Relative risk of illegal pedestrian behaviours

King, M. J.[1], Soole D.[1], Ghafourian, A.[1]
[1]Centre for Accident Research and Road Safety - Queensland (CARRS-Q), Qld University of Technology
email: m2.king@qut.edu.au

Abstract

High numbers of pedestrians are killed and injured each year in urban areas, with about half being considered responsible for the crash. Observations of pedestrian behaviour show widespread non-compliance with legal requirements, which are difficult to enforce in any case. However, there is no information available on the level of crash risk associated with illegal pedestrian behaviours, and hence on the rationale for enforcement and the priorities for public education. An observation survey of pedestrian behaviour was conducted at signalised intersections in the Brisbane CBD, using behavioural categories selected on the basis that the involvement of these behaviours in pedestrian crashes was identifiable in police crash reports. The survey confirmed high levels of crossing against the lights or close to the lights. The observation data were weighted to provide a measure of the exposure of pedestrians crossing legally, against the lights, and close to the lights. Eleven years of crash data were analysed to determine numbers of pedestrian crashes which fell into these categories, and relative risk ratios were calculated. 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 implications of these results for enforcement and education are discussed. The limitations of the study are discussed in terms of the constraints of police report data and the logistical challenges of conducting observation at locations other than signalised intersections and other than in the CBD.

Keywords

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

Introduction

In the past two decades there has been an ongoing emphasis on the importance of encouraging walking for reasons which include health benefits and the reduction in motorised vehicle travel with its associated impacts on greenhouse gas emissions and congestion. At the same time, walking exposes pedestrians to the risk of a collision with a vehicle. Pedestrian crashes account for around 15% of fatalities each year in Queensland and about 8% of hospitalised casualties [1].

Although walking and driving are both major forms of road use, there are distinct differences between them which present challenges when developing countermeasures. First, driving on a road is an activity which is subject to a number of controls:

- drivers must be licensed, which entails being old enough, undertaking a period of learning, and passing a test;
- drivers must meet certain impairment criteria to be allowed to drive, such as particular alcohol limits, medical restrictions applied because of prescription drug use, and (for heavy vehicle drivers) hours/days of work criteria which are taken as a proxy for fatigue;
- while on the road, drivers must obey an extensive range of rules.

In contrast, pedestrians are allowed to use the road without restrictions on age, skill or impairment, and according to a limited number of rules.

Second, most driving rules are both easy to enforce and are subject to a degree of enforcement which is appropriate to the incidence and risk associated with their transgression. Speeding is common and is widely enforced; drink driving is less common than speeding, but there is a much higher risk of a crash per drink driving incident, so that considerable resources are devoted to drink driving enforcement. Many

2008 Australasian Road Safety Research, Policing and Education Conference
November 2008, Adelaide, South Australia
This paper has been peer-reviewed

768

other rules (not coming to a complete stop at a stop sign, changing lanes without indicating) are frequently broken and easy to enforce, but are not widely enforced because of their relatively lower average risk.

Although rules for pedestrians are few, their enforcement is difficult and rarely undertaken. Crossing at signalised pedestrian crossings is the area of greatest legal clarity for pedestrians, as there are clear permissions and restrictions associated with the green, flashing red and steady red phases. In Queensland, however, the fine for breaching these rules is quite low, and police express a degree of helplessness about the process of enforcing the rules. Whereas vehicles have registration plates and drivers have licences, pedestrians can only be identified by asking for their details and demanding proof of identity, which they may not have on their person. There is a degree to which making such a demand is perceived to be an unjustified intrusion into the rights of normal citizens to move around unhindered, because transgression of the pedestrian rules is seen to be minor and normal. To detain a person who has no proof of identity simply because they walked across a road illegally seems unnecessarily authoritarian. Many potential offenders would be juveniles as well, which presents other problems for police. Such offences would rarely be taken to court, because they would almost certainly lead to no action, and the resources involved in pursuing the case would be wasted.

Third, driving for most people is a "bounded" activity. Most drivers only leave a legally defined road to enter a driveway. Roads are well-defined, even gravel roads in rural areas, and vehicles stay on them. In contrast, pedestrian activity is less bounded because of its nature as an intrinsic part of human behaviour. Being a pedestrian is a "natural" activity. Children learn to walk at around twelve months of age, after which walking becomes an everyday experience, like eating and talking. Roads are well-defined areas that must be crossed, and have their particular hazards, i.e. vehicles, which necessitate formal rules. However, most pedestrian activity does not involve roads, and is subject only to informal rules. Crossing a road is a special instance in which these informal rules, the special hazards of a road, and the formal rules for crossing come together

Observations of pedestrian behaviour show widespread non-compliance with legal requirements. Several studies conducted between 1940 and 1982 found that about 25% of pedestrians crossed illegally at intersections [2]. A more recent study of pedestrian crashes at crossing facilities in New South Wales and Victoria [3] 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). 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 [4].

The imperative to promote walking as a transport alternative with health and environmental benefits has involved a "benign" approach to pedestrians, seeking to provide both broader and specific environments which foster safer walking [5, 6]. 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. However, there is a limit to the flexibility with which pedestrian crossings can be located. Engineering measures also tend to be resisted, with measures such as overpasses and underpasses [7] and pedestrian barriers [8] having little effect on illegal crossing behaviour.

Ultimately there is an implicit assumption that the safety of these pedestrian facilities relies on the compliance of drivers and pedestrians with the crossing rules. Education of pedestrians is one strategy used to foster compliance with safety-based rules, but 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 [7, 9-11].

Enforcement of the rules is another means of influencing compliance, but pedestrian rules are difficult to enforce: which corner(s) police are stationed at the intersection will limit which offenders can be intercepted. Police can only issue offence notices through the use of police powers (demanding supply of name and address) which are typically associated with more serious misdemeanours when used outside the driving context. Police occasionally conduct high profile enforcement exercises, but they are generally unpopular with pedestrians [12].

Taken together, these issues lead to a policy dilemma. Engineering solutions are important but can only go so far, education has limited effectiveness, and enforcement is resented. Turning this around, the widespread flouting of these rules by pedestrians raises the possibility that there is a mismatch between the rules and safety needs, i.e. the rules imposed on pedestrians may unnecessarily restrict their mobility for the sake of safety benefits which are only modest or intermittent. In this case, information about the risks involved in illegal crossing behaviour would provide a firm and justifiable basis for enforcement efforts which could be supported by education campaigns. However, there is only limited information available on the level of crash risk associated with illegal pedestrian behaviours.

The purpose of the research reported in this paper was to conduct a pilot study on the relative risk of illegal crossing behaviours, both to obtain indicative information and to test the methodology. Because only limited funds were available, there were several constraints on the research. In particular, it was decided to restrict the focus of the research to crossing at signalised intersections, where the rules for crossing legally are reasonably clear: a pedestrian must not start crossing once the red man begins to flash or is steady. Pedestrians must also use the pedestrian crossing if they are within 20 metres of it, and cross between the marked lines.

It was also decided to confine the research to metropolitan areas, which in effect restricted the study to the Brisbane central business district (CBD). Approximately half of all pedestrian crashes in Queensland occur in metropolitan areas (with almost half in turn occurring at intersections), with a further third occurring in other urban areas [13]. Looking at crashes by day of week and hour of day, a disproportionate share of crashes occurs on weekdays and in daylight (8am-6pm) [13]. 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, accounting for just over half of all pedestrian crashes in Brisbane City.

Methods

The methodology involved several steps:
- determination of which illegal pedestrian behaviours could be identified from crash data;
- determination of which illegal pedestrian behaviours were observable;
- selection of sites for observations of illegal crossing behaviours;
- development of the observation methodology;
- comparison of observation data between sites;
- review of crashes to determine numbers of crashes resulting from illegal crossing; and
- calculation of the relative risks of illegal crossing behaviours.

Constraints

The methodology involved a compromise between several considerations. The study had limited resources, which would best be used by conducting observations in a compact area over a limited time period, at sites where sufficient pedestrian crashes had occurred to enable the calculation of crash rates. The Brisbane CBD was chosen, because it has both the greatest concentration of pedestrian crashes, and the highest number of pedestrian movements. There were also logistical and safety constraints on the times of observation which meant that observations were restricted to weekdays between 8am and 6pm. These constraints were incorporated into the site selection process. Some of the issues are explained in more detail below.

Illegal pedestrian behaviours identifiable in crash data

Analysis of pedestrian crashes at signalised intersections in the Brisbane CBD in the period 2000-2004 was undertaken using WebCrash 2 [14] to determine which legal, illegal or unsafe pedestrian behaviours could be identified in crash data. This revealed that it was possible to identify legal crossing, crossing against the red man, "pedestrian at fault" and drink walking. For each category there were about 10% of cases where no determination could be made. The "pedestrian at fault" category was not useful, and there was no identification of cases where the pedestrians crossed within 20 metres of the crossing. Subsequent inspection of crash data for midblocks showed that this category could be found there, so that both

intersection and midblock data would need to be collected. More importantly, the data showed that there were sufficient numbers of these crashes in the Brisbane CBD to supply a reasonable numerator for the risk calculations.

One constraint which emerged from this preliminary analysis was that it was not possible to distinguish reliably between pedestrian movements against a steady versus a flashing red man, a point which had already been noted in the literature [3]. It is possible to observe these movements separately, and this was done, but this information could not be used separately to calculate relative risks. The crash data were therefore 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

Illegal pedestrian behaviours identifiable through observation

Preliminary fieldwork showed that, unlike the crash data, observations could readily distinguish entry on the flashing red man from entry on the steady red man. It was decided to count these categories separately, even though they would need to be aggregated for the relative risk calculations, because they would be of interest from both engineering and behavioural perspectives. Crossing within 20 metres of the crossing was also easy to observe, given adequate resourcing (although the decision as to when a crossing movement was not near enough to the crossing to be "legal enough" had to be addressed in the methodology). On the other hand, it was clear that drink walking could not be reliably observed and therefore had to be excluded from consideration. The observations were thus 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

Data were also collected on other behaviours including the frequency of pedestrians impeding vehicles from completing their intended action, and vice versa. In practice, there was little data obtained on these behaviours and hence this information is not reported.

Site selection

Since the sites were in the Brisbane CBD, there was no concern about obtaining sufficient observations of pedestrian behaviour. There were two temporal restrictions related to resourcing and safety issues: it was decided to restrict observations to daylight hours during the week, i.e. Monday-Friday 8am-6pm. Initial selection of candidate sites therefore involved a ranking of Brisbane CBD signalised intersections by pedestrian crashes. The list was then refined by excluding sites which were considered to be too different (primarily for reasons of layout or signal phasing, both of which were checked *in situ*) or at which significant roadworks were taking place (which was the case along Albert Street from the Queen Street intersection northwest to Turbot and Roma Streets, and at the intersection of George and Adelaide Streets). Available resources limited the observations to the following six intersections:

> Edward and Adelaide Streets
> Edward and Ann Streets
> Albert and Elizabeth Streets
> Wharf and Adelaide Streets
> Creek and Queen Streets
> Edward and Elizabeth Streets

Observation methodology

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). Thus, each intersection was observed for a total of two and a half hours.

Data was collected on the frequency of pedestrians crossing on the green man, the flashing red man, and the steady red man, as well as the number of pedestrians crossing illegally near the lights. These were mutually exclusive and exhaustive categories meaning that the total number of pedestrians crossing could be calculated by adding the frequencies from these categories together.

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). However, 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.

Diagrams were prepared for each intersection indicating lanes, directions of travel, features such as bus stops and taxi ranks, and crossings. 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. An example is given below (Figure 1). Code books were developed and refined through observation, and observers were recruited and trained to ensure consistency in classification of pedestrian movements.
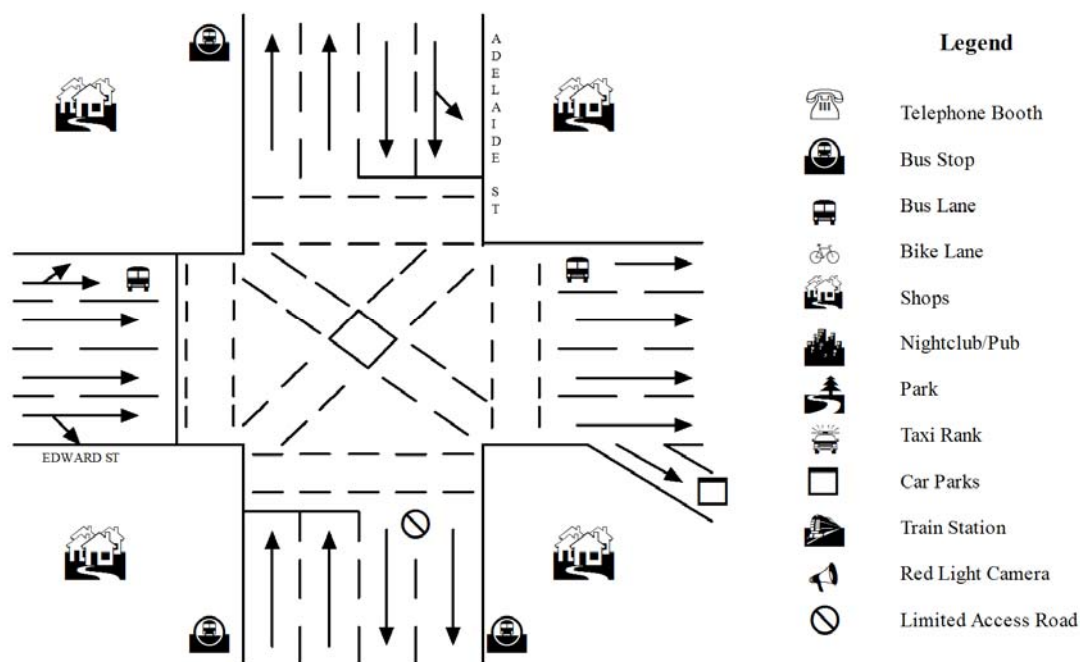

Figure 1: Example diagram of one of the intersections (Edward/Adelaide)

Data storage, descriptive analyses and comparisons

Data were entered into Excel spreadsheets and imported into SPSS for analysis. In addition to overall descriptive statistics, the observation data were analysed to assess the effect of intersection and time of day on a crossing behaviour. Occurrences of these behaviours were first coded as frequencies, and were mutually exclusive, exhaustive categories. That is, adding the number of pedestrians engaging in each of the behaviours equated to the total number of pedestrians who crossed at the intersection during the observation period. The frequency of pedestrians engaging in each of the behaviours was then divided by

the total number of pedestrians to find the proportion engaging in each of the behaviours. To analyse the effect of intersection and time of day on observed crossing behaviours a series of univariate ANOVAs were conducted. Tukey's HSD post hoc comparisons were used to further investigate significant effects.

Crashes resulting from illegal crossing

Crash data were obtained from the WebCrash online database [14] 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 at the signals, entering on the flashing or steady red man, or crossing within 20 metres of the crossing, but not at the crossing. Only crashes meeting these criteria were included.

Calculation of relative risks of illegal crossing behaviours

As noted above, while three categories of illegal behaviour were observed (began crossing while the red man was flashing, began crossing while the red man was steady, or crossing away from the signals but within 20 metres), inspection of the crash data showed that it was not possible to distinguish between the two "red man" categories, which were therefore combined. The relative risk measure for each of the two resulting illegal crossing categories involved comparing the risk of a crash given that one of the two illegal behaviours had taken place with the risk of a crash when crossing legally. Mathematically this was expressed as follows:

Risk of crash per crossing event (R):

R(Red man)   =   Risk of crash when crossing against a flashing or steady red man

$$\text{R(Red man)} = \frac{\text{Number of "red man" crashes per unit time}}{\text{Number of "red man" crossings per unit time}} \qquad (1)$$

R(X near)   =   Risk of crash when crossing away from signals, within 20m

$$\text{R(X near)} = \frac{\text{Number of "cross near" crashes per unit time}}{\text{Number of "cross near" crossings per unit time}} \qquad (2)$$

R(X legal)   =   Risk of crash when crossing legally at signals

$$\text{R(X legal)} = \frac{\text{Number of "cross legally" crashes per unit time}}{\text{Number of "cross legally" crossings per unit time}} \qquad (3)$$

Relative risk of crash (RR):

RR(Red man)   =   Risk of crash when crossing against a flashing or steady red man, relative to the risk of a crash when crossing legally

$$\text{RR(Red man)} = \frac{\text{R(Red man)}}{\text{R(X legal)}} \qquad (4)$$

RR(X near)   =   Risk of crash when crossing away from signals, within 20m, relative to the risk of a crash when crossing legally

$$\text{RR(X near)} = \frac{\text{R(X near)}}{\text{R(X legal)}} \qquad (5)$$

The calculation of these figures required annualisation of both sets of data, which was straightforward for the crash data, but required several steps for the observation data. The 8am-6pm time period was common to both sets of data. The observation data slightly under-sampled the afternoon time slots, and the data were corrected accordingly. In each two hour sampling slot there was a 15 minute break, so the data were adjusted to take account of this. Observations occurred on only two weekdays, so the data were multiplied again to give an estimate of pedestrian behaviour numbers for all weekdays 8am-6pm, and then again to provide an annual figure. The crash data were divided by 11 to give an annual figure.

Results

Incidence of illegal crossing

Results of the observations (Table 1) showed that 79.0% of all pedestrians waited for the green man to become illuminated before crossing; 7.3% began to cross while the red man was flashing and 5.5% while the red man was steady, for a total of 12.8% crossing on the flashing or steady red man. Crossing within 20 metres of the lights was recorded among 8.2% of pedestrians.

Table 1: Proportion of legal and illegal crossing behaviours, overall and minus 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

During observations, the Albert and Elizabeth Streets intersection was identified as problematic given the presence of a limited access road. This limited access road had very little traffic and consequently rates of crossing on the steady red man were noticeably higher at this point of the intersection. Thus, analyses were conducted both including and excluding the Albert and Elizabeth Streets intersection. Removing the Albert and Elizabeth Streets intersection from the analysis changed the findings only slightly. The majority of pedestrians were still found to cross on the green man (79.9%), 7.9% began to cross while the red man was flashing and 3.7% while the red man was steady, for a total of 11.6% crossing on the flashing or steady red man. Crossing within 20 metres of the lights was recorded among just 8.4% of pedestrians.

Comparisons between sites

None of the comparisons revealed a significant effect for time of day, irrespective of the exclusion of the data for the Albert and Elizabeth Streets intersection; however, there were differences between sites on the proportions of behaviours observed (Table 2).

Crossing legally: A significant effect was observed for intersection on the proportion of pedestrians crossing on the green man (F=2.659, df=5, p=0.48). However, post hoc comparisons revealed no significant differences between any of the intersections on this behavioural outcome. The difference between the Wharf and Adelaide Streets intersection and the Albert and Elizabeth Streets intersection approached significance (p=.055), with Wharf and Adelaide Streets having a greater proportion of pedestrians crossing on the green. Upon removal of the Albert and Elizabeth Streets intersection, the ANOVA was no longer significant (F=1.876, df=4, p=0.15).

Crossing on the flashing red man: A highly significant effect was observed for intersection on the proportion of pedestrians crossing on the flashing red man (F=36.027, df=5, p<.001). Investigation of the post hoc comparisons revealed that the Edward and Adelaide Streets intersection differed significantly from all other intersections (p<.001 in all cases), with significantly more pedestrians crossing on the flashing red man at this intersection than the others. No other intersections differed significantly on this outcome. These findings remained essentially the same upon removal of the Albert and Elizabeth Streets intersection from the analysis.

Crossing on the steady red man: A highly significant effect was also observed for intersection on the proportion of pedestrians crossing on the steady red man (F=14.088, df=5, p<.001). Post hoc comparisons revealed that the Albert and Elizabeth Streets intersection differed significantly from all other intersections (p<.001 in all cases, except the Creek and Queen Streets intersection, p<.01), with significantly more pedestrians crossing on the flashing red man at this intersection than the others. No other intersections differed significantly on this outcome. Not surprisingly, the removal of the Albert and Elizabeth Streets intersection resulted in the effect of intersection becoming non-significant (F=1.448, df=4, p=0.26).

Crossing within 20 metres of the intersection: There was no significant effect of intersection observed on the proportion of pedestrians crossing within 20 metres of the intersection, irrespective of the inclusion or exclusion of the Albert and Elizabeth Streets intersection (F=1.161, df=5, p=0.357 and F=1.710, df=4, p=0.19, respectively).

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

	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
Overall site effect	F=2.659, df=5, p=0.48	F=36.027, df=5, p<.001	F=14.088, df=5, p<.001	Not significant
Individual site effects (post hoc)	None significant	Edward/Adelaide differed from all	Albert/Elizabeth differed from all	-

Summary: Overall, there were few significant differences observed. The proportion of pedestrians crossing on the flashing red man was significantly greater at the Edward and Adelaide Streets intersection then all other intersections. This is a scramble crossing with very high pedestrian demand, and the long diagonal distance means that some pedestrians making one of the shorter crossings can enter on flashing red and complete crossing before some pedestrians who embarked legally on the diagonal crossings. Further, significantly more pedestrians crossed on the steady red man at the Albert and Elizabeth Streets intersection than all other intersections. As mentioned, this is probably a result of the presence of a limited access road on the intersection with low traffic volume. Overall, there were comparable rates of crossing legally and crossing within 20 metres of the intersection at each intersection observed. There were no observed effects of time of day on pedestrian behaviour.

Incidence of illegal crossing in crashes

Analysis of the data on crashes at the study intersections and on the roads approaching them, 8am-6pm on weekdays in the 11 year period 1996-2006, found 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.

Calculation of relative risk

The data were annualised as outlined in the methodology. 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. Table 3 gives the estimated data and the risk and relative risk figures.

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

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.

Discussion

The level of illegal crossing at the intersections studied was around 20% (aggregating all illegal crossing types), which is less than the 25% reported in a review of studies elsewhere [2], though it is not greatly different. The fact that the observations reported here were conducted at high volume pedestrian sites during high volume times of day may have something to do with this.

The involvement of illegal pedestrian crossings in crashes was over 58%, much higher than the 32-44% previously reported in New South Wales and Victoria [3]. However, this disparity was probably due to the inclusion of data on midblock crashes in order to identify crashes that occurred within 20 metres of the crossing. If these crashes are excluded (leaving only legal and "red man" crossings), the figure becomes 36%. This is consistent with the other figures, but also points to the need to take account of crashes which involve illegal crossing relative to a signalised intersection, but which may not be recorded as occurring at the intersection itself.

The fact that the levels of illegal crossing found in this study are so high implies that pedestrians believe that illegal crossing has a low degree of risk. In contrast, the data in this study indicate that the risks are actually quite high, for both "red man" violations and for crossings within 20 metres of the signals. The possibility was raised in the introduction that the widespread flouting of rules by pedestrians might be attributable to a mismatch between the rules and safety, i.e. that the behaviours proscribed by the rules are not associated with a high degree of risk. The results of this study suggest otherwise, with both entering on the flashing or steady red man, and crossing within 20 metres, having a level of risk eight times that of legal crossing.

It was noted that education directed at pedestrians has not been successful, and it is widely understood in road safety that education is most effective when it signals or supports a change in the environment, i.e. the contingencies of behaviour, such as an enforcement campaign. The high level of risk shown in this study – if confirmed in larger and methodologically superior studies – would present an opportunity for a three-pronged approach: (i) an increase in penalties for illegal crossing consistent with the high level of risk involved; (ii) publicity about the risks of illegal crossing as a justification for changes in penalties and

an increase in enforcement; and (iii) increased enforcement using a balanced approach (given the high volume of offences) such that penalties would only be applied to severe offenders in the first instance, and warnings given to other offenders where possible.

At this stage such recommendations need to be tempered due to the limitations of the study, which was intended to be a pilot in any case. The sites selected were CBD sites with high volumes of pedestrians and vehicles, and different results might be obtained at other sites. While there was a high degree of consistency between the sites in the incidence of illegal behaviours (with the exception of Albert and Elizabeth Streets), the sites were close together and probably shared very similar pedestrian profiles in terms of demographics, trip purpose, etc. It would not be surprising if a more diverse sample of sites gave widely varying results, and this is suggested by the high number of illegal entries on the flashing red man at Edward and Adelaide Streets (possibly due to both high pedestrian demand and its being a scramble crossing) and on the steady red man at Albert and Elizabeth Streets (attributable to a limited access road with very low traffic volume). It is also likely that the patterns of illegal crossing would be different on weekends and at night. The study was confined to signalised intersections, whereas there are high numbers of crossings and crashes at pedestrian operated signals, unsignalised crossings at both intersections, and midblocks, midblocks with medians or refuges, and midblocks with no crossing facilities. The rules are different where there are no signals, and much more reliance is placed on the judgement of the pedestrian. Obtaining exposure information for such sites would be a much larger logistical exercise, and the greater geographical dispersion of crashes would make it difficult to calculate risks in the same way as in this study.

Other limitations are not attributable to the resource constraints experienced in this study, but to limitations with observation and with the crash data. Although it is not illegal, drink walking is a behaviour for which risk levels appear to be high, so that estimates of exposure would be valuable. However, apart from breath testing every pedestrian (or a random sample), it is not possible to observe. The exclusion of drink walking presents a potential confound because it would be expected to be associated with both illegal crossing and with crashes. 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. The distinction between types of red man violation is important: entering on the flashing red man, entering on the steady red man following the flashing red man, and entering on the steady red man before the green man are different in terms of the nature of the risks involved. These are easy to observe, but cannot be distinguished in the crash data. The distinctions between "red man" and "close but not at the crossing" crashes and offences are not clear cut for both observation and crash data. The operational definition of a crossing "at the crossing" used in this study was a crossing which occurred within two metres of the marked lines indicating the crossing boundaries. Technically this is not part of the crossing, and while an argument can be mounted as to interpreting the marked boundary loosely, it is hard to justify the two metre tolerance used here rather than (say) one metre. Many pedestrians also take a curved path, starting and sometimes finishing their crossing a few metres from the markings, and curving into the marked area (or close to it, but outside) by about the middle of the crossing. While the observation study developed guidelines for classifying these movements, they would not be apparent in the crash data, and in many cases reliable information would not have been available. Similarly, it is not known how close to the intersection a crash would have occurred for police to have coded it at the intersection rather than away from it.

Finally, this study did not take account of factors such as intersection design, traffic concentrations, crossing distances and vehicle speeds, which are considered to contribute to pedestrian crash risk [15]. Instead, a relatively simple measure of exposure (number of crossings) was used.

Nevertheless, this study was successful in piloting a methodology which could be improved and applied more widely. It also provides limited evidence that illegal crossing behaviours may be associated with a significant level of risk which, if confirmed, would justify a combined approach to the improvement of pedestrian behaviour involving publicity, a change in penalties, and a balanced approach to enforcement utilising warnings as well as ticketing. In terms of the promotion of walking for health and environmental reasons, the findings indicate that the provision of better pedestrian facilities will need to be supplemented by measures which emphasise that, although walking is a positive and largely informal activity, crossing a road is an activity which is formally regulated because of the risks involved.

References

1. Queensland Transport, 'Road Traffic Crashes in Queensland – A Report on the Road Toll 2003', Brisbane, Queensland Transport, 2005.

2. B Mullen, C Cooper, J E Driskell, 'Jaywalking as a function of model behaviour', Personality and Social Psychology Bulletin, 1990 16 320-330.

3. Austroads, 'Pedestrian and Cyclist Safety – Pedestrian Crashes at Pedestrian Facilities', Report No. AP-R156, Sydney, Austroads, 2000.

4. S A Ashur, K J Kroeker, M H Baaj, 'A study of factors contributing to pedestrian crashes in El Paso County, Texas'. Proceedings of the TRB 2003 Annual Meeting, CD-ROM, Washington, Transportation Research Board, 2003.

5. Austroads, 'Traffic Flow Models Allowing for Pedestrians and Cyclists', Report No. AP-R193, Sydney, Austroads, 2001.

6. Austroads, 'Potential Improvements for Non-Motorised and Vulnerable (Unprotected) Users in the Road System', Report No.AP-R195, Sydney, Austroads, 2001.

7. P Holló, I Papp, T Siska, 'Observation of elderly pedestrians on signalized crossings and of jaywalkers in the vicinity of pedestrian subways', Proceedings of the 8th Workshop, International Cooperation on Theories and Concepts in Traffic Safety, Paris, 1995

8. P Kopelias, P Papaioannou, J Vasiliadou, 'Effectiveness of a pedestrian measure in an arterial street in Thessaloniki, Greece: First results', Proceedings of the 13th Workshop, International Cooperation on Theories and Concepts in Traffic Safety, Corfu, 2002

9. P Gårder, 'Pedestrian safety at traffic signals: A study carried out with the help of a traffic conflicts technique', Accident Analysis & Prevention 1989 21 435-444.

10. M M Hamed, 'Analysis of pedestrians' behavior at pedestrian crossings' Safety Science, 2001 38 63-82.

11. V P Sisiopiku, V Akin, 'Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data', Transportation Research Part F, 2003 6 249-274.

12. C Schonfeld, A Musumeci, 'Pedestrian Travel: Getting Queenslanders Walking Safely', *Brisbane*, Centre for Accident Research and Road Safety – Queensland, 2003.

13. Austroads, 'Pedestrian and Cyclist Safety - Comparison of Pedestrian and Bicycle Accidents in New South Wales, Victoria and Queensland', Report No. AP-R158, Sydney, Austroads, 2000.

14. Queensland Transport, 'WebCrash2', Brisbane, Queensland Transport, 2004.

15. S Lassarre, E Papadimitriou, G Yannis, J Golias, 'Measuring accident risk exposure for pedestrians in different micro-environments', Accident Analysis & Prevention 2007 39(6) 1226-1238.