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Illegal pedestrian crossing at signalised intersections: incidence and relative risk

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Abstract

Illegal pedestrian behaviour is common and is reported as a factor in many pedestrian crashes. Since walking is being promoted for its health and environmental benefits, minimisation of its associated risks is of interest. The risk associated with illegal road crossing is unclear, and better information would assist in setting a rationale for enforcement and priorities for public education. An observation survey of pedestrian behaviour was conducted at signalised intersections in the Brisbane CBD (Queensland, Australia) on typical workdays, using behavioural categories that were identifiable in police crash reports. The survey confirmed high levels of crossing against the lights, or close enough to the lights that they should legally have been used. Measures of exposure for crossing legally, against the lights, and close to the lights were generated by weighting the observation data. Relative risk ratios were calculated for these categories using crash data from the observation sites and adjacent midblocks. Crossing against the lights and crossing close to the lights both exhibited a crash risk per crossing event approximately eight times that of legal crossing at signalised intersections. The implications of these results for enforcement and education are discussed, along with the limitations of the study.

Keywords

Pedestrians, Illegal behaviour, Relative risk, Signalised intersections, Observation

1. Introduction

1.1 Illegal crossing and crashes

Virtually all people travel as pedestrians on the road system. Compared with driving, walking is subject to fewer rules which are confined largely to crossing or travelling on the road, however there is widespread non-compliance with pedestrian legislation. Several studies conducted between 1940 and 1982 found that about 25% of pedestrians crossed illegally at intersections (Mullen et al., 1990). More recently, Keegan and O'Mahony (2003) reported that 35% of pedestrians entered illegally at a signalised crossing. Pedestrian crashes account for around 15% of fatalities each year in Queensland (Australia) and about 8% of hospitalised casualties (Queensland Transport, 2005), and illegal pedestrian movements are a factor in these crashes. A study of pedestrian crashes at crossing facilities in New South Wales and Victoria (Austroads, 2000a) found that illegal pedestrian movements featured in 32-44% of pedestrian crashes at signalised intersections and 45% at pedestrian operated signals (i.e. not at a signalised intersection). In a more recent study, violation of traffic laws by the victim was found to be one of the "predominant contributing factors" in all pedestrian categories examined in a study of pedestrian crashes in El Paso County, Texas (Ashur et al., 2003).

Knowledge of pedestrian rules does not seem to be the issue; rather, pedestrians want to cross where it is convenient for them, and with as little delay as possible (Gårder, 1989; Hamed, 2001; Holló et al., 1995; Sisiopiku and Akin, 2003). Enforcement of the rules by police is infrequent, and considered by the public to be unwarranted (Schonfeld and Musumeci, 2003). Engineering measures also tend to be resisted, with measures such as overpasses and underpasses (Holló et al., 1995) and pedestrian barriers (Kopelias et al., 2002) having little effect on illegal crossing behaviour.

1.2 Rationale and context

Walking is being promoted for its health and environmental benefits, which has influenced approaches to engineering practice (Austroads, 2001a, 2001b). Consistent with this approach is the recognition that many pedestrian crossing facilities are poorly located, as judged by the propensity of pedestrians to cross elsewhere. This propensity for illegal crossing could also be interpreted as indicating the rules imposed on pedestrians may unnecessarily restrict their mobility for the sake of safety benefits which are only modest or intermittent. However, there is a lack of information about the risks involved in illegal crossing behaviour. Such information would provide a basis for both enforcement and education campaigns, and would assist in prioritising engineering interventions. From the outset it needs to be acknowledged that the risks associated with illegal crossing are almost certain to be highly dependent on the context, including legal definitions, engineering practices and site characteristics. However, the existence and scale of such risks in one place would be suggestive of similar results in other places. The primary purpose of this research was therefore to quantify the relative risks of illegal crossing at a particular group of sites, while the secondary purpose was to investigate and comment on the variation between sites and the implications this has for generalisability of the results.

Constraints on resources and concerns about the safety of observers at night ruled out both a geographically widespread study and observations at night or on weekends. Accordingly, a study was undertaken on the relative risk of illegal crossing at signalised intersections in the Brisbane central business district (CBD) on typical workdays. Brisbane is the capital of the Australian State of Queensland and has a population approaching 2 million. Approximately half of all pedestrian crashes in Queensland occur in metropolitan areas (almost half of which occur at intersections), with a further third occurring in other urban areas (Austroads, 2000b). Looking at crashes by day of week and hour of day, a disproportionate share of crashes occurs on weekdays and in daylight (8am-6pm) (Austroads, 2000b). In the period 2000-2004, about 17% of all pedestrian crashes in Queensland took place at "operating traffic lights" (which excludes "pedestrian operated signals"). Of these, a quarter occurred in Brisbane City (essentially the CBD), accounting for just over half of all pedestrian crashes in Brisbane City.

In Queensland, pedestrian lanterns feature the static shape of a man walking which is illuminated in one of three phases: when the illuminating light is a steady green, it is legal to commence and complete crossing; when the illumination changes to a flashing red, pedestrians must not start crossing but may complete a crossing commenced during the green phase; and when the illuminating light changes to steady red, it is illegal to start crossing and pedestrians still on the crossing must clear it as quickly as possible. Pedestrians must also use the pedestrian crossing if they are within 20 metres of it, and cross between the marked lines. Any crash involving injury must be reported to police, and the generally more serious nature of pedestrian crashes means that levels of under-reporting are comparatively low.

2. Method

2.1 Identification of data

The calculation of relative risks requires information on both crashes and exposure. Exposure was measured by conducting observations of crossing behaviour. The behaviours which were observed were determined based on the crossing rules, the kinds of illegal behaviour which are readily observable, and the availability of information in the police-reported crash data from the Queensland Road Crash Database, accessed via the net-based program WebCrash 2 (Queensland Transport, 2004). Observations were conducted only on weekdays between 8am and 6pm, for a mix of logistical and ethical reasons. In practice this period accounts for the majority of pedestrian crashes.

There were constraints on the types of pedestrian behaviour identifiable in the police-reported crash data. From intersection crash data it was possible to identify legal crossing and crossing against the red man (but not the difference between entry on flashing vs. steady red man), but data on midblock crashes was needed to identify crashes which occurred within 20 metres of the signals. It was also possible to determine “drink walking”, which is defined (by analogy with the legal definition of “drink driving” in Australia) as being a pedestrian with a blood alcohol concentration of 0.05mg/100ml. There is no legal alcohol limit for pedestrians, but the high proportion of “drink walking” pedestrian crashes has generated interest in the area (e.g. Öström and Eriksson, 2001). As with the distinction between “drink driving” and “drunk driving” (where the latter implies obvious impairment and the former the violation of a legal limit), “drink walking” is defined by the blood alcohol concentration and not by the pedestrian’s behaviour.

Pilot observations showed that observers could readily distinguish between entry on the flashing red man, entry on the steady red man after the flashing period, and entry on the steady red man prior to the green. In practice it was decided to record entry on flashing red and entry on steady red separately, even though the data would need to be combined for calculation of crash risk for entering against the red man. Observation of illegal crossing within 20 metres of the crossing was considered feasible, subject to an operational definition and training of observers, since many pedestrians pursued a curved or angled path that may cross the 20 metre point and may also cross into the legal crossing zone. Observer identification of drink walking was not possible (as only very obvious impairment could be detected), and was not as relevant in the times of day selected for observation, as less than 2% of the pedestrian crashes which occurred between 8am and 6pm on weekdays were drink walking crashes.

In summary, the police-reported crash data were examined for the following categories:

- legal crossing
- crossing against the red man (includes enter on flashing and steady red man)
- crossing within 20 metres of the crossing, but not at the crossing

The observations used for the relative risk calculations were confined to the following categories:

- legal crossing
- entering on the flashing red man
- entering on the steady red man
- crossing within 20 metres of the crossing, but not at the crossing

2.2 Site selection and observation design

Brisbane CBD signalised intersections were ranked by number of police-reported pedestrian crashes and the top ranked sites were inspected. The list was refined by excluding sites which were considered to be too different (primarily for reasons of layout or signal phasing) or at which significant roadworks were taking place. Available resources limited the observations to six intersections. Diagrams were prepared for each intersection indicating lanes, directions of travel, features such as bus stops and taxi ranks, and crossings (Figure 1). An assessment was made as to how many observers would be needed, given the signal phasing, volume of traffic and nature of the pedestrian movements. Code books were developed and refined through observation, and observers were recruited and trained to ensure consistency in classification of pedestrian movements.

(FIGURE 1 ABOUT HERE)

Each intersection was observed for one half-hour period during five different time periods over the day; early morning (8am-10am), mid-morning (10am-12pm), midday (12pm-2pm), mid-afternoon (2pm-4pm), and late afternoon (4pm-6pm), on Thursdays and Fridays in two successive weeks in November. The use of mutually exclusive and exhaustive categories meant that the total number of pedestrians crossing could be calculated by summing the frequencies from the observation categories.

Crossing on the green man was operationalised as any pedestrian who crossed within or very close to (e.g., within two metres of) the designated crossing area while the green man was illuminated. Crossing on flashing red man occurred when a pedestrian began to cross after the red man had begun flashing, while crossing on the steady red man occurred when a pedestrian began to cross when the red man had ceased flashing and was fully illuminated. Neither of these categories included pedestrians who began crossing on the green man and were still crossing when the red man started to flash or became steady (such as some slower elderly pedestrians). Pedestrians who attempted to pre-empt the green man and began walking early were recorded as having crossed on the steady red man. Illegal crossing near the lights was operationalised using the legal definition of the behaviour; that is, when a pedestrian crossed the road within 20 metres of, but outside of, the designated crossing area.

2.3 Data analysis

Data were entered into Excel spreadsheets. In addition to overall descriptive statistics, a compositional analysis (Aitchison, 1994) was undertaken on the observation data to assess the validity of summing intersection and time of day data to calculate relative risks. Compositional analysis takes into account the interdependence of the proportions of legal and illegal behaviours, with the proportions for a given site and time forming one "composition". The analysis was conducted using the statistical package CoDaPack (Thió-Henestrosa, 2007) which utilises Excel. This package generates three "goodness of fit" test statistics (Anderson-Darling A^2, Cramer-von Mises W^2 and Watson U^2) for which critical values (at the 0.05 level) were obtained from Stephens (1974). CoDaPack also calculates "indices of atypicality" of particular compositions (the recommended 0.95 level was specified).

Crash data were obtained from the WebCrash online database (Queensland Transport, 2004) to explore the extent and nature of pedestrian-involved incidents in the Brisbane CBD. Data was collated for all pedestrian-involved incidents that occurred at the six intersections and on the midblocks surrounding them on weekdays between the hours of 8am and 6pm from January 1996 through to and including December 2006. This 11 year period was selected because data had already been collected from 1996 to 2005, and by the time of the analysis a further year of data had become available. Individual crash reports were examined to determine whether the crashes involved legal crossing, entering on the flashing or steady red man, or crossing within 20 metres of the crossing, but not at the crossing.

2.4 Relative risk calculations

For calculation of relative risks, the two "red man" categories were combined, giving two illegal behaviour categories (cross against red man and cross away from the signals but within 20 metres). First, the risk per crossing event was calculated, i.e. number of crashes per unit time in that behavioural category divided by number of crossings per unit time for the category. Next, relative risk was calculated for each illegal behaviour by dividing its risk by the risk involved in legal crossing. Mathematically this was (crashes per crossing event for an illegal behaviour)/(crashes per crossing event for legal crossing), so that a result greater than 1 signified the multiplicative increase in risk associated with the illegal behaviour compared with the legal behaviour. Confidence intervals (95%) were calculated.

Both sets of data were annualised (i.e. converted into a single year equivalent), which was straightforward for the crash data (simple division by 11), but required several steps for the observation data, as it slightly under-sampled the afternoon time slots, included 15 minute breaks, and covered only two weekdays.

3. Results

3.1 Incidence of illegal crossing

Results of the observations (Table 1) showed that the majority of pedestrians waited for the green man to become illuminated before crossing. The most common illegal behaviour was crossing away from the signals but within 20 metres, followed by crossing against the flashing red man, then crossing against the steady red man. During observations, one intersection (Albert and Elizabeth Streets) was identified as problematic given the restrictions on access to one of the legs of the intersection, which had very little traffic and consequently high rates of crossing on the steady red man. Removing the Albert and Elizabeth Streets intersection from the analysis (Table 1) changed most results only slightly, but reduced the proportion crossing against the steady red man by about a third.

(TABLE 1 ABOUT HERE)

3.2 Compositional analysis

Table 2 presents the observation data by intersection, in which the issue noted above (at the Albert and Elizabeth Streets intersection) can be seen. The full breakdown by time of day has not been presented, for reasons of brevity, however the compositional analysis took all sites and times of day into account. Neither the Anderson-Darling nor the Cramer-von Mises statistics were significant for any of the marginal distributions, while the Watson statistic was marginally significant (0.117, compared with a critical value of 0.116) for one marginal distribution. Similarly, the indices of atypicality revealed only one atypical composition, for the Edward and Elizabeth Streets intersection between 4pm and 6pm .

(TABLE 2 ABOUT HERE)

3.3 Relative risks

The observation data were annualised for weekdays 8am-6pm, after adjusting for any over- or under-sampling. It was decided to include the Albert and Elizabeth Streets intersection, as the combining of the two “red man” categories meant that there was little difference between the “red man” proportions with (12.8%) or without (11.6%) the data from the Albert and Elizabeth Streets intersection. Over the 11 year crash period (1996-2006), between 8am-6pm on weekdays at the study intersections and on the roads approaching them, there were 77 crashes (41.8%) which occurred when the pedestrians were crossing legally, 43 (23.4%) which occurred when the pedestrian entered the crossing against the flashing or steady red man, and 64 (34.8%) when the pedestrian crossed within 20 metres of the signalised crossing. This data was annualised, and used for the relative risk calculations given in Table 3.

(TABLE 3 ABOUT HERE)

The risk ratios showed that crossing against the lights and crossing close to the lights both exhibit a crash risk per crossing event approximately eight times that of legal crossing at signalised intersections. The confidence intervals confirm the strength of the results.

4. Discussion

4.1 Comparison with previous research

When all illegal crossing types are combined, they accounted for 20% of observed crossings in this study. This less than the 25% reported in Mullen et al.’s (1990) review, though the sites in this study had high pedestrian volumes and were surveyed at times when volumes were highest. In contrast, illegal pedestrian movements were found to be involved in over 58% of crashes. This is greater than the 32-44% reported by Austroads (2000a), probably because the present study included midblock crash data so that crashes that occurred within 20 metres of the crossing would be captured. Excluding these crashes reduces the figure to a comparable 36%. However it does illustrate the need to take account of pedestrian crashes which may not be recorded as occurring at the intersection, but involve a violation of the rules relative to the intersection.

4.2 Significance and validity of relative risk results

The high levels of non-compliance suggest that such non-compliance is not perceived to be accompanied by a significant increase in risk. The relative risk calculations show that the risk is actually eight times higher than for legal crossing, which is a statistically significant result. The practical significance is open to question since even the higher risk means that only one police-reported crash occurs for every 173,000 illegal crossings. There may be some pedestrians who make multiple illegal crossings each day, for whom the risk over an extended time period is non-trivial; in addition, it was not possible to separately calculate the risk of crossing against the steady red man (especially after the flashing phase has ended rather than just before the light changes to green), and it is reasonable to expect that this risk would be markedly higher (and the risk of crossing against the flashing red man correspondingly lower).

At the outset it was acknowledged that different sites are likely to have different patterns of illegal pedestrian behaviour, and the same can be said of time of day. This begs the question of the validity of summing observation data across sites and times of day. The compositional analysis was reassuring in that it indicated that the breakdown of legal and illegal behaviours across the sites and times of day were consistent.

4.3 Alternative measures of exposure

This study took a different approach to the measurement of pedestrian exposure, compared with typical usage of crashes per trip or per kilometre travelled (e.g. Pucher and Dijkstra, 2003). Some engineering approaches do not even distinguish between legal and illegal crossing (e.g. NCHRP, 2008), even though there are varying implications for countermeasures. The research reported here focused on the risk of crossing itself according to whether it was legal or illegal. Most police-reported pedestrian crashes occur while the pedestrian is crossing the road, so that the level of crash risk per crossing movement has practical implications for allocation of resources to improve pedestrian safety.

4.4 Implications for pedestrian crash prevention

Generally, pedestrian education campaigns have not been successful, and it has become axiomatic in several areas of road safety that public education is most effective when it signals or supports a change in the environment, such as an enforcement campaign. Pedestrian enforcement campaigns have been similarly unsuccessful (Schonfeld and Musumeci, 2003), in part because the fines are very low. Standard deterrence approaches (e.g. Homel, 1986) assume that effective deterrence of illegal behaviour requires a high perceived risk of detection, combined with a high perceived severity of the consequences, and swiftness and certainty in the application of those consequences. For pedestrians in Queensland the risk of detection and the severity of the consequences have been quite low. If the high levels of risk of illegal pedestrian movements are confirmed in larger and better studies, the results would lend themselves to a three-way approach involving penalties, enforcement and education. The high levels of risk could be used to justify an increase in penalties for illegal crossing behaviour, enforcement could be increased, and public education could be undertaken to highlight the risks, publicise the sanctions, and warn of increased enforcement.

4.5 Limitations

4.5.1 Representativeness

The limitations of the study must, however, be acknowledged. The sites are not representative, being located in the CBD and having high volumes of pedestrians and vehicles. The consistency between the sites may have been due to their similarities in terms of pedestrian profiles (age, sex and trip purpose), and different results might be obtained at other sites. This is implied by some of the differences that did occur, such as the high number of steady red man violations at Albert and Elizabeth Streets, where there is a leg which has very little traffic volume due to particular restrictions. There are also likely to be different patterns at night and on weekends, at pedestrian operated signals, and at the variety of formal (e.g. zebra crossings), semi-formal (e.g. median refuges) and ad hoc unsignalised crossing points across the road system. Measuring exposure at these kinds of site presents significant challenges, as would the exercise of relating crashes to crossing locations and movement types. The observations were confined to two Thursdays and two Fridays in November, with the data then being annualised. While the periods were deliberately selected to avoid holiday periods, summer and winter, it is possible that there are variations in rates of illegal crossing over the year, which cannot be addressed without long term observation studies.

4.5.2 Behaviours surveyed

There were other limitations which reflect the constraints of the observation method and the nature of the crash data. A high proportion of pedestrian fatalities have been drinking, with many having a BAC in excess of 0.15 gm/100ml (Austroads, 2004), however because drink walking cannot be reliably observed (requiring random breath sampling methods instead), it was omitted from consideration. A re-check of the 2000-2004 data used to determine the crashes of interest in this study showed that less than 2% of pedestrian crashes in the Brisbane CBD on weekdays between 8am and 6pm were drink walking crashes, so the impact of such a confound would be small. As noted in 2.1, this is therefore not an important omission for the time period observed, but would need to be addressed if weekends and night times were surveyed. The observations also did not distinguish between pedestrians who crossed against the steady red man just before the green man vs. just after the flashing red man, and the crash data did not distinguish between flashing and steady red man violations. These different violations almost certainly have different levels of associated risk, but only a pooled risk could be estimated. There is also a lack of clarity about the classification of both offences and crashes as being within 20 metres of the crossing, but not at it. This study used an operational definition for “at the crossing” which included crossings within two metres of the marked lines, which technically includes many illegal crossings, and there are no defensible reasons for the two metre tolerance as opposed to, for example, one metre. As many crossing movements are not parallel to the lines, a pedestrian may stray across both the marked and operationally defined boundaries during a crossing. Guidelines were developed for classifying these movements in the observation study, but it is not known how reliable, or variable, crash reports are in locating the pedestrian movements relative to the marked lines. This applies equally to the decision about whether a crash is recorded as being at the intersection rather than close to it.

4.5.3 Statistical analyses

Compositional analysis is not widely used in road safety, and there are issues with its underlying assumptions which have been debated in other areas (Aitchison, 1994), in particular the scale invariance assumption, which means that increasing the number of observations for a particular site/time combination should have no impact on the results. This merits further consideration in the context of studies such as this one. The analyses which were performed were limited to the observation data themselves, and were not conducted with the relative risks, even though they share the same interdependencies as the observation data. This was necessitated by the low number of crashes which made it indefensible to disaggregate risk ratios by site or time, but could be addressed in a larger study.

4.5.4 Other issues

Some factors considered to contribute to pedestrian crash risk were overlooked in this study, e.g. intersection design, traffic concentrations, crossing distances and vehicle speeds (Lassarre et al., 2007), although several of these were controlled via the selection of rather similar CBD sites. A more interesting issue is that there is evidence that relative incidence of legal and illegal crossings can be manipulated simply by changing signal phasing (Austroads, 2001c; Keegan and O'Mahony, 2003), though the impact on the incidence of crashes is less clear. The kinds of road user who cross legally and illegally, and when in the phase they do so, may also be of interest but was not examined here.

5. Conclusion

In spite of these limitations, it is considered that the methodology employed in this study has been successfully piloted and can be improved and applied more widely. The results provide evidence that illegal crossing behaviours are associated with an increased crash level of risk. Replication of these results at a more general level would constitute grounds for a pedestrian crash prevention strategy involving publicity, a change in penalties, and enforcement. There are also implications for the promotion of walking for health and environmental reasons: the emphasis on the provision of better pedestrian facilities should be supplemented by drawing attention to the fact that crossing a road is the one part of walking which is formally regulated, and that this is because of the risks involved.

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Table 1: Proportion of legal and illegal crossing behaviours, overall and after excluding anomalous site

	Legal crossing	Cross against flashing red man	Cross against steady red man	Cross away from signals, within 20m
All sites (N=62224)	0.790	0.073	0.055	0.082
Without Albert/ Elizabeth (N=50362)	0.799	0.079	0.037	0.084

Table 2: Proportion of legal and illegal crossing behaviours by site

	Legal crossing	Cross against flashing red man	Cross against steady red man	Cross away from signals, within 20m
Edward & Adelaide (N=13997)	0.780	0.143	0.030	0.047
Edward & Ann (N=9431)	0.798	0.052	0.035	0.115
Albert & Elizabeth (N=11862)	0.750	0.045	0.128	0.076
Wharf & Adelaide (N=4905)	0.849	0.041	0.043	0.067
Creek & Queen (N=11784)	0.772	0.053	0.050	0.124
Edward & Elizabeth (N=10245)	0.835	0.066	0.031	0.067

Table 3: Estimated annual crashes, crossings, risks and relative risks of illegal crossing behaviours, weekdays 8am-6pm, six Brisbane CBD intersections

	Legal crossing	Cross against red man	Cross away from signals, within 20m
Estimated annual crashes	7.00	3.91	5.82
Estimated annual crossings	9.57×10^{6}	0.66×10^{6}	1.02×10^{6}
R (crashes per crossing)	0.73×10^{-6}	5.92×10^{-6}	5.71×10^{-6}
RR (compared to legal crossing)	1.0	8.1	7.8
95% Confidence Interval		5.5-11.7	5.6-10.9