EVALUATION OF THE SAFETY BENEFITS OF THE EXCLUSIVE AND CONCURRENT GREEN MAN PHASINGS FOR PEDESTRIANS IN CAPE TOWN

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ABSTRACT

International research has shown that the crossing behaviour of pedestrians at intersections can significantly affect the likelihood of crashes. Within the South African context, pedestrian traffic fatalities are a major concern, and city authorities are anxious to find effective means of managing pedestrian crossings as safely and efficiently as possible. This study compares crossing behaviour of pedestrians at two different types of signals in the city of Cape Town; first the conventional 'concurrent' signals where pedestrians cross at the same time as vehicles, i.e. where the green pedestrian signal and the green vehicle's signal are aligned with each other; and the second 'exclusive' phasing, where pedestrians have a dedicated green light phase where all other vehicular traffic is stationary (also known as a scramble phase). The study found that whilst the exclusive pedestrian phases had the most promise of safety on paper, in reality there was no discernible difference in safety overall, as the longer waiting periods meant that pedestrians were inclined to cross illegally, when the pedestrian signal was red. The study also found a high level of ignorance and confusion among members of the public about the signals – only 17% of pedestrians surveyed understood what the green, red flashing and red phases permitted them to do.

1. BACKGROUND

In South Africa, pedestrian related fatalities account for 39.5% of all road-related deaths. The mortality rates recorded in low to middle income countries confirm routinely that pedestrians are at particular risk. Low to middle income cities like Mumbai and Mexico City have recorded fatality rates of 2-3 deaths per 100 000, and Sao Paulo reports 10 fatalities per 100 000 (Mohan 2002). A study carried out in 2004 showed that South Africa has the one of the highest mortality rates in its major cities. The fatality ranged from 19.3 per 100 000 in Cape Town to 12.4 in Pretoria (Mabunda, Swart et al. 2008a). In contrast, the mortality rates recorded for high-income cities like London and Tokyo were at 1 per 100 000. These numbers are an indication of the relative safety of the pedestrians in low- to middle-income countries like South Africa compared with high-income countries.

Research has also confirmed that pedestrians crossing illegally at signalized intersections occur frequently and that this is one of the most common reasons for vehicle-pedestrian collisions (Wang, Yang et al. 2011). This suggests that preventative measures should be taken to reduce the number of pedestrians who practice unsafe and illegal crossing movements. A study by King et al. (2009) reported that illegal crossing behaviour at intersections increases the risk of collision between vehicle and pedestrian by eight times. Statistics show that illegal pedestrian crossing accounted for 32-44% of all the pedestrian crashes at signalized intersections in New South Wales and Victoria (Austroads, 2000).

Even though illegal crossing is dangerous and increases the risk of a collision between a pedestrian and a vehicle, a large number of pedestrians still engage in illegal crossing. A study conducted by Keegan & O'Mahony in Dublin (2003) showed that 35% of all pedestrians entered a signalized crossing illegally. A similar study found that illegal crossing behaviour and violations by the victim is a leading factor in pedestrian related incidents in El Paso County, Texas (Ashur et al., 2003). Pedestrians try to avoid any form of delay or waiting period and cross where it is most convenient (Garder, 1989; Hamed, 2001). Even engineering measures put in place - such as overpasses and underpasses (Holló et al., 1995) or pedestrian barriers (Kopelias et. al. 2002) – have reportedly little to no effect on the illegal crossing behaviour of pedestrians.

2. CONCURRENT VS EXCLUSIVE GREEN MAN PHASES

In South African cities a number of different interventions are being used to attempt to reduce illegal crossing of pedestrians at various locations in the city of Cape Town, the signalisation of a number of intersections has been changed to incorporate an exclusive green man phase, which is a very different approach from the conventional concurrent phase commonly used.

2.1 <u>The concurrent phase</u>

The **concurrent** phasing system allows the pedestrians to cross the road, in the same direction as the moving traffic, when the signal for the vehicular traffic changes to green. This means the pedestrians and vehicles cross at the same time. This signal phase normally gives right of way to vehicular traffic. This concurrent pedestrian phase is a commonly used signal phase due to its efficiency for traffic flow.

2.1.1 Advantages of a concurrent phase:

- The concurrent phase does not stop traffic movement completely. This maximises the level of service at the intersection.
- Pedestrians do not have to wait until all traffic is at a standstill before they can begin to cross. This tends to minimise the time the pedestrians have to wait.
- There are no separate movements for the pedestrians and the vehicles. The pedestrian movement works along with the traffic moving in the same direction, so optimizing traffic movement and reducing the length of time it takes to complete the entire cycle.

2.1.2 Disadvantages of the concurrent phase:

- With a concurrent phase there is conflict between turning vehicles and the pedestrians. The signal phase does not protect the pedestrians against the turning vehicle. The vehicle driver, turning at the intersection, has to be aware of any possible pedestrians at the intersection.
- Due to the conflict between the turning vehicle and the pedestrian, the turning vehicle often has to wait for pedestrian(s) to finish crossing the intersection before continuing. This leads to a delay in traffic movement.

2.2 <u>The exclusive phase</u>

The exclusive phase is a dedicated signal phase allowing pedestrians to cross the road without conflict with vehicular traffic. This phase only allows pedestrians to cross once all vehicle movements are completed and when the traffic is at a standstill.

2.2.1 Advantages of an exclusive phase:

- The exclusive signal phase allows pedestrians to cross without any conflict between turning vehicles and the pedestrians.
- With the vehicles at a standstill, the pedestrians may cross in any direction. This phase increases the level of service for the pedestrians.
- At an intersection with an exclusive phase, priority is given to the pedestrians and this increases the level of safety for the pedestrians.

2.2.2 Disadvantages of the exclusive phase:

- This signal phase is not immediately activated once the button is pressed, but only once the traffic is at a standstill. This results in a delay for the pedestrians.
- There is no return or cancelation of the phase once activated. The time allocated to the phase is fixed. If left unused it can result in unnecessary delays for vehicles.
- The level of service of vehicles decreases due to the increase in time allocated to pedestrians.
- Pedestrians themselves have a longer wait for the green man signal.

In both cases the signal phasing system is similar to that of the United States of America (USA). Where South Africa makes use of the green-man signal, USA uses the WALK signal which has the same meaning. The design of the signal control in the USA follows the Manual on Uniform Traffic Control Devices (MUTCD) as published by the US Federal Highway Administration. Below are the three signal phases which form the pedestrian signal cycle:

a). Walk - With this phase, the pedestrians are permitted to cross. The “Walk” phase has minimum time of 4 s. However, the MUTCD recommends a 7 s interval for the “Walk” phase.

b). Flashing Don’t walk – This is the intermediate phase, which serves a transition from the “Walk” to “Don’t walk” phase. The pedestrians who have already started to cross are allowed to finish crossing. The pedestrians who have not started the crossing movement must wait until the next cycle to do so. This signal phase is calculated based on the walking speeds of pedestrian, which is taken as 0.91 m/s to 1.21 m/s.

c). Steady Don’t walk - This signal phase prohibits any pedestrian from crossing. This means the vehicles have right-of-way to cross the intersection.

3. OBJECTIVES OF THE STUDY:

- To determine the safety benefits of both the concurrent and exclusive phases;
- To determine how pedestrians perceive the safety of crossing in the Central Business District Area, Cape Town by means of survey questionnaires;
- To determine how pedestrians behave at pedestrian crossings and how they respond to the pedestrian signal phases.
- To establish the conflict points at the intersections as well as the cause of such conflicts.

4. METHODOLOGY

4.1 <u>Methods of data collection</u>

The study involved observations of pedestrian behaviour; analysis of conflicts and a pedestrian survey.

4.1.1 Observation of pedestrian behaviour
A number of behavioural variables were monitored. These include:

- Illegal crossings: Illegal crossing behaviour includes pedestrians initiating their crossing on either a flashing of a steady red-man signal as well as pedestrians crossing away from the formal crossing (regardless of signal phase).. The aim of this observation was to establish the illegal crossing movements at the intersections as a percentage of the total number of crossings.

- Response to waiting time: Waiting time is an important factor when it comes to pedestrian crossing behaviour. As such, pedestrian behaviour was monitored to see how pedestrians behave when there is a waiting period involved. The aim of this objective was to establish whether there is a correlation between waiting time and number of illegal crossings.

4.1.2 Conflict study

This part of the study involved investigating the extent of conflict between pedestrians and vehicle traffic at the six intersections. .A conflict is defined here in line with Gårder (1989) as: “an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged”.

The study was conducted by making use of two cameras, set up in the corner of the intersections, to get a clear view of the entire intersections. The cameras ran for 30 minutes at each intersection. The footage from these cameras was used to identify the conflict points as well as the cause of the conflict.

This results included in this paper present only the crude number of conflicts per intersection, rather than those normalised against traffic or pedestrian flows. Each of the six intersections is slightly different in terms of traffic flow and geometry, though they are all typical of Cape Town CBD intersections. Two, Buitengracht/Wale and Buitengracht/Riebeek, carry the highest (and similar) volumes of traffic at peak hours, with Strand/Long; Wale/Bree and Hans-Strydom/Long carrying moderate and comparable traffic flows. The intersection of Riebeek and Long streets carries slightly less traffic than the others (both vehicular and pedestrian) and is also the intersection with the shortest crossing distances. The other five intersections encompass multiple lanes with some pedestrian refuges (see Table 3 for details).

All observations were carried out during peak traffic hours in the city’s CBD, and in all cases the pedestrian population was almost exclusively adult (i.e. no children) with most people being pedestrians en route to work. In all cases the weather was consistently clear and fine. The conflict analysis results presented in section 5.2 are indicative only and more details work would need to be done to fully quantify the conflict level at each one.

4.1.3 Survey of pedestrians

In addition to the observations at pedestrian crossings, pedestrians were asked to complete survey questionnaires. Surveys were completed b 92 pedestrians, half at each of the two signal types. Of the 92 adult pedestrians, 53 were male (seven of whom were elderly) and 39 were female, of whom four were elderly.

4.2 Site selection

Sites were chosen in consultation with the Cape Town City Council, and were selected based on geometric and traffic flow comparability with each other. It was a priority to choose intersections that carried a significant amount of pedestrian traffic so as to maximise the collection of data. It is worth mentioning that in all cases, while pedestrian flows were high at the study intersections, none experienced an abnormal level of pedestrian activity, or flows (even at peak) that were higher than capacity allowed. The sites selected are as follows:

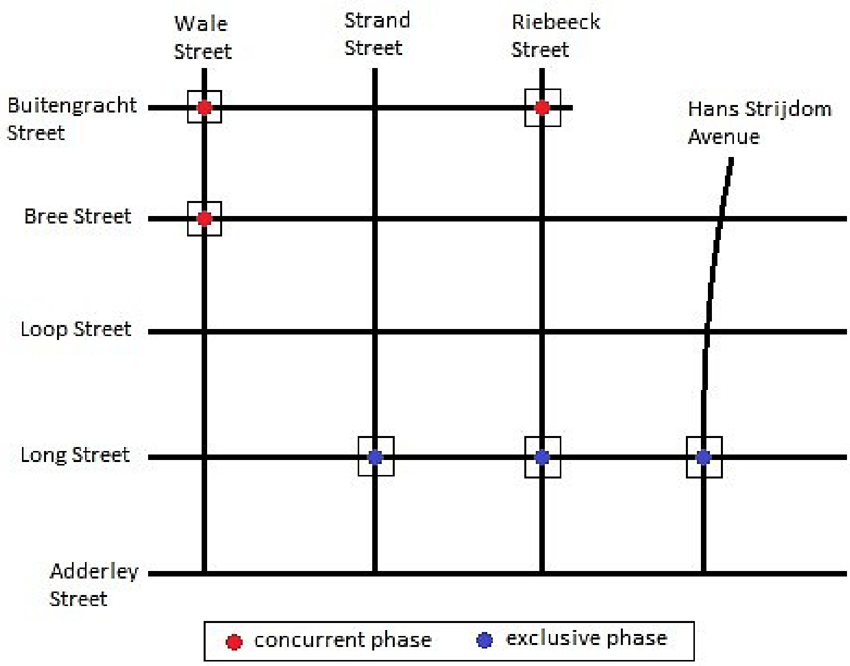

Figure 1: Schematic location of study intersections in Cape Town CBD

4.1.2 Crash history of intersections

Five of the six intersections have some history of pedestrian-related crashes over the previous six years, ranging from 12 to two pedestrian crashes, as shown in Table 1 below:

Table 1: Crash history of selected intersections

	Intersection	All pedestrian related crashes (2010-2015)	Number recorded as pedestrian causing crash	Pedestrian crash recorded off crossing
Exclusive green man	Hans Strydom & Long	4	2	3

	Riebeeck & Long	2	1	2
	Strand & Long	12	9	10
Concurrent green man phase	Wales & Bree	0		
	Wales & Buitengracht	4 (1)	2 (1)	1 (1)
	Riebeeck and Buitengracht	7 (2)	3 (2)	5 (0)

(Numbers in brackets indicate crashes recorded post change of signalization)

The table indicates that pedestrian movements appear to have been the most commonly identified cause of crashes over this period, and also that the majority of crashes occurred away from a formal crossing point, suggesting an illegal “jaywalking” movement. The numbers of crashes reported at those intersections since signal timings have changed are as yet too small to be statistically reliable, but at face value there is not yet an appreciable difference in crash rates since the change.

5. RESULTS:

5.1. Behavioural analysis

Table 2 shows the observed pedestrian behaviours recorded at each intersection over peak and off peak periods. The results show that pedestrian legal crossing rate rate was extremely low at all intersections; on average only 16.1% of all crossings occurred legally (initiated on the green man signal, at the formal crossing). The lowest level of legal crossing was found at the intersection of Riebeeck and Buitengracht streets, and the highest at Strand and Long.streets. This particular intersection (Strand and Long) was also the intersection at which most conflicts were recorded (refer to Table 3), so this particular intersection does appear to present a higher risk to pedestrians than the others, which may explain the elevated compliance rate here.

Table 2 shows that the vast majority of crossings – 83.9% on average, occurred illegally. When looking at the breakdown of these crossings per signal type, there is very little difference between the results from the Exclusive and Concurrent phases – in the former an average of 17.3% of crossing were legal, compared with 14.9% for the concurrent phase. It is possible that the rather higher compliance rate at Strand and Long has distorted the averages slightly.

What is particularly notable about the results in Table 2 is that crossings initiated on the solid red-man signal make up the majority of the illegal crossings (56.8% off-peak and 60.6% peak times). These are crossings that most pedestrians would clearly understand to be illegal, yet such crossings are being made regardless. Likewise, crossings away from formal crossings are high at both types of signal, though slightly higher at the exclusive phase intersections (16.2% of all crossings here were illegal compared with 9.2% at the concurrent phase).

Table 2: Observed pedestrian crossing behaviour at peak and off-peak periods.

Intersection	Crossings initiated on green man		Average **legal** crossing	Flashing red man crossing		Steady red man crossings		Crossings off pedestrian crossing		Average **illegal** crossing
	Off-peak (%)	Peak (%)		Off-peak (%)	Peak (%)	Off-peak (%)	Peak (%)	Off-peak (%)	Peak (%)	
Hans Strydom & Long	7.4	16.5	*12.0*	16.4	11.9	47.1	41.5	29.1	30.1	*88.1*
Riebeeck & Long	12.9	15.2	*14.1*	7.6	9.8	66.9	66.6	12.6	8.4	*86.0*
Strand & Long	29.0	22.5	*25.8*	18.1	10.7	46.1	56.6	6.8	10.3	*74.3*
Wales & Bree	15.7	22.3	*19.0*	6.9	8.0	66.8	57.4	10.6	12.2	*81.0*
Wales & Buitengracht	24.5	10.3	*17.4*	16.6	18.3	48.3	61.9	10.6	9.5	*82.6*
Riebeeck and Buitengracht	9.6	7.1	*8.4*	20.8	2.2	65.6	79.8	4.0	10.9	*91.7*
Average	16.5	15.7	***16.1***	14.4	10.2	56.8	60.6	12.3	13.6	***83.9***

Assuming that some pedestrians believe the flashing red phases allows a crossing to be initiated, even with factoring in these crossings as 'perceived to be legal', the vast majority of crossings still occur illegally – either initiated on the steady red phase of crossing away from the formal crossing point (70.4% at Exclusive phase crossings and 71.6% at Concurrent phase crossings). This suggests rather conclusively that there is very little respect for the crossing regulations by pedestrians in this study area.

5.2 Conflict study analysis

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Typical diagrams were drawn up for each intersection to identify the location of conflicts observed. Figures 1 and 2 are examples of the diagrams for the intersection of Long and Riebeeck streets.

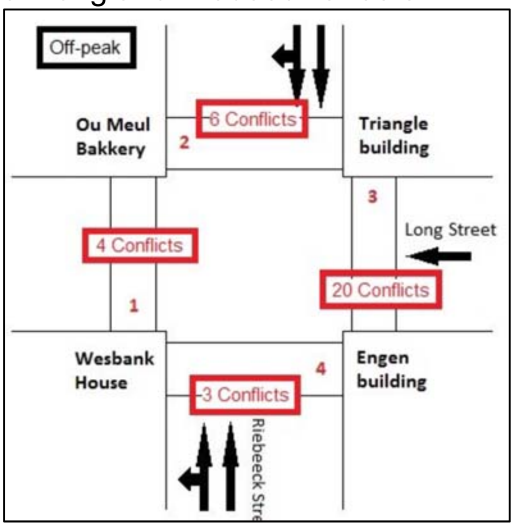

Figure 2: Conflicts Off peak

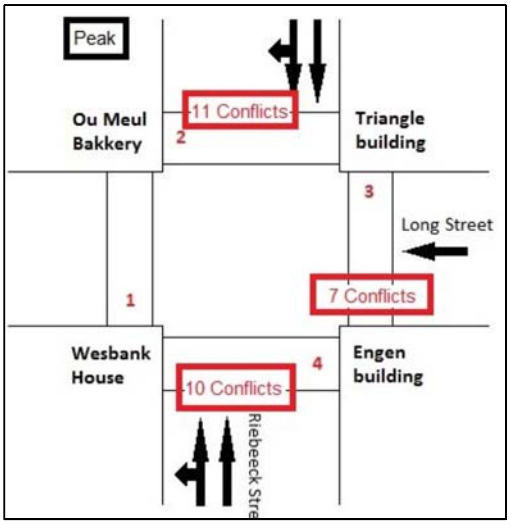

Figure 3: Conflicts Peak

The total number of conflicts per leg of each intersection are summarised in Table 3.

Table 3: Conflicts recorded at each intersection

	Intersection	Total number of recorded pedestrian-veh conflicts at each leg of the intersection (30 minute period)		Comments
		Off-peak	Peak	
Exclusive green man phase	Hans Strydom & Long	14,8,0,0 = 22	17,14,3,4 = 38	Conflicts most common at one crossing in both peak and off-peak. This was a crossing that did not include a pedestrian refuge. Some higher speed conflicts noted here in off peak.
	Riebeeck & Long	6,4,3,20 = 33	11,0,10,.7 - 28	Only intersection to evidence fewer conflicts during peak time than off peak. Two of the legs were served with central medians (pedestrian refuges).
	Strand & Long	8,22,6,1 = 37	20,9,10,2 =41	Highest conflict count of all intersections with similar levels during both peak and off-peak times. This intersection had no pedestrian refuges mid-way across the crossing, and thus presented to most risk exposure for pedestrians.
Concurrent green man phase	Wales & Bree	1,3,2,2 = 8	2,8,3,4 = 17	Lowest number of conflicts recorded here. This is also the only intersection in the study that had no crashes with pedestrians recorded in the six year history. All intersection legs are served with pedestrian refuges.
	Wales & Buitengracht	1,6,2,2 = 11	2,7,5,10 = 24	All intersection legs are served with pedestrian refuges.
	Riebeeck and Buitengracht	0.8.0.14 = 22	1,13,1,16 = 31	All intersection legs are served with pedestrian refuges.

In most cases the frequency of conflicts increased over the peak period (except at the intersection of Riebeeck and Long Street as shown in Figures 2 and 3).. The number of pedestrians at every intersection increased during the peak period, as did the traffic at the intersection. This is in line with international research which confirms that an increase in the traffic and pedestrian numbers results in an increase in the pedestrian-vehicle conflicts (Leden 2002)

The presence of a central median/pedestrian refuge appears to have an influence on the number of recorded conflicts, possibly because it gives the pedestrians a safe place to wait out of the path of on-coming vehicles. However it is useful to bear in mind that these refuges were in place during the six years prior to the study, and that only a single intersection recorded no pedestrian crashes during this time. They probably have an effect on the likelihood of crashes but do not appear to have prevented them altogether.

The signal types (exclusive or concurrent) affect exposure to risk of conflicts in that the concurrent phasing exposes pedestrians to conflicts from turning vehicles, while they are protected from these in the exclusive phase. However there was a higher average incidence of illegal crossings at excusive phase crossing points than at concurrent phase crossings, as well as an elevated number of crossings away from the formal crossing, at exclusive phase crossing points. Crossing during the phase of vehicles movement exposes pedestrians to significant risk, especially if vehicles are moving in free flow at the time.

Responsibility for the conflict at concurrent phase crossings was shared between pedestrians and vehicles. At exclusive phase crossings all conflicts recorded were exclusively the result of pedestrians crossing illegally.

5.3 Pedestrian survey results

Surveys were conducted to find out how pedestrians experienced crossing at both signal types, and to gain a better understanding of the pedestrian crossing experience in the City.

Among other questions, pedestrians were asked about the perceived waiting time at the specific signal type they were crossing at, at the time of survey. The responses (see Table 4) indicate some differences in attitude towards the waiting time at each:

Table 4: Survey responses to waiting time

	Percentage of pedestrian responses at concurrent signals (n = 46)	**Percentage of pedestrian responses at exclusive signals (n/=46)**	**Total Percentage of pedestrian responses (n=92)**
Only experienced a minimal. wait	0%	1%	1%
Wait was considered not long	68%	55%	61%
Wait was considered long	28%	26%	27%
Wait was considered excessively long	4%	18%	11%

There were clearly some differences regarding the waiting periods in the exclusive phasing signals, where more pedestrians reported that waits were excessively long, than in the concurrent phases. This was borne out by the observations which showed slightly higher numbers of pedestrians crossing illegally during the red phase at exclusive phase intersections

In the observations of pedestrian crossing, it was seen that around 60% of all crossings were initiated when the pedestrian signal was on the steady red man. One explanation for this could be intentional lawlessness – i.e. that pedestrians knowingly - out of frustration or impatience – cross, irrespective of the signals, whenever they can see a clear break in the traffic. Certainly, in the surveys, the majority of respondents felt that, regardless of signal type, the actual crossing time provided to them was too short. Sixty-three percent of the respondents felt this to be the case; with only 19% indicating that the time provided was sufficient. So there does appear to be a sense that the legal crossing time is at odds with pedestrian needs. That said, it is also possible that this crossing behaviour may also have to do with pedestrians failing to understand that the legal crossing periods comprises the green man phase as well as the flashing red man phase, not simply the green man phase alone. During the observations some pedestrians had been observed starting to run when the signal changed from the green-man to the flashing red-man – possibly indicating that they did not fully understand that they still had sufficient time to cross safely.

Quite shockingly, the survey results confirm fairly conclusively that few pedestrians do in fact understand the rules of the red light man. Of the 92 pedestrians surveyed, only 9 respondents were able to accurately explain the signals rules. 43 explained them inaccurately, and a further 40 said they were unsure of the rules.

6. CONCLUSION

In closing, in the South African context the safety benefits of the exclusive phase of the green man are questionable. There was almost no indication that the safety of the pedestrians at the exclusive intersections was improved. This was not because of a design flaw in the signals themselves, but because of the behaviour of the pedestrian during the non-green phase of the signals. Higher percentages of pedestrians were observed crossing illegally at exclusive phases than at concurrent phases, probably because of waiting time frustrations. More pedestrians were also observed crossing away from the formal crossings at these locations, placing them at higher risk of serious conflict with vehicles. It would appear that unsafe crossing behaviour of pedestrians is common at all intersections types but there is greater opportunity for it at the exclusive phase because of the longer waiting time.

The most significant finding from the study is arguably the fact that pedestrians do not appear to understand the rules of the crossing phases. They appear to see the different light contexts as rough guidance, and in fact the flashing light induces a fair amount of panic. Many pedestrians began crossing on the flashing phases, without apparently understanding that this is ‘illegal’, and even more started crossing when the solid red man was showing.

Unsafe pedestrian behaviour is a complex and difficult problem to solve, but introducing phases which ostensibly protects pedestrians better does not appear to work when there is a culture of poor pedestrian behaviour; when waiting times are considered high; and in the context of pedestrians not fully understanding crossing rules.

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