Crossing conditions and kerb delay assessment for better safety and accessibility of road pedestrian crossings at urban intersections

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Abstract

The accessibility of urban contexts is closely connected to analysis of geometric and functional details that can influence the actions of road vulnerable users. The correct design of the spaces and their accessibility must consider all age groups and problems related not only to safety but also to perception and comfortable movement. This research investigated the behavior of 3887 pedestrians (both elderly and non-elderly people) in two pedestrian crossings located in an urban intersection of Catania. Two video cameras were used to record oncoming vehicles and pedestrians at the intersection. An initial analysis of the number of legal/illegal crossings was developed in order to understand if different crosswalk setback distances lead pedestrians to illegal crossings. The results show that pedestrians prefer to cross choosing the shortest way, even if this leads to illegal crossing. Then, the kerb delay was calculated, i.e. the time interval between the moment in which the rear part of the last vehicle in the queue exceeds the pedestrian waiting for crossing and the moment when the pedestrian takes the first step to cross. The hypothesis that older pedestrians have longer kerb delay because of declines in their physical, sensory, perceptual or cognitive abilities was tested.

1. Introduction

Pedestrians are the most vulnerable road users' category in traffic accidents, especially in urban areas. Despite public, political and scientific efforts to reduce the amount of pedestrian accidents in traffic all over the world, there are still a considerable number of severely hurt or even killed pedestrians every year. The World Health Organization [1] reported that more than 1.2 million people die every year in traffic accidents worldwide, and that 22% of these casualties are pedestrians. Learning about pedestrians' crossing decisions and movement prior to and while crossing the road may portray pedestrians' intentions and behaviours.

The reality of an aging population, particularly in ''economically developed'' countries, has made the everyday mobility of seniors an issue of growing interest. According to the United Nations' World Population Ageing report [2], nearly every country is experiencing growth in the elderly population that will create challenges and transformations in various socioeconomic domains. In transportation, the ageing population poses mobility-related challenges in ensuring sufficient access to facilities and services for the elderly. In order for walking to become an attractive, efficient, and safe mode of transportation for the elderly, the way public spaces are designed must be rethought/reconsidered in order to accommodate to their needs and preferences. Urban structure plays a key role in providing available paths [3] for pedestrian flows through urban areas. Improvement of accessibility between transit nodes and destination need to take into consideration urban facility designs. The correct design of the spaces and their accessibility must consider all age groups and problems related not only to safety but also to perception and comfortable movement. The body of literature dealing with accessibility of urban areas for vulnerable road users is extensive [4-7] The mobility of older people in particular has been intensely investigated [8-10]. Various authors have emphasized that to facilitate mobilities in later life, it is important that accessible, clearly structured and predictable urban environments are provided [8], [11].
Crash statistics show that older people make up an extremely vulnerable road-user group. There are several reasons for the higher proportion of fatality among older pedestrians. Existing literature suggests that cognitive deficits [12], diminished capabilities of human sensors [12], [13] or changes in the crossing behaviours [13], [14] could contribute to the increased crash rate for older pedestrians. Crossing the street can be regarded as a challenging and demanding task because it requires several processes, decisions, and actions to be performed quickly, sometimes in parallel. The act of crossing the street requires pedestrians to weigh up the time saving against the probability of a collision. Older people are often thought to precipitate their own accidents because of the way they cross the road. Their reduced physical capabilities result in less mobility and a reduced ability to move out of the way of approaching cars. Furthermore, their traffic judgements may also be quite different to those of younger people because of perceptual, sensory and cognitive deficits. A number of human factors studies suggest that such factors contribute to increased road behaviour risks [15-16-17]. Previous research has shown that aging pedestrians have difficulty selecting safe gaps to cross the street [13], [14]. Older people have also been shown to have difficulty handling challenging traffic situations such as two-way streets. Whereas their street-crossing safety is significantly greater on one-way streets, older pedestrians are more likely to get hit by a car during the second half of the crossing, i.e., on the far side of the street [14].

This study set out to investigate the behaviour of both older and younger adult pedestrians to establish whether the older group experience particular problems when crossing the road. In particular, it aimed to highlight behavioural differences between younger and older pedestrians, and to suggest countermeasures to reduce the frequency and severity of older pedestrian crashes. Road crossing behaviour was analysed from unobtrusive video recordings of road crossings for a sample of younger and older pedestrians at one four-leg urban intersection. The study focuses on two crosswalks of the selected intersection, located respectively on a one-way divided road and on a two-way divided road. An initial analysis of the number of legal/illegal crossings was developed in order to understand if different crosswalk setback distances lead pedestrians to illegal crossings. Then, for the legal crossings, the video footage was processed in order to calculate a parameter named *kerb delay*, i.e. the time interval between the moment in which the rear part of the last vehicle in the queue exceeds the pedestrian waiting for crossing and the moment when the pedestrian takes the first step to cross. The hypothesis that older pedestrians have longer *kerb delay* because of declines in their physical, sensory, perceptual or cognitive abilities was tested.

2. Methodology

2.1 Study locations

Observations were made in an urban four-leg at grade intersection (Fig. 1) located in Sant'Agata Li Battiati, a small town in the Metropolitan Area of Catania.

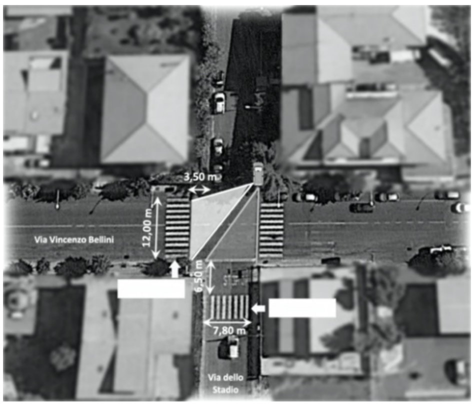

Fig. 1. Plan view layout of study locations and observational filming.

The site was selected after screening of local streets via field observations. The main street (Via Vincenzo Bellini) is a two-way undivided road with one lane on each side. Each lane is 6 meters wide. The sidewalk on the main street is 3 meters wide. There are two crosswalks on the main street. The secondary street (Via dello Stadio) is a one-way undivided road with one lane (7.8 meters wide). The sidewalk on the secondary street is 1.3 meters wide. There is only one crosswalk on the secondary street. This study focuses on a crosswalk located on the main street and a crosswalk located on the secondary one. The crosswalks analysed have the following features (Fig. 1): *A)* Crosswalk 1 is located on the secondary street, i.e. one-way undivided road with one lane. It is 7.8 meters long and 4 meters wide. The crosswalk setback distance is 6.50 meters. There are no bollards or other disposals to avoid illegal crossings; *B)* Crosswalk 2 is located on the main street, i.e. a two-way undivided road with one lane on each side. It is 12 meters long and 4.5 meters wide. The crosswalk setback distance is 3.50 meters. There are no bollards or other disposals to avoid illegal crossings.

2.2 Video data collection and analysis

Two synchronized cameras were used to record the natural scene at the sites. A car parked in front of Via dello Stadio on the side of the road was set up with two video cameras positioned to provide images of both oncoming traffic and crossing pedestrians. The cameras were hidden into the car so that pedestrians could not see them. Filming occurred without pedestrian's knowledge to overcome possible changes in behaviour. Figure 1 shows a plan-view layout of observational filming. Camera 1 was used to record pedestrians on crosswalk 1, while camera 2 was used to record pedestrians on crosswalk 2. Video recordings of 1578 elderly pedestrians (estimated to be $\geq$ 65 years) and 2309 non-elderly pedestrians (estimated to be $<$ 65 years) were made for a total of 24 hours. The video recordings were made between 10:30 a.m. and 12:30 a.m. on weekdays for four days in September 2019, eight days in January 2020, eight days in February 2020 and four days in June 2020. The hourly intervals of the video recordings were chosen so that the vehicle flows and the approaching speeds were comparable on all four legs of the intersection. A random and concurrent selection of participants was used, that is, as they entered the site without any selection bias. The video was played in Adobe Premiere Pro CS4 version 4.0.1 to perform a frame by frame analysis.

2.3 Indicators to describe crossing behaviour

In order to analyse pedestrians crossing behaviour, two variables were considered: the crossing conditions (*legal* and *illegal*) and the *kerb delay*.

By the law, in Italy, on intersections controlled by STOP signs there has to be a crosswalk setback distance of at least 5 meters. However, the crosswalk setback results in a deviation from the linear path that pedestrians are led to follow spontaneously. People indeed naturally hope to reach their destinations quickly, so they are not likely to make a detour. The two crosswalks studied were chosen purposely with different setback distances, in order to understand the availability of pedestrians to deviate from the linear path when there are no bollards or other disposals which force them to cross on the crosswalk. When a pedestrian does not cross at crosswalk, the crossing has to be considered illegal. The number of *illegal/legal crossings* was calculated for all the crossing pedestrians observed.

The *kerb delay* was the time from when the back of the last vehicle passed a waiting pedestrian to the first step forward onto the roadway [14]. Figure 2 schematically explain the *kerb delay*. The *kerb delay* was calculated only for the pedestrians who stopped before deciding to cross after a vehicle passed their line of crossing. Most of pedestrians observed did not stop waiting for a vehicle to pass, but, although slowing down, they continued walking in a "zigzag" among cars. Only 426 pedestrians (198 elderly pedestrians and 228 non-elderly pedestrians) crossed in a way which allowed to calculate the *kerb delay*.

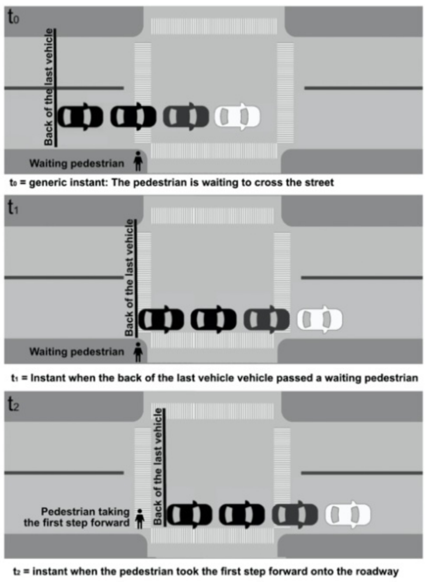

Fig. 2. Schematic explanation of *kerb delay*.

3. Results and discussion

3.1 Analysis of crossings conditions

Table 1 shows the number of *illegal/legal crossings* for younger and older pedestrians for the two crosswalks analysed. Almost the totality (96.01%) of crossings on crosswalk 1 are illegal. The percentage of non-elderly pedestrians crossing illegally (97.38%) is slightly higher than the percentage of elderly pedestrians crossing illegally (93.88%). Only 24.66% of crossings on crosswalk 2 are illegal. The majority (75.34%) of crossings on crosswalk 2 is legal. The percentage of non-elderly pedestrians crossing illegally (29.11%) is slightly higher than the percentage of elderly pedestrians crossing illegally (19.40%). These results clearly show that pedestrians prefer to cross choosing the shortest way, even if this leads to illegal crossing. The setback of crosswalk 1, which is more than 6 meters long, leads indeed more than 95% of pedestrians to cross illegally and choose the shortest path (that is as close as possible to the corner of the intersection). Conversely, crosswalk 2 is regularly used by over 75% of pedestrians, as it is very close to the corner of the intersection and, therefore, consistent with the need of minimizing the length of the route.

Table 1 – Number of illegal/legal crossings for non-elderly and elderly pedestrians for crosswalk 1 and crosswalk 2.

	Crosswalk 1					
	Non-elderly (<65)		*Elderly (≥65)*		*Total (non-elderly + elderly)*	
	Count	Percent	Count	Percent	Count	Percent
Illegal crossings	1787	97.38	1104	93.88	2891	96.01
Legal crossings	48	2.62	72	6.12	120	3.99
Total crossing	1835	100.00	1176	100.00	3011	100.00
	Crosswalk 2					
	Non-elderly (<65)		*Elderly (≥65)*		*Total (non-elderly + elderly)*	
	Count	Percent	Count	Percent	Count	Percent
Illegal crossings	138	29.11	78	19.40	216	24.66
Legal crossings	336	70.89	324	80.60	660	75.34
Total crossing	474	100.00	402	100.00	876	100.00

As for the influence of the age, the results allow to conclude that there is no clear difference between elderly and non-elderly users regarding the way they cross on crosswalk 1. The percentage of non-elderly and elderly pedestrians crossing illegally on crosswalk 1 are indeed similar (97.38% and 93.88% respectively). Anyway, these results can be interpreted in a different way for younger and older pedestrians: younger pedestrians probably cross illegally on crosswalk 1 because they want to reach their destinations quickly; older pedestrians, instead, probably choose to cross illegally because they choose the less tiring route (which is the shortest one). On the other hand, there is a certain difference as for the number of illegal crossings of non-elderly and elderly pedestrians on crosswalk 2. About 80% of elderly pedestrians cross legally on crosswalk 2, while a smaller percentage of non-elderly pedestrians (about 70%) cross legally. Although the setback is small on crosswalk 2 (3.5 m), there is still a non-negligible percentage of non-elderly pedestrians (29.11%) who choose the shortest and fastest route; the elderly, on the other hand, show greater caution preferring to cross legally even if this involves a slightly longer path.

3.2 Analysis of kerb delay

Table 2 shows the average *kerb delay* values for elderly and non-elderly pedestrians for crosswalk 1 and crosswalk 2.

Table 2 – Average *kerb delay* for non-elderly and elderly pedestrians for crosswalk 1 and crosswalk 2.

Kerb delay (seconds)		
	Crosswalk 1	Crosswalk 2
Non-elderly pedestrian (< 65 years)	-0.784	-0.034
Elderly pedestrian (≥ 65 years)	+0.042	+0.517

The *kerb delay* allows to determine, respectively, the delay or the anticipation of the pedestrian in crossing with respect to the incoming vehicle. The delay occurs when, after the vehicle passes, leaving the space free for the pedestrian to cross, the pedestrian hesitates to cross immediately. The advance occurs when the pedestrian, from a static position, starts to cross before the incoming vehicle has left the free space behind it to allow the pedestrian to cross.

From Table 2 it can be seen that older pedestrian delayed on both crosswalk 1 and 2 (+0.042 s and +0.517 s) before making their first step forward after the rear of the last vehicle has passed them. By contrast, younger pedestrian commenced the cross before the rear of the last vehicle has passed them on both crosswalk 1 and 2 (-0.784 s and -0.034 s). This is in line with the findings of Oxley et al. [14] who also found that older pedestrians delayed before making their first step forward after the rear of the last vehicle had passed them, while younger pedestrians commenced the road cross immediately.

Older pedestrians took longer to make their first step forward after a vehicle passed their line of crossing. It might be that older adults adopt an inefficient crossing strategy in comparison with younger adults by waiting for the last vehicle to pass before commencing the road cross. In older adults, increased *kerb delay* may be the result of reduced reaction time, slower decision making capacity and/or slower motor coordination, or simply greater prudence. On the other hand, the negative values of the *kerb delay* for younger pedestrian are indicative of greater reactivity and confirm the tendency of non-elderly pedestrian to cross quickly and minimize time wasters that was already stressed in paragraph 4.1.

By comparing the *kerb delay* values obtained for the two crosswalks it can be observed that the *kerb delay* values are higher for crosswalk 2 for both elderly and non-elderly pedestrians. By contrast, pedestrians have more rapid reactions on crosswalk 1. This shows that the *kerb delay* is also influenced by the complexity of the crosswalk. Crosswalk 2, which is 12 meters long and located on a two-way undivided road, leads indeed to greater delays, compared to crosswalk 1, which is 8 meters long and located on a one-way undivided road.

4. Conclusions

Pedestrian safety is related to the concept of accessibility and is assessed by taking into account different aspects of both the functional geometry and the pedestrian's attitude.

Specifically, the delay of the sidewalk by a certain type of user is influenced by the complexity of the adjacent pedestrian crossing and by what surrounds it (i.e. traffic flow, signs, traffic lights...).

The present work lays the basis for future research on the correlation between pedestrian safety and city accessibility, paying particular attention to the crossing areas. The results obtained allow to define specific actions to be taken in the analysed area and therefore support the choices of future planning and/or mitigation of current critical issues by the Local Administration. In addition, a more in-depth and protracted analysis over a longer period of time on infrastructure geometries and illegal crossing actions will make it possible to define and calibrate some synthetic safety parameters that may include the assessment of pedestrian safety near an intersection but also the comfort of the portion of the road (crossing) and pavement dedicated to the weak user of the road.

The aim of these assessments is therefore a general increase in the safety of urban and suburban mobility for residents and tourists, particularly in areas where there is a high level of pedestrian transit, through safer solutions for pedestrian crossings.

Therefore, future research steps will include an analysis of the current safety situation of existing pedestrian crossings, with the identification of the most critical areas (e.g. near schools, hospitals, etc.), in order to guarantee everyone, especially the most vulnerable such as children, elderly and disabled people, the right to walk safely and independently in their city.

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