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A stated-preference survey

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How do bike types and cycling frequency shape cycling infrastructure preferences? A stated-preference survey

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ABSTRACT

We examine the difference in preferences among different cyclist groups, being the first to examine differences in cycling infrastructure preferences among s-pedelec, e-bike and conventional bike riders. We also examine how the cycling frequency of individuals shapes these preferences. To do so we develop a stated-preference choice experiment varying cycling infrastructure and car traffic features impacting cycling for both main and neighborhood streets.

We find that while the sign of the preferences is the same for all cyclist types and is consistent with previous findings from the literature on cycling infrastructure preferences, e-bikers and especially s-pedelec riders do have a lower willingness to pay (WTP) for improvements of cycling infrastructure and are more comfortable in sharing the street space with cars. E-bikers do have similar preferences as conventional cyclists for the most important safety-related elements, i.e. for cycling paths instead of cycling lanes on main streets and "cycling-street" designation of neighborhood streets. For these same features, the WTP decreases with cycling frequency, less frequent cyclists valuing such elements more. At the same time, those who cycle less have a lower WTP for car traffic related features.

Keywords: Cycling infrastructure, stated-preference, cycling frequency, e-bikes, s-pedelecs

INTRODUCTION

Cycling plays a vital role in a true sustainable mobility transition and has historically been recognized as a key element of national, regional and local sustainable mobility plans (*1*). The evidence shows that more and better cycling infrastructure tends to increase cycling volumes and reduce cycling risk (*2–6*). Cycling encompasses different types of bicycles and cyclists. There are varying levels of vehicle characteristics such as max. speeds, acceleration and motorization as well as different types of cyclists in terms of human power output, handling skills and preferences. Most notably there is the difference between purely human powered bicycles and electric motor assisted bicycles (e-bikes or pedelecs). In the latter category there is a further difference between e-bikes with a speed limitation of 25 km/h and e-bikes with an upper speed boundary of 45 km/h (also called s-pedelecs). In Switzerland, where the present study was conducted, e-bikes have been booming (*7*), with the latest mobility microcensus (2021 national travel diary) reporting 20% of households owning an e-bike in 2021 (*8*). As a comparative figure, 12% of adults owned an e-bike in The Netherlands in 2017 (*9*).

As discussed by Rérat (*7*), the e-bikes expand the practice of cycling to individuals who have not cycled previously, for example due to lack of physical capability or will to pursue more intense physical activity. This is one of the main limiting factors for cycling in Switzerland as showed by a study of the present authors (*10*). The same study also evidences the relevance of e-bikes for mode-shifts: the higher average speeds of e-bikes could make bikes substitute up to 72% of present car trips in Swiss cities and 56% of car trips in rural areas.

E-bikes are on the rise and are an essential part of a transition to a sustainable mobility system. It is therefore imperative to better understand the behavior, perceptions and needs of e-bikers concerning cycling infrastructure. To this end, the EBIS (E-Biking in Switzerland) study was launched with the objective of better understanding e-biking as a phenomenon. This paper focuses on a route-choice stated-preference experiment conducted as part of the study to understand the preferences that study participants (e-bikers and conventional bikers alike) have, concerning the cycling infrastructure. These population values are crucial in any future investment and policy for cycling. We want to fill this gap in the Swiss norms.

RELATED WORK

Improved cycling infrastructure, generally providing more road space for bicycles has been shown to increase cycling rates (*11–15*). In this context, the term of “subjective safety” has been highlighted as the most important factor to improve cycling rates (*16–19*). Generally speaking these studies show that the more separated from car traffic and the more prioritized in terms of street design, the higher the subjective safety feeling is. Research has shown that cyclists are not homogeneous in terms of their preferences and behavior (*19–25*). Different cyclist types have also been found to have different preferences towards cycling infrastructure (*24–28*). Generally, the findings of these studies all show the same pattern: Higher requirements on good quality cycling infrastructure, namely more separation from automobile traffic, is usually found with individuals who cycle less often, children and the elderly and women. Generally, men who commute by bicycles are the ones who have lower requirements for high quality infrastructure.

Methodologically, the studies evaluating the preferences of cyclists towards cycling infrastructure can be split among three groups: revealed-preference surveys (*29–32*), stated-preference surveys (*26*, *27*, *33–40*) and other statistical methods (*16*, *17*, *19*, *22*, *25*, *28*, *41*). Revealed preferences surveys have the advantage of capturing actual behavior and actual trade-offs (if those are available) incurred in the route choice of cyclists. The downside of most revealed preference methods is the fact that the model results are highly influenced by the selection of the choice-set generation algorithm (*42*), a shortcoming overcome by recursive logit models (*32*, *43*). Also, revealed preferences are unsuited to evaluate preferences towards improvements on existing cycling infrastructure. Stated-preference (SP) surveys allow to evaluate preferences under different, hypothetical scenarios, but are prone to respondent’s hypothetical bias (*44*).

Cycling Route Choice SP Studies

Stated-preference surveys on cycling route choice date as far back as the 1980's (eg. *36*). Here we focus on reviewing more recent literature. All evaluated studies find that subjective safety levels are valued the highest for the highest level of separation to car traffic. Stinson and Bhat (*37*) find, in a study in the US, that cyclists prioritize travel times over cycling infrastructure quality, although frequent cyclists dominate in their sample. Hunt and Abraham (*38*) also evaluate facilities at destinations, finding that secure parking is more important than shower options for commuters. Rossetti et al. (*27*) found out in a study in Santiago that unexperienced riders often prefer to ride on the sidewalks than on street-level. In Rossetti et al. (*35*), it is shown how younger men from higher income groups place a far lower value on subjective safety, a finding in line with the remaining literature on cycling preferences of different groups. Sener et al. (*33*) study's results emphasize that it is important to consider sociodemographic attributes to understand cycling route choice preferences. For example, they show that younger cyclists value travel times higher than older ones. In a study in India, Majmudar and Mitra (*34*) find that individuals who cycle less often have a significantly higher monetary willingness to pay (WTP) towards better cycling infrastructure than those who travel less often. Poorfakhraei and Rowangould (*39*) also find that those who cycle less have a lower WTP towards improved cycling infrastructure. Hardinghaus and Weschke (*26*) estimate separate models for different user groups based on gender, age and whether individuals were riding with children to find that females, individuals with children and elderly tend to favor more separation from car traffic.

Willingness to pay for infrastructure improvements

Sener et al. (*33*), Poorfakhraei and Rowangould (*39*), Majmudar and Mitra (*34*), Hardinghaus and Weschke (*26*) and Börjesson and Eliasson (*40*) provide estimates of willingness to pay for improvements of cycling infrastructure. This is an important value because it has imminent policy implications, for example for the conduction of cost-benefit analyses. The most commonly WTP value in transportation being the value of travel time (VTT). Sener et al. (*33*), Poorfakhraei and Rowangould (*39*) and Majmudar and Mitra (*34*) provides such estimates for cycling infrastructure. These are estimated by incorporating travel times as a variable in the choice experiment and forcing respondents into a trade-off between cycling infrastructure improvements and travel times. This allows for a direct estimation of WTP or marginal rates of substitution between travel times and infrastructure variables.

The ensuing estimation of the values of travel times in the three studies is then conducted by a multiplication of these hourly WTP (in units of time/improvement) by a value of travel time (monetary units/units of time) to obtain a monetary WTP (monetary units/improvement). Such constructs are needed because the marginal cost of cycling, different than that for motorized modes, is zero or perceived as close to zero, since there are no significant fuel or ticket costs. Börjesson and Eliasson (*40*) do the same, but since their experiment has an integrated mode-choice experiment they use the estimates from that one to estimate WTP for cycling infrastructure improvements. These authors find that the value of travel time for cycling is higher than that of motorized modes, a finding corroborated by short-term mode choice experiments conducted in Switzerland for all travel purposes besides leisure (*45*). This shows that the methodology to derive monetary WTP's for cycling infrastructure by simply multiplying hourly WTP with average VTT might underestimate actual WTP's by not taking mode-specific WTPs into account.

METHODS

Recruitment of participants

The stated preference survey was carried out as part of the EBIS (E-Biking in Switzerland) project. Study participants were contacted after the end of the tracking part and after answering two surveys to participate in the stated-preference survey. Since study participants had already completed these two surveys plus a tracking period of 4 to 9 weeks, it was decided to conduct this survey separately and to attempt to keep it rather compact to reduce the burden on study participants. 3342 participants who completed the EBIS study were contacted via e-mail to participate in the SP survey, out of which 2928 completed the SP survey. Participation bias is a common issue faced by researchers in behavioral studies and has been reported in cycling research (*46*). This is a concern for the recruitment strategy of the EBIS study. To participate in the study, one had to own a bicycle of any type or ride shared bikes at least once a week. In the resulting sample, 64.2% of the SP respondents from EBIS alone cycle at least 2 times a week and only 13.5% of respondents cycle 3 days per month or less.

With the goal of also including more individuals who cycle less often, we recruited 525 additional participants through a private opinion research institute who were screened by the same cycling frequency question asked in the EBIS survey. Individuals who did not cycle more than once a week where then allowed to participate in the SP-survey. The resulting sample by cycling frequency is visible in Table 1.

Table 1: Study participants composition by age, gender and cycling frequency

Age	Never	<1-3 days/month	1-3 days per month	1 day per week	>1 day per week
[15,20)	17.6	21.6	14.9	18.9	27.0
[20,30)	8.7	7.9	13.6	9.4	60.4
[30,40)	9.3	13.1	12.5	10.0	55.0
[40,50)	8.2	12.5	13.9	10.4	54.9
[50,60)	10.7	17.9	14.4	10.2	46.9
[60,70)	15.0	17.3	12.1	9.8	45.9
[70,80)	26.0	16.7	16.0	13.3	28.0
Gender					
Female	15.3	18.1	15.4	10.0	41.2
Male	8.9	12.5	12.6	10.8	55.3
Total	11.4	14.7	13.6	10.5	49.8

Survey design

The SP survey design included images showing the different cycling infrastructures from the cyclist perspectives as well as travel time variations. One of the goals was to keep the survey simple for the respondents. The cross-sections used in the experiment were the ones exemplarily shown in Figures 1-3, i.e.: main street with cycling lane, main street with cycling path on the sidewalk and neighborhood streets. The parameters which were varied in the experiment are shown in Table 2. All variables besides travel times are visualized in the images. The experiment design was generated with the software Ngene (*47*).

Table 2: Experiment variables and their levels

Variables	Neighborhood street	Main street
Car traffic intensity	Low/High	Low/High
Speed signalisation	No variation	30 km/h / 50 km/h
Travel time (min)	7/10/15	7/10/15
Car parking	Yes/No	Yes/No
Cross-section	No variation	Cycling lane/Cycling path
Cycling lane phys. Separation to car lane	Not applicable	Painted lane/Physical elements/Buffer zone*
Neigh. Street markings	No marking/Small bike symbol on side of the lane/Large symbol and "Cycling street" marking on street/Red painted road with bike symbol (dutch-style)	Not applicable
Cycling lane/path width	Not applicable	1.5m/2.2m

*Elements are also combined with each other in images. Physical separation elements are bollards when there is no parking and round, low-profile kerbs for cases when there is parking

Figure 1: Example of main street with cycle lane

Figure 2: Example of main street with cycle path on sidewalk

Figure 3: Example of neighborhood street

To increase the number of evaluated combinations without increasing the response burden too much, the experiment was divided into four different blocks, which were randomly assigned to respondents. The SP experiment itself was divided into three parts. The first consisted of 5 choice situations between main and neighborhood streets, the second between main street variants only and the third between neighborhood street variants only (both consisting of 4 choice situations each). By doing so, we were able to evaluate the trade-offs between the two main street types as well as gathering enough data to understand the preferences towards design elements of each of these street typologies.

Model estimation

To evaluate the preferences of owners of different bike types on cycling infrastructure, multinomial logit models were estimated on the SP data. The models estimated the WTP for cycling infrastructures, which were scaled by behavioral dummy variables, related to cycling frequency and bike type ridden while controlling for sociodemographic variables. The functions were relatively large in terms of included variables and parameters (>50)., Equations 1-3 show the construct of the utility function for a certain street type (main street or neighborhood street). The function is constructed by a part dedicated to estimating the willingness-to-pay ratios (in min/improvement), U_{WTP}, added to a part where the influence of sociodemographic variables is added to control for these factors in the WTP estimation, namely U_{soz}.

$$U_{WTP} = \beta_{tt} \cdot tt + \beta_{tt} \sum_k \sum_i \left[\sum_j \left(SP_{ij}\ d_{ij} \right) \cdot \left(WTP_{ijk}\ \cdot k \right) \right] \quad (1)$$

Where:

SP is the scaling parameter for behavioral factor i and group j

i is the behavioral factor (here the bike type or cycling frequency)

j is the group within the behavioral factor (visible in Tables 1-2)

d is a dummy that takes the value 1 or 0 for each individual representing the class j

k is the feature under study

β_{tt} and tt are respectively the travel time parameter and variable

$$U_{soz} = \sum_g (\beta_{soz_g} \cdot \sum_k [soz_g \cdot (k)]) \quad (2)$$

Where:

β_{soz} and soz are respectively the parameter and variable for each sociodemographic variable

$$U_{final} = U_{WTP} + U_{soz} \quad (3)$$

RESULTS

Tables 2 and 3 shows the results of the MNL choice model. The WTP values are shown in three units: The estimate itself in min/improvement, as a percentage of the average travel time in the experiments of 10.6 minutes, as well as multiplied by the value of travel time savings for cycling in Switzerland to obtain a WTP in monetary terms, following the approach adopted in the literature (*33*, *39*, *40*). The base value of time of 11.07 CHF/h was used, corresponding the long-term cycling value of time for work travel purposes in Switzerland estimated by Schmid et al. (*45*). The conversion of the WTP in minutes directly estimated from the survey results to a CHF/h estimate is then obtained by multiplying the WTP in % avg. travel time by the 11.07 CHF/h from the study mentioned above.

The tables are divided by features rather than by the equations above for an easier interpretation of the impacts of each feature. The scaling parameters (SP) for each WTP are shown. The corresponding WTP for a specific group then becomes a simple multiplication of the SP values with the corresponding WTP. Taking an example from Table 3, the WTP for lower traffic on neighborhood streets by e-bikers who in average cycle 1 day/week becomes 1.103 x 0.915 x (-7.00 CHF/h) = -7.06 CHF/h

Variables were kept in the model if the resulting parameters were significant at the 25% level at least. The sociodemographic variables income and education were tested but were not statistically significant, but age and gender were, corroborating previous findings from the literature (*10*, *48*). Despite being significant, the interactions between the choices, age and gender have a small effect in most cases, exceptions being the fact that female individuals have a clear preference for no car parking in neighborhood streets and a clear preference towards cycling paths on main streets. These low effects show that most of the trade-offs and preferences in the experiment were not a function of socio-demographics, but of cycling infrastructure features and traffic variables.

For the interpretation of the WTP we highlight that, as discussed by Sener et al. (*33*), positive values indicate how additional travel time cyclists are willing to pay to avoid a certain element, while negative values indicate how much additional time cyclists are willing to spent to cycle on a route with the corresponding attribute.

In the following discussion of the results we first discuss the global WTP effects and then focus on the different perceptions of the three different types of cyclists concerning these WTP values for each street type. The street designs for each street type that provide the highest utility for cyclists are shown in Figures 4 and 5.

Neighborhood streets

The results (Table 3) show that the WTPs are higher for most improvements in the quality of neighborhood street infrastructures than for main streets. An exception is the WTP for cycling paths instead of cycling lanes for main streets (Table 3). The ASC shows that individuals have a clear preference towards cycling on main streets as opposed to neighborhood streets. When looking at the highest WTP values on neighborhood streets, namely for low car traffic and no parking, it appears that the mixed traffic between cars and bicycles as well as potentially dangerous situations with parked cars are the main reason for such a low valuation. The survey respondents therefore prefer cycling on infrastructures with the least amounts of conflict, a finding also highlighted by parameter estimates for main streets discussed in the next subchapter.

When looking at different types of street markings for neighborhood streets, the respondents did not prefer the option with asphalt painted red as much as other options. This is in a way surprising, since this is a known and effective measure to lower risk for cyclists due to its nudging effects for cyclists and car riders alike (*49*). Interestingly though, respondents do not prefer this option in comparison to the option shown in Figure 4. This outcome might be related to the fact that the other two variants are common in Switzerland and therefore better known to the respondents.

When looking at the WTP scaling parameters (SP) for the different cyclists, the preferences concerning features on neighborhood streets are less pronounced than for main streets, preferences towards parked cars being an exception here. There is no significant effect of cycling frequency towards car traffic volumes or street markings on neighborhood streets. Concerning car parking, those who cycle often have a clear preference towards less car parking, while others appear to care less about it. Experience, or bad experience with opening doors of parked cars or maneuvering cars, which is likely to be more frequent for these individuals may play an important role, given their danger (*50*).

It becomes clear that e-bikers have similar preferences as conventional bikers for neighborhood street features, while S-pedelec riders appear to be somewhat more comfortable with car traffic. S-pedelec riders have a 15-25% lower WTP than conventional cyclists for the features listed in Table 3. The latter show a lower WTP for all elements, especially for the removal of car parking. We investigated whether this could be related to a possible higher affinity of E-bikers towards car traffic by looking into the car ownership shares by bike ownership of our respondents. While 59% of conventional cyclists also own a car, 77% of E-bikers and 75% of S-pedelec owners own cars. While this difference could perhaps explain an underlying latent different perception of cycling infrastructures of both slow and fast E-bikes, it does not explain the difference in preferences between S-pedelecs and E-bikes. A plausible explanation could be, that S-pedelecs are better integrated with car traffic because of their higher speeds and usually higher acceleration rates due to the more powerful motors they have, leading their users to be more comfortable sharing space with car traffic in general.

Concerning sociodemographic effects, there was no significant effect at the 25% level for age and gender on car traffic, but a significant effect of parking, both for increasing age and females having a preference against parked cars, which is expected because of the higher risk-awareness of these groups found in the literature (*51*). Socio-demographics played a less important role for preferences towards street markings. The only observable substantial and significant effect is the disinclination of females towards simple bike symbols as street markings.

Table 3: Model results (part 1/2 neighborhood street and global parameters)

Feature	Evaluation		est	WTP [% avg. travel time]	WTP [CHF/h]	t.rat.(0)	t.rat(1)
SP experiment both			1.000				-
SP experiment main street			1.212				4.05 ***
SP experiment neigh. Street			0.920				-2.37 ***
ASC Neigh. street			0.000			-	
ASC Main street			1.160			11.87 ***	
Traffic	SP WTP cycling freq.	Never	1.000				-
		<3 days per month	1.066				0.81 '
		1-3 days per month	1.070				0.85 '
		1 day per week	1.103				1.15 '
		>=2 days per week	1.089				1.14 '
	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	0.915				-1.88 **
		S-Pedelec 45 km/h	0.834				-3.77 ***
	WTP [min]	Traffic High	0.000			-	
		Traffic Low	-6.707	63%	-7.00	-12.20 ***	
Car parking	SP WTP cycling freq.	Never	1.000				-
		<3 days per month	1.296				1.29 *
		1-3 days per month	1.353				1.47 *
		1 day per week	1.290				1.21 '
		>=2 days per week	1.796				2.46 ***
	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	1.105				1.47 *
		S-Pedelec 45 km/h	0.755				-3.46 ***
	WTP [min]	Parking Yes	0.000			-	
		Parking No	-2.985	28%	-3.12	-4.48 ***	
	Age	Parking No	0.000			-	
		Parking Yes	-0.003			-2.18 **	
	Gender Female	Parking No	0.000			-	
		Parking Yes	-0.204			-4.53 ***	
Street markings	SP WTP cycling freq.	Never	1.000				
		<3 days per month	0.871				-1.20 '
		1-3 days per month	0.941				-0.53
		1 day per week	1.087				0.64
		>=2 days per week	0.904				-0.90 '
	SP WTP bike type	Conventional bike	1.000				
		E-Bike 25 km/h	1.010				0.13
		S-Pedelec 45 km/h	0.866				-1.61 *
	WTP [min]	No markings	0.000				
		Bike symbol	-5.302	50%	-5.54	-5.19 ***	
		Cycling road with large bike symb.	-5.861	55%	-6.12	-6.34 ***	
		Bike symbol and red paint	-4.545	43%	-4.75	-5.25 ***	
	Age: Street marking	No markings	0.000				
		Bike symbol	-0.006			-3.00 ***	
		Cycling road with large bike symb.	-0.003			-1.33 *	
		Bike symbol and red paint	0.000			0.13	
	Gender Female: Street marking	No markings	0.000				
		Bike symbol	-0.110			-1.69 **	
		Cycling road with large bike symb.	0.022			0.36	
		Bike symbol and red paint	0.043			0.67	
Travel time			-0.178			-35.82 ***	

Sign. Codes 0***0.001**0.05*0.10'0.25

Figure 4: Neighborhood street design with highest utility

Main streets

For main streets (Table 4), the WTP values are, with the exception of changing cycling lanes into cycling paths, not as high as for neighborhood streets. One possible reason for that lies in the experiment design itself, which had a cycling lane as a base feature already. This was chosen since it is oftentimes the type of cycling infrastructure found on Swiss main urban main streets.

The lower level of interaction with car traffic and higher subjective safety of cycling paths make these attractive options for cyclists, especially when these are wide. Börjesson and Eliasson (*40*), Hopkinson and Wardman (*52*) both also find a higher willingness-to-pay to cycle on cycling paths and Von Stülpnagel and Binning (*17*) find cycling paths to be the best cycling infrastructure from a subjective safety perspective, which corroborates our findings and cyclists risk and injury research evidence (*5*, *6*). An outcome of Von Stülpnagel and Binning's (*17*) analysis, which uses very similar images to those employed in this project, is that upgrading cycling lanes to have buffers and physical separation to car traffic can provide similar levels of subjective safety than cycling paths. We cannot corroborate this finding. For physical separations of cycling lanes the WTP is even positive (pointing towards a negative effect), while being only negative in the case of wide cycling lanes (meaning a positive effect), as indicated by the interaction factor between wide lanes and having physical separation. While often having a positive effect on objective safety (*53*), bollards can increase the danger for cyclists if designed poorly (*54*). The inclusion of a buffer on the other hand had a negative albeit small WTP, showing that this alternative is preferred to increase subjective safety. The positive interaction WTP between wide cycling lane and car parking shows that even under a wider cycling infrastructure, car parking is valued negatively.

The difference in the valuation of Von Stülpnagel and Binning's (*17*) and our experiment on the trade-off between cycling lanes with bollards versus cycling paths might partly be due to the different methodology chosen. Von Stülpnagel and Binning's (*17*) did not conduct an SP-survey but used data from a qualitative Likert-scale rating of each single image, meaning that study participants did not have to make a trade-off among the different aspects in a choice situation.

The scale parameter values for cycling lane or path width are surprisingly lower for s-pedelecs and e-bikes. given the fact that one could expect that these individuals would, due to their faster bikes, value a wider lane to overtake slower conventional cyclists. On the other hand, cycling frequency is considerably more influential in determining the WTP for wider cycling paths or lanes than the bike a person rides, with more frequent cyclists valuing wider cycling paths and lanes more. The WTP increases with a higher cycling frequency, which here might correlate with faster speeds and the desire for more space for comfortable overtaking of other cyclists as well as more distance to cars.

Concerning preferences towards infrastructure types, all groups show a high WTP for cycling paths, although for more frequent cyclists it is ca. 40% lower than for individuals who never cycle. Individuals who cycle less therefore put more value on separation between cycling traffic and car traffic. There is already a significant and large WTP for having a buffer on a cycling lane already, showing that these can considerably improve cycling rates. Still, this effect is only a fraction (32% to be exact) of the WTP for having a separated cycling path, which is the feature with the overall highest WTP in the entire experiment. Figure 5 exemplarily shows the main street cross-section with the highest WTP. The difference among bike types shows that again, s-pedelec riders are the most comfortable with less separation from car traffic, while the slower E-bikers do value that even more than conventional cyclists. An unexpected effect here is how age influences the preference towards the infrastructure type. Older individuals do not prefer more separation from car traffic. Although one has to highlight the very small effect found. A significantly larger effect (by 15 times) is found for females clearly preferring cycling paths versus cycling lanes.

The WTP for car traffic related parameters, namely traffic volume, speed limit and presence of car parking was considerably lower for main streets than for neighborhood streets. This is expected, since other than in neighborhood streets, in all alternatives, cycling traffic has a different lane from car traffic. Cycling frequency had no significant effect at the 25% level on car traffic volumes, but was valued significantly less by e-bikers and s-pedelec riders. The WTP for lower traffic on main streets by these groups was the lowest in the entire experiment. Increased cycling frequency had a decreasing effect for the WTP for speed limit reductions, with more experienced cyclists being less willing to pay for that, along with e-bikers and s-pedelec riders.

Lower speed limits were only highly valued by individuals who cycle rarely to never. Here again, e-bikers and particularly s-pedelec riders had a significantly lower WTP for car traffic variables, with the scale parameters for these two groups being even negative for the traffic volume WTP. Nevertheless, the low negative scaling parameter values for traffic volume of owners of e-bikes and s-pedelecs was not significantly different from zero, meaning that in the end one can state that these two groups have no WTP at all for lower traffic volumes at main streets, but would also like to have cars driving at lower speeds than 50 km/h.

The differentiation in WTP by the different groups for parked cars followed a very similar pattern on main streets as on neighborhood streets, being especially important for individuals who never cycle or do so very seldom. The WTP is as low as 30% when compared to the neighborhood street one. This difference might be explained by the lack of conflicts with driving cars for those on cycling lanes and paths and the larger distance available to stay away from parked cars.

Table 4: Model results (part 2/2 – main streets and experiment scale parameters)

Feature	Evaluation		est	WTP [% avg. travel time]	WTP (CHF/h)	t.rat.(0)	t.rat(1)
Traffic	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	0.129				-3.15 ***
		S-Pedelec 45 km/h	0.117				-3.75 ***
	WTP [min]	High	0.000			-	
		Low	-0.710	7%	-0.74	-3.70 ***	
	Gender Female: Traffic	Low	0.000			-	
		High	-0.057			-1.12 .	
Speed limit	SP cycling freq.	Never	1.000				-
		<3 days per month	0.785				-0.95 '
		1-3 days per month	0.540				-2.11 **
		1 day per week	0.435				-2.73 ***
		>=2 days per week	0.365				-4.79 ***
	SP WTP speed limit	Conventional bike	1.000				-
		E-Bike 25 km/h	0.547				-2.78 ***
		S-Pedelec 45 km/h	0.427				-3.96 ***
	WTP [min]	50 km/h	0.000			-	
		30 km/h	-4.175	39%	-4.36	-2.74 ***	
Car parking	SP WTP cycling freq.	Never	1.000				-
		<3 days per month	1.314				1.10 '
		1-3 days per month	1.158				0.61
		1 day per week	1.402				1.28 '
		>=2 days per week	1.430				1.43 *
	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	1.324				2.15 **
		S-Pedelec 45 km/h	0.879				-1.01 '
	WTP [min]	Yes	0.000			-	
		No	-2.098	20%	-2.19	-3.80 ***	
	Age: Parking	No	0.000			-	
		Yes	0.003			2.57 ***	
	Gender Female: Parking	No	0.000			-	
		Yes	0.104			1.74 **	
Width cycling lane/path	SP WTP cycling freq.	Never	1.000				-
		<3 days per month	2.095				1.97 **
		1-3 days per month	2.208				2.04 **
		1 day per week	1.910				1.74 **
		>=2 days per week	2.705				2.34 ***
	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	0.923				-1.00 '
		S-Pedelec 45 km/h	0.890				-1.41 *
	WTP [min]	Narrow	0.000			-	
		Wide	-1.395	13%	-1.46	-3.22 ***	
	Gender female: Width lane/path	Narrow	0.000			-	
		Wide	-0.106			-2.05 **	
Physical separation cycling lane	SP WTP physical sep. Cyc. lane	Conventional bike	1.000				-
		E-Bike 25 km/h	-0.032				-3.71 ***
		S-Pedelec 45 km/h	0.487				-2.37 ***
	WTP phys. sep. cyc. Lane	No	0.000			-	
		Yes	1.130	11%	1.18	3.70 ***	
Infrastructure type	SP WTP cycling freq.	Never	1.000				-
		<3 days per month	0.696				-4.32 ***
		1-3 days per month	0.611				-5.54 ***
		1 day per week	0.593				-5.64 ***
		>=2 days per week	0.595				-6.90 ***
	SP WTP bike type	Conventional bike	1.000				-
		E-Bike 25 km/h	1.245				2.26 **
		S-Pedelec 45 km/h	0.843				-1.93 ***
	WTP [min]	Cycling lane	0.000			-	
		Cycling lane with buffer	-3.230	30%	-3.37	-6.55 ***	
		Cycling path	-10.110	95%	-10.56	-8.28 ***	
	Age: Infrastructure type	Cycling lane	0.000			-	
		Cycling lane with buffer	-0.008			-7.85 ***	
		Cycling path	-0.012			-5.91 ***	
	Gender Female: Infrastructure type	Cycling lane	0.000			-	
		Cycling lane with buffer	0.000			0.00	
		Cycling path	0.178			2.11 **	
Interaction	WTP Wide cycling lane x Physical separation		-1.651			-4.74 ***	
Interaction	WTP Wide cycling lane x Parking		1.0115			2.45 ***	

Sign. Codes 0***0.001**0.05*0.10'0.25

Figure 5: Main street design with highest utility

CONCLUSION

In this project an SP-experiment was conducted to assess the preferences of cyclists concerning cycling infrastructures and related aspects for main and neighborhood streets in Switzerland. To assess how the Swiss e-bike boom affects preferences, e-bike, s-pedelec and conventional bikers as well as individuals who seldom cycle were recruited to assess their preferences so that the differences in their preferences could be analyzed.

We found a clear and consistent difference in the preferences of fast s-pedelec (45 km/h) riders from conventional cyclists, while the preference of e-bikers (25 km/h) is mixed. E-bikers do value all the most important cycling safety related feature, namely cycling paths on main streets, cycling markings on neighborhood streets as well as the lack of car parking on the streets at the same level or higher than conventional cyclists do. On the other hand, their preferences are consistently lower, for features of the interaction with car traffic such as speed limits and traffic volumes. The reason for that is likely to be due to the fact that e-bikes and s-pedelecs especially do usually travel at higher speeds than conventional bikes do for most individuals (*10*).

Still, given all the differences, we do not find opposed signs in the preferences among the bike types and individuals and the WTP are always negative in sign, meaning a positive valuation, for all the examined features that are usually found to increase the attractivity of cycling. An exception here is the preference of e-bikers towards physical separations to cycle lanes on main streets, but the scale parameter is so small that it leads to a WTP close to zero. The found effects thus corroborate findings from the existing literature on cycling infrastructure aspects.

While a number of situations and infrastructure types were studied, not all could be incorporated in this experiment. An example is contra-flow cycling lanes on one-way streets. Further experiments should include such situations. Future work will aim to develop further understanding of the preferences by incorporating RP-route choice data of cyclists from the EBIS project as well as testing other model formulations, such as mixture models, to examine the heterogeneity of preference among and within the different groups, as well as latent-class models.

REFERENCES

1. Tsoi, K. H., B. P. Y. Loo, and D. Banister. "Mind the (Policy-Implementation) Gap": Transport Decarbonisation Policies and Performances of Leading Global Economies (1990–2018). *Global Environmental Change*, Vol. 68, 2021, p. 102250. https://doi.org/10.1016/j.gloenvcha.2021.102250.

2. Pedroso, F. E., F. Angriman, A. L. Bellows, and K. Taylor. Bicycle Use and Cyclist Safety Following Boston's Bicycle Infrastructure Expansion, 2009-2012. *American Journal of Public Health*, Vol. 106, No. 12, 2016, pp. 2171–2177. https://doi.org/10.2105/AJPH.2016.303454.

3. Gu, J., B. Mohit, and P. A. Muennig. The Cost-Effectiveness of Bike Lanes in New York City. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*, Vol. 23, No. 4, 2017, pp. 239–243. https://doi.org/10.1136/injuryprev-2016-042057.

4. Harris, M. A., C. C. O. Reynolds, M. Winters, P. A. Cripton, H. Shen, M. L. Chipman, M. D. Cusimano, S. Babul, J. R. Brubacher, S. M. Friedman, G. Hunte, M. Monro, L. Vernich, and K. Teschke. Comparing the Effects of Infrastructure on Bicycling Injury at Intersections and Non-Intersections Using a Case–Crossover Design. *Injury Prevention*, Vol. 19, No. 5, 2013, pp. 303–310. https://doi.org/10.1136/injuryprev-2012-040561.

5. Pucher, J., and R. Buehler. Safer Cycling Through Improved Infrastructure. *American Journal of Public Health*, Vol. 106, No. 12, 2016, pp. 2089–2091. https://doi.org/10.2105/AJPH.2016.303507.

6. Reynolds, C. C., M. A. Harris, K. Teschke, P. A. Cripton, and M. Winters. The Impact of Transportation Infrastructure on Bicycling Injuries and Crashes: A Review of the Literature. *Environmental Health*, Vol. 8, 2009, p. 47. https://doi.org/10.1186/1476-069X-8-47.

7. Rérat, P. The Rise of the E-Bike: Towards an Extension of the Practice of Cycling? *Mobilities*, Vol. 16, No. 3, 2021, pp. 423–439. https://doi.org/10.1080/17450101.2021.1897236.

8. BFS, B. für S. *Mobilitätsverhalten Der Bevölkerung: Ergebnisse Des Mikrozensus Mobilität Und Verkehr 2021*. Swiss Federal Office for Spatial Development (ARE), Swiss Federal Statistical Office (FSO), Berne and Neuchâtel, 2023.

9. de Haas, M., M. Kroesen, C. Chorus, S. Hoogendoorn-Lanser, and S. Hoogendoorn. E-Bike User Groups and Substitution Effects: Evidence from Longitudinal Travel Data in the Netherlands. *Transportation*, Vol. 49, No. 3, 2022, pp. 815–840. https://doi.org/10.1007/s11116-021-10195-3.

10. Meyer de Freitas, L., and K. W. Axhausen. Evaluating Mode-Shift Potentials to Cycling Based on Individual Capabilities. *Arbeitsberichte Verkehrs- und Raumplanung*, Vol. 1763, 2022. https://doi.org/10.3929/ethz-b-000561700.

11. Pucher, J., and R. Buehler. Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews*, Vol. 28, No. 4, 2008, pp. 495–528. https://doi.org/10.1080/01441640701806612.

12. Buehler, R., and J. Pucher. Cycling to Sustainability in Amsterdam. *Sustain: A journal of environmental and sustainability issues*, Vol. 21, 2010, pp. 36–40.

13. Goel, R., A. Goodman, R. Aldred, R. Nakamura, L. Tatah, L. M. T. Garcia, B. Zapata-Diomedi, T. H. de Sa, G. Tiwari, A. de Nazelle, M. Tainio, R. Buehler, T. Götschi, and J. Woodcock. Cycling Behaviour in 17 Countries across 6 Continents: Levels of Cycling, Who Cycles, for What Purpose, and How Far? *Transport Reviews*, Vol. 42, No. 1, 2022, pp. 58–81. https://doi.org/10.1080/01441647.2021.1915898.

14. Marqués, R., V. Hernández-Herrador, M. Calvo-Salazar, and J. A. García-Cebrián. How Infrastructure Can Promote Cycling in Cities: Lessons from Seville. *Research in Transportation Economics*, Vol. 53, 2015, pp. 31–44. https://doi.org/10.1016/j.retrec.2015.10.017.

15. Hull, A., and C. O'Holleran. Bicycle Infrastructure: Can Good Design Encourage Cycling? *Urban, Planning and Transport Research*, Vol. 2, No. 1, 2014, pp. 369–406. https://doi.org/10.1080/21650020.2014.955210.

16. Gössling, S., and S. McRae. Subjectively Safe Cycling Infrastructure: New Insights for Urban Designs. *Journal of Transport Geography*, Vol. 101, 2022, p. 103340. https://doi.org/10.1016/j.jtrangeo.2022.103340.

17. von Stülpnagel, R., and N. Binnig. How Safe Do You Feel? – A Large-Scale Survey Concerning the Subjective Safety Associated with Different Kinds of Cycling Lanes. *Accident Analysis & Prevention*, Vol. 167, 2022, p. 106577. https://doi.org/10.1016/j.aap.2022.106577.

18. Yang, Y., X. Wu, P. Zhou, Z. Gou, and Y. Lu. Towards a Cycling-Friendly City: An Updated Review of the Associations between Built Environment and Cycling Behaviors (2007–2017). *Journal of Transport & Health*, Vol. 14, 2019, p. 100613. https://doi.org/10.1016/j.jth.2019.100613.

19. Dill, J., and N. McNeil. Revisiting the Four Types of Cyclists: Findings from a National Survey. *Transportation Research Record*, Vol. 2587, No. 1, 2016, pp. 90–99. https://doi.org/10.3141/2587-11.

20. Francke, A., J. Anke, S. Lißner, L.-M. Schaefer, T. Becker, and T. Petzoldt. Are You an Ambitious Cyclist? Results of the Cyclist Profile Questionnaire in Germany. *Traffic Injury Prevention*, Vol. 20, No. sup3, 2019, pp. 10–15. https://doi.org/10.1080/15389588.2019.1702647.

21. Larsen, J., and A. El-Geneidy. A Travel Behavior Analysis of Urban Cycling Facilities in Montréal, Canada. *Transportation Research Part D: Transport and Environment*, Vol. 16, No. 2, 2011, pp. 172–177. https://doi.org/10.1016/j.trd.2010.07.011.

22. Berghoefer, F. L., and M. Vollrath. Cyclists' Perception of Cycling Infrastructure – A Repertory Grid Approach. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 87, 2022, pp. 249–263. https://doi.org/10.1016/j.trf.2022.04.012.

23. Gatersleben, B., and H. Haddad. Who Is the Typical Bicyclist? *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 13, No. 1, 2010, pp. 41–48. https://doi.org/10.1016/j.trf.2009.10.003.

24. Damant-Sirois, G., M. Grimsrud, and A. M. El-Geneidy. What's Your Type: A Multidimensional Cyclist Typology. *Transportation*, Vol. 41, No. 6, 2014, pp. 1153–1169. https://doi.org/10.1007/s11116-014-9523-8.

25. Dill, J., and N. McNeil. Four Types of Cyclists?: Examination of Typology for Better Understanding of Bicycling Behavior and Potential. *Transportation Research Record*, Vol. 2387, No. 1, 2013, pp. 129–138. https://doi.org/10.3141/2387-15.

26. Hardinghaus, M., and J. Weschke. Attractive Infrastructure for Everyone? Different Preferences for Route Characteristics among Cyclists. *Transportation Research Part D: Transport and Environment*, Vol. 111, 2022, p. 103465. https://doi.org/10.1016/j.trd.2022.103465.

27. Rossetti, T., V. Saud, and R. Hurtubia. I Want to Ride It Where I like: Measuring Design Preferences in Cycling Infrastructure. *Transportation*, Vol. 46, No. 3, 2019, pp. 697–718. https://doi.org/10.1007/s11116-017-9830-y.

28. Cabral, L., and A. M. Kim. An Empirical Reappraisal of the Four Types of Cyclists. *Transportation Research Part A: Policy and Practice*, Vol. 137, 2020, pp. 206–221. https://doi.org/10.1016/j.tra.2020.05.006.

29. Meister, A., M. Felder, B. Schmid, and K. W. Axhausen. Route Choice Modeling for Cyclists on Urban Networks. *Transportation Research Part A: Policy and Practice*, Vol. 173, 2023, p. 103723. https://doi.org/10.1016/j.tra.2023.103723.

30. Prato, C. G., K. Halldórsdóttir, and O. A. Nielsen. Evaluation of Land-Use and Transport Network Effects on Cyclists' Route Choices in the Copenhagen Region in Value-of-Distance Space. *International Journal of Sustainable Transportation*, Vol. 12, No. 10, 2018, pp. 770–781. https://doi.org/10.1080/15568318.2018.1437236.

31. Menghini, G., N. Carrasco, N. Schüssler, and K. W. Axhausen. Route Choice of Cyclists in Zurich. *Transportation Research Part A: Policy and Practice*, Vol. 44, No. 9, 2010, pp. 754–765. https://doi.org/10.1016/j.tra.2010.07.008.

32. Zimmermann, M., T. Mai, and E. Frejinger. Bike Route Choice Modeling Using GPS Data without Choice Sets of Paths. *Transportation Research Part C: Emerging Technologies*, Vol. 75, 2017, pp. 183–196. https://doi.org/10.1016/j.trc.2016.12.009.

33. Sener, I. N., N. Eluru, and C. R. Bhat. An Analysis of Bicycle Route Choice Preferences in Texas, US. *Transportation*, Vol. 36, No. 5, 2009, pp. 511–539. https://doi.org/10.1007/s11116-009-9201-4.

34. Majumdar, B. B., and S. Mitra. A Study on Route Choice Preferences for Commuter and Non-Commuter Bicyclists: A Case Study of Kharagpur and Asansol, India. *Transportation*, Vol. 46, No. 5, 2019, pp. 1839–1865. https://doi.org/10.1007/s11116-018-9898-z.

35. Rossetti, T., C. A. Guevara, P. Galilea, and R. Hurtubia. Modeling Safety as a Perceptual Latent Variable to Assess Cycling Infrastructure. *Transportation Research Part A: Policy and Practice*, Vol. 111, 2018, pp. 252–265. https://doi.org/10.1016/j.tra.2018.03.019.

36. Axhausen, K. W., and R. L. Smith Jr. Bicyclist link evaluation: A stated-preference approach.. *Transportation Research Record*, No. 1085, pp. 7-15, 1986.

37. Stinson, M. A., and C. R. Bhat. Commuter Bicyclist Route Choice: Analysis Using a Stated Preference Survey. *Transportation Research Record*, Vol. 1828, No. 1, 2003, pp. 107–115. https://doi.org/10.3141/1828-13.

38. Hunt, J. D., and J. E. Abraham. Influences on Bicycle Use. *Transportation*, Vol. 34, No. 4, 2007, pp. 453–470. https://doi.org/10.1007/s11116-006-9109-1.

39. Poorfakhraei, A., and G. M. Rowangould. Estimating Welfare Change Associated with Improvements in Urban Bicycling Facilities. *Journal of Transportation Engineering*, Vol. 141, No. 11, 2015, p. 04015025. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000799.

40. Börjesson, M., and J. Eliasson. The Value of Time and External Benefits in Bicycle Appraisal. *Transportation Research Part A: Policy and Practice*, Vol. 46, No. 4, 2012, pp. 673–683. https://doi.org/10.1016/j.tra.2012.01.006.

41. Ma, L., J. Dill, and C. Mohr. The Objective versus the Perceived Environment: What Matters for Bicycling? *Transportation*, Vol. 41, No. 6, 2014, pp. 1135–1152. https://doi.org/10.1007/s11116-014-9520-y.

42. Fosgerau, M., E. Frejinger, and A. Karlstrom. A Link Based Network Route Choice Model with Unrestricted Choice Set. *Transportation Research Part B: Methodological*, Vol. 56, 2013, pp. 70–80. https://doi.org/10.1016/j.trb.2013.07.012.

43. Meyer de Freitas, L., H. Becker, M. Zimmermann, and K. W. Axhausen. Modelling Intermodal Travel in Switzerland: A Recursive Logit Approach. *Transportation Research Part A: Policy and Practice*, Vol. 119, 2019, pp. 200–213. https://doi.org/10.1016/j.tra.2018.11.009.

44. Loomis, J. What's to Know About Hypothetical Bias in Stated Preference Valuation Studies? *Journal of Economic Surveys*, Vol. 25, No. 2, 2011, pp. 363–370. https://doi.org/10.1111/j.1467-6419.2010.00675.x.

45. Schmid, B., T. Schatzmann, C. Winkler, and K. W. Axhausen. A Two-Stage RP/SP Survey to Estimate the Value of Travel Time in Switzerland: Short- versus Long-Term Choice Behavior. *Arbeitsberichte Verkehrs- und Raumplanung*, Vol. 1724, 2022. https://doi.org/10.3929/ethz-b-000536709.

46. Branion-Calles, M., M. Winters, T. Nelson, A. de Nazelle, L. I. Panis, I. Avila-Palencia, E. Anaya-Boig, D. Rojas-Rueda, E. Dons, and T. Götschi. Impacts of Study Design on Sample Size, Participation Bias, and Outcome Measurement: A Case Study from Bicycling Research. *Journal of Transport & Health*, Vol. 15, 2019, p. 100651. https://doi.org/10.1016/j.jth.2019.100651.

47. ChoiceMetrics. Ngene 1.1.1 User Manual & Reference Guide. Australia, , 2012.

48. Hudde, A. The Unequal Cycling Boom in Germany. *Journal of Transport Geography*, Vol. 98, 2022, p. 103244. https://doi.org/10.1016/j.jtrangeo.2021.103244.

49. Fyhri, A., K. Karlsen, and H. B. Sundfør. Paint It Red - A Multimethod Study of the Nudging Effect of Coloured Cycle Lanes. *Frontiers in Psychology*, Vol. 12, 2021.

50. Pulugurtha, S. S., and V. Thakur. Evaluating the Effectiveness of On-Street Bicycle Lane and Assessing Risk to Bicyclists in Charlotte, North Carolina. *Accident; Analysis and Prevention*, Vol. 76, 2015, pp. 34–41. https://doi.org/10.1016/j.aap.2014.12.020.

51. Griffin, W., N. Haworth, and D. Twisk. Patterns in Perceived Crash Risk among Male and Female Drivers with and without Substantial Cycling Experience. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 69, 2020, pp. 1–12. https://doi.org/10.1016/j.trf.2019.12.013.

52. Hopkinson, P., and M. Wardman. Evaluating the Demand for New Cycle Facilities. *Transport Policy*, Vol. 3, No. 4, 1996, pp. 241–249. https://doi.org/10.1016/S0967-070X(96)00020-0.

53. von Stülpnagel, R., and J. Lucas. Crash Risk and Subjective Risk Perception during Urban Cycling: Evidence for Congruent and Incongruent Sources. *Accident Analysis & Prevention*, Vol. 142, 2020, p. 105584. https://doi.org/10.1016/j.aap.2020.105584.

54. Fabriek, E., D. de Waard, and J. P. Schepers. Improving the Visibility of Bicycle Infrastructure. *International Journal of Human Factors and Ergonomics*, Vol. 1, No. 1, 2012, pp. 98–115. https://doi.org/10.1504/IJHFE.2012.045274.