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Bicyclists' preferences for route characteristics and crowding in Copenhagen – A choice experiment study of commuters

Suzanne Elizabeth Vedel [a], Jette Bredahl Jacobsen [a,b,*], Hans Skov-Petersen [c]

[a] Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark
[b] Centre for Macroecology, Evolution and Climate, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark
[c] Department of Geosciences and Natural Resource Management, University of Copenhagen, DK-1958 Frederiksberg C, Denmark

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ABSTRACT

Cycling as a mode of transportation is increasingly being advocated due to the many positive effects it has on people's health, the environment and to counteract increasing congestion on the transportation infrastructure. There is a long tradition of using cycling as a mode of transportation among the Danish public and this is widespread across people with different socio-demographic characteristics. Copenhagen has an extensive network of cycling facilities and is often used as a role model for other large cities when developing cycling facilities. This setting provides a unique basis for investigating bicycle commuters' preferences for route characteristics and crowding in particular, which is not studied before, but likely to become an issue around the world's cities with increases in number of bicyclists. The study is based on a choice experiment of 3891 active cyclists in Copenhagen. The investigated attributes are cycle track, crowding, stops, environment/road type, green surroundings, and travel distance which is used as a payment vehicle to gain more desirable route characteristics.

On average people state that they are willing to cycle 1.84 km longer if the route has a designated cycle track, and 0.8 km more if there are green surroundings too. Stops and crowding, based on number of cyclists on the route, have significant negative impacts on people's utility of a given route. People were willing to cycle one kilometre longer to avoid high levels of crowding and approximately 1.3 km longer to avoid routes with many stops. The most attractive road environment is a segregated path only for cyclists closely followed by shopping street. Looking into heterogeneity, we find that people who own a car have less disutility of cycling additional distance. The results may support future decision making when creating new infrastructure for cycling in cities by addressing the perceived importance of facilities and crowding in a population where commute cycling is very widespread.

1. Introduction

Cycling is increasingly being promoted as a mode of transportation due to environmental concerns, health benefits, and to reduce congestion on the transportation infrastructure, especially in many large cities. One important task to reach a higher mode share of cycling is to create better infrastructure for cyclists (European Commission, 2011; Krizek et al., 2009; Forsyth

* Corresponding author at: Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark.
E-mail address: jbj@ifro.ku.dk (J.B. Jacobsen).

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and Krizek, 2009). Denmark has a long history of using bicycles for commuting, and Copenhagen is often used as a role model for other large cities across the world, when searching for ways to promote commuting by bicycle and developing sustainable infrastructure of cities (Gössling, 2013; Pucher and Buehler, 2008; Municipality of Copenhagen, 2013).

We investigate the implicit value commuters attach to specific route characteristics and road environments based on the travel distance they are willing to cycle to achieve a more desirable route. Data was gathered from 3891 cyclists in the area of Copenhagen, Denmark, through a web based survey including a stated choice experiment (CE). The facilities included here are presence of cycling track, crowding (with other cyclists), stops, road environment/road type, green surroundings and travel distance. The survey also collected information on travel behaviour, satisfaction with current facilities and socio-demographic information of the respondents in order to investigate potential systematic variation in preferences. An empirical model is constructed using independent socio-demographic and behavioural variables allowing us to assess the added distance people are willing to cycle to achieve or avoid different route characteristics.

In a comprehensive review of studies focusing on increasing the share of cyclists, Pucher et al. (2010) found that success requires an integrated approach consisting of many different types of interventions, among these it is of great importance to provide infrastructural changes which support commute cycling. This study adds knowledge on how to improve and target infrastructural changes based on what is important for cyclists.

Although Denmark has a strong culture for commute cycling, there is still much national focus on possible improvements of the urban infrastructure for cyclists. Commuters choose their routes from the feasible set of alternatives present today. Previous studies have emphasized the gap between routes that are desirable for cyclists and currently available routes (Winters and Teschke (2010). Therefore a stated preference study is applied since it allows us to investigate the importance of route characteristics of which all are not necessarily available to the specific respondent today. Furthermore, the chosen approach allows us to investigate preferences in a setting where respondents are asked to focus only on the selected parameters. Thereby results are less likely to be affected by unobserved multisensory aspects which are difficult to control for city planners.

Sampling active bicyclists, in a city with a large bicyclist mode share, we are investigating a very experienced group of people with a likely well-defined set of preferences.[1] This provides valuable insights for urban planning and the design of infrastructure for cyclists in the future, not only in Denmark but also in other locations where, for example, crowding among cyclists is yet to become an issue. Consequently, the paper adds to this research gab also identified by Buehler and Dill, 2016).

2. Background and theory

The long historical perspective of using bicycles for commuting in Denmark provides a unique opportunity for studying commuters' route preferences in a 'nation of cyclists' where commute cycling is widespread across all socio-economics groups and people are likely to have well-known preferences for route facilities and characteristics. The municipality of Copenhagen – with a population of 594,000 (2016) covering 77.2 km^2 – is a city with a high mode share of bicycles; 35% of trips are made on bicycle which puts the city in the league of top biking cities of the World (Buehler and Pucher, 2012).[2] Since the first bicycle facility was developed in 1905 more than 350 km of cycling tracks have been constructed in the municipality of Copenhagen (Jensen, 2013). And it is a political intention to further increase the mode share of cyclists (Municipality of Copenhagen, 2013).

Across the world, commute cycling has been studied in many empirical settings within both transportation and health literature. Many studies focus on the mode choice between cycling and commuting by car or public transport, since the relative share of commute cycling is lower than the politically desired level in many cities (Buehler and Pucher, 2012). However, some studies have also investigated the route preferences of people who already commute by bicycle which is the main focus here. Early stated preference studies of cyclists' route choices, in a context similar to ours, took place in Delft in The Netherlands and showed that travel time was the most important attribute – in a study which also looked at traffic levels, facility types and surface quality (Bovy and Bradley, 1985). Stinson and Bhat (2003) and Bhat et al. (2015) also found that travel time was the most important attribute although the presence of cycling facilities (lane or paths) and level of car traffic were of importance too. Tilahun et al. (2007) investigated the trade-off between five different cycling environments and found that people were willing to cycle approximately 20 min longer to switch from a route with no facilities and on-street parking to an off-road cycling trail. In studies where respondents' choices are restricted to the available routes and facilities (e.g. revealed preferences studies using GPS trackers), it have been shown that people often do not cycle much longer distances compared with the shortest route (e.g. Menghini et al., 2010; Broach et al., 2012; Winters et al., 2010).

A few previous studies have also looked into potential systematic patterns in preference heterogeneity using behavioural and socio-economic variables. Some studies have linked people's cycling route preferences (and mode choice) with behavioural variables such as individual cycling confidence or experience with cycling for leisure (Caulfield et al., 2012; Willis et al., 2013). Studies also show that both experienced and inexperienced cyclists have large preference for basic facilities such as cycling lanes and off-road trails (Tilahun et al., 2007). Based on socio-economic variables, Tilahun et al. (2007) found

[1] Focus groups conducted before the survey also indicated this.

[2] The municipality the city of Frederiksberg (Population: 103.192 (2015). Area: 8.7 km^2) is geographically embedded in the municipality of Copenhagen – is often regarded as part of the metropolis of Copenhagen, and also so in this study.

that people in larger households were less likely to choose a longer but better quality route. This they ascribe to potential higher constraints on time in households of three or more individuals.

Among the attributes investigated here, crowding in the cycling infrastructure has received the least attention in previous literature. The impact of crowding on people's preferences for cycling routes has to our knowledge only been studied in one other application, where the main focus was the relation between cycling confidence and route choices among cyclists/non-cyclists in Dublin (Caulfield et al., 2012). Crowding has recently been studied in public transportation systems where it was found to be a source of disutility for travellers, thus not including this in models could lead to overestimation of demand for public transportation (Tirachini et al., 2013). Disutility for crowding or congestion for car drivers is also well-established in the literature (e.g. Calfee and Winston, 1998), typically focusing on the time efficiency aspects. However, crowding among bicyclists involves an extra dimension – namely that a consequence of crowding is an increased risk of collision and negative social interaction with other bicyclists. Therefore explicitly identifying preferences for this attribute is crucial.

3. Method

3.1. Data collection and survey design

Data was collected in April and May 2011 among cyclists in the city of Copenhagen[3] by distribution of flyers on the cycling tracks when bicyclists were stopping for a red light. The flyers included brief information about the survey and a link to a website, where a questionnaire could be filled out online. Approximately 30.000 flyers were distributed to cyclists between 7 and 19 o'clock on weekdays at 17 different locations in Copenhagen, including the most frequented roads and intersections in the city as well as the main cycling routes. 3891 respondents completed the online questionnaire (each including 6 route choice sets), which led to 23,159 completed choice sets since some respondents did not respond to all 6 choice sets. The applied sampling approach is purposely targeting people who use their bicycle for commute cycling based on the location of the sampling places and the temporal strata (weekdays and time of day).

In addition to the CE, the survey included questions on current travel behaviour, experience with and attitudes towards cycling, and socio-demographic data.[4] In the CE, respondents were asked to consider a situation where they were to choose a cycling route to work or place of education or another place where they transport themselves to every day. Respondents could choose one of two routes or an opt-out ('I would not like to cycle any of these routes'). Attributes and levels were described in detail prior to the CE and are shown in Table 1. All attributes were displayed as both two route sketches and a text, with the exception of number of stops and travel distance which were only represented in the text. An example of a choice set is shown in Fig. 1. The respondents could use a link to open an information sheet during the CE, which repeated the attribute descriptions and displayed in-street photos as examples.

The questionnaire, and in particular the attributes of the choices experiment, was tested and discussed in 3 focus groups in March 2011. The selected attributes were chosen based on participants' expression of what was of importance and based on variables that are measurable and observable for traffic planners to give it policy relevance. One attribute, cycling track, had two levels – with a painted line or with curb. This was chosen because it is of particular interest for the local traffic planners as the cost hereof is very different. Participants in the focus groups revealed no clear preference hereof. Furthermore, a small pilot study was conducted to identify caveats and to create priors for the statistical analysis.

Image that you are at home and you are about to choose a route to cycle to for example your work/school or another place where you go on a daily basis. If the two routes shown below were your options, which of them would you choose?

3.2. Design of choice experiment

At the generation phase of the design, some combinations of attributes were omitted because they per definition could not be combined. In scenarios with a segregated cycling path or a segregated path for both cyclists and pedestrians, the cycling track always takes the value of one. The same is the case for the road environment 'main road' as all main roads where biking is allowed would have a cycling track in Copenhagen. For the road environment 'single-family house road' the surroundings are always green due to gardens along the road. Likewise the variable 'green' always take the value of zero for the road environment shopping street. Finally we assured that the difference in distances between the two alternatives were not larger than 3 km since a pilot study showed it to dominate if so. We used priors from a pilot study to generate a design using the software Ngene. Optimizing this design for a multinomial logit model gave a d-error of 0.306.

3.3. Econometric model

We assume that a cycling route can be described by a number of attributes and, based on Lancaster's theory from 1966, the value of a route is then made up by the sum of the value of all its attributes. In addition to this, the CE approach uses the random utility theory (McFadden, 1973) where an individual's utility of a good is assumed to consist of the sum of a deter-

[3] Copenhagen and Frederiksberg municipalities.

[4] Results from other parts of the data collection are presented in Skov-Petersen et al. (2017).

Table 1
Attributes in the choice experiment.

Attribute	Label (Coding)	Levels
Road environment	Main road (dummy)	Main traffic road (heavy traffic, 4 lanes, speed limit 50–60 km/h)
	Large road (dummy)	Large road (some traffic, 2–3 lanes, speed limit 50 km/h)
	Shopping street (dummy)	Shopping street (some traffic, 2 lanes, many pedestrians on the sidewalk, speed limit 30–40 km/h)
	Single family-house road (dummy)	Road in area with single family houses (quiet road, 1–2 lanes, houses with gardens along the road, speed limit 20–30 km/h)
	Cycling path (dummy)	Segregated cycling path (completely separated from motorized traffic)
	Segregated shared path (dummy)	Segregated path shared by cyclists and pedestrians (completely separated from motorized traffic)
Cycle track	Cycling track[a] (dummy)	None, with painted line, with curb
Green surroundings	Green (dummy)	Yes, no
Crowding (other cyclists on the route)	Crowding (1, 2, 3)	Few, some, many
Stops (on the route)	Stops (1, 2, 3)	Few, some, many
Route length	Kilometres (3.5–7 km; in steps of 0.5 km)	3.5–7 km

[a] In the CE the attribute cycling track had three levels, but in the analysis the two levels 'with painted line' and 'with curb' are merged into one making cycling track a dummy variable.

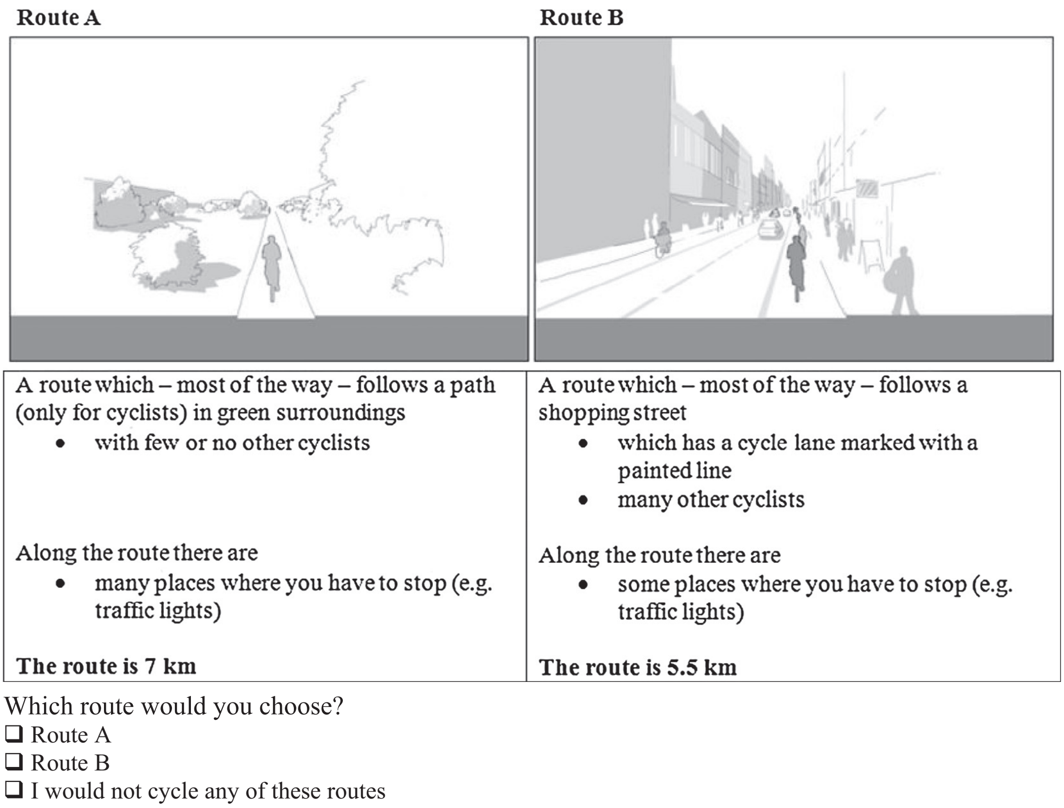

Fig. 1. Example of a choice set (texts translated from Danish; sketches by Richard Hare, University of Copenhagen).

ministic part, V_{ij}, and a random unobservable term, ε_{ij} which is IID extreme value type 1. In the present analysis, the deterministic part consists of the six attributes which describe the route in the CE along with interactions with socio-economic and behavioural variables belonging to each individual. The deterministic part for a specific route j for individual i and choice situation n is specified as follows:

$$V_{ij} = \alpha + \beta_1 Environment_{jn} + \beta_2 CycleTrack_{jn} + \beta_3 Green_{jn} + \beta_4 Crowding_{jn} + \beta_5 Stop_{jn} + \beta_6 Kilometer_{jn} + Female_i * (\beta_7 CycleTrack_{jn} + \beta_8 Green_{jn} + \beta_9 Crowding_{jn}) + Car_i * (\beta_{10} Kilometer_{jn} + \beta_{11} Green_{jn} + \beta_{12i} Crowding_{jn}) + Distance_i * (\beta_{13} Kilometer_{jn} + \beta_{14} Green_{jn} + \beta_{15} Crowding_{jn}) \quad (1)$$

where the attributes are as defined in Table 1; Female and Car (in the household of the respondent) are dummy variables specifying presence of each. Distance is defined as the distance the respondent cycled on the last day they used the bicycle for commuting (levels 1: <5 km; 2: 5–10 km; 3: 10–15 km; 4: 15–20 km; 5: >20 km).

The effect of cycling to work/education frequently (4 days a week or more) was also tested. However, since more than 78% of the respondents do that, no significant differences in preferences were found, and it is therefore omitted here. The effect of income was also investigated, again with no significant effect.

We assume a random parameter logit model where the individual maximizes his/her utility, and that there is independence over choice tasks for the same individual. The probability of choosing a specific alternative, k, is the product of the six tasks presented to the respondent:

$$\Pr(ki) = \int \left(\prod_{n=1}^{N} \left[\frac{\exp(\beta' x_{ik} + \epsilon_i)}{\left(\sum_j^J \exp(\beta' x_{ij} + \epsilon_i)\right)} \right] \right) f(\beta) d\beta \quad (2)$$

where β is a vector of the parameters given in Eq. (1) and X, the corresponding attributes, n is the choice task ($n = 1, \ldots, N$) and j the alternatives they choose between ($j = 1, 2, 3$ i.e. two routes and a status quo). $f(\beta)$ is the distribution function for β, with mean b and covariance W. The distributions for the four parameters cycling track, green surroundings, crowding and stops are assumed to be normal, whereas we assume no random parameter for distance and road environment. Moreover, an additional error term, *sigma*, related to choosing the two non-status quo alternatives is included. Further details of the approach can be found in Train (2009) and Scarpa et al. (2008). Other model specifications were tried, but did not reveal more information or better performance.

Since the interaction effects may also affect the marginal disutility of cycling an additional kilometre, we need to account for that when calculating the 'willingness to cycle' (WTC) for the given attributes:

$$WTC_{attribute,i} = -\frac{\beta_{attribute}}{\beta_{kilometre} + \beta_{10} Car_i + \beta_{13} Distance_i} \quad (3)$$

4. Representativeness

Table 2 shows the socio-demographic distribution of the respondents and the sample is compared to the population in the municipality of Copenhagen and Frederiksberg and the active bicycle population of Copenhagen according to a survey carried out by the municipality. There is an overrepresentation of people with a higher education (defined as more than four years e.g. university degree or similar) compared to the bicyclists of Copenhagen. 78% of the respondents have stated that they use the bicycle for commuting to work etc. four or more days a week so the share of active commuters in the sample is high.

Not all bicyclists cycle year round. We sampled in April and May which is the season with a relatively high number of cyclists and therefore it is likely that the sample captures both year-round bicyclists and people who mainly cycle when the weather is good.

5. Results

5.1. Results of the choice experiment

The results of a random parameter logit model with socio-economic and behavioural interactions as given in equation 1 are shown in Table 3. The model has an adjusted R^2 of 0.50 and is based on 23,159 choice sets. The opt-out was chosen in 146 choice sets.

The two levels for presence of cycling track (with either line or curb) are merged into one since the parameters for the two levels were not significantly different. This was not surprising given the focus group results. All main parameters have the expected sign, i.e. a positive preference for cycling track and a green environment, and negative for crowding and stops.

The alternative specific constant (ASC), takes the value one when an alternative is chosen and zero for the opt-out. It is confounded with a situation where the road environment is 'main traffic road', no cycling track, no green surroundings, no crowding and no stops. This is used as reference. The error component sigma is significant, indicating that there is uncertainty associated with choosing one of the two alternatives rather than the status quo. Some of the heterogeneity in the population is explained by gender, ownership of a car and the distance you normally cycle. However, we still see a large and significant standard deviation around the parameters, revealing unexplained and significant heterogeneity in respondents' preferences for all the main attributes. Cycling track has the smallest standard deviation relative to the size of the parameter estimate, indicating a slightly lower heterogeneity in the population for this attribute.

Table 2
Socio-demographic distribution of respondents and representativeness of sample.

	Present study	Bicyclists of Copenhagen[d]	The population of the municipality of Copenhagen[e]	The population of the municipality of Frederiksberg[e]
Age (<30; 30–60; >60)	30%; 61%; 7%[a]	28%; 52%; 19%	42%; 43%; 15%	36%; 41%; 22%
Gender (female; male)	59%; 39%[b]	57%; 43%	49%; 51%	47%; 53%
Personal annual income before tax (Thousand DKK) (<100; 100–200; 200–500; >500	15%; 15%; 51%; 15%[c]	–	16%; 26%; 47%; 11%	14%; 23%; 48%; 16%
Pct with a university degree (5 years) or more	37%	25%	15%	20%

[a] There were 2.6% missing or mistyped observations.
[b] 2% missing observations.
[c] 4.5% missing observations.
[d] As measured by Municipality of Copenhagen, 2013. Proportions of people who cycle every day (representing 52% of the respondents). Notice that it does not include the city of Frederiksberg.
[e] Population figures for 2011 from Statistics Denmark.

Table 3
Random Parameter Logit model with interactions. The reference situation (ASC) corresponds to a route on a main traffic road, with no cycling track, no green surroundings, no crowding and no stops. Variables included are described in Table 1. Additional variables: Female, indicates respondents gender; Car, indicates whether the respondents' household possesses a car; Distance, Normal cycling distance.

	Coefficient	Standard error	Z
Random parameters in utility functions			
Cycling track	1.69077***	0.07218	23.42
Green environment	0.73883***	0.07473	9.89
Crowding	−0.24402***	0.04700	−5.19
Stops	−0.40794***	0.01918	−21.27
Non-random parameters in utility functions			
ASC	9.10143***	0.16645	54.68
Kilometres	−1.02252***	0.03446	−29.67
Large road	0.36380***	0.04789	7.60
Shopping street	0.86217***	0.05471	15.76
Single-family house road	0.55991***	0.04804	11.66
Segregated cycling path	0.90438***	0.05833	15.50
Segregated shared path	0.61667***	0.04504	13.69
Interactions with main parameters			
Female*cycling track	0.22502***	0.07529	2.99
Female*green	0.14191***	0.04816	2.95
Female*crowding	−0.05892*	0.03182	−1.85
Car*kilometres	0.06760***	0.02271	2.98
Car*green	0.01883	0.04943	0.38
Car*crowding	−0.05136	0.03197	−1.61
Distance*kilometres	0.02588***	0.00874	2.96
Distance*green	0.02272	0.01866	1.22
Distance*crowding	−0.02366*	0.01230	−1.92
Standard deviations of normal distributed random parameters			
Cycling track	1.10864***	0.06660	16.65
Green	0.67608***	0.04152	16.28
Crowding	0.30469***	0.03409	8.94
Stops	0.56510***	0.02570	21.99
Standard deviations of error component			
Sigma*10	0.40941***	0.04759	8.60
Number of respondents/No. of observations	3891/23159		
Log-likelihood/R^2 adjusted	−12655/0.5023		
Restricted LL/χ^2	−25442/25574		

*** Significance at 1% level.
* Significance at 10% level.

Since the denominator in Eq. (3) is affected by the interaction variables, we calculate the willingness to cycle (WTC) for different groups of respondents. Table 4 shows that respondents on average have significant WTC for all the investigated attributes. The distance cycled in the scenarios varies from 3.5 to 7 km. On average they are willing to cycle approximately

Table 4
Willingness to cycle (WTC) to achieve route characteristics.

	Car				No car				The average cyclist	
	Distance = 1 (0–5 km)		Distance = 5 (>20 km)		Distance = 1 (0–5 km)		Distance = 5 (>20 km)			
	Willingness to cycle (km/level)	95% Confidence interval	Willingness to cycle (km/level)	95% Confidence interval	Willingness to cycle (km/level)	95% Confidence interval	Willingness to cycle (km/level)	95% Confidence interval	Willingness to cycle (km/level)	95% Confidence interval
Random parameters										
Cycling track	1.81991***	1.65–2.00	2.04813***	1.86–2.24	1.69648***	1.54–1.85	1.89312***	1.72–2.07	1.83981***	1.69–1.99
Green environment	0.79526***	0.64–0.96	.89499***	0.71–1.08	0.74132***	0.60–0.89	0.82725***	0.66–1.00	.80396***	0.65–0.96
Crowding	−0.28812***	−0.36 to −0.21	−0.43888***	−0.53 to −0.35	−0.26858***	−0.34 to −0.19	−0.40566***	−0.49 to −0.32	−0.34267***	−0.4 to −0.28
Stops	−0.43910***	−0.49 to −0.39	−0.49416***	−0.55 to −0.44	−0.40932***	−0.45 to −0.37	−0.45676***	−0.50 to −0.41	−0.44390***	−0.48 to −0.4
Non-random parameters										
ASC	9.79661***	9.19–10.40	11.0251***	10.36–11.69	9.13215***	8.67–9.59	10.1907***	9.61–10.78	9.90373***	9.55 –10.26
Large road	0.39158***	0.29–0.49	.44069***	0.33–0.55	0.36502***	0.27–0.46	0.40733***	0.31–0.51	.39586***	0.3–0.49
Shopping street	0.92802***	0.81–1.04	1.04439***	0.91–1.18	0.86508***	0.76–0.97	0.96535***	0.84–1.09	.93817***	0.83–1.05
Single-family house road	0.60267***	0.50–0.71	.67825***	0.56–0.80	0.56180***	0.47–0.66	0.62691***	0.52–0.73	.60926***	0.51–0.71
Segregated cycling path	0.97346***	0.85–1.09	1.09553***	0.96–1.23	0.90744***	0.80–1.01	1.01262***	0.89–1.13	.98410***	0.87–1.09
Segregated shared path	0.66377***	0.56–0.76	.74701***	0.63–0.86	0.61875***	0.53–0.71	0.69047***	0.59–0.79	.67103***	0.57–0.77
Interactions with main parameters										
Female*cycling track	0.24220***	0.08–0.40	.27258***	0.09–0.45	0.22578***	0.08–0.37	0.25195***	0.09–0.42	.24485***	0.08–0.41
Female*green	0.15275***	0.05–0.25	.17190***	0.06–0.29	0.14239***	0.05–0.24	0.15889***	0.05–0.26	.15442***	0.05–0.26
Female*crowding	−0.06342*	−0.13 to 0.004	−0.07137*	−0.15 to 0.004	−0.05911*	−0.12 to 0.004	−0.06597*	−0.14 to 0.004	−0.06411*	−0.13 to 0

*** Significance at 1% level.
* Significance at 10% level.

1.84 km longer to switch from a route without cycling track to a route with cycling track. People are on average willing to cycle app. 0.8 km longer to have a route with green surroundings.

Crowding and stops have negative impacts on people's utility when selecting a route, and they are willing to cycle 1.03 km more to avoid high levels of crowding with other cyclists. The number of stops has an even larger negative impact on people's utility, and they are willing to cycle approximately 1.33 km longer to switch from a route with many stops to a route with no stops.

Respondents prefer the road environment with a path only for cyclists, which is completely separated from other traffic. They are willing to cycle approximately 0.98 km more to achieve this type of route compared with a route on a main traffic road (which is the reference for all the five other road environments). However, their preferences for the shopping street are also strong, and they are willing to cycle 0.94 km if the route has this road environment. After these two, respondents prefer the segregated path which is shared by cyclists and pedestrians (0.67 km), the single-family house road (0.61 km) and the large road (0.40 km).

Looking at the heterogeneity in the sample we observe an effect of having a car in the household, which 38.2% of the respondents have. Respondents who have a car have significantly lower disutility of cycling an additional kilometre, which means that this subgroup is willing to cycle slightly longer to achieve all of the above mentioned route characteristics. This is also the case for respondents who are used to cycle long distances as can be seen from the significant effect between 'distance' and 'kilometres'. Respondents are distributed between the 'dist' categories from 1 to 5 as follows: 12%, 29%, 24%, 18% and 17%. The longer an individual cycled the last day of commute cycling, the higher is their willingness to cycle an additional kilometre. Table 4 shows that there is a large difference in the WTC for individuals in these subgroups. For example, with regard to avoiding high levels of crowding, the WTC increases from 0.8 km to 1.32 km when switching from an individual without a car who cycled a short distance the last day to an individual with a car who cycled a long distance the last day they cycled. If the individual is female this distance increases even further to 1.53 km. Both females and people who are used to cycling long distances are more averse to crowding than the average commuter.

The interaction effects also show that female commuters are willing to cycle a longer distance to have a route with cycling track than males. For female commuters, who are used to biking long distances and have a car in the household, the WTC for a cycling track increases from app. 2 km to 2.3 km – a significant increase. Females also express greater utility for a cycling route in green surroundings. A female with the above mentioned characteristics is willing to cycle 0.17 km – in addition to the 0.9 km – to achieve a route with green surrounding.

5.2. Attitudinal questions

Apart from the CE, the questionnaire also included questions on people's stated reasons for cycling and satisfaction with current commute cycling. Two items with potential explanatory links to the choices in the CE are briefly described here. Table 5 shows the stated importance of these reasons and how they vary depending on having a car in the household, since this was correlated with a significant lower disutility of cycling an additional kilometre in the CE.

Table 5 shows that if a respondent has a car in their household, then his/her main reason to cycle for commuting is to get exercise. However, people also cycle it because they like it, and because it is flexible. For respondents without a car in the household, the main reason is flexibility, and secondly that it is fast. Moreover, for respondents who do not own a car, the reason 'to get exercise' is significantly less important whereas the fact that it is cheap matters much more.

Although the amount of pollution was not an explicit attribute in the CE, it may be argued that it could be highly correlated with some of the road environments present in the study (e.g. main road, local road, shopping street) where people cycle close to high levels of motorized traffic. Likewise, respondents may also link segregated paths, which are completely separated from motorized traffic, to lower levels of pollution. Respondents satisfaction with this particular element is included here for this reason and because it stands out as being of high importance in the results from the rest of the survey.

Respondents were asked to state their level of satisfaction with several factors, where they normally cycle on an everyday basis – as commuting. The amount of pollution is the single factor which the largest group of respondents (47%) stated to be very dissatisfied/dissatisfied with. For comparison, the number of respondents who state that they are very dissatisfied/dissatisfied with how even the surface is constitutes a distant second with 30.75% of the respondents having stated this.

Respondents were also asked what they dislike when cycling and what makes them feel unsafe. Regarding crowding, 82% stated that crowding on cycle tracks made them feel very unsafe or unsafe, but only 21% are very unsatisfied or unsatisfied with the current amount of other bicyclists on their daily route. 69% mention scolding as an unpleasant experience when cycling.

6. Policy implications for new infrastructural changes for cyclists

6.1. Crowding

Seen in an international context, the city of Copenhagen has been a front runner when it comes to creating facilities for cyclists. That makes it an interesting setting for studying commuters' preferences and in particular emerging issues such as crowding which has yet to become a problem in other large cities where a higher cycling frequency is anticipated in the

Table 5
Reasons for commute cycling and ownership of car. Respondents were asked to select the two most important reasons for using their bicycle for commuting.[a]

	Car in the household	No car
Cheap	21.64	36.70
Fast	37.37	40.74
Flexible	40.05	46.90
To get exercise	51.81	33.46
For the sake of the environment	12.30	13.73
I like to cycle	41.80	36.75
It is a pleasant way to get through the city	31.72	32.79
To experience the elements	6.12	5.78
Other	2.82	2.12

[a] Note, that many respondents ticked more than two boxes, since the online survey did not restrict the number to two. However, these observations are kept in the table displayed here.

future. Similar to the literature on public transportation, where not accounting for crowding effects could lead to overestimation of demand (Tirachini et al., 2013), we find that crowding with other cyclists implies a significant cost for cyclists and they are willing to cycle longer to avoid it. This is also indicated in more open attitudinal questions. It is similar to studies from car congestion (e.g. Calfee and Winston, 1998). Our results show for example that a respondent without a car in the household who is used to cycling a long distance is willing to cycle 1.2 km extra to avoid high levels of crowding. During peak hours, cycling tracks are congested many places in Copenhagen which therefore has a significant negative impact on commuters' utility when cycling. However, when creating new infrastructure for cyclists the knowledge of commuters' willingness to cycle an additional distance to avoid heavily crowded cycling tracks, opens possibilities for creating new and slightly longer routes to alleviate congestion. Moreover, it also emphasises the potential lower demand among cyclists for continued use of specific cycling tracks if congestion increases. An additional component mentioned in focus groups is that crowded cycling tracks increase the risk of collision and negative social interaction between bicyclists. A large proportion of the population mentions both of these aspects in the attitudinal questions. Consequently, crowding may involve a larger disutility than the mere extra time consumption.

6.2. Cycling track

As shown in other studies, cycling tracks remain an important facility for cyclists and they are willing to cycle the furthest additional distance (1.84 km on average) to obtain this facility. However, the type of track did not matter. It cannot be completely ruled out that the similarity between the two levels of cycling track (painted line or curb) may be related to the visual set-up where could have been difficult for respondents to distinguish between the two levels when comparing the pictures in the choice sets. However, focus group results indicated little concern for these differences when asked explicitly. In Copenhagen, the majority of cycling tracks are built with a curb, and in a separate level from both road and sidewalk, so this is likely to be the common reference for respondents, when they think of a cycling track.

6.3. Road environment and stops

Green surroundings also matters significantly (0.8 km) for commuters. This is interesting as it shows that pleasure is not only relevant for recreational cycling but also for commuting. Furthermore, it is an attribute which may be difficult to analyse in a revealed preference study due to the lack of availability of routes with green surroundings.

Besides the general positive impact of cycling tracks and green surroundings on route choice, the study also provides evidence on how long a distance it is possible to add to existing routes (i.e. based on detours) and still provide an attractive option for commuters which will be used in practice.

A high number of stops on the route were also a strong deterrent for choosing a route. The average cyclist was willing to cycle approximately 0.9 km longer to switch from a route with many stops to one with few. This also creates much scope for establishing new slightly longer routes which avoid these elements or for creating 'green waves' of traffic lights for cyclists.

6.4. Segregation from motorized traffic

Cyclists prefer a route which is completely separated from other traffic (Segregated cycling path). This is in line with other studies (Buehler and Dill, 2016) and may be due to both safety and pollution concerns. Separation from motorized traffic also involves less pollution which 47% of respondents find is a great problem on their current commutes in Copenhagen. Even though stops and crowding are analysed as separate attributes independent of the road environment, we still see that commuters are more reluctant to choose a segregated path if it is shared with pedestrians. Comments from the focus groups when developing the survey indicate that people connect the shared path with a route which is more time consuming. Moreover, they also mentioned potential safety concerns when pedestrians and bicyclists pass each other at very different speeds.

People show strong preferences for the shopping street and it may fulfil the needs of flexibility for many people who use the bicycle for short commutes combined with grocery shopping etc. Together these preferences may seem a bit contradictory – a wish for proximity and integration with the city, but also a wish for designated bike path separated from other users where speed can be prioritized. We were not able to attribute these preferences to different groups of people. Bicycle infrastructure in Copenhagen is for a large part integrated in the city, and thus the current presence of segregated cycling paths is not that common. The findings indicate that this may be reasonable when proximity is important, but also that segregated cycling paths could play a more important role than it does today.

6.5. Cycling for leisure or necessity?

In this study we have investigated cycle commuters' route preferences. However, many respondents indicate pleasure related motivations for choosing to cycle on their daily commute. In the present study, having a car in the household means that you are more likely to choose a slightly longer route than if you do not have a car in the household. Notice that we do not have a representative sample of car owners – rather of bicyclists, where some also owns a car. This indicates that when commuting by bicycle is more an option than a necessity, people associate less disutility with cycling an additional kilometre. In a study focusing on cycling motivation and trip satisfaction, Willis et al. (2013) finds that year round cyclists are less satisfied with their mode choice than those who only cycle when the weather is favourable. Moreover, the stated reasons for choosing the bicycle for commuting support the findings in the CE; people who have a car in the household state 'to get exercise' as the main reason for cycling and that they like it, whereas people without a car in the household state 'flexibility' and that it is 'fast' most often.

6.6. Income

As opposed to other transportation studies we do not find that people in high income groups have higher opportunity costs of time and therefore trades off additional time spent on commuting at a higher cost (Johansson et al., 2006). One possible reason hereof is a small income difference in the population (cf Table 2), and high-income jobs, high living expenses being related to the centre of the city where car use is not convenient. The missing connection with opportunity costs of time may also be because commute cycling involves health benefits from exercise which perhaps outweighs the negative effect from increased time spent on cycling. This line of argument is supported by people in high income groups' (greater than € 67,110/year) stated reasons for biking where the most preferred option is 'to get exercise'. The high/low income groups are also partly overlapping with the car/no car in the household. However, only ownership of car provided a strong and significant signal in the RPL model.

6.7. Gender

In Denmark, statistics show that men and women are equally often involved in traffic accidents, when correcting for differences in how much they cycle. Yet, we see a clear difference in their preferences for cycling track. Females are also slightly more averse to crowding with other cyclists, which may be a source for accidents, than men. Moreover, they are willing to cycle longer than men for a route with green surroundings. This is consistent with findings in e.g. Alred et al. (2016) who find a larger safety concern among women than men.

6.8. Caveats and limitations

The selected range of the attribute describing route length is 3.5–7 km. People who are used to cycling in the upper end of this scale or more could have a very low elasticity for distance in the range used here, but potentially a higher elasticity for distances above this range. People who cycled longer during the last working day have a lower disutility of cycling on the margin, which may indicate that the selected range is rather low for this group.

Furthermore, in our sample there is an overrepresentation of women and people with a long education.

As previously mentioned, the focus of the present study is people who already commute by bicycle. It is likely that the preferences would differ if we had targeted people who cycle for leisure.

Lastly, the study applies a stated preference study. While this is a strength in that it allows us to analyse the effect of the selected parameters (also parameters not present today), without noise from unobserved parameters, it is also a limitation – if the preference for them depends on affective parameters not included. This is an issue for future research to investigate.

7. Conclusion

Using bicycles for commuting has a long and widespread tradition in Denmark. In the present sample of 3891 active cyclists, more than 78% of the respondents use their bicycle for commuting at least 4 days a week. This forms a solid basis for studying commuting cyclists' preferences for route characteristics with the scope of informing urban planners and future infrastructural design. By using added travel distance as the 'price' people have to pay to achieve or avoid certain route characteristics, we are able to make comparisons between different facilities and their relative importance. We find that people on average are willing to cycle approximately 1.84 km longer if the route has a cycling track and 0.8 km to gain green surroundings on their route.

The intense use of cycling tracks during rush hours in the city of Copenhagen provides a unique setting for analysing commuters' preferences for crowding with other cyclists – a situation which has yet to become an issue in many other cities around the world. We find that crowding and stops have a negative impact on people's preferences, and they are willing to cycle approximately 1 km and 1.33 km longer to avoid high levels of crowding and stops, respectively. These results provide valuable information for other large cities when planning new infrastructure for promoting commute cycling. The results show both how much a route may be prolonged and still constitute an attractive option for commuters. Moreover, the results highlight commuters' perceived cost of crowding and stops which may affect the future attractiveness and ultimately the use of cycling facilities if intense crowding occurs.

With regard to road environment, we find that people on average are willing to cycle the longest distance to achieve an road environment with a segregated path which is separated from other traffic. Using main traffic road as baseline scenario, people are willing to cycle approximately 0.98 km longer to switch to a segregated path only for cyclists and close to this follows a route where the road environment is a shopping street (0.94 km). On average, people have approximately the same preferences for a segregated path shared between cyclists and pedestrians as they do for a small road with single family houses (0.67–0.6 km). People are willing to cycle 0.4 km longer to switch from a main traffic road to a large road with 2–3 lanes.

Moreover, we find that having a car in the household makes commuters more prone to choose slightly longer routes. The main argument for commute cycling for this group is to get exercise.

In addition to providing knowledge for the design of infrastructure, these results may also be applied to route planners for bicyclists and to create more reliable transportation models for cyclists.

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