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Estimating preferences for different types of pedestrian crossing facilities

Paulo Rui Anciaes *, Peter Jones

Centre for Transport Studies, University College London, Chadwick Building, Gower Street, London WC1E 6BT, United Kingdom

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ABSTRACT

This paper reports the results of a study to understand the preferences of pedestrians towards using different types of road crossing facilities. A preliminary qualitative study found that people's perceptions about crossing facilities are shaped by aspects such as safety, convenience, crossing time, accessibility, and personal security. The main quantitative study consisted of a stated preference survey implemented in three neighbourhoods in English cities near busy roads. Participants were first asked to indicate how comfortable they felt using different types of crossing facilities. Footbridges and underpasses were systematically rated below signalised crossings. Participants were then asked to choose between walking different additional times to use certain types of crossing facility or avoid crossing the road altogether. The analysis of the choices using a mixed logit model found that on average participants are willing to walk an additional 2.4 and 5.3 min to use a straight signalised crossing and avoid using footbridges and underpasses, respectively. Women and older participants were willing to walk longer additional times to avoid those facilities. Participants only avoid crossing the road if the additional time to use straight signalised crossings is at least 20.9 min. The estimated values for the willingness to walk were slightly smaller when using a conditional logit model. The study provides information that is useful for policy decisions about the frequency and the type of pedestrian facilities provided to cross busy roads.

1. Introduction

The major shift from non-motorised to motorised forms of urban transport that occurred during the 20th century throughout the world has led to traffic dominance of urban streets. As a result, pedestrians became the most vulnerable road user group. An estimated 275,000 pedestrians die every year globally as a result of traffic collisions (WHO, 2015). Roads are also physical and psychological barriers to the movement of pedestrians, with negative impacts on accessibility and social inclusion (Appleyard, Gerson, & Lintell, 1981; Anciaes, Jones, & Mindell, 2016). 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 road networks that exclude or limit provision for non-motorised modes of transport (Illich, 1974). The construction or improvement of pedestrian crossing facilities often become the main alternative to mitigate the impacts of roads on pedestrians, when solutions such as reducing traffic levels or lowering speed limits meet with social and political resistance due to their impact on the accessibility of users of private and public motorised transport.

* Corresponding author.
E-mail addresses: p.anciaes@ucl.ac.uk (P.R. Anciaes), peter.jones@ucl.ac.uk (P. Jones).

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However, the provision of crossing facilities does not necessarily improve the ease of crossing busy roads. There is evidence that some types of facilities are generally disliked by pedestrians, which leads to a high incidence of informal road crossing behaviour, away from crossing facilities (Demiroz, Onelcin, & Alver, 2015; Obeng-Atuah, Poku-Boansi, & Cobbinah, 2017; Sinclair & Zuidgeest, 2016) and even to an aggravation of the perceived barrier effect of the road (James, Millington, & Tomlinson, 2005). The assessment of schemes to build new crossing facilities or improve existing ones and the decision on their optimal location along busy roads requires, therefore, an understanding of the preferences of pedestrians regarding different types of crossing facility.

This paper estimates preferences for different types of crossing facilities in terms of pedestrians' willingness to walk to access them. The study commenced with a preliminary stage using focus groups and in-depth interviews to understand perceptions about different types of facilities. The information collected at that stage informed the design of the main stage, a stated preference survey of residents from the catchment areas of three busy roads in England (in London, Birmingham, and Southend-on-Sea), that were perceived to lack a sufficient number of pedestrian crossing facilities. This paper reports the results of two exercises included in this survey: one where participants rated four different types of crossing facilities, and another where they chose between different alternative crossing facilities and varying walking times to access them.

The rest of the paper is organised as follows. Section 2 is a review of the theoretical and empirical background for this study. Section 3 reports the main conclusions of the preliminary qualitative study and the implications for the design of the main survey. Section 4 describes the three study areas and the sampling process. Sections 5 and 6 report the results of the rating and stated preference exercises in the main survey, and Section 7 concludes the paper with a summary and recommendations for policy and future research.

2. Background

The decisions taken by pedestrians about where to cross a road usually involve trade-offs between safety and convenience (Sharples & Fletcher, 2001; Rankavat & Tiwari, 2016). The option of crossing away from designated crossing facilities increases the risk of vehicle-pedestrian collision but is often chosen because it is the quickest and most direct way to reach the other side (Demiroz et al., 2015). The preference for particular facilities also depends on their design and maintenance, which are associated with perceptions about crime and concerns about aesthetics and hygiene (Sharples & Fletcher, 2001; James et al., 2005; Sinclair & Zuidgeest, 2016). Choices may also be explained by personal or contextual factors such as habit (Räsänen, Lajunen, Alticafarbay, & Aydin, 2007), the lack of alternatives (Sinclair & Zuidgeest, 2016), and the location of the crossing facilities relative to the direction of the trip (Yannis, Golias, & Papadimitriou, 2007).

Signalised crossings (Fig. 1a and b) are usually safer than uncontrolled crossings, but may involve detours and delays to the trip due to additional waiting and walking times. In a study in China, 25% of respondents stated they were not willing to use signalised crossings, 60% of them stating time losses (including walking to access the crossing and waiting for the red time) as the main reason (Tanaboriboon & Jing, 1994). Detours and delays are particularly relevant in the case of staggered crossings, where the crossing is completed in two stages (with a time delay) and the crossings on each carriageway are not aligned (Fig. 1b).

Grade-separated crossing facilities, such as footbridges and underpasses (Fig. 1c and d) tend to be safe in terms of vehicle-pedestrian collision but are almost universally disliked, due to the time and effort required to use them, and issues of personal security. This is confirmed in many recent studies in different countries, such as James et al. (2005) in the UK, Räsänen et al. (2007) in Turkey, Mfinanga (2014) in Tanzania, Tao, Mehndiratta, and Deakin (2010) in China, Rankavat and Tiwari (2016) in India, and Villaveces et al. (2012) in Colombia. Some groups such as women and older people are particularly averse to using grade-separated crossing facilities, especially at night time (Rankavat & Tiwari, 2016; Tanaboriboon & Jing, 1994).

The extensive literature on pedestrian crossing behaviour has used a wide variety of methods, including self-completed questionnaires (Bernhoft & Carstensen, 2008), personal interviews (Hine, 1996), video surveys (Sisiopiku & Akin, 2003), pedestrian tracking (Papadimitriou, 2012), experiments (Granié, Brenac, Montel, Millot, & Coquelet, 2014), GIS analysis (Lassarre et al., 2012), and revealed preference analysis (Olszewski & Wibowo, 2005). Most studies found that long waiting times and elements that decrease safety, accessibility, and personal security influence road crossing behaviour, route choice, and the propensity to walk.

Advances in choice modelling techniques have increased the use of stated preference surveys to study pedestrians' choices for crossing locations and types of facilities. This method is based on surveys where participants 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 trade marginal changes in the attributes can be derived (Bateman et al., 2002).

Stated preference surveys can be applied to elicit preferences among alternative measures that might be provided to improve the ease of crossing the road. The most radical and most effective of these measures is to build a road tunnel, so that pedestrians can walk 'over' the road, at grade. This scenario was studied by Grisolía, López, and Ortúzar (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 Closed Circuit Television (CCTV). The ease of crossing can also be improved by traffic calming measures or by the reallocation of road space. For example, Garrod, Scarpa, and Willis (2002) estimated preferences for traffic calming measures in terms of cost and reductions in traffic speed,

(a) straight signalised crossing (b) staggered signalised crossing

(c) footbridge (d) underpass

Fig. 1. Types of crossing facilities.

noise, aesthetics, and time to cross the road. Stated preference analysis has also been used to estimate preferences for interventions such as shared space (ITS & Atkins, 2011; Kaparias, Bell, Miri, Chan, & Mount, 2012) and improvements in pedestrian infrastructure at roundabouts (Perdomo, Rezaei, Patterson, Saunier, & Miranda-Moreno, 2014). Information about different types of crossing facility can also be included as an attribute in wider models of pedestrian route choice (Hensher, Rose, Ortúzar, & Rizzi, 2011) or residence location (Eliasson, Dillén, & Widell, 2002).

However, preferences are determined not only by the crossing situation and the characteristics of the crossing facility, but also by the additional distance or time required to access them. For example, Sisiopiku and Akin (2003) found that the main factor influencing the decision to cross a road in a particular location is the distance to the destination of the trip. A study in London in the 1960s estimated that almost all pedestrians would use a footbridge or underpass if the time spent was the same as the time to cross at surface level (in a place without crossing facilities), but almost no one would use the footbridge or underpass if that took 50% more time than crossing at surface (Road Research Laboratory, 1963, Ch.3; Moore & Older, 1965).

Walking distance has been included in recent stated preference studies of pedestrian crossing situations. For example, Meltofte and Nørby (2013) modelled the choice between crossing the road informally and using crossing facilities, under varying conditions of number of lanes and traffic volumes and speeds and different walking distances to the nearest crossing facility, finding that longer distances increase the probability of crossing informally. Cantillo, Arellana, and Rolong (2015) considered different types of facility, finding that people are less willing to walk to footbridges than to a signalised crossing. However, age, gender, educational qualification levels, and the circumstances of the trip are also relevant factors.

The present study builds on these developments, by estimating pedestrian preferences in a scenario where informal road crossing (away from designated facilities) is impossible. The analysis separates general preferences for different types of crossing facilities, in a rating exercise, and trade-offs between the use of those facilities and walking times to access them. Unlike in the studies mentioned above, the alternative to use a crossing facility is not to cross informally but to use a different type of facility or to give up crossing the road altogether. As such, the study produces new knowledge about preferences regarding using different types of facilities, which complements existing knowledge about the propensity to cross away from these facilities. The study also provides detail about the personal and contextual aspects explaining the preferences and about the reasons that lead people to use or avoid each type of facility.

3. Qualitative phase

The main survey was preceded by a qualitative study to understand people's perceptions about using different types of road crossing facilities. The study consisted of four 90-min focus groups (with a total of 27 participants) and seven 30-min telephone interviews. To obtain a broader set of views, the participants were not recruited from the three areas studied in the main survey, but from two other areas, in London (New Cross) and another in Birmingham (Perry Barr), representing a more diverse geographic, demographic, and socio-economic context. Participants were recruited door-to-door using a screening questionnaire. The four focus groups had different compositions in terms of age (>50 or <50 years old) and socio-economic group (ABC1 or C2DE). The definition of socio-economic group was based on the classification of the UK Market Research Society (Meier & Moy 2004). The participants in each group represented a mix of ethnicities and household compositions, and used different means of transport.

Most of the participants were able to spontaneously list the advantages and disadvantages of different types of crossing facilities. Signalised crossings were perceived as being generally safe, as traffic lights control motorised traffic. However, there was also concern about the lack of space for pedestrians to stand while waiting to cross, especially for wheelchair users and people using pushchairs. Strong views were also expressed, especially by younger participants, about the extended waiting time involved in using some facilities:

> *"Remember when you used to press it once and it used to change? Now, you press it ten times and it doesn't change, then you have to wait there and you've got to go to the other side and you've got to press it again and you've got to wait another... so it's not consumer friendly for the public, it's more for the traffic now ...*
>
> [Younger male, London C2-E focus groups]

Staggered signalised crossings were seen as more inconvenient than straight crossings, as they are not direct and require longer times to cross. However, some participants preferred staggered crossings because the time allocated to pedestrians to cross the carriageway in some straight crossings was felt to be insufficient, increasing collision risk. The two quotes below illustrate the opposite views participants held about staggered crossings:

> *"You don't want to be really sent off in a direction... You know, if you want to cross the road, you don't want to be sent off in that direction to go over there. You know, and it is really annoying*"
>
> [Older female, London A-C1 focus groups]

> *"Because you can cross the road in stages and you kind of have more time to cross the road. So if it's just one pelican [signalised] crossing, you have to cross a whole road but, if it's staggered, you go and you can wait.*"
>
> [Younger female, London C2-E focus groups]

The main issues with footbridges and underpasses were the delay, detour, inconvenience, and effort in using them, and their lack of accessibility, especially for people with disabilities or with temporary mobility restrictions, such as using pushchairs or carrying shopping bags:

> *"For me, it's not about the timing, it's about the comfort and sometimes I don't want to climb stairs. I don't want to climb stairs, especially in the winter and it's icy. I am a walking hazard. I would be from top to bottom in half a second because I'll trip.*"
>
> [Younger female, London C2-E focus groups]

Footbridges and underpasses were also disliked for reasons that are not directly related to walking. Personal security was a major concern when using underpasses and (to a lesser degree) footbridges. This was perceived to be of particular importance for certain groups (such as women and older people) and in certain walking situations (walking alone, with children, or at night-time). However, lighting levels would influence the decision to use an underpass. Lack of cleanliness was another major reason for disliking footbridges and underpasses:

> *"Personally I don't use the underpass unless I'm with my husband or with my son or something like that, even during the day because I find you could be the only one down there and I get a bit concerned that you [might] come across someone [undesirable].*"
>
> [Younger female, Birmingham interviews]

> *"I took my kids under the underpass. Mum why have I got to come down here, I don't want to come down here. You can see them...they are looking at all the graffiti in there and the way it smells. I don't even want to take my kids down to those kinds of things.*"
>
> [Younger female, Birmingham A-C1 focus groups]

Other negative aspects included vibration and claustrophobia when using footbridges and underpasses and fear of heights when using footbridges. On the other hand, a participant mentioned that "it's quite nice to go over the road like that and get a bit of a view".

In general, participants tended to relate to their own experiences, with some people recalling underpasses being closed off and bridges being removed in their local area, and unusual events such as footbridges collapsing and crime incidents in underpasses. Many opinions were based on concerns about the mobility needs of others, especially the elderly and people using wheelchairs and pushchairs. Some preferences were also justified in terms of the overall benefits for all road users, not for pedestrians alone. For example, footbridges and underpasses were seen as a good solution for some participants because they do not impede the flow of motorised transport. On the other hand, there were concerns with the feasibility of building footbridges in urban areas due to the lack of space for ramps and steps and with possible vandalism (for example, youths throwing things from the bridges).

Almost all participants were willing to walk a few minutes extra to use designated pedestrian crossing 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:

> *You've got a choice. You can either go under the subway and whoever's under there, you don't know, or you can just walk all the way round to get across to the other side.*
>
> [Older female, Birmingham C2-E focus groups]

The focus groups with older participants demonstrated more tolerance for walking further to use crossing facilities, stating that it would be acceptable to detour up to about 10 min, whereas younger groups were limited to 5 min, with some only willing to add 2–3 min. In some extreme cases, participants admitted they might walk up to 20 min. A participant proposed "half a bus stop" as the maximum walking distance to use a formal road crossing. Most participants were willing to walk extra to avoid underpasses. The walking situation was also important, with choices depending on weather, time of day, mobility restrictions (including carrying shopping bags), and walking context (participants accompanied by children were willing to walk further to avoid some crossing facilities).

The focus groups also provided feedback on the preliminary design of the stated preference exercises and the ways to illustrate the attributes of roads and crossing facilities in the main survey. Reasonable logic was displayed when making selections throughout these exercises. However, it was not always clear to participants whether the footbridges and underpasses in the images shown had a ramp. Some participants also mentioned that views from the ground level were more suitable than aerial images because they show how tall a footbridge is. These and other issues were taken into consideration in the design of the main stage survey.

4. Main survey: study areas and sampling

The main stage survey was conducted among residents in three areas in London, Birmingham, and Southend. The London survey focused on Finchley Road, a major arterial road with traffic levels comparable to those of some motorways, in a section with major shopping facilities and 3 lanes for motorised traffic in each direction, and with physical barriers preventing pedestrians crossing away from designated crossing facilities (six staggered signalised crossings and one underpass over a distance of 1.7 km). The Birmingham survey focused on Stratford Road, a busy suburban high street with a 2-lane per direction, unsegregated road, and 10 signalised crossings (one of them staggered) over a distance of 2 km. The Southend survey looked at Queensway, a 2-lane per direction road with medium traffic levels and a small number of formal pedestrian crossing facilities over 1.8 km (five long and complex staggered signalised crossings, one footbridge, and two underpasses). The road divides the city centre (on the west side) from residential areas (on the east side).

The survey consisted of 100 interviews in London, 121 in Birmingham, and 100 in Southend, in the areas surrounding the main road. The interviews were computer-assisted and were conducted in the second half of 2015 and first half of 2016. Participants were recruited from those answering a previous survey related to the same research project (Scholes, Boniface, Stockton, & Mindell, 2016) and received a £10 voucher as a token of appreciation. The composition of the sample is described in Table 1. The samples in each site were based on quotas and were designed to have similar number of males and females and individuals aged below and over 50 years old. This was only partly achieved in the Birmingham study area, due to problems in recruiting men and older people.

The questionnaire included a rating and stated preference exercise and questions about demographic and socio-economic characteristics of participants and about their most recent walking trip (purpose and situation). The data was also linked to the data obtained from a separate questionnaire answered by the same participants focusing on their perceived health and wellbeing, disabilities affecting walking, and perceptions about traffic conditions and about their neighbourhood in general (Scholes et al., 2016).

5. Rating exercise

In the first exercise, participants were asked to indicate how comfortable they felt crossing busy roads using different types of pedestrian crossing facilities, as shown on a card. The rating scale 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 sunk and covered over.

Four types of facilities were shown: a straight and a staggered signalised crossing, a footbridge, and an underpass. Both footbridges and underpasses were represented with steps and ramps. The images had the same number of traffic lanes as in the main road at the relevant site, so that participants could relate the options shown to their own experience. Fig. 2 shows an example of the questions presented in the London survey, showing a footbridge over a road with three lanes for motorised traffic in each direction.

Table 1
Sample characteristics (%).

		London (n = 100)	Birmingham (n = 121)	Southend (n = 100)
Gender	Male	45	40	54
	Female	55	60	46
Age	18–34	34	33	24
	35–49	20	31	29
	50–64	22	28	25
	65+	24	8	22
Qualifications	Degree	47	22	23
	Technical qualification	36	43	41
	No qualifications	16	35	36
Employment status	Full-time employment	40	26	36
	Part-time employment	12	6	14
	Unemployed	7	10	11
	Retired	28	13	25
	Student	8	8	4
	Carer/looking after home	4	34	7
Housing tenure	Own house	30	57	19
	Private rent	34	24	36
	Social rent	31	17	45
Car ownership	No car	53	26	53

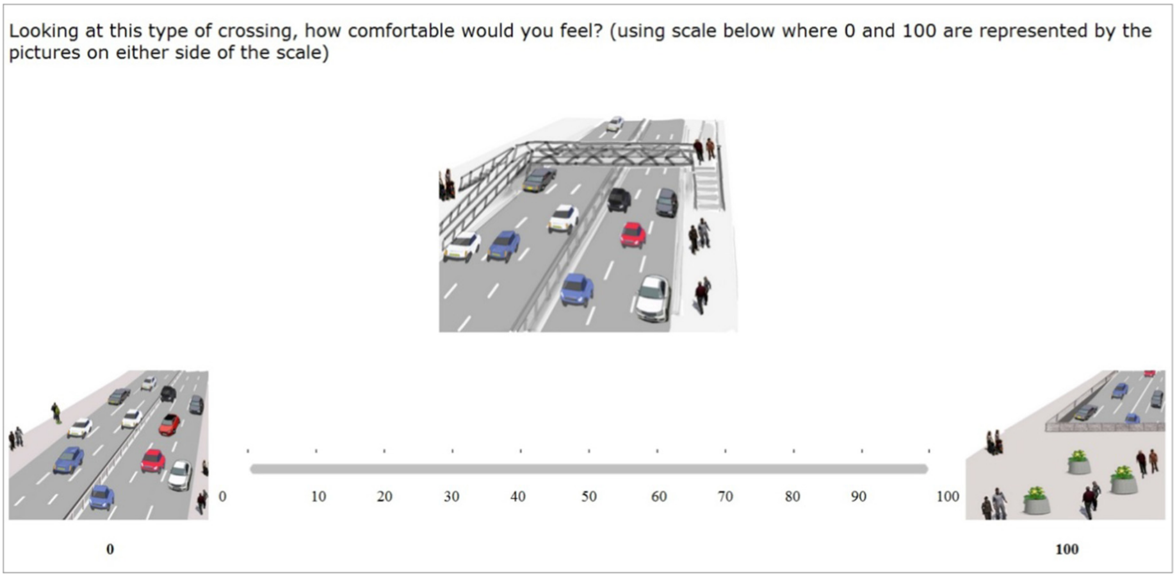

Fig. 2. Example of question in the rating exercise.

Fig. 3 shows the cumulative frequencies of the rating values of the four types of crossing for the three samples combined. Surface crossings (straight and staggered signalised crossings) were systematically rated above footbridges and underpasses. The ratings of staggered crossings were higher than those of straight crossings and the ratings of footbridges higher than those of underpasses. The figure also shows that collectively participants used the whole range of values available, from 0 to 100, for all four types of crossing facilities.

Table 2 presents descriptive statistics for the ratings of the four types of facilities and Table 3 shows the number of times the facilities were ranked in each position (from 1st to 4th) in the ordered ratings of each participant. The results confirm that the ratings of grade-separated facilities were lower, on average, than the ratings of signalised crossings. Footbridges and underpasses were the least comfortable crossing types for most participants (85 and 129 participants, respectively), although they also obtained the highest ranking for 57 and 63 participants, respectively. Staggered crossings were rated slightly higher than straight crossings, although both types of facility have the same median rating value. The average and median rating of footbridges is higher than those of underpasses. Preferences for footbridges and underpasses seem to be polarised, as shown by a high standard deviation, comparing with the average value.

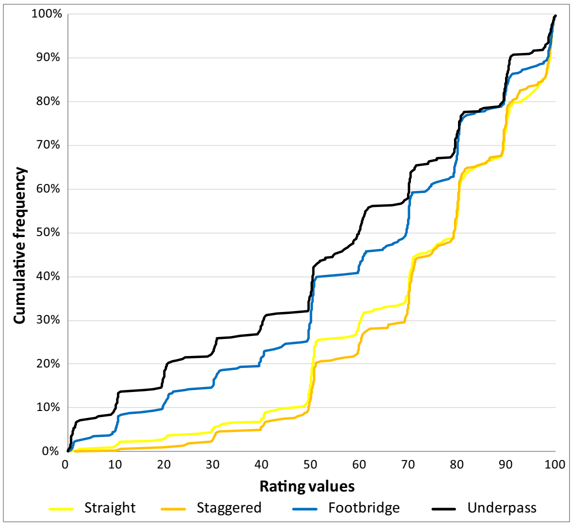

Fig. 3. Cumulative frequencies of rating values for each type of crossing.

Table 2
Rating exercise: descriptive statistics.

	Straight	Staggered	Footbridge	Underpass
Average	72	74	61	56
Standard deviation	23	20	28	30
Median	79	79	69	60
Average (London)	70	73	59	53
Average (Birmingham)	75	73	62	52
Average (Southend)	70	75	64	63

Table 3
Number of times facilities were ranked in each position.

	Straight	Staggered	Footbridge	Underpass
Highest ranked	114	111	57	63
Second highest ranked	90	113	76	41
Third highest ranked	60	65	103	88
Lowest ranked	57	32	85	129

Table 4 shows the results of regression models explaining the differences between the ratings of footbridges or underpasses, and the ratings of signalised crossings, across the three samples as a whole. The dependent variable is defined as

$$\begin{cases} -\log(1 - Y/100) & \text{if } 0 \leqslant Y \leqslant 100 \\ \log(1 + Y/100) & \text{if } -100 \leqslant Y < 0 \end{cases} \quad (1)$$

where Y is the difference between the rating of footbridges or underpasses and the maximum of the rating of straight and staggered signalised crossings. The explanatory variables are the characteristics of participants and walking trips. All the explanatory variables are dummy variables assuming values 0 or 1.

Women, people aged above 50, and individuals with a disability affecting walking have a weaker preference for **footbridges**, relative to signalised crossings, comparing with other groups, as seen by the negative coefficients of the respective dummy variables. The relative ratings of footbridges are also negatively associated with the conditions in their local area, such as the lack of crossing facilities (in places near the road but with no formal pedestrian crossing facilities nearby).

Aversion for footbridges, relative to signalised crossings, is also explained by (i) trip purpose (leisure trips), (ii) concerns about personal security (for participants who crossed the road after dark or whose perceived walking mobility is affected by fear of crime), and (iii) perceptions about local traffic (for participants who do not perceive traffic levels as heavy, do not have to wait to cross the road, and whose walking mobility is affected by the time to cross the road but not by the traffic volume or

Table 4
Models of differences in crossing ratings.

	Footbridge – signalised		Underpass – signalised	
	Coefficient	*Std. error*	*Coefficient*	*Std. error*
Constant	−0.07	0.11	−0.41	0.21*
Individual characteristics				
Female	−0.15	0.08**	−0.20	0.10*
Age 50–65	−0.24	0.09***	−0.21	0.12*
Age >65	−0.23	0.10**	−0.36	0.15**
Owned house			−0.38	0.13***
Social housing			−0.39	0.13***
Characteristics of walking trips				
Cross the road 2–3 times a week			0.35	0.12***
Leisure	−0.34	0.14**	−0.33	0.18*
After dark	−0.41	0.22*		
Perceived health and wellbeing				
Disability affecting walking	−0.35	0.12***	−0.51	0.16***
Perceived neighbourhood				
Do not trust others in neighbourhood			−0.20	0.11*
Walking affected by traffic volume/speed	0.15	0.08*	0.44	0.12***
Walking affected by time to cross	−0.29	0.08***	−0.27	0.12**
Walking affected by fear of crime	−0.25	0.09***	−0.24	0.12*
Local traffic: Heavy volume	0.19	0.09**	0.21	0.12*
Local traffic: No wait to cross	−0.40	0.14***	−0.70	0.19***
Location				
London: east of road			0.31	0.18*
Southend: west of road	0.30	0.15*	0.53	0.21**
outhend: east of road	0.22	0.09**	0.36	0.14**
Near road (<400 m)			0.28	0.15*
Near road (<400 m) but no crossings (<200 m)	−0.24	0.08***	−0.37	0.12***
Observations	290		277	
R^2	0.23		0.30	

The "do not trust others in the neighbourhood" variable represents the case where participant gave a rating below 4, in a scale from 1 (disagree) to 7 (agree), to the statement "Most people in this area can be trusted".
Note: Significance levels:
* 10%.
** 5%.
*** 1%.

speed). This last result may be explained by the fact that signalised crossings are relatively more attractive than footbridges when traffic levels or speeds are low, as waiting times at traffic lights are also low.

The set of significant variables in the model explaining preferences for **underpasses**, relative to signalised crossings, is broadly similar to the one obtained in the case of footbridges. The preference for underpasses, relative to signalised crossings, is weaker for women and decreases with age, as the coefficient for participants over 65 years old is more negative than the one for the 50–65 age group. Individuals with disabilities affecting walking and living in owner-occupied dwellings or in social housing also gave lower relative ratings to underpasses, comparing with other groups. Lower levels of need to cross the road (in locations that are not near the road) and lack of crossing facilities in the local area are also associated with lower relative ratings of underpasses.

The aversion for underpasses is also explained by (i) frequency of crossing the road (for both participants who cross the road most days and those who only cross the road once a week or less often), (ii) trip purpose (leisure trips), (iii) concerns about personal security (for participants whose walking mobility is affected by fear of crime, and who stated they do not trust others in the neighbourhood), and (iv) perceptions about local traffic (as measured by the same variables that were significant in the case of footbridges).

Variables that were not found to be significant in the two models include dummy variables representing age groups below 50, household composition, length of residence in the area, qualification levels, employment status, car ownership, walking context (i.e. walking with children or not), perceived health condition, subjective wellbeing, perceived levels of vandalism and cleanliness in the neighbourhood, and distance to nearest footbridge and underpass in the busiest road in the local area.

The results confirm previous expectations regarding the aversion of some groups (such as women, older people, and people with disabilities) to grade-separated facilities. Perceived health condition is probably insignificant because for people with poor health condition, the disadvantage of exposure to noise and air pollution while waiting at traffic lights in signalised crossings is cancelled out by the disadvantage of using steps in grade-separated crossings. The results also confirm the importance of local road and traffic conditions and fear of crime. Perceptions about cleanliness and vandalism in the neighbourhood may be insignificant because, as suggested by the qualitative study, they are intrinsically related to fear of crime, and as such their impact may be accounted for by the variable measuring perceptions about crime.

There is also evidence of nonlinearities in the factors affecting crossing behaviour. For example, higher aversion towards underpasses is observed both on people who cross the road daily (who may be forced to use underpasses if there are few alternatives or if they have tight time constraints) and on those who cross infrequently (who are less familiar with underpasses and may then perceive them as dangerous places). A similar rationale may explain why the distance to the nearest footbridge and underpass in the participants' own local area is insignificant, as there is probably a strong aversion towards using these facilities both among people who live very near and very far from them.

6. Stated preference exercise

6.1. Design

The objective of the stated preference exercise was to estimate participants' willingness to walk further to cross the road using specific types of crossing facilities. Participants were shown a scenario where crossing at the current location was impossible due to the high traffic levels and guard railings in the middle of the road. Three options were then presented:

- Walk an additional specified time for the trip to use one of two types of crossing facility shown (options A and B); or
- Avoid crossing the road altogether (option C).

The exercise consisted of six questions in the London survey and eight questions in the Southend and Birmingham surveys. The types of crossing facility and the additional walking times in options A and B were systematically varied. An efficient design was used, which generates data that allows for the minimization of the standard errors of the parameter estimates (Rose & Bliemer 2009). The design was obtained using the *Ngene* software. The types of facility were the same as in the rating exercise. The time added to the trip ranged between 2 and 20 min, in 2 min increments. Fig. 4 shows an example of the questions, illustrating a choice between using a footbridge adding 20 min' to the trip (Option A), an underpass adding 4 min (Option B), and avoiding crossing the road altogether (Option C).

6.2. Model specification

The choices were analysed using discrete choice models. The data was reshaped so that each record captured the choice regarding each of the three options presented in each of the questions answered by each participant. This procedure generated a dataset with 7104 records. The dependent variable is a dummy variable where 1 represents the case where the participant chose that option. The explanatory variables are the presented walking time, dummy variables for staggered

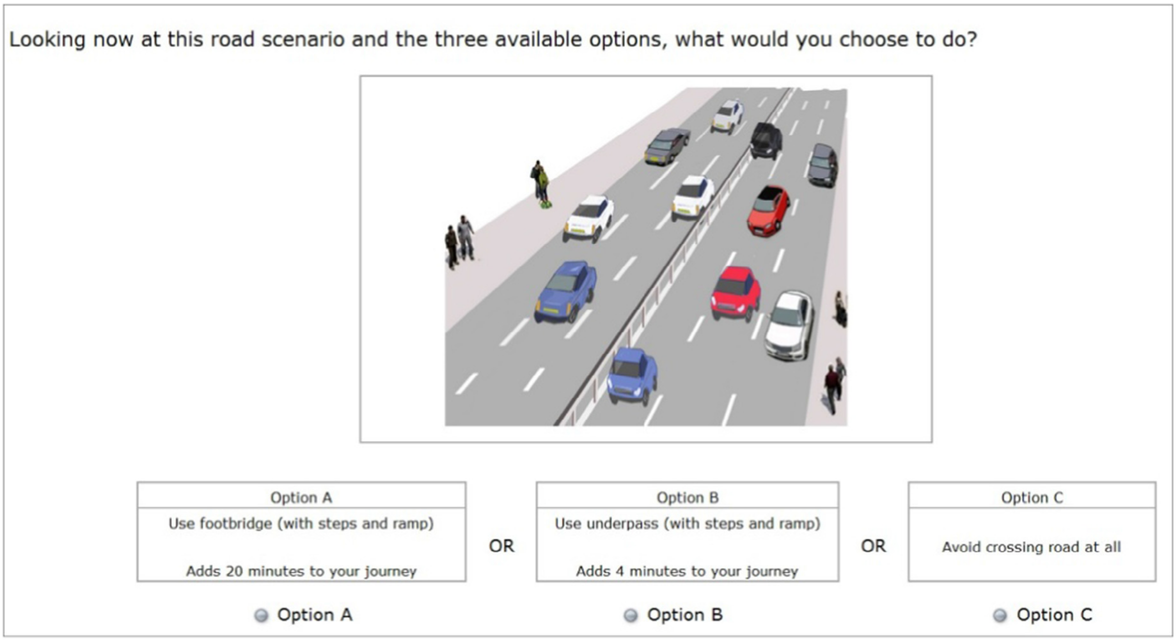

Fig. 4. Example of question in the stated preference exercise.

signalised crossings, footbridges and underpasses (equal to 1 when an option included these facilities), a dummy for the possibility of not crossing, and interaction terms between the variables above and dummy variables representing the characteristics of participants and their walking trips. Straight signalised crossings were treated as the "base value" and were thus omitted from the models.

Two specifications were tested: mixed and conditional logit. In the mixed logit model (Ben-Akiva & Bolduc, 1996; McFadden & Train, 2000), the coefficients of all variables except walking time were assumed to be random, with the utility of an option depending on the attribute levels and on the characteristics of the participants. The model can be specified as

$$Y_{i,j} = \begin{cases} 1 & \text{if } U_{i,j} \geqslant U_{i,k}, \quad \forall k \neq i \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$U_{i,j} = \beta_i x_{i,j} + \varepsilon_{i,j} \tag{3}$$

where $Y_{i,j}$ is the observed choice made by individual i regarding alternative j, $U_{i,j}$ is the utility of that alternative, k are the other alternatives, $x_{i,j}$ is a vector measuring the attributes of alternative j, β_i is a vector of random parameters, and $\varepsilon_{i,j}$ is an error term that follows the Extreme Value Type I distribution. The probability that individual i chooses alternative j is

$$P_{i,j} = \int L_{i,j}(\beta) f(\beta) d\beta \tag{4}$$

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

$$L_{i,j}(\beta) = \frac{\exp(\beta_i x_{i,j})}{\sum_k \exp(\beta_i x_{i,k})} \tag{5}$$

In the conditional logit models, 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.

6.3. Model results

Table 5 shows the results of models that include only the attributes presented to the participants (types of facility, walking time, and the "do not cross" option), and not the interaction terms. The mixed logit model includes estimates of the average and standard deviation of the coefficients obtained for each individual.

The coefficients of staggered signalised crossings were insignificant (and were thus removed from the final model). This shows that, on average, participants are indifferent between using staggered and straight signalised crossings (the "base value" omitted from the model). The coefficients of the other variables are negative and significant, which confirms that people prefer to cross, rather than not to cross the road; shorter, rather than longer walking times; and to use straight signalised crossings, rather than grade-separated facilities. The coefficient of underpasses is more negative than the one of footbridges, suggesting that on average people have a greater aversion to underpasses than to footbridges. The coefficients of the standard deviations of the coefficients of the mixed logit model are significant, confirming that there are relevant variations in preferences within the sample.

Table 6 shows the results of the models that include interactions between the attributes of the problem and the characteristics of participants and their walking trips. In these models, the coefficients of footbridges are only significant for the

Table 5
Stated preference models (without interactions).

	Conditional logit		Mixed logit			
			Mean		Std. Dev.	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Staggered	–	–	–	–	–	–
Footbridge	−0.24	0.11**	−1.01	0.23***	3.55	0.30***
Underpass	−0.72	0.12***	−2.19	0.27***	3.58	0.31***
Do not cross	−3.23	0.21***	−8.71	0.52***	4.23	0.34***
Time	−0.19	0.01***	−0.42	0.02***		
Observations	7104		7104			
Clusters	321		321			
Initial log-likelihood	−2602		−2602			
Log likelihood	−2139		−1561			
Pseudo R^2	0.18		0.40			

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

Table 6
Stated preference models (with interactions).

	Conditional logit		Mixed logit			
			Mean		Std. dev.	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Staggered	–	–	–	–	–	–
Footbridge	–	–	–	–	–	–
Underpass	−0.39	0.21*	−1.90	0.45***	2.45	0.27***
Do not cross	−3.47	0.27***	−9.43	0.56***	4.30	0.31***
Time	−0.20	0.02***	−0.48	0.03***		
Staggered						
Female	0.25	0.14*	–	–	–	–
Footbridge						
Female	−0.36	0.21*	−1.34	0.31***	0.33	0.38
Age 50–65	−0.71	0.24***	−2.22	0.49***	2.88	0.40***
Age >65	−1.16	0.33***	−4.02	0.60***	4.18	0.57***
Purpose: work	0.86	0.31***	1.61	0.53***	1.95	0.44***
Purpose: shopping	0.54	0.19***	1.78	0.44***	3.97	0.46***
After dark	−0.96	0.49**	−2.19	0.81***	1.79	0.61***
Underpass						
Female	−0.51	0.24**	−1.22	0.44***	4.03	0.39***
Age 50–65	−0.82	0.28***	−2.35	0.59***	−2.85	0.58***
Age >65	−1.42	0.34***	−4.87	0.85***	−3.61	0.77***
Purpose: work	0.81	0.32**	2.79	0.63***	−0.66	0.44
Southend (East)	0.60	0.23**	2.35	0.51***	1.04	0.55*
Cross 2–3 times a week	0.54	0.22**	2.35	0.53***	−1.39	0.40***
Do not cross						
Age > 65	0.57	0.34*	–	–	–	–
Time						
Southend	0.07	0.02***	0.16	0.03***	−0.09	0.02***
Employed	−0.04	0.02**	−0.16	0.03***	0.33	0.04***
Cross most days	−0.02	0.02*	–	–	–	–
Purpose: leisure/visit	0.03	0.02*	–	–	–	–
Observations	7104		7104			
Clusters	321		321			
Initial log-likelihood	−2602		−2602			
Log likelihood	−1972		−1420			
Pseudo R^2	0.24		0.45			

Note: As Table 5.

interactions, and not when standing alone. Women have a higher probability of choosing staggered signalised crossings than men, but this result is only significant in the conditional logit model.

The probabilities of choosing footbridges and underpasses are lower for women, and decrease with age, which confirms the aversion of women and older pedestrians for using those facilities, found in the qualitative study, and in the rating exercise. The propensity for choosing footbridges is also higher for people who walked to go to work or to go shopping, and lower for people who walked after dark. The propensity for choosing underpasses is higher for participants who walked to go to work and who cross the road 2–3 times a week.

The propensity for choosing the "do not cross" option is higher for participants aged above 65. This suggests that older people are more likely to suppress walking trips when the existing crossing facilities are not satisfactory or are located too far away. However, this result is only significant in the conditional logit model and at the 10% level, and as such, more evidence is needed to confirm this hypothesis.

Participants who are employed, and who cross the road most days (in the conditional logit model only) are more sensitive to walking time (i.e. less prepared to walk for longer times to use a certain type of crossing facility). This result is consistent with previous expectations as those participants usually have tighter time restrictions than those not in employment or who cross the road infrequently. Participants in Southend and those who walked for leisure or to visit someone (in the conditional logit model only) are less sensitive to walking time. The positive coefficient obtained for Southend participants may be explained by the lower provision of public transport in their area, comparing with the other case study areas.

The other interaction terms tested were not found to be significant at the 10% level in the final model. These include interactions with age groups below 50, household composition, length of residence in the area, qualification levels, housing tenure, car ownership, walking context, distance to nearest footbridge and underpass in the participants' own local area, disability affecting walking, perceived health condition, subjective wellbeing, and perceptions about traffic and about the neighbourhood.

The estimated models are broadly consistent with previous expectations and confirm the results of the previous analysis regarding the preferences of women and older people and the nonlinearity in the effect of some variables (which may explain the positive coefficient of underpasses for people who cross the road neither cross their own road daily nor rarely, and the insignificance of the distance to nearest footbridge and underpass). The role of fear of crime is not as visible as in the ratings model, although it is implicit in the significance of the coefficient of footbridges for trips made after dark.

6.4. Willingness to walk additional times to use straight signalised crossings

The estimated models can be used to derive trade-off values between walking times and the choice of different alternatives. Those values are the ratios between the coefficients of the variables indicating the presence of each type of facility (or the "do not cross" alternative) and the coefficient of walking time.

Table 7 shows the estimated confidence intervals for the willingness to increase walking time for the trip to use straight signalised crossings, comparing with using other types of facilities, or giving up crossing altogether. The values can also be understood as the willingness to accept shorter additional walking times to use other types of facilities, or to give up crossing, compared with the base scenario of using straight signalised crossings. The values were obtained from the conditional and mixed logit models that do not include interaction terms, and so represent the average values for the sample.

The values for footbridges and underpasses (relative to the straight signalised crossing) are positive, which shows that on average participants only choose these facilities if they are closer than straight signalised crossings. The willingness to walk further to use to straight crossings is higher when the alternative is an underpass, comparing with a footbridge. Participants are also willing to walk relatively long additional times (17.4 or 20.9 min, depending on the model) to use a straight crossing, rather than give up crossing.

Fig. 5 disaggregates the results by trip purpose (work, shopping, or leisure/visiting someone), gender, and age. The values were obtained from the models that include interaction terms. The value for a given sample segment and alternative is the ratio between the sum of the overall and segment-specific coefficients of that alternative and the sum of the overall and segment-specific coefficient of the walking time attribute. The values displayed in the charts only apply to the London and Birmingham areas and to trips during daytime, and assume that employed people cross the road most days and non-employed people cross 2 or 3 times a week. Values for other segments can easily be derived from Table 6.

The charts show that for some segments, the estimated willingness to walk additional time to use straight crossings is negative, which means participants in those segments are willing to walk to footbridges or underpasses in order to avoid using straight signalised crossings. This is especially the case of males aged below 50, walking to work or to go shopping.

The maximum values of the willingness to walk to use straight crossings and avoid footbridges and underpasses are 11.3 and 11.8 min respectively, in the segment of women aged above 65 making trips for leisure or visiting someone, using the mixed logit model. Depending on trip purpose and model, participants in the 50–65 age group are willing to walk an additional 2.5–4.5 min to avoid footbridges and 3–5 min to avoid underpasses, comparing with those aged below 50. Participants over 65 are willing to walk an additional 2–4 min to avoid footbridges and 1.5–5.5 min to avoid underpasses, comparing with those in the 50–65 age group. Women are willing to walk an additional 2–3 min to avoid footbridges or underpasses, comparing with men in the same age group.

In the mixed logit model, the willingness to walk additional time to straight signalised crossings in order to able to cross the road at all, is 14.9 and 19.8 min for trips to go to work and trips with other purposes, respectively. In the conditional logit, the values are more variable, with a minimum of 11 min (for women above 65 making work trips) and a maximum of 21.1 min (for men below 65, making leisure/visiting trips).

The values for staggered signalised crossings are not shown in the charts as they are only significant in the conditional logit model. Women are willing to add 0.9, 1.3, and 1.5 min to their trips to walk to staggered signalised crossings instead of straight crossings, for work, shopping, and leisure/visiting trips, respectively.

6.5. Reasons for choices

The survey included an open-ended question asking the reasons for the choice in the first question of the stated preference exercise. These reasons were coded and counted. Fig. 6 shows the reasons given for each combination of facilities cho-

Table 7
Average willingness to walk additional time to use to straight signalised crossings (minutes) and 95% confidence interval, by model and alternative.

Alternative	Conditional logit			Mixed logit		
	Lower	Central	Upper	Lower	Central	Upper
Staggered signalised crossing	0	0	0	0	0	0
Footbridge	0.1	1.3	2.5	1.4	2.4	3.5
Underpass	2.7	3.9	5.1	4.1	5.3	6.4
Do not cross	16.0	17.4	18.8	19.3	20.9	22.5

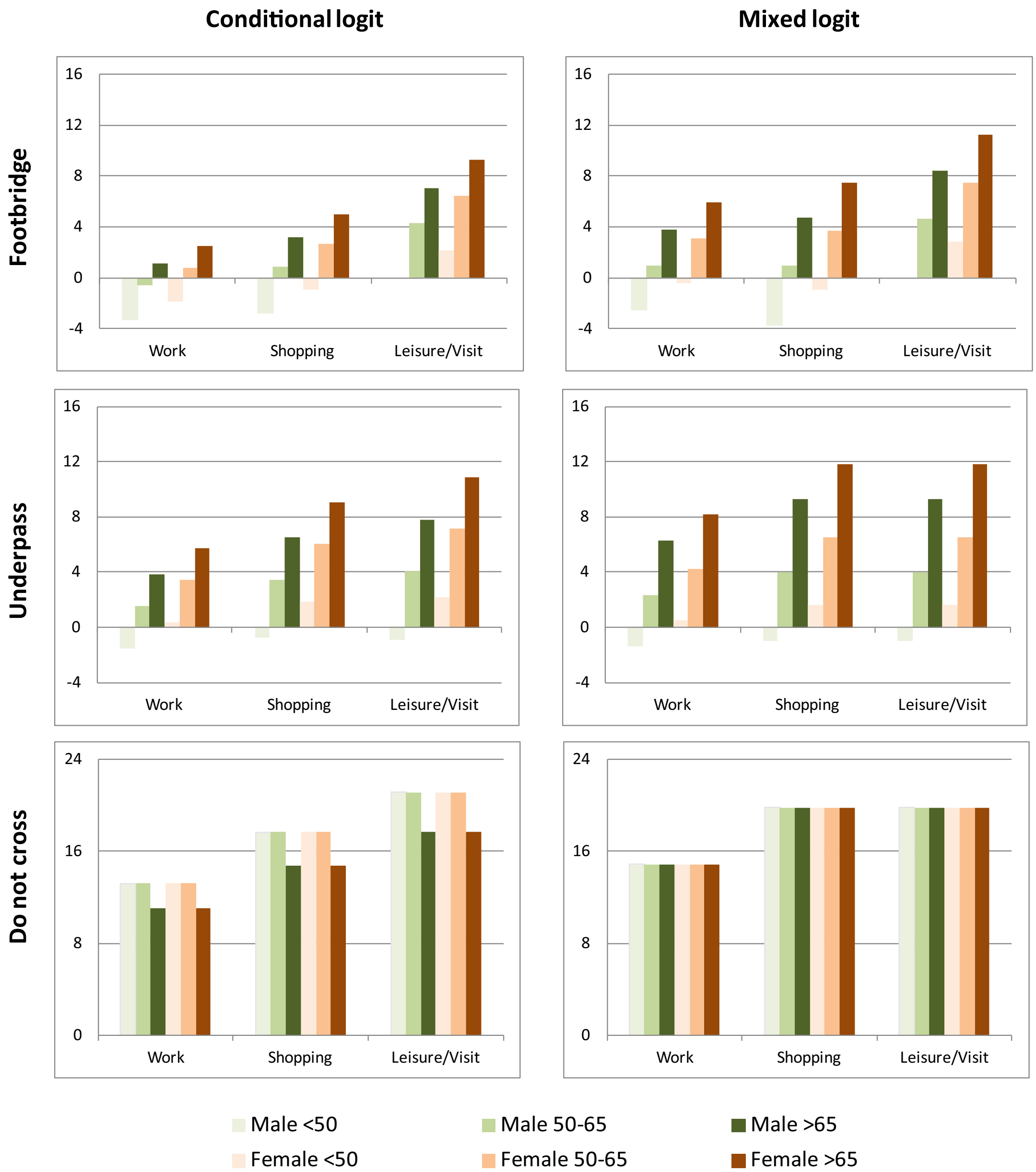

Fig. 5. Willingness to walk additional time to use straight signalised crossings (minutes), by model, alternative, trip purpose, gender, and age.

sen and rejected (from the pair shown in Options A and B), and for the case where the two facilities chosen were rejected (i.e. the participant chose Option C: do not cross).

The reason for choosing grade-separated crossings rather than signalised crossings was in the majority of cases justified by the longer walking time required to use signalised crossings. In contrast, the choice for signalised crossings rather than grade-separated crossings was justified by aspects related to the use of the crossings themselves. The main reason to reject footbridges was their lack of accessibility (due to the presence of steps or ramps) and the main reason to reject underpasses was concern with personal security. The choice between different types of signalised crossings was mainly a trade-off between the convenience and the shorter crossing time of straight crossings, and the perceived extra safety provided by staggered crossings. The vast majority of participants who chose the "do not cross" option did so because of the long additional walking times to use the crossing facilities in the other two options, and not because of the characteristics of those facilities.

The results confirm those obtained in the qualitative phase and stated preference exercise and suggest that the improvement of the ease of crossing the road can be achieved either by reducing walking times to signalised crossings (by adding new crossings) or by improving the conditions of grade-separated facilities.

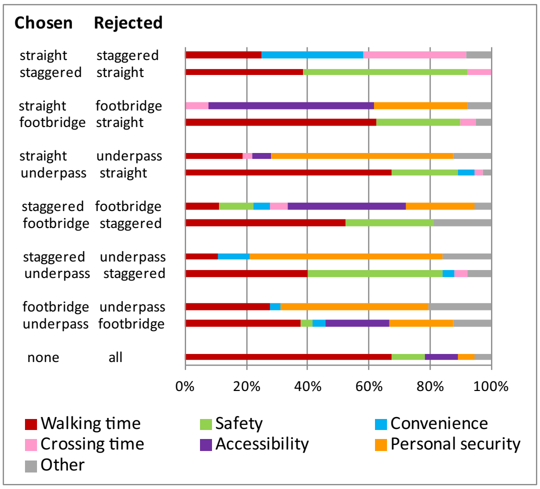

Fig. 6. Reasons for choices by chosen and rejected crossing facility.

7. Conclusions

This paper has estimated preferences for the use of different types of road crossing facilities relating to busy roads in three urban areas, using a stated preference survey. The survey was designed taking into account the results of a preliminary qualitative study. In the first exercise, participants rated footbridges and underpasses systematically below signalised crossings, especially in the case of women, older people, and people with disabilities that limit walking. The modelling of the choices among different alternatives for crossing facilities and walking time to access them revealed that, on average, participants choose footbridges and underpasses only if these facilities are nearer than straight signalised crossings, although there are significant variations according to gender, age, and trip purpose. The study found only weak evidence that people are willing to walk to use straight signalised crossings instead of staggered crossings, or vice versa.

The results confirm some of the results found in previous literature, such as the general dislike of grade-separated crossing facilities, especially among women and older pedestrians, and the role of aspects such as crossing time, accessibility, and fear of crime in the choices over using different types of facilities. However, the use of a stated preference survey brings additional knowledge, as it measures the trade-offs that people implicitly make when they choose among different types of crossing facilities. The values found for the additional walking times that people are prepared to walk to use straight signalised crossings are a useful input for guiding engineering interventions that involve the construction of new crossing facilities, or the modification of existing ones. For example, they can be used to determine the optimal location of different types of facilities along the road, considering the distance to existing alternatives. They can also be combined with available data on the economic values of walking time, to estimate the benefits of potential interventions expressed in monetary units. These benefits can then be compared with the cost of the interventions. The values for the additional walking times above which participants prefer to avoid crossing the road altogether can also be used to map the areas around major roads where residents are unlikely to make trips across the road, as an indicator of the negative impacts of the road on accessibility and active travel.

By combining quantitative and qualitative analysis, the study also provides insights on the required type of interventions to improve existing crossing facilities. The quantitative analysis suggests that reducing fear of crime would improve people's perceptions and propensity to use grade-separated facilities, as participants who stated that their walking trips are affected by fear of crime gave lower relative ratings to footbridges and underpasses and concern about personal security was the main reason given by participants to reject underpasses in the stated preference exercise. The qualitative results then suggest the type of interventions that would reduce fear of crime, such as improving lighting and cleanliness. The quantitative study also showed that the aversion towards footbridges and underpasses is also explained by their lack of accessibility, as older people and people with disabilities gave low relative rankings to those facilities, and lack of accessibility was the main reason given by participants to reject footbridges in the stated preference exercise. Again, the qualitative results suggest specific interventions that can improve accessibility, such as adding or improving ramps.

It should be noted that the choice set available for a pedestrian in this survey contained only the use of designated crossing facilities and the option of not crossing the road. In most cases, the pedestrian also has the option of crossing the road in places without any facilities, a scenario that, as mentioned in the background section, has been studied by some stated preference studies focusing on pedestrian safety. The analysis in this paper could be complemented by incorporating that scenario in the context of a stated preference exercise focusing on preferences over crossing facilities. The choices in this exercise would balance the characteristics of the road (such as number of lanes and presence of a central reservation) and motorised traffic (such as volume and speed), with the distance to the nearest crossing facility and the characteristics of this facility, providing a deeper understanding of the factors influencing crossing behaviour.

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