Estimating preferences for pedestrian crossing facilities

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Abstract

This paper reports the results of a study to understand the preferences of pedestrians towards different types of crossing facilities in an area surrounding a 6-lane busy road in London. Participants were first asked to indicate how comfortable they feel using different types of crossings. Footbridges and underpasses were systematically rated below signalised crossings, but staggered signalised crossings were rated slightly higher than straight ones. Participants were then presented with a scenario where crossing the road is impossible and asked to choose between walking a given time and use a certain type of facility or avoid crossing the road altogether. The analysis of the choices using a mixed logit model revealed that participants chose staggered signalised crossings, footbridges, and underpasses, if the walking times to those crossings were respectively 1.5, 4.2, and 5.7 minutes smaller than the times to access straight crossings. The “don’t cross” alternative was chosen only if the straight crossings were located 18.5 minutes away. Older participants required higher reductions in order to use underpasses rather than straight crossings, and people who cross the road most days require lower reductions to use the three types of alternative facilities. The study provides information that is useful when planning changes in the frequency and type of facilities to cross busy roads.

1. Introduction

The shift from non-motorised to motorised types of urban transport that occurred in the 20th century throughout the world has led to several economic, social and environmental problems. Transport and urban planners have increased their efforts to rehabilitate the cities for pedestrians during the present century, but they are constrained by the legacy of a road network that excludes or limits non-motorised modes of transport (Illich 1974). In fact, roads are often a barrier for the movement of pedestrians because of the risk and unpleasantness of crossing to the other side (Appleyard *et al.* 1981). However, solutions such as the reduction traffic levels or speeds may not always be feasible, especially in the cases of roads that are crucial for the accessibility of private and public transport users and where there are no alternative links. In these cases, the construction or improvement of crossing facilities are possible alternatives to reduce the barrier effect of roads for pedestrians.

The effectiveness of crossing facilities in improving the ease of crossing busy roads depends nevertheless on their characteristics. There is evidence that some types of facilities are generally disliked by pedestrians and can even aggravate the barrier effect (James *et al.* 2005). The assessment of schemes to improve road crossings requires therefore the estimation of the benefits that pedestrians will derive from them.

This paper is an output of the Street Mobility and Network Accessibility project being conducted at University College London to develop tools to reduce barriers to walking that are caused by busy roads. These tools include not only methods to understand the incidence of those barriers and their impact on people's health and wellbeing, but also methods to develop and assess solutions to mitigate those barriers. These solutions include the reformulation of the set of facilities available for pedestrians wishing to cross the road.

A survey was developed to estimate preferences for different types of crossing facilities and walking times to access them. The study included a preliminary stage using focus groups and in-depth interviews to understand people's general views about crossing busy roads. The information collected at this stage informed the design of the main survey, applied in the area around Finchley Road, a particularly busy artery in North London. This paper reports the results of two exercises included in this survey: a question where participants rated four different types of crossings and a series of questions where they chose between different alternatives of facilities and walking times to access them.

The rest of the paper is organised as follows. Section 2 is a brief review of the theoretical and empirical background for this study. Section 3 reports the main conclusions of the qualitative study and the implications for the design of the main survey. Section 4 describes the study area and the sampling process. Sections 5 and 6 report the results of the rating and stated preference exercises in the main survey. Section 7 concludes the paper.

2. Background

The decisions of pedestrians to cross the road usually involve a trade-off between safety and convenience. People often cross the road away from designated facilities because that is the fastest and most direct and convenient way to cross. Signalised crossings are safer than informal crossings, but may involve detours and delays to the trip. Non-level crossings such as footbridges and underpasses are also safe in terms of pedestrian collision but are almost universally disliked, due to the time and effort required to use them, and to issues of personal security. This is confirmed among many others in the studies of James *et al.* (2005) in the UK, Mfinanga (2014) in Tanzania, and Tao *et al.* (2010) in China. Some groups such as females and the elderly are especially adverse to use non-level crossings, especially at night. Despite the advantages and disadvantages or each type of facility, the use of a particular facility may be explained due to the lack of alternatives (Sinclair and Zuidgeest 2015) or the location of the crossing along, and not across, the direction of the trip (Yannis *et al.* 2007).

The extensive literature on pedestrian crossing behaviour has used a wide variety of methods, including questionnaires and interviews (Bernhoft and Carstensen 2008), video surveys (Sisiopiku and Akin 2003), pedestrian tracking (Papadimitriou 2012), GIS analysis (Lassarre *et al.* 2012), and experiments (Granié *et al.* 2014). Advances in choice modelling techniques have increased the use of stated preference surveys to estimate pedestrians' preferences for crossing situations and facilities. In this type of surveys, participants are asked to choose from hypothetical alternatives, defined by several attributes. The choices are then related to the attribute levels using statistical models, from which the willingness to accept marginal changes in the attributes can be derived.

This method can be applied to elicit preferences among alternative measures to improve the ease of crossing the road. The most radical and most effective of these measures is to build a road tunnel. This scenario was studied by Grisolía and López (2015), who modelled the preferences for burying a road taking into consideration the cost of the project and the types of land use on the surface (paved square or garden) and the existence of street furniture and CCTV. The ease of crossing can also be improved by traffic calming measures or by the reallocation of road space. For example, Garrod *et al*. (2002) estimated preferences for traffic calming measures in terms of reductions in traffic speed, noise, aesthetics, and time to cross the road. Choice modelling has also been used to estimate preferences for interventions such as shared space (ITS and Atkins 2011, Kaparias *et al.* 2012) and improvements in pedestrian infrastructure in roundabouts (Perdomo *et al.* 2014). Information about the type of crossing facility can also be included as an attribute in wider models of pedestrian route choice that take into account elements such as the crossing situation and the monetary cost of interventions (Hensher *et al.* 2011).

However, for a given individual, preferences are determined not only by the crossing situation and the characteristics of the crossing facility, but also by the distance to access them. For example, Sisiopiku and Akin (2003) found that the decision to cross the road in a particular location depends on its position in relation to the origin and destination of the trip. Walking distance has also been included in some studies of choices of pedestrian crossing situations. Meltofte and Nørby (2013) derive people’s trade-off values between number of lanes, traffic characteristics, and distance to the nearest crossing facility. Cantillo *et al.* (2015) also modelled the choices between crossing the road informally and using signalised crossings and footbridges, taking into account the walking distance to these two facilities, delay, road traffic flow, and whether the participant is travelling with children. The study found that longer distances to facilities increase the probability of informal crossing, especially in the case of footbridges. However, age, gender, qualification levels, and circumstances of the trip are also relevant. The present study follows these developments, by estimating the trade-offs pedestrians make between the use of different types of crossing facility, walking times to access them, and the possibility of avoid crossing altogether.

3. Qualitative phase

The main survey was preceded by a qualitative study, with the objective of obtaining information about the problems people faced when crossing busy roads and the perceptions about different types of crossing facilities. The study consisted in four 90-minute focus groups and seven in-depth 30-minute interviews. To obtain a broader set of views, the participants were not recruited from the study area of the main survey, but from two other areas, in London and in Birmingham, representing a more diverse geographic, demographic, and socio-economic context.

Most of the participants in the focus groups and interviews were able to spontaneously make suggestions to what would improve the situation and to list out the advantages and disadvantages of different types of crossing facilities. Strong views were expressed regarding the waiting time in some signalised crossing facilities, the inconvenience of two-stage crossing facilities, and personal security issues and the lack of accessibility of footbridges and underpasses. Zebra crossings were either not mentioned by or did not elicit strong views and were therefore excluded from the main survey. Interestingly, some preferences were justified in terms of overall benefits for all modes of transport and not for pedestrians alone. For example, some participants considered footbridges and underpasses a good solution because they do not stop road traffic flow.

In general, participants were willing to walk a few minutes to use designated facilities, rather than crossing the road informally. However, they were prepared to walk less if those facilities were footbridges or underpasses, rather than signalised crossings. The focus groups with older participants demonstrated more tolerance for walking further to use the preferred crossings. The walking situation was also important, with choices depending on time of day, mobility restrictions and on whether the pedestrian is alone or is walking with children.

The focus groups also provided feedback on the design of the stated preference exercises and the ways to illustrate some of the attributes of roads and crossing facilities in the main survey. Reasonable logic was displayed when making selections throughout the exercises. However, it was not always clear to participants whether the footbridges and underpasses in the images shown had a ramp. Lighting levels also influence the decision to use underpasses. These and other issues were taken into consideration in the design of the main stage survey.

4. Main survey: study area and sampling

The main survey was conducted in the area surrounding Finchley Road, one of the case studies of the *Street Mobility and Network Accessibility* project. This road is a major artery in North London and represents a major barrier to pedestrian movement due to the high traffic levels, which are of similar magnitude as some motorways in London. Crossing the road is particularly problematic in the 1km section between Swiss Cottage tube station and Finchley Road and Frognal overground station, where the road has 3 lanes for motorised traffic in each direction and guard railings or walls preventing pedestrians to cross outside designated crossing facilities (Figure 1). The existing facilities in this section of the road include six signalised crossings and two underpasses.

Figure 1: Barriers to crossing Finchley Road

Participatory mapping workshops done as a part of the *Street Mobility and Network Accessibility* project revealed that local residents perceive Finchley Road as an unpleasant place and dislike crossing the road due to delays, confusion in complex junctions, and exposure to road traffic. Participants stated they cross the road mostly to access specific facilities and design their walking routes to reduce the time spent on the road. They have also developed strategies to enable crossing safely and for avoiding the worst impacts of heavy traffic, such as driving, using public transport, or using alternative walking routes to reduce the number of times they need to cross the road or to avoid particular crossings points. This information shows that local residents trade-off walking time and the decision to cross the road and to use particular crossing facilities.

The main stage of the survey consisted of 100 computer-assisted interviews, conducted during the period 27 July-14 August 2015. The sample was designed to have similar number of individuals aged below (54%) and over 50 years old (46%). The sample is also split almost equally by gender (45% males and 55% females) and reveals aspects characteristic of Inner London areas, such as a high proportion of individuals with high qualifications (36%), working or studying (60%) and living in households without a car (53%). The composition of the sample in terms of demographic and socio-economic variables, frequency of crossing the road, and characteristics of the last walking trip (purpose, situation, and mobility restrictions) is described in detail in the second column of Table 1.

5. Rating exercise

In a first exercise, participants were asked to indicate how comfortable they feel crossing busy roads using different types of pedestrian crossing, shown in a card. The scale used ranged from 0 to 100, where a score of 0 represents a road with no crossing facilities and a score of 100 represents the case where the road is covered over.

Four types of facilities were shown: a straight and a staggered signalised crossing, a footbridge, and an underpass. In the staggered facility, the crossing is done in two stages and the crossings on each side of the road are not aligned. Both footbridges and underpasses were represented with steps and ramps. The images had the same number of lanes as in Finchley Road so that participants could relate the options shown to their own experience. Figure 2 shows an example of the questions, representing the footbridge.

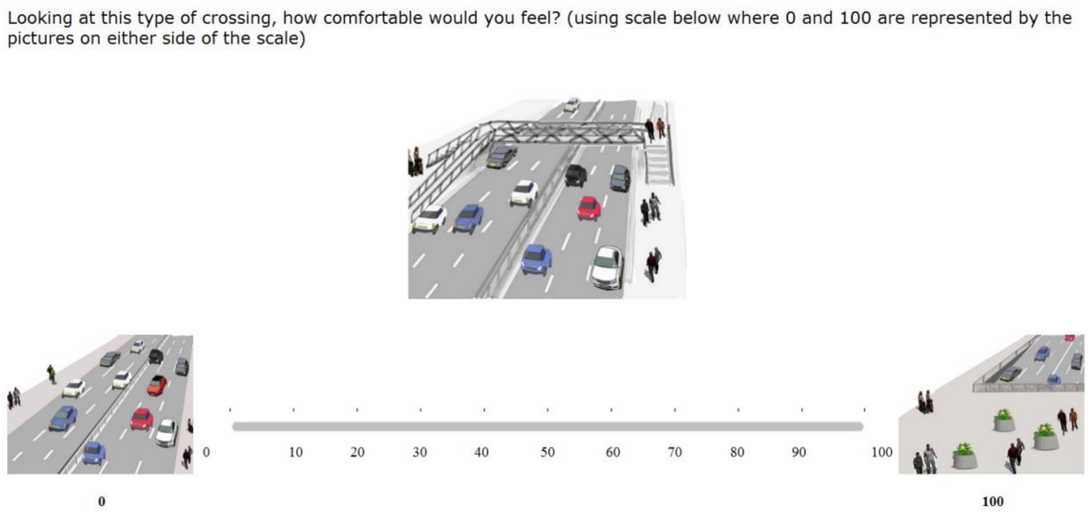

Figure 2: Example of question in the rating exercise

Figure 3 shows the rating values for the four types of crossing, in ascending order. Crossings at grade (straight and staggered signalised crossings) are systematically rated above crossings not at grade (footbridges and underpasses). The ratings of footbridges are slightly higher than those of underpasses. The figure also shows that participants used the whole range of values available, from 0 to 100%, for all four crossings.

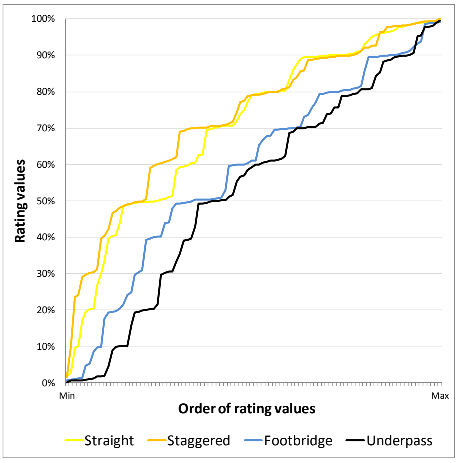

Figure 3: Rating values for each type of crossing, in ascending order

Table 1: Rating exercise: descriptive statistics

	n	Straight	Staggered	Footbridge	Underpass
Average	100	0.70	0.73	0.59	0.53
Standard deviation		0.26	0.23	0.28	0.31
Median		0.79	0.79	0.61	0.60
Number of #1		36	39	14	12
Number of #2		31	37	24	12
Number of #3		16	16	29	36
Number of #4		17	8	33	40
Average by group					
Age					
18-34	34	0.74	0.75	0.73	0.60
35-50	20	0.69	0.80	0.58	0.62
51-65	22	0.73	0.75	0.48	0.52
65+	24	0.64	0.62	0.48	0.36
Gender					
Male	45	0.76	0.77	0.66	0.64
Female	55	0.65	0.69	0.52	0.44
Income					
<10k	6	0.61	0.52	0.62	0.33
10-20k	8	0.81	0.77	0.67	0.34
20-30k	15	0.75	0.70	0.63	0.51
30-40k	7	0.69	0.72	0.69	0.63
40-50k	10	0.57	0.76	0.59	0.58
50-60k	10	0.69	0.80	0.53	0.68
>60k	7	0.68	0.67	0.63	0.49
Number of cars					
None	53	0.68	0.72	0.62	0.54
One	40	0.71	0.73	0.56	0.55
Two or more	7	0.78	0.75	0.46	0.33
Employment					
Full-time work	40	0.70	0.77	0.62	0.61
Part-time work	12	0.70	0.77	0.59	0.64
Unemployed	7	0.61	0.67	0.67	0.58
Retired	28	0.68	0.66	0.46	0.35
Student	8	0.81	0.73	0.74	0.57
Qualifications					
Degree	47	0.68	0.71	0.58	0.54
Technical	36	0.71	0.74	0.53	0.46
None	16	0.77	0.75	0.76	0.66
Frequency of crossing the road					
Most days	53	0.70	0.76	0.59	0.51
2-3 times a week	29	0.70	0.72	0.54	0.58
< 2-3 times a week	18	0.70	0.65	0.63	0.50
Trip purpose					
Work	22	0.68	0.80	0.62	0.64
Shopping	45	0.64	0.68	0.57	0.51
Visit family/friends	9	0.82	0.86	0.59	0.55
Leisure	16	0.83	0.75	0.59	0.47
Situation					
Alone	73	0.69	0.73	0.57	0.53
With another adult	17	0.75	0.70	0.67	0.58
With children	10	0.69	0.72	0.52	0.46
Mobility					
Full mobility	86	0.72	0.74	0.60	0.55
Restricted mobility	14	0.60	0.66	0.49	0.39

Table 1 presents descriptive statistics for the ratings of the four facilities, including the average, standard deviation, median value, and the number of times the facilities had each position (from 1st to 4th) in the ordered ratings of each participant. The table also shows the average ratings split by the characteristics of the participants and their walking trips.

The table confirm that the ratings of footbridges and underpasses are lower in average than the ratings of signalised crossings and are also the least comfortable crossings for most participants (33% and 40% respectively). Footbridges are rated higher than underpasses and staggered crossings are rated slightly higher than straight crossings.

In average, the older age group (over 65) gave the lowest ratings to all four types of crossings. The difference is especially noticeable in the case of underpasses, which have an average rating of 53% for the whole sample and 36% for the older age group. The ratings of participants with mobility restrictions were similar to the ones of the older age group. The group aged 50-65 also gave lower ratings to footbridges and underpasses than younger groups. The youngest group (aged 18-34) gave high ratings to footbridges, comparing with the sample average and with the ratings that group gave to signalised crossings.

Females gave lower ratings than males to the four types of facilities. The difference between the ratings is highest in the case of underpasses (20%). A gap of similar size was found between the ratings given to underpasses by participants in the two lowest income groups, comparing with the average. Participants with no qualifications gave markedly higher ratings to footbridges and underpasses than average.

As expected, participants who walked for leisure in their last trip, and walked with children gave lower than average ratings to underpasses. The frequency of crossing the road seems to have little impact on the rating values.

6. Stated preference exercise

6.1. Design

The objective of the stated preference exercise was to estimate willingness to walk to cross the road and to use different types of crossing facilities. Participants were shown a scenario where crossing is impossible due to the presence of high traffic levels and guard railings in the middle of the road. Three options were then presented:

- Walk a given distance and use a certain type of crossing facility (options A and B).
- Avoid crossing the road altogether (option C)

The exercise consisted of six questions. The type of crossing facility and the walking time in options A and B were systematically varied. The types of facility are the same as in the rating exercise (straight and staggered signalised crossings, footbridges, and underpasses. The time added to the journey varied from 2 to 20 minutes, in 2 minute increments. Figure 4 shows an example of those questions, showing a choice between using a footbridge 20 minutes away, an underpass 4 minutes away, and avoid crossing. A restriction was imposed on the design so that footbridges and underpasses were always nearer than straight or staggered signalised crossings. An efficient design was used, which generates data that allows for the minimization of the standard errors of the parameter estimates (Rose and Bliemer 2009). The design was obtained using the *Ngene* software.

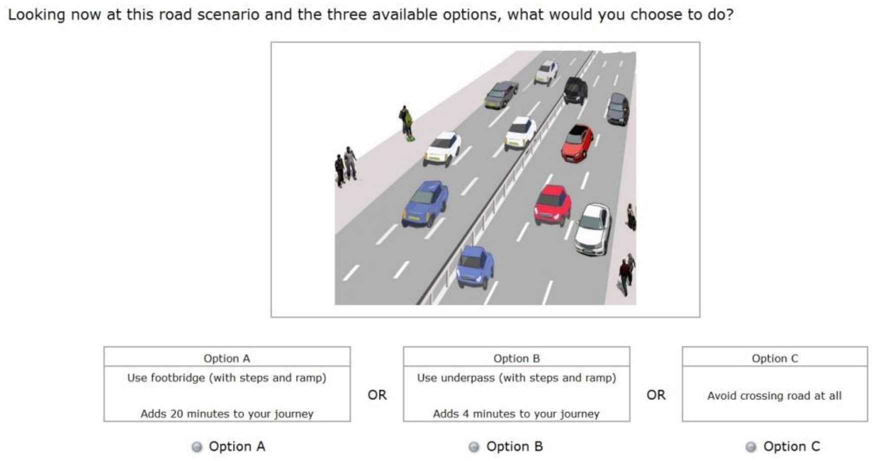

Figure 4: Example of question in the stated preference exercise

6.2. Econometric models

This section presents the results of the econometric models explaining choices in the stated preference exercise. The data was reshaped so that each record represents the choice regarding each of the three options presented in each of the seven questions to each participant. This procedure generated a dataset with 1800 records.

The dependent variable is a dummy variable where 1 is the case where the participant chose the option presented. The explanatory variables are walking time and dummy variables where 1 is the case where the option included a given crossing facility, or the possibility of not crossing. Straight signalised crossings are treated as the "base value" and are thus omitted from the models.

Three alternative models were estimated. Models 1 and 2 include only the attributes presented to the participants (types of facility, walking time, and the "don't cross" option). In the mixed logit model (Model 1), the coefficients of all variables except walking time are assumed to be random (Ben Akiva and Bolduc 1996, McFadden and Train 2000). In this case, the utility of an option depends on attribute levels and on the characteristics of the participants. The utility can be specified as follows:

$$U_{i,j} = \beta_j x_{i,j} + \varepsilon_{i,j}$$

where $U_{i,j}$ is the utility of alternative i for individual j, $x_{i,j}$ is a vector measuring the attributes of each alternative, β_j is a vector of parameters, and ε_{ij} is an error term that follows the Extreme Value Type I distribution. The parameters β_j are assumed to be random. The probability that individual i chooses alternative j is

$$P_{i,j} = \int L_{i,j}(\beta) f(\beta|\theta) d\theta$$

where $L_{i,j}$ is the probability of choice for a fixed value of β, defined as

$$L_{i,j}(\beta_i) = \frac{e^{\beta_i x_{i,j}}}{\sum_k e^{\beta_i x_{i,k}}}$$

In the conditional logit model (Model 2), the coefficients of all variables are assumed to be fixed across participants. In other words, the utility of an option depends only on the attribute levels. In the specification above, β is assumed to be fixed across all participants, and not random as in the mixed logit specification.

Model 3 adds interaction terms between the attributes and the characteristics of the participants and their most recent walking trip. Only a mixed logit was estimated in this case, as there was no significant interaction terms in the conditional logit model.

6.3. Results

Table 2 shows the estimated coefficients and significance levels of the variables in the three models. All the crossing facilities have a negative sign, which means that participants prefer to use straight signalised crossings rather than staggered crossings, footbridges, or underpasses. Staggered crossings have a negative coefficient despite having been rated higher, in average, than straight crossings in the rating exercise. However, the coefficient is only significantly different from 0 in the mixed logit model that does not include interaction terms. The coefficients of the crossings that are not at grade (footbridges and underpasses) are higher, in absolute value, than the staggered crossings coefficient, as expected from the empirical studies described in Section 2. However, the coefficient of footbridges is only significant in the mixed logit model with interaction terms. The "don't cross" and time coefficients are negative, which confirms that participants prefer to cross rather than not to cross the road, and prefer shorter to longer walking times.

Three interaction terms were significant in Model 3. The probability of choosing underpasses is lower for participants aged above 50 than for other participants, which confirms the dislike of older pedestrians for using underpasses, found in the rating exercise and in previous literature. The probability of not crossing the road is lower for participants who walk to work. These participants are also more sensitive to the walking time attribute. These results are also consistent with previous expectations, as people who walk to work usually have tighter time restrictions and less scope for not making the trip comparing with people who walk for leisure, shopping, or visiting someone.

The other interaction terms tested were not found significant at the 10% level in the final model. These include interactions with variables such as gender, age below 35, income, length of residence in the area, frequency of crossing the road, and presence of mobility restrictions on the last walking trip. Interactions between the types of facility, their ratings in the rating exercise, and their distance to participants' homes were also insignificant.

Table 2: Stated preference models

Variables	**Model 1** *conditional logit*		**Model 2** *mixed logit*		**Model 3** *mixed logit*	
	coefficient	*p>|z|*	*coefficient*	*p>|z|*	*coefficient*	*p>|z|*
staggered	-0.05	0.84	-0.39	0.00***	-0.63	0.14
footbridge	-0.30	0.21	-0.57	0.16	-1.44	0.00***
underpass	-0.65	0.00***	-1.63	0.00***	-0.98	0.10*
don't cross	-2.81	0.00***	-2.23	0.00***	-6.81	0.00***
time	-0.18	0.00***	-7.05	0.00***	-0.37	0.00***
underpass * age>50					-2.56	0.00***
don't cross * work					-7.62	0.06*
time * work					-1.06	0.00***
n	*1800*		*1800*		*1800*	
R^2	*0.19*		*0.36*		*0.39*	

Note: Significance levels: *** 1%, ** 5%, * 10%

6.4. Willingness to accept shorter walking times to use crossing facilities

The trade-offs values between walking times and the use of each type of facilities and the "don't cross" alternative can be derived from the estimated econometric models. Those values are the ratios between the coefficient of the variables indicating the presence of each facility or the "don't cross" alternative and the coefficient of walking time. Table 3 shows the estimated willingness to accept shorter walking times to use certain crossing facilities, or to avoid crossing, compared with the base scenario of using straight crossings. The values can also be understood as the willingness to walk to use straight crossings, when the alternative is another type of facility or to avoid crossing altogether.

The values obtained for the three types of facilities are positive, which shows that participants only choose these facilities if they are nearer than straight signalised crossings. Most of the values are below 5 minutes. This means that participants are willing to walk up to 5 minutes to use a straight signalised crossing instead of another type of crossing. The only exception is the value for underpasses in the case of the population over 50 in Model 3, which is close to 10 minutes. The magnitude of the values found for the three types of facility follow the order that was to be expected from the theory and previous literature. The walking time reduction required to choose a facility other than a straight signalised crossing is lower when the alternative is a facility not at grade (footbridge or underpass). In all cases, the values are lower for participants who walk to work, due to the time restrictions they face comparing with other participants.

Participants only avoid crossing if the walking times to access a crossing facility are located 15 minutes (in the conditional logit model) or 18 minutes away (in the mixed logit models). However, participants who walk to work are only willing to walk 10 minutes. This result is explained by the tighter time restrictions these participants face when they walk, which cancel out the effect of a lower propensity for not crossing the road.

Table 3: Willingness to accept shorter walking times to use crossing facilities, comparing to use a straight signalised crossing (minutes)

	Model 1	Model 2	Model 3		
	conditional logit	*mixed logit*	*mixed logit*		
			All	Age>50	Work
staggered	0.3	1.5	1.7		0.4
footbridge	1.6	4.2	3.9		1.0
underpass	3.6	5.7	2.7	9.6	0.7
don't cross	15.6	18	18.5		10.1

7. Conclusions

This paper estimated preferences for the use of different types of road crossing facilities, using a stated preference survey. The survey was designed based on the results of a preliminary qualitative study. In a first exercise, participants rated footbridges and underpasses systematically below signalised crossings, especially in the case of females and participants with mobility restrictions or in the older age group. The modelling of the choices among different alternatives for crossing facilities and walking time to access them revealed that participants choose staggered signalised crossings, footbridges, and underpasses only if these facilities are nearer than straight signalised crossings.

The results confirm the evidence found in previous literature, such as the general dislike of crossing facilities that are not at grade, especially among older pedestrians. However, the use of a stated preference survey brings additional information, regarding the disutility of avoiding those facilities in terms of walking time. The values found for the maximum walking times that people are prepared to walk to access straight crossings (0.3 to 5 minutes, depending on the alternative) are a useful input for interventions that involve the construction of new crossing facilities, or the reformulation of existing facilities. The values for the times above which participants prefer to avoid crossing the road altogether (15 to 18 minutes) can also be used to map the areas around major roads where residents do not make trips across the road, an indicator of the negative impacts of the road on accessibility and active travel.

The choice set available for a pedestrian in this survey contained only the use of designated crossing facilities and the option of not crossing. In most cases, the pedestrian also has the option of crossing the road in places without any facilities. The analysis in this paper should then be complemented with the modelling of the decision to cross the road in those places, considering the attributes of the road (such as number of lanes and presence of a central reservation), the attributes of the traffic (such as volume and speed), the distance to the nearest safe place to cross, and the value of accessing a specific destination on the other side of the road.

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