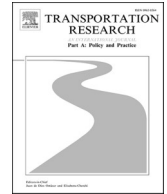




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Effects of crowding on route preferences and perceived safety of urban cyclists in the Netherlands

Teun Uijtdewilligen^{a,b,*}, Mehmet Baran Ulak^a, Gert Jan Wijnhuizen^b, Karst T. Geurs^a

^a University of Twente, Faculty of Engineering, Transport Engineering and Management, PO Box 217, 7500 AE Enschede, the Netherlands

^b SWOV Institute for Road Safety Research, Henri Faasdreef 312, 2492 JP, The Hague, the Netherlands

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ABSTRACT

Bicycle use increases in many cities around the world. In the Netherlands, cycling is one of the main transport modes in cities and bicycle use is still growing. This leads to crowded cycling infrastructure in cities with high cycling shares, including in the four largest Dutch cities. Since few studies have been done to the effects of high crowding levels on cyclists' route preferences and perceived safety, the present study aims to examine this for Dutch urban cyclists. Moreover, the relationship between perceived safety and route preferences is established. To investigate this, a questionnaire, including a route choice experiment, is completed by 1,329 cyclists from the four largest Dutch cities. The effects of varying crowding levels on route preferences and perceived safety are analysed with Mixed Logit models. Logistic regression is used to investigate the consistency between route preferences and perceived safety. The results show that crowding negatively affects route preferences as well as perceived safety, and that the impact is stronger for older cyclists and women. Furthermore, high crowding levels have a negative impact on the preference for and perception of safety of cycling infrastructure. Moreover, it is shown that all investigated route attributes have a significant effect on perceived safety, implying a more direct relationship between perceived safety and route preferences. In addition, the results show that most cyclists prefer routes they also perceive as safe. Concludingly, crowding seems an important issue for cyclists in large Dutch cities. Moreover, the perception of safety is likely to increase with the implementation of cycling infrastructure suitable for large flows of cyclists, leading to a safer cycling network for all types of cyclists.

1. Introduction

Cycling is often seen as a substitute for short distance car trips in urban areas. As such, it may help cities to decrease car use and become greener. Therefore, bicycle use increases as it is being promoted as a sustainable and healthy mode of transport. In the Netherlands, the bicycle is already one of the main transport modes for a long time and the country has the highest cycling level in the world (Goel et al., 2022). Moreover, the share of intra-urban trips made by bicycle keeps increasing from 2010 to 2019 in the four largest Dutch cities: Amsterdam (35 % to 40 %), Utrecht (39 % to 48 %), Rotterdam (21 % to 27 %), and The Hague (26 % to 32 %) (de Haas & Hamersma, 2020). Consequently, the cycling infrastructure in these cities becomes crowded, a phenomenon also observed in Copenhagen, Denmark, another cycling capital (Vedel et al., 2017).

* Corresponding author.

E-mail address: t.ujtdewilligen@utwente.nl (T. Uijtdewilligen).

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Although several studies showed that an increase in cycling levels may reduce bicycle crash risk, as shown as the safety-in-numbers effect (Elvik & Goel, 2019), hardly any studies investigated the impact of the relatively new phenomenon of crowding among cyclists on cyclists' route preferences and perceived safety. Vedel et al. (2017) showed that cyclists in Copenhagen are willing to make a detour to avoid high levels of crowding along their route. Similarly, studies in Dublin, Ireland and Nanjing, China show that cyclists prefer infrastructure with low levels of bicycle traffic (Caulfield et al., 2012; Li et al., 2012). Vedel et al. (2017) also briefly mention that crowding makes 82 % of the cyclists feel (very) unsafe. In terms of stress, Gadsby et al. (2021) found that cyclists in the Netherlands perceive other cyclists as an important stressor, although motorised vehicles are still the main source of stress.

The aim of this paper is twofold: 1) examining the impact of high crowding levels on cyclists' route preferences and perceived safety, and 2) investigating the impact of perceived safety on route preferences. Studies examining the effects of crowding on cyclists' route preferences and perceived safety are scarce and available studies have several limitations. For instance, the study by Vedel et al. (2017) only includes commuter cyclists; however, commuter cyclists are already most likely to encounter crowding along their route, making them more familiar with it. Therefore, it is necessary to include other types of cyclists such as older cyclists who might be more affected by crowding. Moreover, the effect of crowding on perceived safety is only briefly mentioned by Vedel et al. (2017) since the primary focus is on the impact of crowding on route preferences. Furthermore, cycling levels and infrastructure in both Dublin and Nanjing are not comparable to the Netherlands, which makes that the results are difficult to transfer to Dutch cities (Caulfield et al., 2012; Li et al., 2012). A drawback of most perceived safety studies is the exclusion of the impact of other cyclists. Most studies focus on the negative impact of traffic volume (e.g. Berghoefer & Vollrath, 2022, 2023; Manton et al., 2016; von Stülpnagel & Binnig, 2022), presumably because the cycling levels in the examined study areas are too low to have an impact on perceived safety. Lastly, studies in the field of cyclists' route preferences are unable to establish a direct link between perceived safety and route preferences. These studies only implicitly include perceived safety by mentioning the indirect effects of, for example, traffic volume, intersections and cycling infrastructure (Berghoefer & Vollrath, 2023; Sener et al., 2009; Zhu et al., 2017). To the authors' knowledge, this paper presents the first comprehensive analysis of the impact of crowding on cyclists' route preferences and perceived road safety, to address these knowledge gaps.

This paper describes the results of a route choice survey, including a choice experiment, among residents of the four largest cities in the Netherlands. In our study, a heterogeneous sample of over 1,300 cyclists in terms of socioeconomic and demographic characteristics is collected to examine the impact of crowding for a diverse group of cyclists, including older cyclists and commuters. Moreover, a perceived safety choice is added to the route choice experiment to examine the relationship between route preferences and perceived safety. Although crowding among cyclists is relatively rare in most of the cities outside of the Netherlands, the results are still relevant for urban policy makers since bicycle use is emerging in many cities all over the world. Furthermore, crowding is a subjective notion, meaning that some cyclists may perceive their routes as crowded even though cycling numbers are not very high; therefore, even low cycling levels may be perceived as crowded in less cycling-oriented countries. The findings of the present study can help policy makers to safely manage increasing cycling levels and counter problems of crowding on cycling routes.

2. Literature review

This section discusses the relationships between crowding and route preferences of cyclists as well as cyclists' perceptions of road safety. Moreover, it is outlined what the difficulties are in examining the relationship between perceived safety and route preferences. The section concludes with a description of the scope of this study.

2.1. The effect of crowding on cyclists' route preferences

Cyclists' route preferences have been studied before and several attributes are verified to affect these preferences. The most important attributes are cycling infrastructure, traffic volume, intersections, and travel time (Caulfield et al., 2012; Sener et al., 2009; Stinson & Bhat, 2003; van Overdijk et al., 2017; Vedel et al., 2017; Zhu et al., 2017). The effect of crowding on cyclists' route preferences, on the other hand, is examined in only a few studies, which is why this section specifically focusses on this relationship. One study in this regard is carried out in Dublin, Ireland. A stated preference survey is applied to determine bicycle infrastructure preferences. One of the attributes in the choice experiment includes the amount of bicycle traffic on the route. The findings show a slight preference for lower levels of bicycle traffic along the route in general for all cyclists. It is also shown that males have a stronger preference for lower levels of bicycle traffic than females. Moreover, the utility of a route with low levels of bicycle traffic is higher for unconfident cyclists compared to confident cyclists (Caulfield et al., 2012). In Copenhagen, Denmark, it is shown in a stated preference study that crowding has a negative impact on the utility of a route. To avoid high levels of crowding, cyclists are willing to take a detour of 1.03 km. For females, this distance is even larger (1.53 km) (Vedel et al., 2017), which is contradictory with the results in Dublin.

Li et al. (2012) investigated cyclists' perception of comfort on separated and on-street cycling facilities when cycling with low and high levels of bicycle traffic exposure. It is shown that separated cycling facilities provide more comfort than on-street cycling facilities when bicycle traffic exposure is low. Conversely, with high bicycle traffic exposure levels, on-street cycling facilities are more comfortable. Presumably, there is not enough space on separated cycling facilities when there are high numbers of cyclists, decreasing the perception of comfort.

2.2. Cyclists' perceptions of road safety

The perception of safety is also related to the perception of crowding. In Copenhagen, for example, 82 % of the cyclists feel (very)

unsafe as a result of crowding on bicycle tracks (Vedel et al., 2017). Moreover, numerous studies found that one of the major concerns of cyclists is high motorised traffic volumes, followed by high traffic speeds and, to a lower extent, parked cars along the route (e.g. Berghoefer & Vollrath, 2022; Chen et al., 2018; Desjardins et al., 2021; Lawson et al., 2013; Manton et al., 2016; Parkin et al., 2007; Rossetti et al., 2018; von Stülpnagel & Binnig, 2022; von Stülpnagel et al., 2022; Zhu et al., 2017). On the other hand, type of cycling infrastructure positively affects the safety perception, where separated bicycle tracks are perceived as the most safe, followed by bicycle lanes and bicycle priority streets¹ (Berghoefer & Vollrath, 2022; Branion-Calles et al., 2019; Chen et al., 2018; Desjardins et al., 2021; Parkin et al., 2007; Rossetti et al., 2018; von Stülpnagel & Binnig, 2022; von Stülpnagel et al., 2022; Zhu et al., 2017). Also, the width of the cycling infrastructure and whether it has coloured pavement plays a role in perceptions of safety (Rossetti et al., 2018; von Stülpnagel & Binnig, 2022).

Individual characteristics are also found to play a role in safety perception. In contrast to Branion-Calles et al. (2019), both Lawson et al. (2013) and von Stülpnagel and Binnig (2022) found that older cyclists are more likely to perceive cycling as safe compared to younger cyclists. They argue that this may be explained by older cyclists having more experience than younger cyclists. Males perceive cycling as safer compared to females and the same goes for cyclists without children relative to cyclists with children (Branion-Calles et al., 2019; von Stülpnagel & Binnig, 2022). It is worth mentioning that perceived safety does not always align with the objective safety. For example, von Stülpnagel et al. (2022) found some discrepancies between objective risk and perceived risk in Munich, Germany. This illustrates that cyclists are sometimes unaware of the actual crash risk at specific places in the urban cycling network. Moreover, in a study by Shah and Cherry (2021), it is shown that cyclists avoid historic crash locations on their route. It is assumed that cyclists are aware of the locations of historic crashes or that they perceive more risk at such locations. In addition, it is found that regular cyclists took a longer detour to avoid such locations compared to occasional cyclists. This could be a result of regular cyclists being more aware of risky locations and being more aware of suitable detours.

2.3. The relationship between safety and route preferences

Existing studies have difficulties indicating a direct link between perceived safety and route choice of cyclists. In most studies, safety is argued to be an indirect factor resulting from other route attributes (e.g. Berghoefer & Vollrath, 2023; Sener et al., 2009; Zhu et al., 2017). Safety is therefore not explicitly included as an attribute in route choice experiments for cyclists, presumably because it is difficult to conceptualise perceived safety as an attribute. Another method to implement perceived safety of cyclists in a choice model is to construct a latent variable for perceived safety. For example, a study in Santiago, Chile constructed such a latent variable by letting respondents rate the safety of one of the alternatives in the choice experiment. The result of including this perceived safety latent variable in the choice model shows that cyclists prefer to ride on streets where they feel safer. Moreover, this perception of safety is positively related to cycling on streets with cycling infrastructure, especially when this infrastructure separates cyclists from motorised traffic and where this infrastructure is wide. Cyclists feel also safer where speed limits are lower and on streets without public transport lines (Rossetti et al., 2018).

Some studies examining the route choice of car drivers directly included safety as an attribute in the choice experiment (e.g. Flügel et al., 2019; Rizzi et al., 2003). Such studies examine the preference for safer routes or the willingness-to-pay to decrease the number of casualties on a route. The safety attribute is then defined as the number of (serious) road crashes per year occurring on a specific alternative. However, it may be questioned how reliable this approach is, since it may be unrealistic to have such a number of road casualties per year on a specific route and road users may not be aware of these crash numbers when travelling as outlined in Section 2.2. Furthermore, the levels of the safety attribute seem to be arbitrary established and sometimes exaggerated.

2.4. Scope of the present study

This section showed that, to date, the effect of crowding on cyclists' route preferences received little attention in the literature. Similarly, studies examining the impact of crowding on cyclists' perceived safety are scarce. The present study tries to fill these gaps by adding crowding as an attribute to a route choice experiment and investigating the effect of crowded cycling routes on perceived safety. Moreover, most existing studies only established an indirect link between perceived safety and route preferences. This paper, therefore, tries to verify the impact of crowding and other route attributes (i.e. cycling infrastructure, traffic volume, intersections, and travel time) on perceived safety. However, since conceptualising (perceived) safety as an attribute in a route choice experiment seems difficult or unrealistic, the present study integrates a perceived safety choice into the route choice experiment by letting respondents make two choices. One choice for the preferred route and one choice for the safest route. Both choices are analysed in separate models in order to compare the similarities between the attributes and to verify the effect of the route attributes on perceived safety. Lastly, it is shown how many cyclists actually prefer the safest route and what the characteristics of these cyclists are. Fig. 2.1 shows a schematic overview of the scope of this study as described in this section.

¹ Bicycle priority streets in the Netherlands are a special type of access road, designed for large flows of cyclists and functioning as important connection for cyclists. Car traffic is allowed, but to a limited extent, at low speeds, and they are inferior to cyclists.

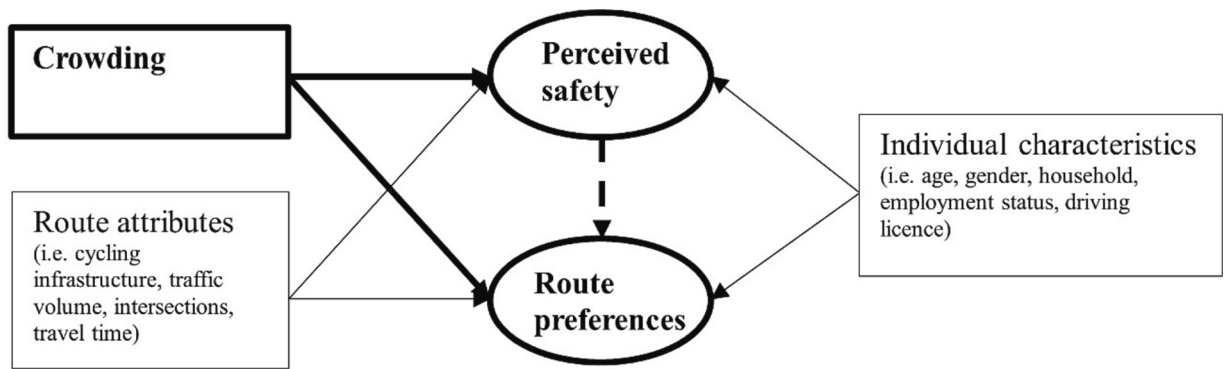


Fig. 2.1. Schematic overview for the effects of crowding on route preferences and perceived safety and the potential relationship between perceived safety and route preferences. Bold arrows and shapes illustrate the scope of the study; the dashed arrow implies a presumed relationship.

3. Data and methods

3.1. Survey design and data collection

To collect data regarding cyclists’ perceptions, an online questionnaire was developed using *LimeSurvey*. A panel company was used to recruit the respondents. Respondents were invited to participate in the questionnaire when they live in the selected postcode areas in the four largest Dutch cities (Amsterdam, Utrecht, Rotterdam, and The Hague), or in adjacent agglomerations, and when they use a bicycle at least three times per month. The survey consists of five sections: characteristics of the most frequent cycling route, the perception of crowding on this route, the perception of road safety on this route, a route choice experiment (described in Section 3.2), and personal characteristics. Most questions were validated in previous surveys. In the first three sections, respondents had to describe the cycling route they most frequently take. To prevent respondents describing a very short route with a low chance of experiencing crowding, the respondents were asked to choose a destination which is at least 1 km further away from their home address. The last section contains general questions about personal characteristics and general travel behaviour, which helped to compare results with the Dutch National Travel Survey (ODiN) (Statistics Netherlands (CBS), 2022). To provide representativeness, the responses were monitored and recruitment was adapted to provide that the distribution of the sample is similar to socioeconomic and demographic characteristics of ODiN. The full survey, including the route choice experiment, was pretested internally by ten people and in a pilot study with a randomly selected sample of 33 panel members.

3.2. Choice experiment design

The choice experiment consists of five attributes (Table 3.1) which, according to existing literature, are assumed to impact cyclists’ route preferences and the perception of safety. All attributes have three levels, except the cycling infrastructure attribute which has four levels. The infrastructure types which are the most common types of cycling infrastructure in the Netherlands are used. Some combinations of attribute levels are omitted since it is very unlikely to coincide with them in reality (e.g. bicycle priority streets with high traffic volumes).

Table 3.1
The attributes, levels and descriptions of the levels in the choice experiment.

Attributes	Levels	Description
Crowding among cyclists	Low	Almost no other cyclists on this route
	Medium	A reasonable number of cyclists on this route
	High	A lot of other cyclists on this route
Cycling infrastructure	Mixed traffic conditions	
	Separated bicycle tracks	
	Bicycle lanes	
	Bicycle priority streets	
Traffic volume	Low	Nearly no cars around you
	Medium	A passing car every now and then
	High	A lot of cars around you
Intersections	Low	3 or less intersections, you do not have to stop
	Medium	4–6 intersections, you have to give way sometimes
	High	More than 6 intersections, including traffic lights where you have to wait
Travel time	Shorter	25 % shorter than your current route
	Same	The same travel time as your current route
	Longer	25 % longer than your current route

An efficient design approach is utilised since such designs are robust and collect (nearly) maximum information. Moreover, efficient designs are flexible in a sense that it is possible to remove unrealistic attribute level combinations, which is useful in the case of our study to omit such combinations. Efficient designs heavily rely on prior knowledge about the expected choice probabilities, which are determined by the priors, being estimated approximations of the unknown parameter values. This is also the disadvantage of this design approach since the efficiency is sensitive to these priors. Priors can be noninformative and informative (Bliemer & Rose, 2024). In the present study, informative priors are used based on prior knowledge gathered from existing studies that also examine route preferences of cyclists and that used similar attributes (Bovy & Bradley, 1985; Caulfield et al., 2012; Gleave, 2012; Hardinghaus & Papantoniou, 2020; Sener et al., 2009; Stinson & Bhat, 2003; van Overdijk et al., 2017; Vedel et al., 2017; Zhu et al., 2017).

The priors can be set as point estimates or as a probability distribution using an interval. The latter are referred to as Bayesian priors, which are preferred since they are more robust than fixed values (Bliemer & Rose, 2024; Traets et al., 2020). The present study uses Bayesian priors for which the intervals are estimated based on the coefficients of the existing studies. These intervals are expected to contain the estimated coefficients in this study. To quantify the intervals, the mean parameter values of the prior coefficients are used and are assumed to be normally distributed. The interval is based on the variance of these mean parameter values. Wider variances lead to more robust designs, while narrower variances lead to more informative designs (Traets et al., 2020). The present study uses a semi-informative design, where the variance (i.e., the interval) is calculated as two times the standard deviation from the normalised mean values. To optimise the design, the mean DB-error is minimised. A modified Fedorov algorithm is used to calculate the DB-error. Compared to informed designs (smaller variance) and uninformed (greater variance), the semi-informative design for a multinomial logit model gave the lowest DB-error (1.450). The choice experiment is designed with the *idefix* package in R (Traets et al., 2020).

The final design has 13 choice tasks, which are presented in a random order to the respondents. Moreover, the literature review showed it is difficult to conceptualise perceived safety as an attribute directly in the choice experiment. Therefore, the respondents are asked to make two choices per task: 1) the route alternative they prefer, and 2) choosing which route they think is the safest. A “None of these” option is added, which implies none of the route alternatives is preferred or they have similar perceived safety levels. A picture is used to visualise the cycling infrastructure attribute, which is filled with symbols of cyclists (conventional, e-bikes, and cargo-bikes) and cars to show the level of crowding and traffic volume (Fig. 3.1). The Appendix shows a full overview of the choice tasks and a distribution of the choices made by the cyclists. The following introduction is presented to the respondents before the choice experiment started:

The following points are important for the next 13 tasks

- Assume you are taking a **new route** to your just specified most visited destination.
- Every task shows two routes that vary on a few characteristics, which are present on a large share of that route.
- Indicate which **route** you **prefer**.
- Also indicate which **route** is the **safest**.
- If you would choose none of these routes you can click “None of these”.

You are taking this route on a sunny day in September. It is 20 degrees and hardly any wind.

3.3. Methods

3.3.1. Modelling route preferences and safety perceptions of route attributes

To analyse data from stated choice experiments, Random Utility Models (RUM) are widely applied. A model that allows for random taste heterogeneity is the Mixed Logit model. The probabilities of this model are the integral of standard logit probabilities over a density of probabilities (Train, 2009). Since there are multiple choice tasks per cyclist, the data is structured as panel data that allows for correlations over choice tasks per cyclist. In other words, preference varies over cyclists, but remains constant over choice tasks. Let β_n be a vector of the true, but unobserved taste parameters for cyclist n . It is assumed that β_n is *independent and identically distributed* (i.i.d.) over cyclists with density $g(\beta|\Omega)$, where Ω is a vector of parameters of this distribution, the mean μ and standard deviation σ . If $j_{n,t}^*$ is the chosen alternative by cyclist n in choice situation t , then $P_n(\Omega)$ gives the probability of the observed choices for cyclist n , conditional on β . The Mixed Logit probability of the sequence of choices for cyclist n is then given by (Hess & Train, 2011):

$$P_n(\Omega) = \int_{\beta} \prod_{t=1}^{T_n} P_{n,t}(j_{n,t}^*|\beta) g(\beta|\Omega) d\beta \quad (1)$$

Please choose which route you will most likely take and which one you think is the safest.



	Route A	Route B	None of these
			
Crowding among cyclists	Almost no other cyclists on this route	A reasonable number of cyclists on this route	
Cycling infrastructure	Mixed traffic conditions	Bicycle lanes	
Number of cars on the road	A passing car every now and then	A lot of cars around you	
Intersections	4-6 intersections, you have to give way sometimes	3 or less intersections, you do not have to stop	
Travel time	The same as your current route	25% shorter than your current route	
Your route choice:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safest route:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 3.1. Example of a choice task (translated from Dutch).

In the route preference model, all parameters are assumed to be normally distributed, except travel time which is assumed to be negative log-normally distributed. Moreover, only high crowding levels, separated bicycle tracks, bicycle lanes, and travel time are identified to have random parameters. In the perceived safety model, all parameters are assumed to be normally distributed. Furthermore, high crowding levels, separated bicycle tracks, bicycle lanes, bicycle priority streets, and low traffic volumes are identified to have random parameters.

The utility Eq. (2) and safety Eq. (3) of route j ($j = A, B, None$) for cyclist n ($n = 1, \dots, N$) in choice task t ($t = 1, \dots, T$) are specified as follows:

$$V_{n,j,t} = \delta_j + \beta_n \text{Crowding}_{n,j,t} + \beta_n \text{Infrastructure}_{n,j,t} + \beta_n \text{Traffic}_{n,j,t} + \beta_n \text{Intersections}_{n,j,t} + \beta_n \text{Travel time}_{n,j,t} (\gamma_n \text{Commute}_n) + \text{Age}_n (\beta_n \text{Crowding}_{n,j,t}) + \text{Women}_n (\beta_n \text{Crowding}_{n,j,t}) + \text{Crowding}_{n,j,t} (\beta_n \text{Infrastructure}_{n,j,t}) \quad (2)$$

$$V_{n,j,t} = \delta_j + \beta_n \text{Crowding}_{n,j,t} + \beta_n \text{Infrastructure}_{n,j,t} + \beta_n \text{Traffic}_{n,j,t} + \beta_n \text{Intersections}_{n,j,t} + \beta_n \text{Travel time}_{n,j,t} + \text{Age}_n (\beta_n \text{Crowding}_{n,j,t}) + \text{Women}_n (\beta_n \text{Crowding}_{n,j,t}) + \text{Crowding}_{n,j,t} (\beta_n \text{Infrastructure}_{n,j,t}), \quad (3)$$

where the attributes are defined in Table 3.1 and δ_j are alternative specific constants (ASC) to account for left-right bias, with δ_B set to zero for normalisation. Both δ_A and δ_{None} are identified as random parameters. The ‘None of these’ option is an empty alternative with only an ASC. The current travel time of the most frequent route of the respondents is used to transform the travel time attribute into a continuous variable. Moreover, in the route preference model, a deterministic multiplier is added to travel time to allow for preference heterogeneity between commuter and non-commuter cyclists. Age groups (35–64, and 65 + years, with 18–34 years as reference) and women (compared to men and other genders) interact with high crowding and are included as dummy variables; the crowding attribute interacts with the cycling infrastructure attribute. The models are estimated by simulated maximum likelihood, taking 2,000 MLHS (Hess et al., 2006) random draws of the posterior distribution of each parameter for each cyclist. The resulting estimates are the mean and standard deviation of these draws from the posterior. The R package *Apollo* is used to estimate the models (Hess & Palma, 2019).

3.3.2. Analysing consistency between route preferences and perceived safety

Since respondents are asked to make two choices, one about route preferences and one about perceived safety, the consistency between these choices can be analysed. For this purpose, a binary dependent variable is used that specifies whether the route choice and perceived safety choice coincide, with 1 being coinciding choices and 0 being inconsistent choices. The predictor variables are personal characteristics. Since the dependent variable is binary, logistic regression can be applied to estimate the probability that cyclists choose the route they also perceive as safer compared to an alternative route. The parameters are estimated using maximum likelihood estimation. Please refer to Hosmer and Lemeshow (2000) for more details about logistic regression.

4. Sample characteristics

After cleaning the data, 1,329 respondents completed the full survey, leading to 17,277 completed choice tasks. Table 4.1 presents the socioeconomic and demographic characteristics as well as trip characteristics of the respondents. The sample is also compared with the weighted sample of a representative Dutch National Travel Survey (ODiN) (Statistics Netherlands (CBS), 2022). In the ODiN data,

Table 4.1

Descriptive statistics of the sample compared to a representative longitudinal Dutch travel behaviour study.

Variable	Categories	Sample		ODiN		
		N	%	N	N (weighted)	% (weighted)
	Total	1,329	100.0	7,594	1,742,143	100.0
Age	18–34 years	481	36.2	2,795	664,099	38.1
	35–64 years	645	48.5	3,626	848,907	48.7
	65 + years	203	15.3	1,173	229,137	13.2
Gender	Women	694	52.2	3,712	859,483	49.3
	Men	623	46.9	3,882	882,660	50.7
Household composition	Other/prefer not to say	12	0.9	–	–	–
	Single	430	32.3	2,060	534,829	30.7
	Couple	416	31.3	2,543	507,717	29.1
	Couple + child(ren)	377	28.4	2,414	543,422	31.2
	Single-parent family	75	5.6	387	104,307	6.0
Employment status	Other	31	2.3	190	51,868	3.0
	Employed	910	68.5	5,027	1,156,352	66.4
	Occupational disability	40	3.0	151	46,970	2.7
	Unemployed	44	3.3	166	45,231	2.6
	Retired	173	13.0	1,039	202,981	11.7
	Student/school-going	84	6.3	728	163,618	9.4
	Housewife/houseman/other	50	3.8	360	97,448	5.6
	Volunteer work	5	0.4	123	29,543	1.7
Driving licence	Prefer not to say	23	1.7	0	0	0.0
	Yes	1,053	79.2	5,973	1,227,778	70.5
Net income per month*	No	276	20.8	1,621	514,365	29.5
	Less than 1,500 euro	178	13.4	–	–	–
	1,501 – 2,500 euro	344	25.9	–	–	–
	2,501 – 3,500 euro	346	26.0	–	–	–
	More than 3,500 euro	266	20.0	–	–	–
Trip frequency	Prefer not to say	165	12.4	–	–	–
	4 days or more per week	462	34.8	–	–	–
	1–3 days per week	594	44.7	–	–	–
Trip purpose	1–3 days per month	273	20.5	–	–	–
	To/from work	503	37.8	–	–	–
	To/from school/study/course	124	9.3	–	–	–
	Business (as part of your job)	53	4.0	–	–	–
	Visit friends/family/other relatives	143	10.8	–	–	–
	Shopping/doing groceries	269	20.2	–	–	–
	Going out, to/from sports, for a hobby	102	7.7	–	–	–
	Recreation (the route is the purpose)	57	4.3	–	–	–
Type of bicycle	Physical activity (sporting)	40	3.0	–	–	–
	Other	38	2.9	–	–	–
	Conventional bicycle	874	65.8	–	–	–
	E-bike (max. 25 km/h)	332	25.0	–	–	–
	Racing bicycle	31	2.3	–	–	–
Travel time	Mountain bike	56	4.2	–	–	–
	(E-)cargo bicycle	19	1.4	–	–	–
	Speed pedelec (max. 45 km/h)	4	0.3	–	–	–
		Min	Max	Mean	Median	
	Travel time current route	1	70	20.79	20	

*The question does not specify household or individual income.

respondents from the same municipalities as the present study are selected, as well as people aged above 17 that use a bicycle, e-bike, or speed pedelec at least a few times per month.

In terms of age, gender, household composition, and possession of a driving license, the distribution of our sample is nearly similar to the weighted ODiN sample. It is not possible to compare the distribution of income, since ODiN uses a different representation of the income classes. Instead of income, employment status can be compared and it is shown that the distribution is similar to ODiN. Because of the similarities between the distribution of the personal characteristics in the sample of the present study and the weighted sample of ODiN, it is chosen not to weigh our sample. For the trip characteristics, around 80 % of the respondents uses their most frequently cycled route multiple days per week. Furthermore, 37.8 % of the respondents use their most frequent route for commuting. Lastly, most cyclists use a conventional bicycle for their route (65.8 %), followed by e-bikes (25.0 %).

5. Results and discussion

5.1. Descriptive summary of perceived crowding on current route

Before starting the route choice experiment, respondents had to answer questions about crowding on their current most frequently

Table 5.1
Perception of crowding on current route.

Variable	Categories	N	%
Crowding on current route (N = 1,329)	1 – Totally not crowded	123	9.3
	2	262	19.7
	3	543	40.9
	4	299	22.5
	5 – Very crowded	102	7.7
Parts of route that are crowded (N = 1,206)	No crowding	223	18.5
	Some roads	702	58.2
	A lot of roads	227	18.8
	The whole route	54	4.5
Cycling infrastructure on which crowding is most experienced (N = 983)	Separated bicycle track	334	34.0
	Bicycle lane	393	40.0
	Bicycle priority street	70	7.1
Crowding experienced as problem (N = 983)	Mixed traffic conditions	186	18.9
	1 – Totally no problem	96	9.8
	2	221	22.5
	3	445	45.3
	4	180	18.3
	5 – A very big problem	41	4.2

cycled route. The answers to these questions are relevant to explain the results from the choice experiment. Table 5.1 shows how many cyclists (90.7 %) perceive some extent of crowding on their current route. From this share of cyclists, 82.5 % experiences crowding at least at some roads of their current route. These cyclists are also asked at what type of cycling infrastructure crowding is most experienced. Most cyclists experience crowding at bicycle lanes (40.0 %), followed by separated bicycle tracks (34.0 %). Lastly, the group of cyclists that experience crowding at least at some roads of the route is asked to what extent they perceive crowding as a problem. More than two thirds of these cyclists (67.8 %) perceive crowding as a problem to some extent (≥ 3).

5.2. Route preferences and safety perceptions of cyclists

To examine the impact of crowding on route preferences and the perception of safety, two Mixed Logit models with interaction terms are used (Table 5.2). The ASC for Route A is included to account for possible left–right bias. The “None of these” option is an empty alternative with only an ASC and is chosen 617 times (3.57 %) for the route preferences and 719 times (4.16 %) for perceived safety. The Appendix shows the full distribution of choices per choice task. Since the travel time parameter is negative log-normally distributed in the route preference model, the estimated mean and standard deviation are the log of these parameters. These are difficult to interpret; therefore, the estimated parameters of the underlying normal distribution are also presented. Fig. 5.1 is added for better comparison of the two models and shows that most parameters point in the same direction across the models, with only some slight differences in magnitude. The figure also shows the true values of the variables with interactions for better interpretation of these relationships.

5.2.1. Effects of crowding on route preferences and perceived safety

The results show a significant decrease in the utility of a route when this route is crowded, both with medium and high levels of crowding. This is expected since both in Dublin and in Copenhagen it was shown that crowded routes (i.e. high levels of cyclists on the road) have a higher disutility (Caulfield et al., 2012; Vedel et al., 2017); although, the difference in preference between high and low bicycle volumes in Dublin is relatively small. However, note that only the cycling levels in Copenhagen are comparable to the Dutch situation. The perceived safety model shows that crowding also has a negative impact on perceptions of safety, with similar coefficient magnitudes as in the route preference model. Similarly, Gadsby et al. (2021) showed that one of the main stressors for cyclists in Delft, the Netherlands are other cyclists, following the presence of motorised vehicles in the list. This might be caused by the increased number of interactions, as found by Berghoefer and Vollrath (2022). The indicated negative impact of crowding on perceived safety of cyclists may seem as a contradiction with the safety-in-numbers effect (Elvik & Goel, 2019); however, note that safety-in-numbers effect is an objective notion mostly based on motorised-vehicle interactions. It is also debatable how relevant a safety-in-numbers effect is in a country where cycling infrastructure is widely implemented and where car drivers are already aware of large numbers of cyclists for a long time (Schepers et al., 2017; Wegman et al., 2012).

To explain the heterogeneity in preferences and perceptions of safety associated with high levels of crowding, interaction terms are included. These interaction terms provide a clearer understanding of which cyclists are most affected by crowding. While several interactions were tested, only a few are statistically significant and are shown in the results table. Older age groups have a significantly higher disutility and decreased perceived safety of high levels of crowding compared to the youngest age group (18–34 years). Presumably, older cyclists are more safety conscious than younger cyclists and are therefore more affected by crowding. Moreover, it is shown that for the age group 18–34 years, 71 % of the distribution is below zero, while for 35–64 years this is 78–83 % and for 65 + this is 89–92 % (Fig. 5.2). This implies that the older a cyclist is, the higher the disutility and the lower the perceived safety of a route when there are high levels of crowding. For women, also a significantly higher disutility and decreased perceived safety of crowding is observed compared to men and other genders. It is shown that for women 93–96 % of the distribution is below zero, while for men and

Table 5.2
Mixed Logit models with interactions for route preferences and safety perceptions of cyclists in large Dutch cities.

Variables	Route preferences			Perceived safety					
		Est.	S.E.	t-ratio	Est.	S.E.	t-ratio		
ASC	Route A	μ	-0.408***	0.07	-5.74	μ	-0.416***	0.07	-5.91
		σ	0.484***	0.03	-14.81	σ	-0.584***	0.03	-17.94
	Route B		-	-		-	-	-	-
None		μ	-9.367***	0.44	-21.19	μ	-4.369***	0.22	-20.09
		σ	-5.263***	0.33	-15.80	σ	-2.680***	0.14	-19.23
	Low		-	-		-	-	-	-
Crowding	Medium		-1.070***	0.09	-11.78		-0.873***	0.09	-10.12
		μ	-0.096***	0.03	-3.72	μ	-0.095***	0.03	-3.58
	High	σ	-0.516***	0.05	-11.26	σ	-0.677***	0.05	-14.41
Interactions with high crowding	* age (18–34)		-	-		-	-	-	-
	* age (35–64)		-0.214***	0.06	-3.38		-0.159*	0.07	-2.23
	* age (65 +)		-0.430***	0.09	-4.82		-0.482***	0.10	-4.73
	* men + other * women		-0.189**	0.06	-3.24		-0.271***	0.07	-4.11
Cycling infrastructure (incl. interactions with high crowding)	Mixed traffic conditions		-	-		-	-	-	-
	Separated bicycle tracks	μ	1.032***	0.06	17.67	μ	1.192***	0.06	20.43
		σ	-0.772***	0.05	-14.64	σ	1.129***	0.06	19.45
	* crowding (low + med)		-	-		-	-	-	-
	* crowding (high)		-1.141***	0.26	-4.33		-0.855***	0.25	-3.46
	Bicycle lanes	μ	0.390***	0.03	11.57	μ	0.413***	0.03	12.79
		σ	-0.478***	0.05	-9.21	σ	0.642***	0.05	12.98
	* crowding (low + med)		-	-		-	-	-	-
	* crowding (high)		-0.389*	0.15	-2.56		-0.380*	0.15	-2.52
	Bicycle priority streets	μ	0.579***	0.06	10.20	μ	0.599***	0.05	11.01
σ		-	-	-	σ	-0.495***	0.09	-5.27	
* crowding (low + med)		-	-		-	-	-	-	
* crowding (high)		-0.753***	0.21	-3.53		-0.812***	0.20	-4.02	
Traffic volume	Low	μ	0.666***	0.07	10.02	μ	0.899***	0.07	13.44
		σ	-	-	-	σ	0.416***	0.07	6.27
	Medium		0.762***	0.05	13.75		0.806***	0.05	15.35
Intersections	High		-	-		-	-	-	-
	Low		0.409***	0.03	12.45		0.298***	0.03	8.96
	Medium		0.184**	0.06	3.24		0.160**	0.05	2.92
Travel time	-Log-normal	μ	-3.403***	0.12	-27.24		-0.013***	0.00	-4.50
		σ	-1.435***	0.06	-24.36		-	-	-
	Underlying normal	μ	-0.093***	0.01	-11.35		-	-	-
		σ	0.244***	0.03	8.70		-	-	-
	Commute	γ	-1.536***	0.18	-8.36		-	-	-
Simulated Log Likelihood at convergence			-11,622			-11,533			
No. of individuals/choice tasks			1,329/17,277			1,329/17,277			
Adj. rho-squared			0.386			0.391			
AIC			23,294			23,116			

*** p < 0.001.

** p < 0.01.

*p < 0.05.

Note: Est. = Estimate; S.E. = Standard error.

other genders this is 86–92 % (Fig. 5.2). Also in Copenhagen routes with high levels of crowding have a higher disutility for females compared to males (Vedel et al., 2017).

In addition, crowding has a significant impact on the preference for and safety perception of **cycling infrastructure**. The results show a strong preference for separated bicycle tracks relative to mixed traffic conditions, as previous studies also found (Vedel et al., 2017; Zhu et al., 2017), and an even higher perception of safety. However, this is only the case when separated bicycle tracks have low or medium crowding levels. With high crowding levels on separated bicycle tracks, the utility of a route decreases. In terms of safety, separated bicycle tracks are still perceived as safer than mixed traffic conditions when there are high crowding levels, but the magnitude decreased compared to low and medium crowding levels. Moreover, it is also shown that 85–91 % of the cyclists prefer and feel safer on separated bicycle tracks with low and medium crowding levels, while for high crowding levels this decreased to 44–62 % (Fig. 5.2). Similarly, the study by Li et al. (2012) showed that separated bicycle tracks are perceived as less comfortable than on-street cycling facilities with high levels of bicycle traffic exposure. It could be argued that some separated bicycle tracks are too narrow when it is crowded and that cyclists therefore prefer mixed traffic conditions since these provide more space.

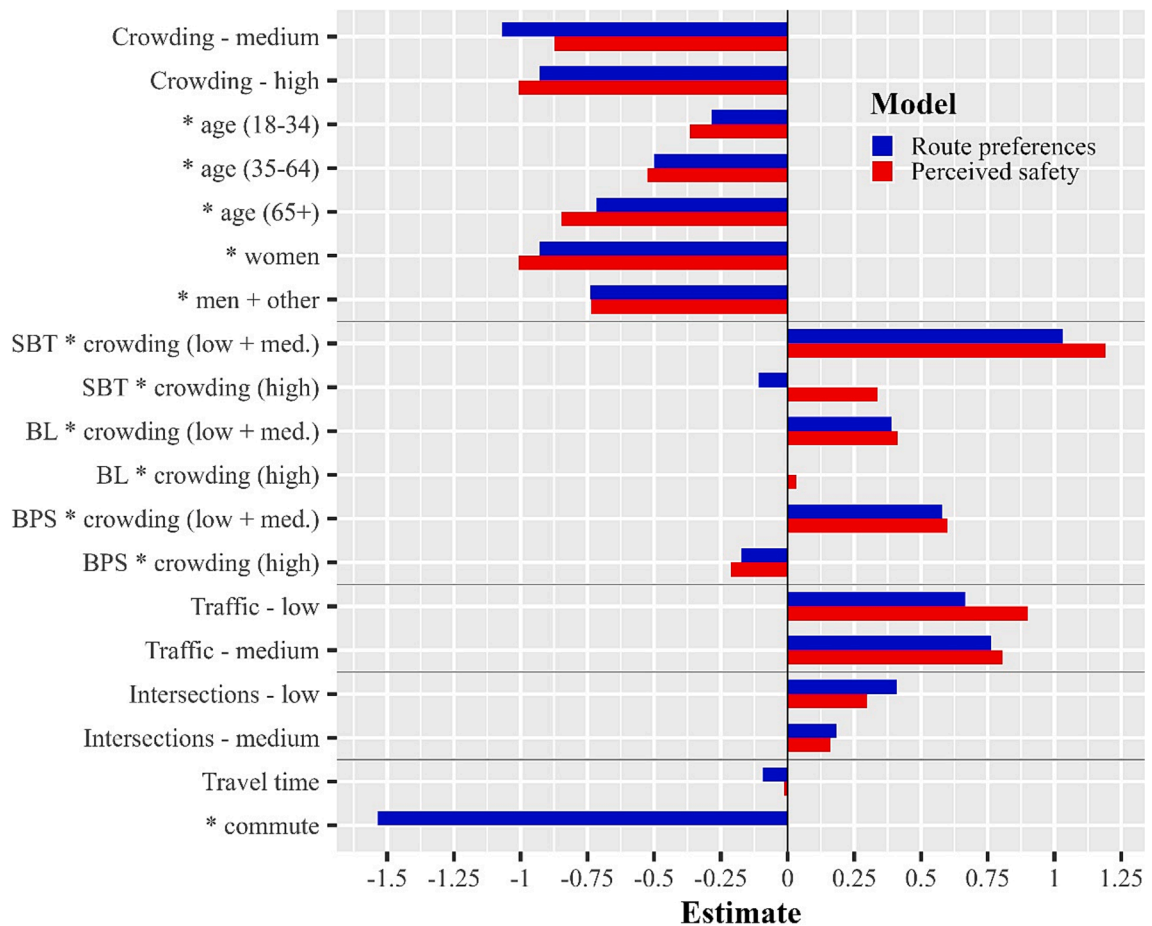


Fig. 5.1. Comparison of the estimates of the route preference and perceived safety model, including the true parameter estimates of the variables with interactions. SBT = Separated bicycle tracks; med. = medium; BL = Bicycle lanes; BPS = Bicycle priority streets.

Moreover, like in the study by [van Overdijk et al. \(2017\)](#), bicycle lanes increase the utility of a route with low or medium levels of crowding, but to a lower extent than separated bicycle tracks. Similar results are found for the perceived safety of bicycle lanes. When there is high crowding nearly no difference is found with mixed traffic conditions. Around 74–79 % of the cyclists prefer bicycle lanes over mixed traffic conditions and perceive them as safer with low and medium crowding levels, with high crowding levels this is 50–52 % ([Fig. 5.2](#)). Similarly, [von Stülpnagel and Binnig \(2022\)](#) found that cyclists in Berlin, Germany perceive both separated bicycle tracks and bicycle lanes as safer than roads with mixed traffic conditions, with the highest level of perceived safety on separated bicycle tracks.

Lastly, bicycle priority streets increase the utility of a route compared to mixed traffic conditions when there are low or medium levels of crowding. In terms of perceived safety, it is shown that 89 % of the cyclists feels safer on bicycle priority streets than on road with mixed traffic conditions when crowding levels are low or medium ([Fig. 5.2](#)). When it is crowded, however, only 33 % of the cyclists feel safer. It is noteworthy that, despite this type of cycling infrastructure being designed to handle large flows of cyclists, two third of the cyclists feels less safe on bicycle priority streets relative to mixed traffic conditions. In [von Stülpnagel et al. \(2022\)](#), similar findings for bicycle priority streets (named cycling boulevards in that study) are presented, although when correcting for cycling volumes subjective risk is much lower relative to mixed traffic conditions.

5.2.2. Other factors that impact route preferences and perceived safety

Cyclists prefer routes with low and medium **traffic volumes** over routes with high traffic volumes and perceive them as safer. In other words, lower traffic volumes increase the utility and perception of safety of a route. Only for low traffic volumes in the perceived safety model significant preference heterogeneity is found, the others are therefore treated as non-random parameters. Other route preference studies show similar results, with the highest preference for low traffic volumes ([Sener et al., 2009](#); [Zhu et al., 2017](#)). Also in terms of perceived safety, existing studies show that motorised vehicles are one of the major concerns for cyclists ([Gadsby et al., 2021](#); [Parkin et al., 2007](#)).

For **intersections**, it is shown that cyclists significantly prefer a low number of stops along their route compared to a high number of stops, also in terms of perceived safety. A medium number of stops is also acceptable since the parameters of medium number of

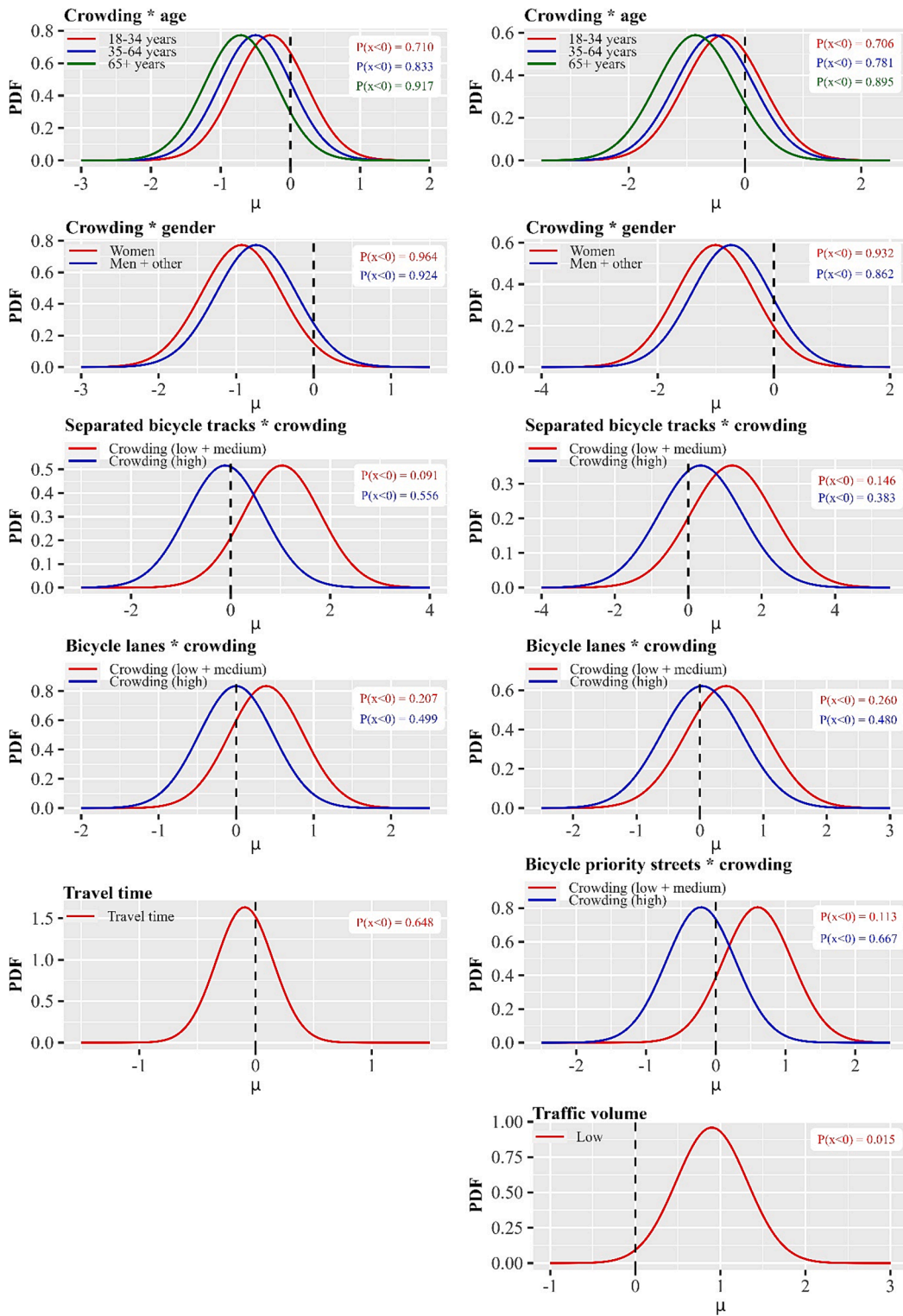


Fig. 5.2. The probability of normally distributed random parameters to be below zero. The left pane are parameters from the route preference model, the right pane from the perceived safety model.

intersections are significant, but lower than for low number of intersections. No heterogeneity in the population is found for the number of intersections. Similar results about intersections, or the number of stops, are found in other studies (Caulfield et al., 2012; van Overdijk et al., 2017; Vedel et al., 2017). Moreover, the results might be explained by studies showing that intersections increase the waiting time and are perceived as less safe than road sections (Shin, 2016; Wang & Akar, 2018).

Lastly, **travel time** is a significant negative parameter. This implies that cyclists prefer shorter routes and that a higher travel time leads to a higher disutility of a route. However, there is relatively high preference heterogeneity, since only 65 % of the distribution is below zero (Fig. 5.2). Presumably, these are mostly the commuter cyclists, as it is shown that travel time has a stronger negative impact on the utility of a route for commuters compared to non-commuter cyclists. This implies that the utility of a route for cyclists with more time dependent trip purposes is more affected by travel time compared to cyclists with less time dependent trip purposes (e.g. leisure trips) (Zhu et al., 2017). Both Berghoef and Vollrath (2023) and Stinson and Bhat (2003) also indicate that travel time is an important factor in route preferences of commuter cyclists.

5.3. Consistency between route preferences and perceived safety

In Section 5.2 it is shown that the route attributes affect route preferences and perceived safe in a similar way. For example, high levels of crowding have a negative impact on the utility of a route as well as it has negative consequences for perceptions of safety. Consequently, in 72.5 % of the cases cyclists prefer a route they also perceive as the safest route. Here, consistency between route preferences and perceived safety is observed, implying that nearly three quarter of the cyclists take safety into account when choosing a route. Conversely, more than a quarter (27.5 %) of the cyclists achieves a higher utility from a route based on attributes less related to perceived safety. Presumably, these cyclists have a stronger preference for shorter travel times rather than for attributes contributing to the safety of routes. To examine which cyclists prefer the routes they also perceive as safe, logistic regression is used to model the probability of a coinciding choice between route preferences and perceived safety based on characteristics of the cyclists (Table 5.3).

The results show that both age classes have a significant positive coefficient, with the oldest age class having the highest coefficient. This implies that older cyclists are more likely to choose a route they perceive as safe compared to cyclists aged between 18 and 34 years. This might explain the findings in von Stülpnagel and Binnig (2022), where it was found that the level of subjective safety is higher for older cyclists, presumably because they are choosing routes they perceive as safe. On the other hand, it might be that older cyclists are more safety conscious, because they are more likely to perceive cycling as unsafe (Branion-Calles et al., 2019), making them more motivated to choose safer routes. The same can be argued for women, since they are more likely to choose a route they perceive as safe compared to men and other genders. Branion-Calles et al. (2019) also found that women are less likely to perceive cycling as safe compared to men. Lastly, cyclists having a driving licence are also more likely to choose routes they perceive as safe.

On the other hand, the results show that cyclists with children in their household are less likely to choose routes they also perceive as safe compared to cyclists without children in their household. This result is difficult to explain since existing studies show opposite results (Branion-Calles et al., 2019; von Stülpnagel & Binnig, 2022). One explanation could be that cyclists with children in their household value faster routes more, because they have less spare time. It could also be that this result is affected by the fact that 72.1 % of the respondents with children in their household is employed and that 44.5 % indicated a commute trip as most frequent route. In this way, this is related to the result of employed cyclists, where it is shown that they are slightly less likely to choose routes they also perceive as safe. Presumably, employed cyclists have a stronger preference for shorter routes than for routes perceived as safer since they more often use their bicycle for commuting purposes. This is what the route preference model in Section 5.2 also shows.

Table 5.3

The probability of a coinciding choice between route preferences and perceived safety.

		Est.	S.E.
	(Intercept)	0.210**	0.07
Age	18–34 years	–	–
	35–64 years	0.529***	0.04
	65 years and older	1.644***	0.07
Gender	Women	0.301***	0.04
	Men and other	–	–
Household	With child(ren)	–0.147**	0.05
	Without children	–	–
Employment status	Employed	–0.086*	0.04
	Unemployed	–	–
Driving licence	Yes	0.188***	0.04
	No	–	–
	No. of observations	17,277	
	Log Likelihood	–9,760	
	Likelihood ratio χ^2 (df = 6)	817***	
	Deviance	19,520	
	AIC	19,534	

*** p < 0.001.

** p < 0.01.

*p < 0.05.

Note: Est. = Estimate; S.E. = Standard error.

6. Conclusions

This study aims to examine the impact of high crowding levels on cyclists' route preferences and perceived safety as well as investigating the impact of perceived safety on route preferences. For this purpose, a questionnaire with a route choice experiment is distributed across a sample of 1,329 cyclists living in the four largest Dutch cities and adjacent agglomerations. The main conclusions are:

1. Crowding has a negative impact on both route preferences and perceived safety; and older cyclists and women are more affected by crowding.
2. After adding crowding to the choice experiment, the route attributes cycling infrastructure, traffic volume, intersections, and travel time are still influential.
3. High crowding levels have a negative impact on the preference for and perceived safety of different cycling infrastructure types, with the strongest impact on separated bicycle tracks.
4. A more direct relationship between perceived safety and route preferences is established since the large majority of cyclists prefer routes they also perceive as safe.

Crowding seems an important issue for cyclists from large Dutch cities. Since crowding among cyclists is a relatively new phenomenon, studies addressing this topic and the relationship with perceived safety are limited. The present study therefore adds to the literature by providing insights on how cyclists in a mature cycling country incorporate crowding in their route preferences and perceptions of safety. Moreover, studies showing a direct link between route preferences and perceived safety are scarce. Existing studies (e.g. [Berghoefer & Vollrath, 2023](#); [Sener et al., 2009](#); [Zhu et al., 2017](#)) only implicitly mention perceived safety to be of importance in route preferences based on effects of, for example, traffic volume, intersections, and cycling infrastructure. Our study extends this literature by adding a perceived safety choice to a route choice experiment. As such, it is possible to validate the relationship between perceived safety and route preferences by showing the significant effect of several route attributes on perceived safety.

The findings of this study are relevant to policy makers, not only from cities that already have a crowded cycling network, but also from cities with emerging cycling levels. Such cities can learn from this study as it may help them to take measures in an early stage against (future) problems with crowding. Moreover, crowding is a subjective notion and may already be experienced (as a problem) by cyclists outside the Netherlands. To counter the negative impact of crowding on perceived safety, policy makers can think of providing cycling infrastructure suitable for large flows of cyclists. Accordingly, the perception of safety and objective safety is likely to increase ([Campos Ferreira et al., 2022](#); [DiGioia et al., 2017](#)), leading to a safer cycling network for all types of cyclists. However, it might be difficult to fully adapt the infrastructure to the increasing numbers of cyclists for several reasons, such as lack of space or lack of financial resources. Therefore, it may be helpful to think of other measures as well. For example, policy makers and city planners may find ways to distribute large flows of cyclists over several routes in the network by making more routes available and attractive to cyclists. This is inspired by the idea to separate the fast-flowing bicycle through-traffic (e.g. commuters) from vulnerable bicycle traffic (e.g. older cyclists and children) ([Uijtdewilligen et al., 2022](#)).

Since the main focus of the study is on crowding, only a selection of factors affecting cyclists' route preferences and perceptions of safety are examined. Factors like the built environment or more detailed infrastructural characteristics are excluded. Future studies should further investigate the effects of these factors on route preferences and perceived safety in relation to crowding. More complex modelling techniques, such as Structural Equation Modelling, may potentially be useful in such studies. Moreover, a detailed investigation of how cyclists perceive the phenomenon of crowding itself is beyond the scope of this study. It could be worthwhile to look more in-depth into the perceptions of crowding to understand why it has such a negative impact on route preferences and perceived safety. For example, an experiment in the form of naturalistic cycling or ride-alongs could be carried out in order to investigate the relationship between perceived crowding and cycling infrastructure on a more detailed level. On top of this, a relationship between perceptions of crowding and objective crowding and crash risk has yet to be explored to find out what the effects of crowding are on road safety in general.

CRedit authorship contribution statement

Teun Uijtdewilligen: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Mehmet Baran Ulak:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Gert Jan Wijlhuizen:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization. **Karst T. Geurs:** Writing – review & editing, Supervision, Resources, Project administration, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix

Complete overview of choice tasks and distribution of the choices.

Choice task	Attributes	Route A		Route B		None of these	
		N	%	N	%	N	%
1	Crowding among cyclists		Low		Medium		–
	Cycling infrastructure		Mixed traffic conditions		Bicycle lanes		–
	Number of cars on the road		Medium		High		–
	Intersections		Medium		Low		–
	Travel time		Same		25 % shorter		–
	Preferred route:	617	46.4	666	50.1	46	3.5
	Safest route:	675	50.8	589	44.3	65	4.9
2	Crowding among cyclists		Low		High		–
	Cycling infrastructure		Separated bicycle tracks		Bicycle lanes		–
	Number of cars on the road		Low		Medium		–
	Intersections		Low		High		–
	Travel time		25 % longer		25 % shorter		–
	Preferred route:	947	71.3	349	26.3	33	2.5
	Safest route:	1,102	82.9	196	14.7	31	2.3
3	Crowding among cyclists		Medium		Medium		–
	Cycling infrastructure		Bicycle priority streets		Mixed traffic conditions		–
	Number of cars on the road		Low		Low		–
	Intersections		Medium		High		–
	Travel time		25 % shorter		Same		–
	Preferred route:	1,008	75.8	275	20.7	46	3.5
	Safest route:	919	69.1	355	26.7	55	4.1
4	Crowding among cyclists		Low		Medium		–
	Cycling infrastructure		Bicycle lanes		Mixed traffic conditions		–
	Number of cars on the road		High		Medium		–
	Intersections		High		Low		–
	Travel time		25 % longer		Same		–
	Preferred route:	587	44.2	676	50.9	66	5.0
	Safest route:	646	48.6	601	45.2	82	6.2
5	Crowding among cyclists		High		Medium		–
	Cycling infrastructure		Separated bicycle tracks		Bicycle lanes		–
	Number of cars on the road		Medium		High		–
	Intersections		High		Medium		–
	Travel time		25 % shorter		Same		–
	Preferred route:	917	69.0	341	25.7	71	5.3
	Safest route:	900	67.7	344	25.9	85	6.4
6	Crowding among cyclists		Low		High		–
	Cycling infrastructure		Mixed traffic conditions		Separated bicycle tracks		–
	Number of cars on the road		Low		High		–
	Intersections		Medium		Low		–
	Travel time		25 % shorter		Same		–
	Preferred route:	854	64.3	436	32.8	39	2.9
	Safest route:	716	53.9	563	42.4	50	3.8
7	Crowding among cyclists		High		Medium		–
	Cycling infrastructure		Bicycle priority streets		Separated bicycle tracks		–
	Number of cars on the road		Low		Low		–
	Intersections		Low		High		–
	Travel time		25 % longer		25 % shorter		–
	Preferred route:	328	24.7	963	72.5	38	2.9
	Safest route:	354	26.6	933	70.2	42	3.2
8	Crowding among cyclists		Low		High		–
	Cycling infrastructure		Bicycle lanes		Bicycle priority streets		–
	Number of cars on the road		Medium		Low		–
	Intersections		Low		High		–

(continued on next page)

(continued)

Choice task	Attributes	Route A		Route B		None of these	
		N	%	N	%	N	%
9	Travel time		25 % longer		Same		–
	Preferred route:	807	60.7	472	35.5	50	3.8
	Safest route:	819	61.6	456	34.3	54	4.1
	Crowding among cyclists		Medium		Low		–
	Cycling infrastructure		Separated bicycle tracks		Mixed traffic conditions		–
	Number of cars on the road		Medium		Low		–
10	Intersections		High		Low		–
	Travel time		25 % longer		Same		–
	Preferred route:	605	45.5	693	52.1	31	2.3
	Safest route:	802	60.3	502	37.8	25	1.9
	Crowding among cyclists		Low		High		–
	Cycling infrastructure		Separated bicycle tracks		Mixed traffic conditions		–
11	Number of cars on the road		High		Low		–
	Intersections		Medium		High		–
	Travel time		Same		25 % longer		–
	Preferred route:	1,131	85.1	166	12.5	32	2.4
	Safest route:	1,060	79.8	228	17.2	41	3.1
	Crowding among cyclists		High		Medium		–
12	Cycling infrastructure		Mixed traffic conditions		Bicycle priority streets		–
	Number of cars on the road		High		Low		–
	Intersections		Medium		High		–
	Travel time		25 % shorter		Same		–
	Preferred route:	346	26.0	917	69.0	66	5.0
	Safest route:	209	15.7	1,057	79.5	63	4.7
13	Crowding among cyclists		Low		Medium		–
	Cycling infrastructure		Bicycle lanes		Mixed traffic conditions		–
	Number of cars on the road		Medium		High		–
	Intersections		High		Medium		–
	Travel time		Same		25 % longer		–
	Preferred route:	1,173	88.3	122	9.2	34	2.6
13	Safest route:	1,110	83.5	175	13.2	44	3.3
	Crowding among cyclists		Low		High		–
	Cycling infrastructure		Mixed traffic conditions		Bicycle lanes		–
	Number of cars on the road		High		Low		–
	Intersections		High		Medium		–
	Travel time		25 % shorter		Same		–
Preferred route:	480	36.1	784	59.0	65	4.9	
Safest route:	347	26.1	900	67.7	82	6.2	

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