The Willingness to Cycle:

a stated-preference experiment on the effect of crowding and congestion on the route length of cyclists

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Abstract

Purpose The objective of this paper is to investigate the impact of crowding and congestion on the willingness-to-pay in length for cycling trips.

Methods A stated-preference survey was designed, including questions on respondents socio-demographics as well as structured scenarios with alternative routes. These routes were made up of differing levels of the attributes; crowding, congestion, number of stops and distance. The estimated conditional logit model coefficients were then used to calculate the willingness to cycle for specific cycling routes. This willingness to cycle was then converted to the willingness to pay.

Conclusions The willingness to cycle showed that cyclists are willing to cycle an additional distance of 0,99 km to avoid high levels of crowding, 2,78 km to avoid heavy congestion and 1,2 km to avoid the highest number of stops on the route. Moreover, it was found that there isn't a large difference in the willingness to cycle for three stops or two stops. Using a value of travel time of 9,00 euro per hour the distances mentioned above would translate to a willingness to pay of: € 0,57 to avoid high levels of crowding, € 1,58 to avoid heavy congestion and € 0,66 to avoid a large number of stops on the route. In addition, the results show that when taking gender into account female cyclists have a 30% higher willingness to cycle and therefore willingness to pay then male cyclists. These findings are consistent with the literature.

Recommendations Future research should focus on if the willingness to pay for non-crowded bicycle routes will increase over the next decade as it is estimated that bicycle crowding in cities is an exponentially increasing trend. Another possibility for further research is to verify the stated-preference results with actual cycling data. This would generate a more realistic interpretation on the behavior of cyclists regarding crowding and congestion. This research can also be used by stakeholders such as infrastructure designers and policy makers in cost-benefit analysis as the willingness to pay for specific route characteristics was calculated.

Keywords · bicycle crowding · bicycle congestion · willingness to cycle · willingness to pay · stated-preference experiment · conditional logit model

1 Introduction

According to the Road Safety Research Foundation (*Stichting Wetenschappelijk Onderzoek Verkeersveiligheid,* also SWOV) the 35 thousand kilometers of bicycle lanes in the Netherlands are ever-increasing in busyness and crowding (Weijermars, van Schagen, & Aarts, 2018). For example, the city of Amsterdam has registered an enormous increase in the number of bicycle movements in the past ten years.

The increase of cyclists on bicycle paths is both visible inside and outside of urban areas. In the larger cities within the Netherlands the number of cyclists increases exponentially, and new faster vehicles are entering the cyclers domain such as the electric bicycle (Niemantsverdriet, 2019).

Speed difference between cyclists may cause uncomfortable and unsafe situations on bicycle paths. These speed differences result in overtaking manoeuvres causing obscure and complex cycling situations (Weijermars et al., 2018). Not only does the increased bicycle density result in safety issues, it also effects the individual cyclist's comfort-level. Professor of social psychology van Lange (2019) mentions that cyclists underestimate how much stress they can impose on one another. The Dutch Bicycle-counting week has tried to give insight into how cyclists perceive the current cycling traffic. By using a specifically designed app, participants kept track of where and how long they cycled and how safe they experienced their bicycle ride. The survey shows that 20% of all participants perceived their bicycle ride as unsafe. The reason behind this unsafe feeling was mostly due to traffic congestion, traffic lights and behaviour of other cyclists (Fietstelweek, 2017).

The Road Safety Research Foundation (2018) predicts that bicycle traffic within the Netherlands will continue to grow in the coming years both inside and outside of cities. It is expected that these bicycle crowds may even increase considerably by 2020. It was found that this increase is due to the raised attractiveness of cycling, as well as actions undertaken by the Dutch government (Sophie van der Meer, 2019). For instance, the Dutch government currently aims at decreasing car-traffic and thereby increasing sustainability by switching current car-drivers to the alternative of the bicycle. The government wants to realize the set goal by switching 200,000 commuters to bicycle traffic by 2021. The director of the Dutch Cyclists union (2019) states that unfortunately they are currently not capable of handling this growth in bicycle traffic properly and safely.

Therefore experts, government officials, administrators and groups of interest are currently occupied with the question: how do these large amounts of cyclists impact our wellbeing? And how can we cope with these large amounts of cyclists within the Netherlands?

The transport literature underlines the relation between cycling volumes and safety. However, the literature lacks specific research on the impact of bicycle crowding on the cycling individual. And more so on the effect this has on choosing alternative and longer routes. This paper therefore aims to fill this research gap by answering the following research question:

"What is the willingness to pay for cyclists for a non-crowded bicycle route?"

The objective of the research is to provide knowledge on the subject of the attractiveness to reroute in order to avoid crowding. This research creates a more complete understanding of cycling behaviour with regards to crowding and thereby inform the public policy makers of cycling infrastructure on possible route alternatives. After all, the Dutch Minister of Environment and Housing argues that “we must ensure that we guarantee sufficient space and safety on the cycle paths” (Rijksoverheid, 2018). The results of this research are useful to cost-benefit analysis used to compare potential courses of actions to decrease crowding on cycle routes against the cost of the infrastructural project.

The remainder of this paper is organized as follows. The next section first discusses recent literature on cycling behaviour with regards to crowding. Thereafter, I present the methodology including the design of the stated-preference survey and the econometric modelling approach. The paper then continues with the findings, followed by a discussion. Finally, this paper closes with a conclusion and considerations of their implications for policymaking and further research.

2 Cycling Behaviour and Congestion

Cycling can be defined as a form of exercise that can also be used as a mode of transportation if the surrounding environment facilitates such use (Rashad, 2007). The topic of cycling behaviour has already been widely researched and a concise summary of this research is presented below. However, it must be noted that the summary below is mainly focussed on general literature on the topic of bicycle behaviour, rather than specifically directed at bicycle crowding as literature on crowding and congestion with regards to cycling is scarce. The process of conducting this literature review has been written out and attached in Appendix I.

There is a large and diverse literature concerning the determinants of bicycle usage (Hunt & Abraham, 2007) , routing (Bovy & Bradley, 1985; Vedel, Jacobsen, & Skov-Petersen, 2017), safety (Van Der Horst, De Goede, De Hair-Buijssen, & Methorst, 2014), comfort (Zhu & Zhu, 2019), behaviour (Wang, Palm, Chen, Vogt, & Wang, 2016), levels (Buehler & Dill, 2016) and trends (Harms, Bertolini, & te Brömmelstroet, 2014). For instance, research on cycle route choices dates back to the early 1980s (Bovy & Bradley, 1985). While cycling research in these early years seems scarce the last decade research on cycling has been developing and emerging.

Different research has endeavoured to identify reasons for cycling, varying from physical- and mental exercise (Rashad, 2007) to sustainability reasons (Parkin, 2012, p. 4). For instance, Parkin (2012) states that cycling produces less greenhouse gas relative to motorised transport, emits virtually no air pollution and is nearly noiseless. Zhu & Zhu (2019) expand and broaden the reasons behind cycling by stating that for densely populated countries with rising congestion levels, cycling can be a good choice to help alleviate congestion, reduce pollution emissions and save energy consumption and travel costs. Other research by Vedel, Jacobsen & Skov-Petersen (2017) connects underlying reasons for cycling to household characteristics. For example, they found that if there is a car in the household the main motive for cycling is exercise. For households not owning a car cycling for exercise is significantly less important whereas the fact that the transportation price is low matters relatively more. In addition to the above, this article identifies another reason for cycling, namely flexibility as many people use the bicycle for short commutes combined with grocery shopping or other purposes.

In addition to varying reasoning behind cycling as mentioned above, multiple additional factors have effect on the usage of bicycles. In the research by Hunt & Abraham (2007) a collection of different factors of influence on the usage of bicycles was presented. All factors were grouped under facility characteristics, non-cycle traffic characteristics, individual and trip characteristics, and environmental/situational characteristics. The influences in the category of environmental and situational characteristics have been presented in Table 1 below:

Table 1: Influences on usage of cycling collected by Hunt & Abraham (2007)

Influence	**Source**
Weather	City of Calgary Transportation Department (1993)
Sweeping/snowplowing	Copley & Pelz (1995)
Nature of abutting land uses	Axhausen & Smith (1986), Davis (1995), Epperson (1994), Landis, Vattikuti & Brannick (1994)
Aesthetics along route	Antonakos (1994), Sacks (1994)
Degree of political and public support for cycling	Clarke (1992), Copley & Pelz (1995), Wynne (1992)
Level of public assistance for cyclists, including maps, route advice and emergency aid	James Mackay & Mayor Bicycle Committee (1993)
Education and enforcement regarding cycling	Antonakos (1994), James Mackay & Mayor Bicycle Committee (1993), Wynne (1992)
Availability of public transport	(1993), Wynne (1992)
Cost and other disincentives to use other methods	Moritz (1997), Sacks (1994), Taylor & Mahmassani (1996), Wynne (1992)

In the collection of research above it is remarkable that nothing is mentioned on the volume of cyclists. In the cycling literature, the topic of large cycle volumes is covered by the term *bicycle crowding* which in time might lead to *bicycle congestion*. No clear definition to bicycle crowding can be found yet in the literature. However, bicycle crowding could be compared to pedestrian crowding occurring on sidewalks as it is a relatively slow mode of transport and free movement and manoeuvring is allowed: "Pedestrian overcrowding can simply be defined as the point beyond which movement is restricted and personal space invaded" (Autumn, 2013). In comparison, the term congestion is defined by Falcocchio and Levinson (2015) as a phenomenon in transportation facilities—walkways, stairways, roads, busways, railways, etc.—happens when demand for their use exceeds their capacity. From this perspective congestion is portrayed as a negative externality of transportation; "travellers tend to complain about traffic congestion because it adds to their travel time and takes away from the time they can dedicate to other activities" (2015, p. 3).

Vedel et al. (2017) state that amongst the cycling literature, crowding in the cycling infrastructure has received the least attention. Even though it has received the least attention it is a phenomenon occurring in different cities around the world. For instance, results of the *Fietstelweek* (2016), (Bicycle Counting Week), have shown that several cities within the Netherlands have large numbers of cyclists with relatively lower average speed (Fietsbond, 2016). Bicycle Counting Week 2016 measured the average cycling speed in the Netherlands to be 15,8 km/hour. However, when looking at individual but relatively large cities the average speed lies lower than the national average. For instance, the average cycling speed in Amsterdam is 14,4 km/hour, which therefore shows a -1,4 km/hour difference. This lower measured speed in larger cities can denote large volumes of cyclists causing traffic to slow down.

The term bicycle congestion is mostly used in multi-modal traffic literature. Falcocchi & Levinson (2015) suggest that bicycle congestion can be impacted by fuelled vehicle congestion. This however depends on the type of road network. "For instance, intersections of major streets are often focal points of traffic congestion during peak periods of travel. The many conflicts between pedestrians, cyclists and motorized traffic between through and cross traffic, and between through and turning vehicles are major sources of congestion" (Falcocchio & Levinson, 2015, p. 83). The National Association of City Transportation Officials (2014) also mentions this aspect of bicycle congestion; "On roadways with shared travel lanes such as bicycle boulevards, motor vehicle traffic volumes significantly impact bicyclist comfort." This discomfort could also be translated into congestion causing time delays.

Wang et all. (2016) researched the bicycle network level of traffic stress in relation to bicycle behaviour. They measured this by including ten different attributes[1] in their choice experiment, including vehicle traffic volume (Wang, Palm, Chen, Vogt & Wang, 2016). Results of this research show that the longer the trips, the less likely a rider will have a low stress route. In addition, women and children are more likely to travel to their destinations when low stress routes are available.

Vedel et all. (2017), conducted a choice experiment among 3,891 active cyclists in Copenhagen (Denmark) and investigate the implicit value commuters attach to specific routes characteristics and road environments. These specific route characteristics also included bicycle crowding. They concluded that people were willing to cycle approximately 1 kilometre more to avoid heavy bicycle crowding on routes. In addition, they found that both females and people who are used to cycling long distances were more averse to crowding than the average commuter. Regarding crowding, 82% of the respondents stated that crowding on cycle tracks made them feel (very) unsafe. However, only 21% of the respondents were (very) unsatisfied with the current amount of bicyclist on their daily route.

The above review of literature suggests that a number of studies have been carried out to study bicycle behaviour and factors of influence on this behaviour. Most of these studies have been including bicycle crowding as one of many factors researched, rather than purely researching bicycle crowding on itself. The scope of most of the existing research is therefore limited to a larger perspective on bicycle crowding. Moreover, there are no studies known on the willingness to pay for a non-crowded bicycle route in the Netherlands.

As the current bicycle volume in the Netherlands is experiencing a significant growth (Bruntlett & Bruntlett, 2018; Harms et al., 2014; Rijksoverheid, 2018; Sophie van der Meer, 2019) comprehensive study on understanding bicycle behaviour regarding crowding becomes relatively important. This research therefore aims to isolate bicycle crowding behaviour and bridge the mentioned research gap. By understanding the general preferences with regards to cycling and crowding and identifying the factors of most importance, this research can strengthen the literature of interest to policy makers within the Netherlands.

3 Methodology

Due to the behavioural aspect of the research objective and the lack of available cycling behaviour data a choice-experiment methodology has been chosen. A stated preference survey was carried out in order to measure the willingness to pay for a non-crowded bicycle route.

[1] 1) width of outside lane, 2) width of bike lane, 3) width of shoulder, 4) proportion of occupied on-street parking, 5) vehicle traffic volume, 6) vehicle speeds, 7) percent heavy vehicles, 8) pavement condition, 9) presence of curb, and 10) number of through lanes (Wang, Palm, Chen, Vogt & Wang, 2016).

The next subsection first explains the concept of a stated choice experiment. The second subsection then continuous with the several steps undertaken in the design process and data collection process of the stated preference survey. Finally, the econometric modelling approach is presented by which the data analysis was carried out.

3.1 Stated Choice-Experiment

Preference data can be either revealed preference data or stated preference data. Revealed preference data is generated when an actual real-life choice is made and observed. However, because there is a lack of open source revealed data on bicycle behaviour with regards to crowding stated preference data is required. "The relative advantage of the stated-preference approach is the controlled nature of the choice scenarios. This feature allows greater freedom in defining choice contexts, alternatives and attributes as well as direct comparison with the responses across individuals. In addition, the ability to obtain multiple responses from each individual reduces sample size requirements and also enables the estimation of truly individual models" (Bovy & Bradley, 1985).

A stated choice experiment generates stated preference data which refers to situations where a choice is made by considering hypothetical situations. The validity of the measurement relies on the assumption that hypothetical choices relate closely to actual behaviour (Lindhjem & Navrud, 2011). To arrive at this choice individuals must consider different alternatives. These alternatives side by side are called the choice sets; as it is expected that a choice is made between the alternatives. Choice sets must always consist of at least two alternatives in order to be able to make a choice. However, it is also possible that one of these choices is 'not to make a choice'.

Henscher, Rose & Greene (2005) underline that determining the set of alternatives to be evaluated in a choice set is a crucial task in choice analysis. They mention that when these alternatives aren't chosen correctly it means that subsequent tasks in the development of the applied choice analysis model are missing relevant information. Every alternative consists of several attributes with different attribute levels. These attributes and attribute levels function as characteristics of the alternative. Because each alternative consists of different characteristics (attribute levels) they can be weighed against one another in order to make a choice.

Often stated preference data also consists of sociological, demographic or economic profiles of each respondent. This additional personal information gives the analyst plenty of scope to explore contributions of attributes, alternatives and characteristics of the individual to explain choice behaviour (Hensher, David A., Rose, John M., Greene, 2005). The findings of a stated preference experiment can be used in various ways such as forecasting, scenario analysis, valuation and understanding of the role of particular attributes and characteristics (Hensher, David A., Rose, John M., Greene, 2005). The stated-preference data in this experiment are especially used for valuation in the form of willingness to cycle to avoid bicycle crowding.

3.2 Experimental Design

The experimental design process first identifies all alternatives and then labels all attributes and attribute levels. The alternatives are presented as route choice. In the choice experiment respondents are asked to consider a situation where they are to choose a cycling route to work or place of education. Respondents are then asked to choose one of the two routes presented; Route A or Route B. Every route consists of different attributes. Based on previous research presented in the literature review four attributes were chosen (see Table 2 below). Attribute one shows the number of other cyclists on the route as this determines the level of crowding. Attribute two and three are a based on the different types of congestion. For instance, attribute three is caused when the level of crowding increases. Attribute three on the other hand can be caused by traffic lights abruptly disrupting cycling flow. The last attribute; bicycle distance was added as different length of routes have different popularity and therefore different level of crowding.

Table 2: Attributes in the choice experiment

	Attribute	Levels
1	Crowding: other cyclists on route	Few, some, many
2	Congestion: in the form of slower biking	Light, moderate, heavy
3	Stops	1 stop – 3 stops
4	Bicycle distance	1 km – 8 km

Due to lack of quantitative literature on bicycle crowding the above attribute level categories were chosen. Attribute 1 and 2 were defined in three different categoric levels (Table 2). Attribute 3 and 4 are however presented as numeric levels so the respondent has a better understanding of the situation. These numeric levels are based on open source data regarding cycling statistics in the Netherlands provided by Statistics Netherlands (CBS). As Table 4 shows the average distance per trip destination was measured. The total average of all different trips was 3,99 km (Centraal Bureau voor de Statistiek, 2020). The distance of 4km was therefore considered a normal cycling distance. The longest distance of 8km was double this normal cycling distance.

Table 3: Descriptions of attribute levels in the choice-experiment

Attribute	Levels	Description
Crowding: other cyclists on route	Few	Another cyclist comes along from time to time. Cyclists can easily ride next to each other.
	Some	Quite a few cyclists use this route but this is not hindering. Cyclists can still ride next to each other when it does not present problems.
	Many	Many cyclists ride along this route causing it to be very busy. It is often difficult to pass one another or ride next to other cyclists.
Congestion	Light	There is no to light congestion on the route as a result of the few cyclists. You are able to cycle as fast as you prefer.
	Moderate	There is a moderate level of congestion due to quite a few cyclists using the cycling route. This therefore results in sometimes having to slow down your speed.
	Heavy	There is a heavy level of congestion due to the many cyclists on the cycling route. This congestion results in you often having to lower your cycling speed.
Stops	One stop	You have to step off your bike and wait for a traffic light once.
	Two stops	You have to step off your bike and wait in front of a traffic light traffic light twice.
	Three stops	You have to step off your bike and wait for a traffic light three times.
Bicycle distance	1 km – 7 km	Refers to the total distance you are travelling.

Table 4: Average distances travelled by bicycle (Centraal Bureau voor de Statistiek, 2020)

	Total Average	**From and to work**	**Shopping/ groceries**	**Education/ day-care**	**Sport/hobby/ other**
Average Distance	3,99 km	4,74 km	2,11 km	3,60 km	4,06 km

3.3 Survey Design & Data Collection

Data collection is carried out through an online survey. With survey is meant; any form of data collection involving the elicitation of preferences and/or choices from samples or respondents (Hensher, David A., Rose, John M., Greene, 2005).

The survey consists of the following elements:
1. Introduction to the survey
2. Instruction to the stated choice experiment
3. Socio-demographic questions: age, gender and cycling question
4. Route-choice questions

Comprehension problems are kept to a minimum by providing descriptions of attributes and attribute levels (Table 3) to the respondents in the instruction section of the survey. In addition, an attempt is made to achieve a wide cross section across characteristics such as age and gender.

A total of thirty choice pairs are created (Appendix II). Every respondent is randomly shown six of these choice pairs and had to choose the route they prefer. By having a large range of choice pairs more data can be collected. However, by only presenting six of these route choices to each respondent the time to complete the survey can be minimized. In total there are nine questions on the survey therefore reducing the risk of lower completion rate.

Before the actual survey was published a pilot has been conducted. The results of this pilot were then used to improve the actual survey. The changes that have been made to the published survey due to the pilot survey can be found in Appendix II. The final survey that was published can be found in Appendix III.

3.4 Data Analysis

Once data collection has been completed the data is first examined using descriptive statistics and correlation analysis. Afterwards, the data is analysed using the random utility theory by McFadden, as discussed below.

In the choice-experiment every respondent (n) makes a decision between two alternative routes $(i$ and $j)$. In this discrete choice framework, the respondent facing the choices obtains utility from each alternative and chooses the one with the highest utility (McFadden, 1973). This is represented by the following, where alternative i is chosen if larger than alternative j:

$$u_{ni} > u_{nj} \quad \forall \ i \neq j \tag{1}$$

Discrete choice models are widely used to analyse individual choice behaviour (Bhatta, 2016). These discrete choice models belong to random utility maximization. The random utility theory states that an individual's utility of a good is assumed to consist of the sum of a deterministic part (v_{ni}) and a random unobservable term (ε_{ni}) (Cheng, Pullenayegum, Marshall, Marshall, & Thabane, 2012; McFadden, 1973):

$$u_{ni} = v_{ni} + \varepsilon_{ni} \quad \forall \; i \tag{2}$$

The deterministic part (v_{ni}) of the above formula equals to the sum of all of its measured attributes according to McFaddens Theory (1973). Formula 3 below shows this general formula, where α is the constant, β_m is the estimated coefficient that corresponds to attribute m of alternative i, and X_m relates to the level of attribute m.

$$v_{ni} = \alpha + \beta_m * X_m \tag{3}$$

Lastly, in order to calculate the willingness to pay (WTP) for a non-crowded bicycle route the willingness to cycle (WTC) needs to be calculated first. This willingness to cycle will then be converted into monetary values by using the value of travel time (Kennisinstituut voor Mobiliteitsbeleid, 2013). The willingness to cycle can be calculated by the estimated coefficients of the model above. This can be calculated per attribute with the following formula below, where β_x is estimated coefficient for attribute x is divided by the estimated coefficient of distance (Vedel et al., 2017).

$$WTC_x = \frac{\beta_x}{\beta_{distance}} \tag{4}$$

A second model was used to analyze the data, using interaction effects between the distance and age, and the distance and gender. This was done by Formula 5 and Formula 6. The inclusion of these interaction effects is especially valuable when an independent variable (such as age or gender) has a different effect on the estimated coefficients.

$$WTC_x = \frac{\beta_x}{\beta_{distance} + \beta_{gender:distance}} \tag{5}$$

$$WTC_x = \frac{\beta_x}{\beta_{distance} + (\beta_{age:distance} * age)} \tag{6}$$

4 Results

This section describes the data and presents the results of the data analysis. The data analysis was carried out with the software R using the *mlogit package* by Croissant (2013). The *mlogit package* computes maximum likelihood estimations of random utility discrete choice models.

4.1 Data-description

The online survey was completed by 129 respondents. This therefore generated 774 answers to the route choice questions as every respondent answered 6 choice sets.

The gender of the respondents was evenly spread as 49,61% was male and 50,39% was female. An attempt was made to include different age groups in the research. However, it must be noted that an evenly distributed age density was not accomplished. Figure I shows that most respondents were in their twenties. In addition, a slight peak around respondents aged 40-60 is noticeable. The age of the respondents had a minimum age of 18, and a maximum age of 78. The mean age is 30,32 with a standard deviation of 11,87.

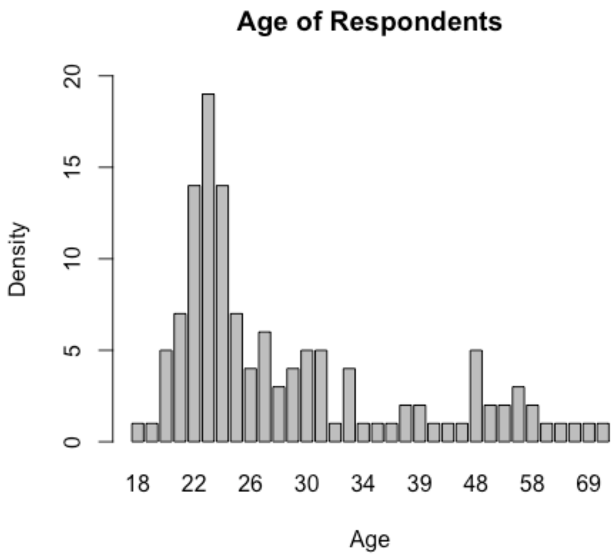

Figure 1: Age of respondents

The daily cycling distance to work or school differed amongst age-groups. The average distances per age group are presented in the following table:

Table 5: Average daily cycling distance per age category

Age Category	Average Daily Distance Cycled (km)
≤ 20	3,4
21 - 30	3,3
31 - 40	5,3
41 - 50	3,4
≥ 51	4,3
Total	3,7

The total average of 3,7 km above corresponds closely to the average daily cycling distance of 3,99 km measured by Statistics Netherlands (2020) in the Netherlands.

In addition, the data shows that there is a difference in average daily cycling distance between males and females. Male respondents cycle an average of 4,3 km daily whereas female respondents cycle 3,1 km daily. It also must be noted that 54 of 129 respondents have mentioned to cycle 0 km on a daily basis. This makes up 41,86% of all respondents.

4.2 Model estimation

4.2.1 Coefficient estimates

The results of two conditional logit models with a sample size of 129 are shown in Table 6. Overall McFadden's R^2 of the first model is 0.41 and 0.42 in the second model. These values are similar to one another and relatively high which means that the model predicts the results respectively well. In addition, the log-likelihood in the first model is -315.11 and -308.76 in the second model, meaning that the goodness of fit of the second model is slightly better.

The first model computes coefficient estimates with choice as a result of distance, crowding, congestion and the number of stops portrayed in the route. The model frequency of the alternatives is similar with 0.5155 for Route A and 0.4845 for Route B. This portrays that in 51.5% of the choice sets presented to the respondent he or she choose for Route A, and 48.5% of the time a decision for Route B was made. This almost equal distribution between the two routes shows that there was equal possibility. In addition, this is supported by the fact that the intercept coefficient (Route B) is not significant showing that there wasn't a constant choice for Route B.

As shown in Table 6, none of the coefficient estimates are significant. The non-significance indicates how uncertain we can be that the coefficient has an impact on the dependent variable. The estimated model takes crowding with level 'few', congestion with level 'heavy' and number of stops with level 'one' as a reference point. The values of the coefficients represent the impact of the variable on the utility of the route. As mentioned in Section 3.4 (Formula 1) the respondent chooses the route with the highest utility.

Light congestion on the route has the largest positive coefficient out of all variables. This means that as the level of congestion on a route decreases (moving from heavy congestion to light congestion) the utility increases. Distance on the other hand has a negative coefficient, meaning that the utility increases as the distance of the cycling route decreases. However, the proportion of the effect of distance is smaller than that of the congestion variable.

In addition, observations can be made of the difference between the various levels of attributes. For instance, the difference of coefficient crowding level 'many' differs a lot from the coefficient crowding level 'some'. However, the coefficients of two stops and three stops are both negative and differ only slightly. As both are negative, utility increases when number of stops decrease. The slight difference in values shows that the utility of the route doesn't increase drastically when going from three stops to two stops.

The second model computes coefficient estimates with choice as a result of distance, crowding, congestion, the number of stops portrayed in the route and includes interaction variables. As shown in Table 6 none of the coefficients are significant and they do not differ largely from the coefficients computed with Model 1 described above. The coefficient of the interaction between distance and gender does however show that utility of a male decreases (increases) more by an increase (decrease) in distance than a female. In addition, the older the cyclists the smaller the distance coefficient. This means that utility of older cyclists is less negatively impacted by an increase in distance. Therefore, the older the cyclists the less they value short distances in making a decision for a specific route.

Table 6: Coefficients and standard errors of the logit models

	Model 1: without socio-demographic interactions		Model 2: with socio-demographic interactions	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Route B (intercept)	0.14	0.11	0.14	0.11
Distance	-0.61	0.05	-0.79	0.12
Crowding – many	-0.60	0.17	-0.59	0.18
Crowding – some	0.04	0.17	0.03	0.17
Congestion – light	1.69	0.19	1.72	0.19
Congestion – moderate	0.97	0.17	0.98	0.17
Number of stops – two	-0.65	0.17	-0.63	0.17
Number of stops - three	-0.70	0.24	-0.71	0.24
Distance:Age			0.01	0.00
Distance:Gender – male			-0.23	0.09
	Model statistics		**Model Statistics**	
Log-Likelihood	-315.11		-308.76	
McFadden R^2	0.41		0.42	

Significance levels: 0.01*, 0.001**, 0***

4.2.2 Willingness to cycle

By calculations as mentioned in Section 3.4 the willingness to cycle for the researched attributes is as presented in Table 7. Again, it must be noted that the willingness to cycle is calculated with insignificant coefficients, therefore taking into account that there is a high uncertainty of the findings.

The values presented in Table 7 show how much additional kilometers people are willing to cycle for a route with a specific level of crowding, congestion or number of stops. Again, it must be taken into account that crowding with level ‘few’, congestion with level ‘heavy’ and number of stops with level ‘one’ is the reference point.

As shown the level of congestion has the biggest impact on the preferred route-choice of the cyclist. Congestion was described as having to decrease cycling velocity. The findings show that people are willing to cycle an additional 2.78 km for a route with light congestion rather than heavy congestion. To change from a route with heavy congestion to a route with some congestion people are willing to cycle 1.59 km more.

The willingness to cycle on a less crowded route (level ‘few’) instead of a route with lots of crowding (level ‘many’) is 0.99 km. The results show that people are not willing to cycle significantly less distance for a level of some crowding rather than few crowding as the coefficient does not differ from 0. Therefore, according to the data of the stated-reference experiment some crowding and few crowding are valued similarly.

The number of stops has a larger negative impact on people’s utility than crowding, and they are willing to cycle approximately 1.07 km longer to switch from a route with two stops to a route with one stop. In addition, people are willing to cycle 1.15 km longer to switch from a route with three stops to a route with one stop. This however shows that there is again not much difference between the preference of two or three stops.

Table 7: The willingness to cycle per attribute according to Model 1

	Willingness to Cycle (km)
Crowding – many	-0.99
Crowding – some	0.07
Congestion – light	2.78
Congestion – moderate	1.59
Number of stops – two	-1.07
Number of stops - three	-1.15

Since the denominator coefficient of distance (Formula 5 in Section 3.4) is slightly affected in the model with socio-demographic interaction the willingness to cycle is calculated per gender as shown in Table 8. As the results below show, females are willing to cycle more to decrease the level of crowding, congestion and number of stops on the route. The difference is especially remarkable in the variable congestion with level 'light', as there is a 0.50 km dissimilarity in the willingness to pay for females and males. The willingness to cycle for the variable crowding doesn't differ highly between females and males. Females only want to cycle 0.01 km further than males for some crowding, and 0.18 km further than males for switching from a route with 'many' crowding to a route with 'few' crowding.

Table 8: The willingness to cycle affected by gender (Model 2)

	Willingness to Cycle (km)	
	Male	**Female**
Crowding – many	-0.58	-0.76
Crowding – some	0.03	0.04
Congestion – light	1.69	2.19
Congestion – moderate	0.96	1.24
Number of stops – two	-0.62	-0.80
Number of stops - three	-0.69	-0.90

In addition, the willingness to cycle is affected by the age of the cyclist. The results of the data-analysis including this interaction effect of age (Formula 6 in Section 3.4) are shown by Figure 2 to the right. As shown, the older the cyclist the more they are willing to cycle an additional distance for a route with the least level of crowding, congestion and number of stops. The figure also shows that the level of congestion is again valued the most, followed by the number of stops. The least valued attribute is the level of crowding.

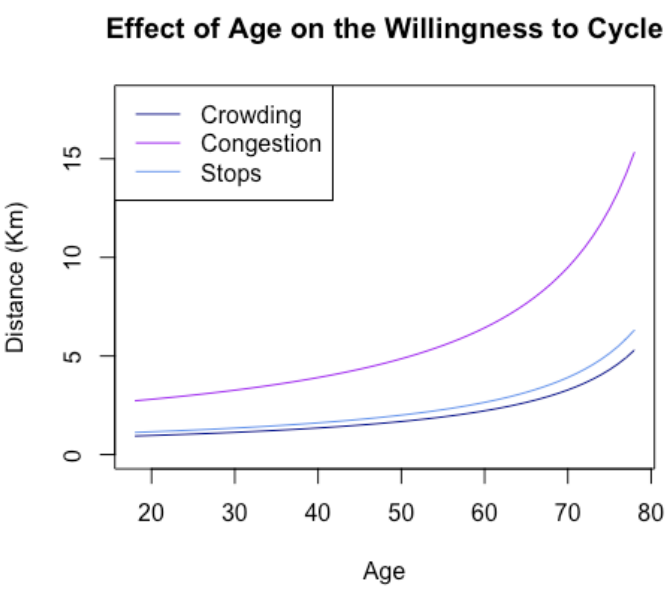

Figure 3: Effect of age on the WTC

As shown in Figure 2 an 18-year-old (minimum age) is willing to cycle an additional 2.73 km to avoid heavy congestion, 0.94 km to avoid heavy crowding and 1.13 km to avoid a high number of stops. On the other hand, a 50-year-old is willing to cycle 4.86 km to avoid heavy congestion, 1.68 km to avoid heavy crowding and 2.00 km to avoid a high number of stops. This again differs largely from the additional distances a 78-year-old (maximum age) is willing to cycle. Namely, according to the data, a 78-year-old is willing to cycle 15.34 km to avoid heavy congestion, 5.30 km to avoid heavy crowding and 6.3 km to avoid a high number of stops. The graph in Figure 2 shows that there is a smaller difference in the willingness to cycle of cyclists in their younger years, while a larger increase occurs as cyclists get older. For instance, the difference in the willingness to cycle between an 18-year-old and a 19-year-old is 1.37%, while there is an 7.15% increase between the willingness to cycle of a 77-year-old and 78-year-old.

4.2.3 Willingness to pay

As mentioned in Section 3.4 the willingness to cycle as presented in Section 4.2.2 above has to be converted into monetary values with the help of information on the value of travel time. To do this, distance first needs to be transformed into time (per hour). This transformation is done with recent data on the average cycling velocity in the Netherlands equaling 15.8 km per hour (Fietstelweek, 2016).

Various international and national studies provide insight into the value of travel time of cyclists. These studies show a wide spread of results between 9.80 and 24.85 euros per hour. Ommeren et al. (2017), in consultation with an expert group, however base the value of travel time for cyclists on that of motor vehicles. They mention that this rating of currency comes closest to that of cyclists. The valuation of time spend in motor vehicles, and now also used for cycling, is 9.00 euros per hour (Kennisinstituut voor Mobiliteitsbeleid, 2013).

As shown in Table 9 the willingness to pay is calculated according to gender. Corresponding to the results shown in Table 8, females have an equal willingness to pay or higher willingness to pay then males in all attributes. As mentioned before, congestion is again the highest valued attribute with a willingness to pay of either 0.96 euros (male) or 1.25 euros (female) to switch from a route with heavy congestion to a route with a light level of congestion. The willingness to pay for a route with some crowding instead of few crowding is for both males and females 0.02 euros.

Both males and females are willing to pay 0.05 euros more to go from a route with three stops to a route with only two stops. This again is a relatively small difference. However, when switching from a route with two stops to a route with one stop the willingness to pay is 0.35 euros more (male) or 0.46 euros more (female) depending on gender. Overall the results show that the attribute with the highest influence, therefore the highest willingness to pay, is congestion. This is followed up by the number of stops. The least preferred attribute on cycling routes, with therefore also the lowest willingness to pay, is crowding.

Table 9: The willingness to pay for different attributes per gender

	Willingness to Pay (Euro)		
	Model 1	Model 2	
		Male	**Female**
Crowding – many	-€ 0.57	- € 0.33	- € 0.43
Crowding – some	€ 0.04	€ 0.02	€ 0.02
Congestion – light	€ 1.58	€ 0.96	€ 1.25
Congestion – moderate	€ 0.91	€ 0.54	€ 0.71
Number of stops – two	-€ 0.61	- € 0.35	- € 0.46
Number of stops - three	-€ 0.66	- € 0.40	- € 0.51

5 Conclusions

This paper presented the willingness to cycle and the willingness to pay of non-crowded cycling routes taking into account other attributes like congestion and the number of stops. A stated-preference experiment was designed, including socio-demographic questions on the respondents, as well as thirty randomly chosen structured scenarios with alternative routes.

The study revealed that congestion has the most influence on route choice and subsequently the willingness to pay. Cyclists are willing to cycle 2.78 km extra to avoid high levels of congestion. The second most influence on route choice was identified as the number of stops as people are willing to cycle an additional distance of 1.07 km to switch from a route with two stops to one stop and 1.15 km to switch from a route with three stops to a route with one stop. Cyclists were willing to bike the least distance (0.99 km) to avoid high levels of crowding. Another result of this study is that the willingness to cycle and willingness to pay differs depending on gender. Women are willing to cycle 30% more distance to avoid crowding, congestion and avoid several stops.

This study also reveals that the variable age has an impact on the additional distance cyclists are willing to cycle to avoid certain characteristics such as high levels of congestion, crowding and number of stops. For instance, an 18-year-old is willing to cycle 2.74 km to avoid heavy congestion while a 50-year-old is willing to cycle 4.86 km to avoid heavy congestion. The results show that the increase in willingness to cycle for congestion, crowding and number of stops ranges between 1.37% and 7.15% per year of age.

As mentioned in the literature review, there was a lot of existing literature on determinants of cycling while relatively little was published considering crowding or congestion of cyclists. Therefore, this research is a contribution to existing literature as it is the first research to mainly focus on bicycle crowding. In addition, the results of this research can contribute to experts, government officials, administrators and groups of interest who are currently occupied with questions on coping with the high density of cyclists within the Netherlands. A concise number of recommendations to these people of interest is presented in Section 6.3 below.

6 Discussion, Limitations and Recommendations

This section first discusses the results presented in Section 4 with regards to the literature on the topic of bicycle crowding. It then continuous with limitations of the research and the applied methodology. This section concludes with suggestions on further research on the topic and recommendations to experts currently occupied with cycling-infrastructure and -policy.

6.1 Discussion

As discussed in the Literature Review (Section 2) there is no prior study on the willingness to pay for non-crowded bicycle routes. Hence, it is difficult to compare the results of this study to previous studies.

However, the only study that does propose the willingness to cycle in distance is conducted by Vedel et al. (2017). Among other attributes they have included crowding and found that avoiding heavy crowding has a general willingness to cycle of 1 km. This value compares to the willingness to cycle found in this research of 0.99 km (Model 1). In addition, Vedel et al. (2017) found that female cyclists have a higher willingness to cycle for several attributes than male cyclists. This result can be confirmed by this study, where crowding, congestion, and the number of stops are more negatively valued by females, resulting in a higher willingness to cycle and therefore a higher willingness to pay to avoid stops. This study shows that the willingness to cycle and the willingness to pay of males is 23% lower than for females. As mentioned in Section 4.2 the willingness to cycle for the attribute congestion was the highest out of all with a distance of 2.78 km. Lastly, the research by Vedel et al. (2017) shows that cyclists are willing to cycle an additional 1.3 km for a route without many stops. The results presented in Table 7 of Section 4.2 shows that cyclists were willing to cycle an additional distance of 1.15 km extra to go from three stops to a route with only one stop. Even though the term 'many' stops in the results of Vedel et al. (2017) is unquantifiable, it compares mostly to the highest level of the number of stops. As mentioned above, the values of 1.15 km and 1.3 km as the willingness to pay for a route with less stops are similar. Overall, the distances mentioned by the only research on the topic by Vedel et al. (2017) are verified by this research.

The only attribute not mentioned in the research by Vedel et al. (2017) is congestion. Since crowding and congestion are similar to one another a similar willingness to cycle was expected. However, there is a relatively large difference between the valuation of crowding and congestion. The difference between these two terms is that they have different effects. As mentioned, congestion described as queuing of cyclists results in having to adapt cycling velocity, whereas crowding is described as the density of cyclists on the route resulting in less cycling comfort. This decreased cycling comfort as the level of crowding rises is valued less than the level of congestion according to the results. Even though the willingness to cycle for congestion and crowding differ largely, the results of this research do show that they can be measured separately.

Moreover, Vedel et al. has not included the interaction effect of age on the willingness to cycle. For this reason, the relation between age and the willingness to cycle presented in Figure 2 (Section 4.2.2) contributes to the literature. The Figure shows that the older the cyclist the more they are willing to cycle an additional distance to avoid either crowding, congestion or the number of stops.

Again it must be noted that the estimated coefficients presented in Section 4 are not significant at all, whereas the results of Vedel et al. (2017) were significant. This therefore means that Vedel et al. (2017) were able to establish that the likelihood of the relationship between many variables was caused by something other than chance. However, the large difference in sample size between the studies must be taken into account. Vedel et al. had 3891 respondents whereas this research was based on a sample size of 129 respondents. The higher sample size allows the researcher to increase the significance level of the findings since the confidence of the results is likely to increase by researching a larger sample size. In addition, another factor that might have influenced the results of this research is that almost 42% of the sample group cycles 0 km on a daily basis. Due to the fact that they hardly cycle this might have had an effect on the interpretations of the questions and the level they can relate to cycling behaviour.

6.2 Limitations & Future Research

Several limitations need to be addressed as they limit the generalizability of the results. In addition to these limitations alterations of this research are suggested for further research.

There are several limitations in the set up and carrying out of the stated preference experiment. Firstly, the survey data shows to have a large underrepresentation of older cyclists as most respondents were in their beginning twenties. Therefore, future research should attempt reaching a larger and more evenly spread sample group. When increasing the sample size it might also have positive effect on the level of significance of the results. However, having said that, a sample size of 129 should be a representative number of respondents considering the nature of a stated-preference experiment.

In addition, by sampling additional data and using a richer model it could further enhance the value of the models. For instance, additional attributes (such as green surroundings, travel time) or additional socio-demographic data (such as income or car-ownership) might provide additional insight to the topic of crowding on cycling route length. Moreover, increasing the number of attribute levels would provide additional granularity in responses.

Another limitation in the setup of the stated preference experiment is the comprehensiveness of the used terminology. For instance, the attribute distance might have been difficult for some of the respondents to visualize. Visualization is especially challenging when the respondent is not familiar with cycling on a daily basis. This could be resolved by using travelling time as an attribute instead of distance. The advantage that travelling time also gives is that calculations from the willingness to cycle to the willingness to pay are simpler. However, having used a distance measurement in this research made it relatively convenient to compare the results to the existing literature as the existing literature also made use of distance cycled.

Besides limitations in the set-up of the experiment, the results also bring forward a limitation. The results of this research show that the willingness to cycle suggests a fairly high sensitivity towards several route factors such as congestion and the number of stops. For example, the results suggest that when a cyclist has regular heavy congested cycling trip of 1.00 km, they are willing to cycle a total of 3.78 km to avoid heavy congestion (as the willingness to cycle for congestion is 2.78 km). This seems rather odd as there is a distance increase of 270%. There is a possibility that the relatively high willingness to cycle lies far away from real actions in route choice when the cyclist is confronted with the alternatives in real life. Therefore, to carry out a more realistic analysis of the willingness to pay for different route attributes it would be suggested to validate the stated-preference models by actual choice-data.

Lastly, to convert the willingness to cycle to the willingness to pay makes use of value of travel time data offered by the Dutch Ministry of Infrastructure (Kennisinstituut voor Mobiliteitsbeleid, 2013). As mentioned in Section 4.2.3 there is no published value for the value of travel time for cycling. For this reason, several reports have found that taking the value of travel time for cars comes closest to the value of travel time for cycling (Ommeren et al., 2017). Ommeren et al. mention that this value will mostly likely be researched in the near future. For this reason, future research should be carried out as soon as the value of travel time for cycling in the Netherlands is published, as this yields more accurate results.

6.3 Recommendations

Besides the recommendations on future research made in Section 6.2 above, several recommendations can be made to stakeholders such as experts or officials currently occupied with cycling infrastructure in larger cities within the Netherlands.

These recommendations are especially important as it is expected that the number of cyclists in the Netherlands will increase exponentially, therefore imposing more straining on the current cycling infrastructure. In addition, the current situation with COVID-19 can possibly inflict an additional demand for car-usage or cycling-lanes. Travelers possibly avoid public transport and choose alternative transport modes to limit risk of infection. For these reasons it is crucial that recommendations are made on the way crowding and congestion should be taken into account.

The first recommendation to infrastructure designers is to focus on constructing additional and longer cycling lanes to relieve high traffic in cities. These additional cycling routes should limit congestion, crowding and the number of stops. Even though these routes aren't the shortest distance from origin to destination, the results of this research show that there is a demand (willingness to cycle) for specific characteristics. In the design of these additional routes the focus should be on relieving congestion as the willingness to cycle for this attribute is the highest. Methods to decrease congestion could possibly be concerning the width of cycling lanes, or the number of cycling routes available to cyclists. The second focus of the design of these additional routes should be on number of stops, as this characteristic has the second highest willingness to cycle.

A second policy recommendation is to take into account the results of the willingness to pay calculations in cost-benefit analysis regarding cycling projects. Even though the values of the willingness to pay (i.e. € 1.58 to avoid congestion, € 0.66 to avoid stops and, € 0.57 to avoid crowding) seem relatively small, due to the large volumes of cyclists these values add up to quite a large sum of money. The willingness to pay makes up the benefit and needs to be weighed against the costs of the cycling infrastructural project. For instance, if 5000 cyclists use a new bicycle path designed to reduce congestion daily, this yields a total 'revenue of €2,88 million a year according to this research. This large sum of money needs to be considered as the beneficial revenue in cost-benefit analysis. This shows that this research therefore gives insights to the monetary valuation of route specifics and can be used in the process of cost-benefit analysis. In addition, the willingness to pay valuation show that limiting congestion on cycling routes has the highest willingness to pay and therefore should be included in future infrastructure projects to yield the largest benefits.

Overall, it is especially important to continue expanding literature on crowding and congestion on cycling infrastructure and use these findings in the design of cycling-infrastructure and the formation of policy regarding cycling.

Appendix I – Literature Review: Process

To conduct the literature review, several primary sources have been consulted such as the *Web of Science*, *VU LibSearch* and *Google Scholar*. From these sources, theory was collected in the form of online books and academic/scientific articles.

The literature review was carried out following this four-step structured approach:

Step 1 - Search
Different terms were used in the search engines mentioned above. First some general terms were used to find the most relevant literature on the topic:

- "cycling congestion"
- "bicycle traffic"

After having read some of the most cited articles on the topic it was found that the most appropriate term to describe the phenomenon was bicycle crowding. For this reason, the term "bicycle crowding" was mainly used to search for further articles. In addition, "willingness to pay" and "willingness to cycle" and "cycling route choice" were terms used to find some of the cited articles.

Step 2 - Collect
After a collection of appropriate scientific articles was build up all articles were read critically. As the articles were read notes were taken and main arguments and components in the research were highlighted. Highlighting was done according to a colour-scheme. This colour scheme made it easy to organize notes according to theme or section within this research.

Step 3 – Read and Analyse
After all articles were read and highlighted, a literature matrix was created. This matrix functioned as a general overview of all appropriate articles, their objectives, findings and themes.

Step 4 - Finalize
The last step in the literature review process was to identify if enough resources were collected. However, as discussed in the Literature Review (Section 2) there are hardly any studies conducted on solely bicycle crowding or the willingness to pay for a non-crowded bicycle route. For this reason, only a small collection of the available literature on the topic was presented in the literature review.

Appendix II – Stated-Preference Experiment: Process

As discussed in Section 3 a stated-preference experiment was carried out to find the willingness to cycle for different attributes. Prior to publishing the final survey a pilot survey was carried out to test the comprehensiveness and effectiveness of the stated-preference survey. Below the pilot survey is explained, and changes made to the final survey are discussed. In addition, the final survey set-up is presented in Appendix III.

Pilot survey

In the pilot survey the attributes were as following:

	Attribute	Levels
1	Crowding: other cyclists on route	Few, some, many
2	Congestion: in the form of slower biking	Light, moderate, heavy
3	Congesion: in form of standing still	Light, moderate heavy
4	Bicycle distance	Short, medium, long

Table 10: Attributes and levels prior to pilot

Feedback from the pilot sample group was that the double attribute congestion is rather confusing. For this reason, ‘Congestion: in the form of standing still’ has been changed to ‘Number of stops’. In addition, a thorough description has been created on the meaning of every term.

Furthermore, an alteration to the attribute levels was made as the pilot respondents found that the levels for distance and congestion (standing still) were subjective and unclear. For this reason, the levels of distance have been changed into numeric levels varying from 1km to 8 km. The levels of standing still were altered to ‘one stop’ ‘two stops’ and ‘three stops’. Therefore, the new attributes and attribute levels were as presented in Table 2 (Section 3.2):

	Attribute	Levels
1	Crowding: other cyclists on route	Few, some, many
2	Congestion: in the form of slower biking	Light, moderate, heavy
3	Stops	1 stop – 3 stops
4	Bicycle distance	1 km – 8 km

Table 11: Attributes and levels after pilot

A second pilot survey with the new attributes and levels was conducted to verify the effectiveness of the improvements described above. The pilot sample group confirmed a better comprehensiveness of the terms and improved visualization of the levels.

Appendix III – Final Survey

Start of Block: Introduction

As part of my master research thesis at the Vrije Universiteit Amsterdam I am conducting a survey to investigate the willingness to pay for non-crowded cycling routes in the Netherlands.

The survey is divided into two sections:
- Socio-demographic questions (3 questions)
- Route choice questions (6 questions)

I would appreciate it if you could complete the following questions, this will take approximately 5 minutes. Any information obtained in connection to this study will remain confidential.

Thank you in advance!

Opmerking: Als u de taal van deze enquête naar Nederlands wilt wijzigen doe dit dan in het keuzevakje rechts bovenin.

End of Block: Introduction

Start of Block: Socio-Demographic Questions

Q1 What is your age?

____

Q2 What is your gender?

- ○ Male
- ○ Female

Q3 How many **kilometers** do you cycle to work/school on a daily basis?

____

End of Block: Socio-Demographic Questions

Start of Block: Route Choice Introduction

The following section requires you to make a choice between two given routes. Both routes have different characteristics.

A description of these characteristics is given below:

- Crowding: crowding has to do with the number of cyclists on the route. The level of crowding in the survey questions is either 'few other cyclists', 'some other cyclists' or 'many other cyclists'
- Congestion: congestion happens when cyclists 'pile' up. As a result you have to bike slower. The level of congestion in this survey is either 'light', 'moderate' or 'heavy'.
- Number of stops: these stops are the number of traffic lights you need to stop for.
- Distance: the total distance of the cycling route is measured in kilometers (km).

Imagine that you are at home and you are about to choose a route to cycle to work/school or another location where you go on a daily basis. If the two routes shown in the next section were your options, which of them would you choose?

End of Block: Route Choice Introduction

Start of Block: Route Choice Questions

Randomly Chosen Route-Choice Question (1/30)

Which of the two following routes would you choose?

	Route A	**Route B**
Crowding	Few other cyclists	Many other cyclists
Congestion	Moderate: therefore you sometimes need to slow down	Heavy: therefore you need to slow down multiple times
Number of stops	One stop	Two stops
Distance	6 km	3 km

○ Route A ○ Route B

End of Block: Route Choice Questions

We thank you for your time spent taking this survey.
Your response has been recorded.

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