681	0.0710	0.0669	0.0574	-0.00461	-0.0430	-0.0619	0.0469
	(0.0788)	(0.0796)	(0.0792)	(0.0787)	(0.0788)	(0.0799)	(0.0930)	(0.0943)	(0.0946)	(0.0913)
Observations	1,064	1,064	1,064	1,064	1,064	1,064	812	777	777	819
Log-Likelihood	-501.9	-488.1	-496	-501.6	-500.7	-485.7	-353.6	-349.1	-348.9	-370.8

Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Model explanation:

Model (1): basic model without interaction terms presented in Table 4 in section 4.2 Model estimation

Model (2): basic model with interaction terms for socio-economic characteristics, active cyclists and level of experience

Model (3): model (2) including an interaction term for male international students living in Amsterdam

Model (4): model (2) including an interaction term for male Dutch students living in Amsterdam

Model (5): model (2) including an interaction term for male international students living in other municipalities than Amsterdam

Model (6): model (2) including an interaction term for male Dutch students living in other municipalities than Amsterdam

Model (7): model (2) including all interaction terms with the reference category “male Dutch students living in other municipalities”

Model (8): segmented model with all female participants and male international students living in Amsterdam

Model (9): segmented model with all female participants and male Dutch students living in Amsterdam

Model (10): segmented model with all female participants and male international students living in other municipalities than Amsterdam

Model (11): segmented model with all female participants and male Dutch students living in other municipalities than Amsterdam

Distribution of the 51 male participants:

	Model (8)	Model (9)	Model (10)	Model (11)
International	X		X	
Dutch		X		X
Amsterdam	X	X		
Other municipality			X	X
Sum	15	10	10	16
Number of observations	105	70	70	112

Table D2: Regression output of logit model including further interaction terms of cycling behavior

	(1)	(2)	(12)
Difference in distance	-1.185***	-1.483***	-1.508***
	(0.0829)	(0.211)	(0.213)
Difference in level of crowding	-0.939***	-0.958***	-0.969***
	(0.0894)	(0.0905)	(0.0922)
Difference in type of infrastructure	-0.524***	-0.516***	-0.523***
	(0.0739)	(0.0732)	(0.0744)
Distance_Male		0.230**	0.239**
		(0.114)	(0.115)
Distance_Amsterdam		-0.0847	-0.0960
		(0.119)	(0.118)
Distance_International		0.260**	0.287**
		(0.121)	(0.122)
Distance_Cyclist		0.230	0.107
		(0.234)	(0.508)
Distance_Experience (very)		-0.142	-0.222
		(0.137)	(0.340)
Distance_Experience (some)			-0.128
			(0.344)
Distance_In_Peak			-0.0293
			(0.149)
Distance_Outside_Peak			-0.190
			(0.144)
Distance_Everyday_Use			0.200
			(0.397)
Distance_Weekly_Use			0.382
			(0.395)
Distance_Monthly_Use			0.513
			(0.404)
Constant	0.0708	0.0709	0.0634
	(0.0765)	(0.0788)	(0.0787)
Observations	1,064	1,064	1,064
Log-Likelihood	-508.5	-501.9	-499.4

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Model explanation:

Model (1): basic model without interaction terms

Model (2): basic model with interaction terms for socio-economic characteristics, active cyclists and level of experience

Model (12): with interaction terms for socio-economic characteristics, active cyclists and levels of experience “very” and “some” with reference category “not confident”; time of the day “inside” and “outside” of peak hours with reference category “flexible according to my needs”; frequency of use with “everyday/multiple times a week”, “once a week” or “once a month” with reference category “less often”

Table D3: Regression output of logit model dropping all observations with either the same distance, the same type of infrastructure or the same level of crowding

	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Difference in distance	-1.064***	-1.468***	-1.783***	-1.597***	-1.464***	-1.541***	-1.889***
	(0.0895)	(0.253)	(0.295)	(0.267)	(0.255)	(0.253)	(0.287)
Difference in level	-0.852***	-0.874***	-0.907***	-0.883***	-0.875***	-0.893***	-0.930***
of crowding	(0.0946)	(0.0967)	(0.0995)	(0.0984)	(0.0965)	(0.0961)	(0.0996)
Difference in type	-0.606***	-0.598***	-0.621***	-0.612***	-0.599***	-0.606***	-0.639***
of infrastructure	(0.0848)	(0.0840)	(0.0850)	(0.0844)	(0.0842)	(0.0853)	(0.0869)
Distance_Male		0.279**	0.523***	0.103	0.293*	0.169	0.773***
		(0.139)	(0.153)	(0.162)	(0.157)	(0.160)	(0.239)
Distance_Amsterdam		-0.120	0.0498	-0.297*	-0.138	-0.0584	-0.147
		(0.138)	(0.145)	(0.153)	(0.172)	(0.145)	(0.194)
Distance_International		0.338**	0.508***	0.561***	0.354**	0.434***	0.827***
		(0.143)	(0.136)	(0.175)	(0.165)	(0.162)	(0.204)
Distance_Cyclist		0.326	0.391	0.396	0.323	0.288	0.379
		(0.270)	(0.283)	(0.269)	(0.271)	(0.267)	(0.270)
Distance_Experience		-0.183	-0.114	-0.142	-0.183	-0.167	-0.0822
		(0.162)	(0.164)	(0.156)	(0.162)	(0.162)	(0.156)
Dist_Male_AMS_Inter			-0.907***				-1.207***
			(0.289)				(0.359)
Dist_Male_AMS_Dutch				0.718**			0.129
				(0.308)			(0.330)
Dist_Male_Muni_Inter					-0.0572		-0.723**
					(0.285)		(0.328)
Dist_Male_Muni_Dutch						0.447*	-
						(0.258)	
Constant	0.0302	0.0335	0.0302	0.0357	0.0335	0.0297	0.0298
	(0.100)	(0.104)	(0.106)	(0.105)	(0.104)	(0.105)	(0.106)
Observations	644	644	644	644	644	644	644
Log-Likelihood	-302.7	-294.9	-289	-292	-294.9	-293.5	-286.2

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Same model specifications as for models (1), (2), (3), (4), (5) and (6) with a reduced number of observations after dropping all choice situations where either the distance, the level of crowding or the type of infrastructure was the same

Table D4: Comparison of willingness to cycle between model specifications including all observations versus excluding observations with same attribute levels. The willingness to cycle for model (2) and (14) is calculated for the base reference of female Dutch students without further interaction terms.

	Model (1)	Model (13)	Model (2)	Model (14)
Number of observations	1,064	644	1,064	644
Infrastructure: Cycle lane	-0.88 km	-1.14 km	-0.70 km	-0.82 km
Infrastructure: Road	-1.33 km	-1.71 km	-1.04 km	-1.22 km
Crowding level: Some	-1.58 km	-1.60 km	-1.29 km	-1.19 km
Crowding level: Many	-2.38 km	-2.40 km	-1.94 km	-1.79 km

Table D5: Multinominal logit model with the infrastructure reference category green surroundings and the level of crowding reference category no crowding

	(20)	(21)	(22)	(23)	(24)	(25)	(26)
Distance	-1.296***	-1.559***	-2.029***	-1.702***	-1.570***	-1.648***	-2.124***
	(0.0916)	(0.228)	(0.279)	(0.247)	(0.236)	(0.226)	(0.270)
Cycle lane	-1.034***	-1.029***	-1.110***	-1.071***	-1.027***	-1.044***	-1.143***
	(0.146)	(0.148)	(0.153)	(0.151)	(0.148)	(0.150)	(0.156)
Road	-1.156***	-1.144***	-1.235***	-1.184***	-1.142***	-1.159***	-1.265***
	(0.160)	(0.158)	(0.164)	(0.159)	(0.158)	(0.161)	(0.166)
Some crowding	-0.0807	-0.0938	-0.138	-0.0960	-0.0956	-0.105	-0.141
	(0.144)	(0.147)	(0.149)	(0.148)	(0.147)	(0.146)	(0.150)
High crowding	-2.016***	-2.049***	-2.189***	-2.078***	-2.048***	-2.084***	-2.222***
	(0.193)	(0.195)	(0.209)	(0.199)	(0.195)	(0.196)	(0.209)
Distance_Male		0.219*	0.583***	-0.00225	0.181	0.110	0.738***
		(0.122)	(0.136)	(0.145)	(0.132)	(0.147)	(0.219)
Distance_Amsterdam		-0.0612	0.190	-0.290**	-0.0115	0.00266	-0.0243
		(0.126)	(0.131)	(0.133)	(0.149)	(0.137)	(0.172)
Distance_International		0.243*	0.500***	0.528***	0.197	0.334**	0.814***
		(0.129)	(0.124)	(0.156)	(0.140)	(0.146)	(0.175)
Distance_Cyclist		0.229	0.291	0.289	0.239	0.202	0.278
		(0.252)	(0.262)	(0.256)	(0.256)	(0.248)	(0.254)
Distance_Experience		-0.195	-0.0897	-0.137	-0.197	-0.172	-0.0484
		(0.148)	(0.146)	(0.145)	(0.147)	(0.149)	(0.144)
Dist_Male_AMS_Inter			-1.317***				-1.516***
			(0.266)				(0.333)
Dist_Male_AMS_Dutch				0.957***			0.260
				(0.258)			(0.285)
Dist_Male_Muni_Inter					0.174		-0.632**
					(0.259)		(0.303)
Dist_Male_Muni_Dutch						0.387	-
						(0.238)	
Constant	-0.0907	-0.0871	-0.0742	-0.0806	-0.0867	-0.0847	-0.0711
	(0.0807)	(0.0831)	(0.0843)	(0.0837)	(0.0831)	(0.0831)	(0.0846)
Observations	2,128	2,128	2,128	2,128	2,128	2,128	2,128
Log-Likelihood	-467.1	-460.9	-445.4	-453.8	-460.6	-459.4	-442

Robust standard errors in parentheses; Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Same model specifications as for models (1), (2), (3), (4), (5) and (6) with a multinominal logit model for the reference categories of "green surroundings" for the type of infrastructure and "no crowding" for the level of crowding. The number of observations is the double of the logistic model as the use of multinominal logit model requires a different notation of alternatives resulting into the double of actual choice situations.

Table D6: Comparison of willingness to cycle between logit and multinomial logit model with the reference categories no crowding and green surroundings for the level of crowding and type of infrastructure. The willingness to cycle for model (2) and (21) is calculated for the base reference of female Dutch students without further interaction terms.

Level of infrastructure/crowding / **Model specification**	**Cycle lane**	**Road**	**Moderate crowding**	**High crowding**
Logit model (1) without interaction terms	-0.88 km	-1.33 km	-1.58 km	-2.38 km
MNL model (20) without interaction terms	-0.80 km	-0.90 km	-0.06 km (insignificant)	-1.56 km
Logit model (2) for female Dutch students	-0.70 km	-1.04 km	-1.29 km	-1.94 km
MNL model (21) for female Dutch students	-0.66 km	-0.73 km	-0.06 km (insignificant)	-1.31 km