Evaluation of an Alternative Pedestrian Treatment at a Roundabout

Nimmi Candappa[1], Nicola Fotheringham[1], Michael Lenné[1], Bruce Corben[1], Charlotta Johansson[2], & Paul Smith[3].

1.Monash University Accident Research Centre (MUARC), Victoria.

2. Luleå University of Technology, (LTU), Sweden.

3. City of Port Phillip, Victoria.

ABSTRACT

Roundabouts are renowned to be one of the safest treatments at intersections. However, a common criticism of roundabouts is that they do not cater well for pedestrians. The City of Port Phillip in Melbourne, Victoria, constructed an innovative treatment at a busy suburban roundabout designed to provide greater safety and convenience for pedestrians. The design provides right-of-way for pedestrians directly at the intersection as opposed to standard roundabout design. A before-and-after study was undertaken to evaluate the success of this design in terms of pedestrian safety and convenience. Vehicle speed was measured at locations indicative of pedestrian crash and injury risk, and pedestrian convenience was measured through changes in total crossing time. Pedestrian compliance was also measured as an indicator of both safety and convenience. Video footage of the site was captured to further establish treatment effects. Finally, surveys were conducted to assess change in pedestrian perceptions of the roundabout. The results indicated a general decrease in mean vehicle speed, greater pedestrian compliance with the crossings, and reduced waiting time for pedestrians, suggesting greater convenience and safety with the new treatment. The surveys of pedestrians reflected these findings, responses being generally positive towards the treatment. Effects on all roadusers need to be determined for future work.

INTRODUCTION

Research has shown that roundabouts are significantly safer than the standard cross-intersection treatment of signals: approach speeds are lower in the event of a crash, speed and angle at impact are generally lower, points of conflict are fewer, and visually, the treatment acts as a traffic calming device. As much as 80% fewer cross traffic crashes occur at roundabouts when compared to cross intersections.

However, accommodating pedestrians at roundabouts has historically created some difficulty. Vehicles usually have right-of-way over pedestrians at roundabouts. A typical pedestrian treatment at a roundabout includes locating a pedestrian refuge a car's length behind the roundabout entry point of each leg, with the onus being with the pedestrian to select an appropriate gap in which to cross. The disadvantages of this are it requires the pedestrian to divert from a preferred route, potentially reducing compliance likelihood; the pedestrian is not directly within the intersection where driver vigilance could be at its highest; gap selection by pedestrians can lead to errors, and it requires the pedestrian to cross between two vehicles, which may impede the visibility of the pedestrian. Blind pedestrians can be particularly disadvantaged at roundabouts. As roundabouts often are located in lower speed environments – where there is greater chance of pedestrian activity - not appropriately allowing for pedestrian movements at roundabouts can create significant safety issues for the pedestrian. One study undertaken in Western Australia found that of the pedestrians interviewed, 54% found the rules associated with roundabouts confusing and 72% found it harder to cross at a roundabout than at a conventional crossing (Browning, 2001), further exacerbating pedestrian safety issues at roundabouts.

As an alternative to this standard treatment, and in an attempt to address a number of pedestrian crashes at the site, the City of Port Phillip in Melbourne, Victoria, re-designed the roundabout at Cecil St/ Coventry St. At this site, in the five years to the end of June 2004, all five casualty crashes that have occurred, have involved a pedestrian, the highest proportion of pedestrian crashes when compared to surrounding intersections. Moreover, in the twelve years prior to this, the intersection has had a total of only four pedestrian crashes. The intersection has a vibrant market on its northwest corner, as well as a hotel and a café, all generating a lot of pedestrian movement. The aim of this treatment therefore was to improve pedestrian safety and convenience at the roundabout, while contributing to one of the Council's Sustainable Transport Framework goals, namely, increasing the level of walking within the local community through increased perceived and actual safety.

Prior to treatment, the roundabout consisted of a large circular central island, pedestrian refuges, pram crossings and standard roundabout signs at roundabout entry points. Linemarking within the intersection consisted of two white stripes within each pedestrian refuge and standard broken lines at the vehicle entry of each leg to the roundabout, as well as bicycle lanes through the roundabout, (Figure 1). In this case the pedestrian refuges are not specifically set back the standard 6 m.

Post-treatment, (Figures 2 and 3) the roundabout consists of zebra crossings (flush with the footpath), placed over gradual speed humps immediately prior to the roundabout entrance. The pedestrian crossings comprise zebra pavement markings - broad white stripes, perpendicular to vehicle travel - and roadside signing. Although approach islands still exist at each leg, the islands do not visually break the continuance of the crossing. Further, crossing signs that are externally-illuminated at night face drivers on each leg, and more pronounced linemarking has been introduced. The bicycle lanes through the roundabout have been removed. No modifications have been made to the central island.

Figure 1 – pre-treatment

Source: City of Port Phillip Council

Figure 2 – post-treatment

Source: City of Port Phillip Council

Figure 1 – pre-treatment

Source: City of Port Phillip Council

Figure 2 – post-treatment

Source: City of Port Phillip Council

Monash University Accident Research Centre (MUARC) was commissioned to design and conduct an evaluation of the treatment to establish its effectiveness in catering better for the needs of pedestrians at roundabouts. The evaluation could then guide future design of pedestrian facilities at roundabouts.

The aim of this study therefore was to evaluate how effectively the new design improves both the safety and convenience attributes for pedestrians in comparison with the previous layout.

METHOD

A study design was completed and the appropriate methodology for the study's objectives established, based on relevant literature and the various forms of analysis that have been employed in similar studies.

The basic design philosophy adopted was a "before and after" evaluation methodology, where the effects of the treatment are evaluated by comparing data collected in the after period with those collected before the treatment was applied. The use of before and after data collection periods has been used widely in applied research studies, including studies of pedestrian treatments (Carsten, Sherborne, & Rothengatter, 1998; Van Houten, Retting, Van Houtin, Farmer, & Malenfant, 1999) and therefore the method was used for this roundabout evaluation.

Pedestrian numbers and traffic operations at the site vary depending on the opening days of the market, namely a Wednesday, Friday and the weekend. Care was therefore taken to collect data both on a market and non-market day to encapsulate both operating conditions. This was undertaken over a six-week period, beginning 28 October 2004. Installation of the pedestrian treatment of raised zebra crossings and associated works were completed by the 25 February 2005. Allowing for adequate settling-in time, as well as avoiding time periods that would result in non-standard data, such as the Grand Prix weekend and Easter, after-treatment data collection commenced on the 5 May 2005 and was completed within a four-week period.

Measures of Safety

Given the significant relationship between vehicle speed at impact and injury consequence to the pedestrian (Anderson, McLean, Farmer, Lee, & Brooks, 1997; Ashton & Mackay, 1979) vehicle speed was selected as the primary quantitative measure of pedestrian safety before and after treatment. Changes to levels of compliance with the crossings, although not explicitly measured to gauge safety, were also used to indicate changes in safety consequences. Perceived safety was established qualitatively through surveys of pedestrians at the site. Pedestrian volumes were not collected during the project. However, where pedestrian behaviour was measured, samples of pedestrians before and after treatment were approximately equal to ensure valid comparisons.

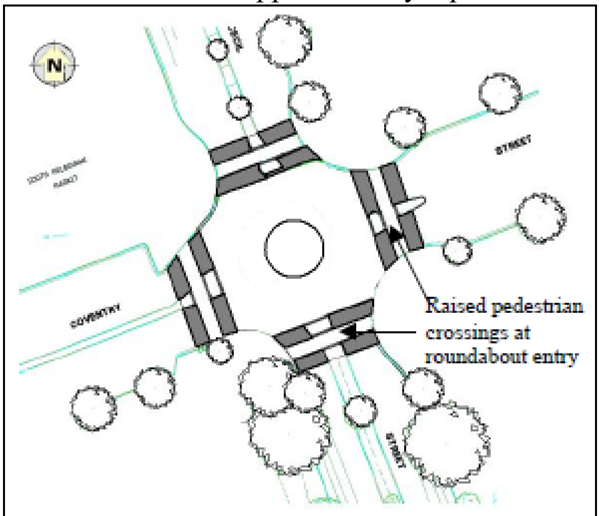

Figure 3 – modified drawing of post-treatment

Source of original: City of Port Phillip Council

The ARRB Group Ltd was contracted to undertake speed surveys at the site. A laser gun was used to measure vehicle speed through a window of a project vehicle parked approximately 90 m away from the crossing. Measurements were generally unobtrusive and made progressively where possible for the same vehicle, beginning at approximately 90 m away from the crossing to five metres away from the crossing. However, only speeds at the 30 m measurement point and five metres were analysed. The five metre point was chosen to gauge speed at impact were a pedestrian/vehicle crash to occur. The 30 m point was selected based on required stopping distance (to avoid a crash at the pedestrian crossing), and vehicle "free" speed, the speed at which a vehicle would travel unhindered (Hakkert, Gitelman, & Ben-Shabat, 2002). Speed measurements were collected as an independent measure of pedestrian safety and not with reference to pedestrian volumes at the site.

2. Compliance

Masking tape marked the footpath within a 1 m vicinity of the pedestrian crossing locations. Pedestrians who crossed within this at least 95% of the time were considered to be "clearly complying" with the crossings; pedestrians who had some intention of crossing within the area and spent between 50-95% time within crossing were considered "mostly complying", including pedestrians that began crossing at the crossing but veered off the crossing before reaching the opposite footpath; while the rest were considered "clearly non-complying".

3. Pedestrian Perceptions

Pedestrian surveys were conducted before and after the new roundabout treatment was in place. The surveys consisted of questions that were used to gauge pedestrian views on safety at the roundabout.

Measures of Convenience

Measures of convenience were also collected, consistent with the council's aim of improving both pedestrian safety and convenience. Total crossing time was used as the main parameter for measuring the level of convenience at the site. Before treatment, it was observed that pedestrians could spend significant time selecting an appropriate gap before crossing one lane of the road and then often were required to wait within the pedestrian refuge before crossing the other lane. Convenience was also gauged through surveys of the pedestrians, and inferred through level of compliance.

1. Total Crossing Times

With the use of stopwatches, total crossing times of pedestrians crossing either leg of Cecil Street were measured and recorded. To maintain consistency and reduce potential for inaccuracies, total crossing time was defined as the time from when the pedestrian approached the crossing with the clear intention to cross, to the time when the pedestrian completed the crossing by physically stepping off the road onto the footpath. Pedestrian eye and head movements were carefully observed on approach, to ensure that slowing down on approach to the crossing to allow vehicles to pass was also included as waiting time.

2. Pedestrian Perception

As part of the pedestrian surveys conducted before and after the treatment, as described above, pedestrians were also asked questions that were used to gauge pedestrian views on convenience associated with the use of the roundabout.

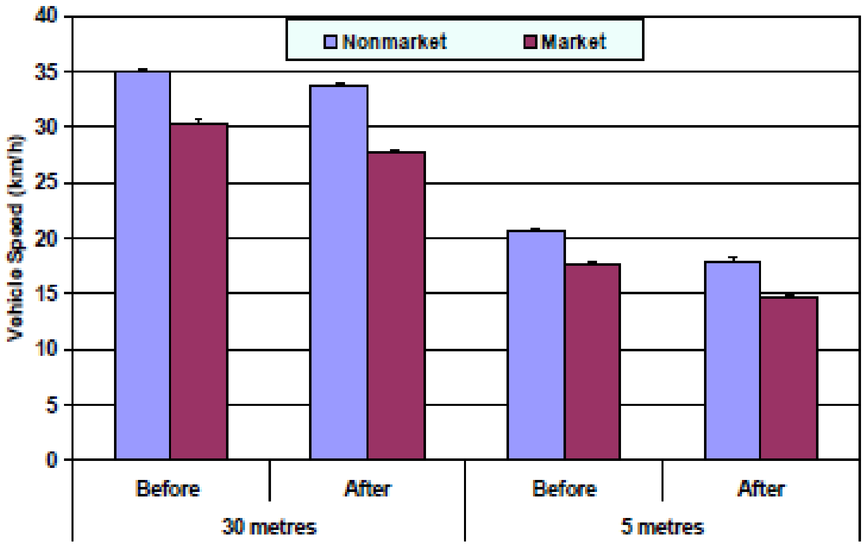

Figure 4: Mean speeds on market and non-market days before and after treatment

Video Surveillance

A video camera was mounted on a tripod and placed on a balcony of the hotel located on site. The balcony provided the optimum view of the site, and convenient access to the camera for tape changes. Video recording of two legs of the roundabout (the east and south legs) was undertaken for four hours each, before and after treatment. Video surveillance provided examples of crossing compliance, vehicle queuing within roundabout, general operation of the roundabout and motorist and pedestrian behaviour.

Data collection and analysis

Data were collected for two days before and after treatment. Measurements were collected for both market and non-market days to examine effects for both operating conditions. Data for various parameters were collected at the site before treatment was introduced, namely, two days of pedestrian surveys and speed measurements, half a day of total crossing time measurements, and half a day of video observations.

All statistical analysis was undertaken using the computer package SPSS. Vehicle speed data and pedestrian crossing times were analysed using two-way Analysis of Variance (ANOVA) with treatment period (before, after) and day (market, non-market) as factors. Measures of pedestrian perceptions were analysed using the chi-square statistic.

RESULTS

This paper details results obtained from speeds measurements, pedestrian compliance and pedestrian waiting time. Results obtained from pedestrian surveys have not been described in detail to allow adequate focus on the results obtained from the physical measurements. The client report provides complete result details. Statistical analysis of the results from video surveillance was not included in the scope of the project.

Speed

Vehicle speeds were measured 30 m and 5 m from the crossing on market and non-market days. A total of 2036 and 1936 speed measurements were recorded 30 m from the crossing (before and after, respectively) and 1370 (before) and 1258 (after) measurements 5 m from the crossing. Mean speeds 5 m from the roundabout were lower in the after period with speeds of 19.10 km/h (before) and 16.31 km/h (after) (see Figure 4). The proportion of vehicle speeds exceeding 20 km/hr and 30 km/h also decreased in the after period. Analyses confirmed that there was a significant main effect for treatment period ($F(1,2620) = 116.04$, $p<0.001$). Mean speeds were also significantly lower on market days (16.13 km/h) compared to non-market days (19.27 km/h) ($F(1,2620) = 146.26$, $p<0.001$). The interaction between the two factors was not significant.

Mean speed 30 m from the crossing was also significantly lower in the after period with mean speeds of 32.7 km/h (before) and 30.7 km/h (after) ($F(1,3964) = 60.99$, $p.<0.001$). Mean speeds were lower on market days compared to non-market days at 30 m (29.1 km/h and 34.4 km/h, respectively). Analysis confirmed there was a significant main effect for day ($F(1,3964) = 462.98$, $p<0.001$) and a significant interaction between treatment period and day ($F(1,3964) = 10.40$, $p<0.001$). Figure 4 shows a greater difference between market and non-market days in the after period compared to the before period, 30 m from the crossing.

Compliance

As shown in Figure 5, the difference between pedestrian compliance with the crossing in the before and after periods was significantly different, ($\chi 2$ (2)=719.6, $p<0.001$). Levels of clear non-compliance with the crossing also dropped from 6% in the before-period to only 2% in the after-period.

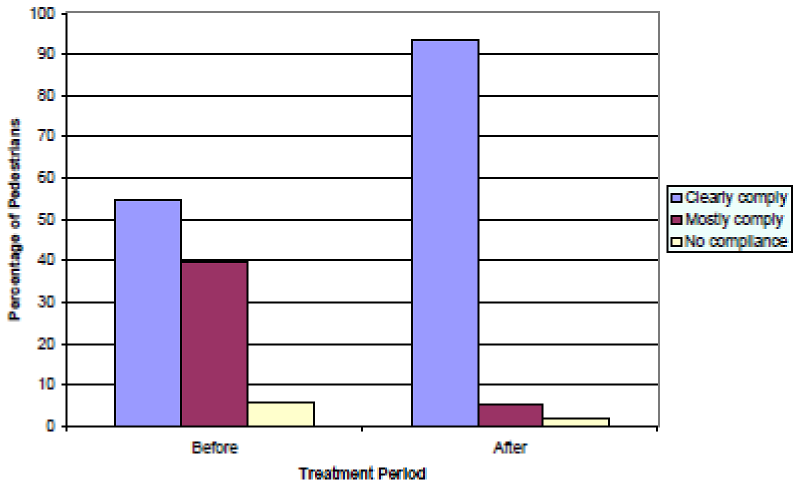

Figure 5: Percentage of pedestrians complying with crossing before and after treatment

Total crossing time

The mean crossing times for pedestrians were 16.7 seconds prior to treatment and 12.6 seconds post-treatment, resulting in a mean difference of 4.1 seconds, which was statistically significant ($F(1,767)= 93.12$, $p<0.001$).

Pedestrian Perception

Two MUARC staff members conducted surveys of pedestrians, both before and after treatment. A total of 326 people were surveyed, 169 prior to treatment and 157 post-treatment. The surveys consisted of twelve questions that were used to gauge pedestrian views on safety and convenience at the roundabout. The questions addressed issues such as the waiting times to cross the road, the vehicle speed through the roundabout, the general perception of safety at the roundabout, and the use of the existing crossings. Overall, there was a noticeable change in comments with a much greater number of positive comments made in the after-period with regard to perceived safety. A significantly larger number of respondents believed the roundabout crossing was safe (24% before compared with 64% after), travel speeds were acceptable (47%, before and 66% after), and more drivers were giving way to pedestrians in the after-period (78%) compared to before treatment (30%).

With respect to comments on convenience, 89% of respondents found the pedestrian crossings easy to use after treatment, compared with 54% before treatment. Similarly, there was a large increase in the proportion of pedestrians believing the waiting time was convenient after treatment, increasing from 15% to 76%.

However, some respondents felt that drivers and pedestrians were confused as to who had right of way in the unconventional treatment. Some respondents even felt that the crossing was 'worse than before [as] drivers are not sure what they have to do'. The use of the more conventional flashing lights used at zebra crossings was suggested to decrease confusion about the treatment, with some commenting that drivers believed pedestrians had right-of-way only when the crosswalk signs were illuminated (at night). Another issue of concern was that the treatment had caused some traffic congestion at the roundabout and increased the likelihood of rear-end vehicle crashes.

Video Observation

Four hours each of video footage before and after treatment was viewed to observe motorist and pedestrian behaviour and general site operation. It should be noted that the comments made in this section are based only on general observations and not detailed analysis, so should not to be considered conclusive. Further investigation would be required to produce conclusive outcomes.

Before treatment, vehicles would be driven to the entry point of the roundabout, drivers would look for traffic within the roundabout, generally to the right, and, when a suitable gap was available, proceed through the roundabout. As a general observation, pedestrians were infrequently given right-of-way at the roundabout entry crossing and rarely given right-of-way at the crossing at the roundabout exit point. It was noted that one couple on foot had to wait for ten vehicles to pass before receiving an opportunity to cross. Following the introduction of the treatment, if a pedestrian was not on the crossing, the driver would drive on to the crossing, look for approaching traffic while on the crossing, drive around the central island, then look for pedestrians on the exit crossing. Similarly, it appeared that vehicles turning left at the roundabout would enter the roundabout, and then look for pedestrians on the roundabout exit pedestrian crossing. Then, if a pedestrian was on the crossing, the driver would pause within the roundabout to give way, thereby impeding other traffic passing through the roundabout. As a consequence, stationary queues of two to three vehicles often were observed within the roundabout

Video observation of the site showed pedestrians walking on to the crosswalks with more confidence after treatment compared with some pre-treatment behaviour, where pedestrians waved through drivers to ensure a vehicle-free opportunity to cross. There were some occasions where heavy braking was involved both in the before and after periods.

In terms of convenience, video observation showed that pedestrians were generally given right-of-way in the after-period, reducing total crossing time although there was some incidence of pedestrians having to walk behind vehicles which were stationary on the crosswalks. The after-treatment period appeared more convenient for people in wheelchairs as well as for those pushing prams or shopping trolleys. There was a noted higher incidence of congestion within the roundabout as vehicles paused to give way to pedestrians on the crosswalks.

DISCUSSION

Lower vehicle speeds at both 30 m and 5 m suggest greater safety for the pedestrian allowing more predictable gap selection; creating longer time to collision - allowing greater chance for effective braking; and critically, producing less severe injury consequences in the event of a crash.

Given people are more likely to select crossing gaps based on distance rather than speed (Simpson, Johnston, & Richardson, 2003) slower speed will allow greater predictability in gap selection. Although gap selection at this treated site is, theoretically, no longer required, lower vehicle speeds will assist in protecting pedestrians from drivers who are not complying with the crossings, while also having a general traffic calming effect. Moreover, in the event of a crash, lower speeds reduce pedestrian injury risk, the probability of fatal injury to a pedestrian reducing dramatically for reductions in impact speeds between 30 km/h and 50 km/h (Anderson et al., 1997).

The difference in speed at the South Melbourne roundabout is not dramatic, and at speeds lower than 30 km/h, the probability of a fatality is not greatly reduced by a speed reduction of around 3 km/h. However, the level of serious injury and minor injury outcomes will be more significantly reduced through lowered speeds. In particular, older pedestrians, for whom injuries sustained are often more severe due to physical frailty (Hull, 2001) stand to benefit from reduced mean speeds. Moreover, older pedestrians in particular can find difficulty with appropriate gap selection (Hull, 2001). Given the substantial number of older pedestrians visiting the market, even minor reductions in speed can mean the difference between a minor injury and a more serious injury.

The more prominent crosswalks, which afford right-of-way to pedestrians, and the raised pedestrian crosswalks have a traffic calming effect, creating a more pedestrian-friendly environment. Perceived sense of safety of pedestrians is also increased through a reduction in vehicle speeds, creating an overall sense of enhanced safety for the pedestrian. Also, it can be argued that a perceived sense of safety directly influences pedestrian confidence and satisfaction levels when using the crossings. Safety is also increased through more defined linemarkings that help clarify rights-of-way, reducing likelihood of collisions caused by confusion.

As a result of increased compliance at the crossings, potential for pedestrian/vehicle conflict is more restricted to a specific location. The location is also directly within the intersection, giving prominence and priority to the pedestrian and potentially heightening driver awareness for pedestrians at this location, thereby increasing level of safety for the pedestrian. It should be noted too, that some of these safety benefits might be diminished if drivers are distracted by the need to look out for both vehicles and pedestrians at the same time. However, any such effects of distraction should, theoretically, be at least partly offset by the lower speeds of approaching vehicles. Similarly, potential rear-end crashes that may occur as a result of the new treatment would generally present a lower threat of overall injury than if pedestrians were struck.

Increased compliance with crossings could imply that pedestrians now find crossing at the pedestrian crossings more convenient. Conversely, it may imply that pedestrians feel that using the crossings are worth any detour required for the added safety benefit, whereas prior to treatment it may have been perceived that the existing pedestrian treatment did not provide adequate safety benefits to warrant any detour. Providing explicit right-of-way for pedestrians has reduced total crossing times, and as a consequence improved convenience for the pedestrian. Ensuring the zebra crossings were located more in line with footpaths further improves convenience.

While pedestrian numbers and traffic operations at the site may vary depending on the opening days of the market, vehicle speeds were found to be lower in the after period for both operating conditions. It is possible that a greater number of pedestrians were encouraged to use the new crossing given that perceived levels of pedestrian safety were higher with the new treatment in place. Future studies should measure pedestrian volumes to further account for this potential effect.

The findings should be interpreted in light of some limitations of the study. For scientifically robust results, it is ideal for a control site, that is, a nearby site with similar characteristics to the target site, to be included in the evaluation methodology to ensure that any noted changes before and after treatment can be attributed to the treatment rather than other influences, such as roadworks or an event occurring in the vicinity. However, available resources did not allow for the inclusion of a control site in the study. Based on Council's knowledge of the general activity in the surrounding area and given that events such as the Australian Grand Prix and Easter weekend were avoided, it was assumed that external factors were unlikely to have significantly affected study results. While not ideal, the lack of a control site in this instance is not considered a major limitation of the study design.

While the aim of this project was to increase safety and convenience for the pedestrian, adversely affecting the safety of other road users could also indirectly impact on the safety of pedestrians. For example, creating a situation where rear-end collisions are more likely to occur as a result of the pedestrian treatment could result in a secondary collision with a pedestrian. Similarly, creating an environment that excessively delays or frustrates drivers could possibly result in impatience or aggressive behaviour being shown towards pedestrians. Although brief video surveillance indicates no evidence of adverse effects on other road users, more detailed investigation may be desirable.

Also, several other modified designs exist for creating a safer environment for pedestrians at roundabouts, including pedestrian signals at roundabouts; and zebra crossings set back approximately one-car's length. No attempt has been made in this study to compare the study's design with other existing designs for comparison of safety outcomes.

CONCLUSION/RECOMMENDATIONS

The aims of this re-designed roundabout were to increase both safety and convenience for the pedestrian. Based on evaluation of the parameters mean speed and speeds over 30 km/h, pedestrian compliance, total crossing time and pedestrian perception of the new and previous designs, the new pedestrian facilities installed at the Cecil St/Coventry St roundabout appear to have had a positive effect on safety and convenience for pedestrians: lower mean vehicle speeds, greater driver and pedestrian compliance with the crossings, clearer definitions of rights-of-way potentially resulting in less confusion, and reduced pedestrian crossing times are consistent with the verbal comments from pedestrians interviewed at the site.

Future work could involve further investigation into the expected impacts of this treatment on all road users, in particular vehicle crash trends. In addition, various aspects of the roundabout design can be modified individually to ascertain the effects on safety, convenience and other factors. For example, it may be worth investigating whether having the same raised crossings but set back one-car's length from the stop line, would still provide safety and reasonable convenience and compliance levels, while alleviating some of vehicle congestion.

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