IMPROVED SAFETY FEATURES FOR MULTI-LANE ROUNDABOUTS

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Abstract

This paper is a brief summary of some findings from a two-year research project recently completed for the New Zealand Transport Agency (NZTA), three topics of interest being:

- How do you safely cater for pedestrians at a multi-lane roundabout? Pedestrian safety and accessibility can be a motivating factor to install traffic signals in urban areas, however this research demonstrates that with appropriate facilities and adequate speed control, pedestrians should be able to be well catered for at a multi-lane roundabout.
- Are vertical deflection devices appropriate to install as a means of speed control at main road roundabouts? This research demonstrates they are a viable option for main road roundabouts in many circumstances where safety is a concern, particularly for pedestrians or cyclists. Some issues for consideration include adverse effects to emergency vehicles; increased noise adjacent to the device; wear and tear on vehicle suspension (especially heavy vehicles); and discomfort to vehicle passengers. The only likely issue of significance was found to be increased noise from a minority of heavy vehicle types as they traverse the device, the effects of which can feasibly be estimated beforehand.
- Is excessive visibility of opposing vehicles a desirable feature or a contributor to crashes at roundabouts? Sightline screens have been used in the UK to address reduce crashes at roundabouts, and UK design guidelines suggest that excessive sightlines can be a contributor to unsafe vehicle speeds. This research found that restricted sightlines can reduce vehicle approach speeds and improve safety, and it is considered there is scope to use them even in lieu of conventional means of speed control at roundabouts such as horizontal or vertical vehicle deflection. Additional research that includes some on-road experimentation is desirable to more fully develop these concepts.

A major recommendation of this research project is that for safety reasons primarily, a ‘Roundabout First’ policy be adopted in New Zealand. The above research is anticipated will assist engineers design better roundabouts for pedestrians and cyclists in particular, and preliminary guidelines for their application will be included in the NZTA report due for publication later in 2011.

1.0 Introduction

New Zealand has used roundabouts for many decades and has generally followed the historical lead taken by the UK in this regard. However in the recent decade or so their prominence has declined in urban areas (particularly so for multi-lane roundabouts), and a significant reason for this has been concern for pedestrians and cyclists. This situation motivated a two-year research project recently completed for the NZTA which included a review of the available measures for improving safety for pedestrians and cyclists, as well as a comparison of the safety performance between traffic signal intersections and multi-lane roundabouts. The findings were such that, similar to precedents from the USA, a 'Roundabout First' policy is now being recommended for adoption in New Zealand. This paper discusses several issues of safety relevance that may be of interest to roundabout designers worldwide.

2.0 Safer Facilities for Pedestrians at Multi-lane Roundabouts

2.1 Pedestrian Safety at Roundabouts compared to Traffic Signals

Appearing to indicate that roundabouts are not a serious safety problem for pedestrians in New Zealand, a search of the New Zealand Crash Analysis System (CAS) showed that nationwide there have been zero pedestrian fatality (and 24 serious injury) at 1097 urban roundabouts for the five year period 2004-2008, compared to 11 fatal (and 160 serious injury) at 1461 urban traffic signal intersections. These eleven fatalities at signals included five pedestrian jaywalking incidents, and four where vehicles were making left or right turns during pedestrian green phases but did not give way.

However the above figures do not include all jaywalking incidents or crashes at nearby pedestrian facilities which might be entered into the CAS System as mid-block locations instead of associated with an intersection – for example only half of the zebra crossing pedestrian crashes at the eleven multi-lane roundabout sites studied in section 2.3 of this paper were classified as a roundabout control under CAS. It is also the authors' experience that jay-walking pedestrian crashes often occur a distance away from signalised intersections, so these types of incidents are also likely to be under-represented in national statistics.

Thus although the above recorded statistics appear to be inferring that traffic signals may be presenting considerably more safety problems for pedestrians than roundabouts in New Zealand, further research is required to elaborate on this.

2.2 Literature Review and Evaluation of International Practice

International practice with pedestrian crossing facilities was researched and evaluated in the context of multi-lane roundabouts. The more vulnerable pedestrians at roundabouts include children, elderly and mobility or visually impaired, and several of the identified treatments should improve the situation for them.

Improvements to zebra crossings that have demonstrable benefits are activated flashing road studs or signs as shown in Figure 1 (Parevedouros 2001, Van Derlofske et al 2002, Hakkert et al 2002, Huang et al 1999), and the road studs in particular have already been successfully trialled in New Zealand cities Auckland and Christchurch (Smith et al 2008). A 2001 study from California (Malek 2001) compared effectiveness of flashing road studs and overhead yellow flashing lights, both using identical infra-red systems for motion detection of pedestrians. The pavement lights were found to be substantially more effective in alerting drivers to the presence of pedestrians. However a recent development from the USA called the Rectangular Rapid Flashing Beacon or RRFB has also demonstrated improved performance and could be considered as a viable alternative to flashing road studs. Raised speed platforms are also an option that could also be considered for multi-lane zebra crossings, and these are further discussed in Section 3 of this paper.

Signalised crossings in general are not inexpensive to install and operate, but they are viable facilities to consider for multi-lane crossings where speeds might be higher. ‘Hawk’ and ‘Pelican’ crossings which reduce pedestrian signal walk times will reduce disruption to traffic flow compared to standard set-time signal facilities as used in New Zealand. Alternative on-road pedestrian detection technology which can extend or cut short walk times does also offer potential in this regard (for example as used by ‘Puffin’ crossings in the UK), but it was considered their practicality does need to be better demonstrated for New Zealand conditions.

Signalised roundabouts (of which several have been installed in New Zealand during the past few years) can also effectively deal with pedestrians. Their part time operation is also deemed worthy of consideration in order to reduce vehicle delays during off-peak periods – even though pedestrian amenity would need to be taken into account with respect to operation of signalised crossing points.

FIGURE 1: Flashing road sign (left) and road stud (right) installations in the US, with the more recently developed RRFB shown inset left.

2.3 Safety performance of some pedestrian facilities at multi-lane roundabouts in Auckland, New Zealand

As a means of assessing the safety performance of pedestrian facilities at multi-lane roundabouts, crash histories were reviewed at eleven busy arterial road roundabouts in Auckland which has a regional population of around 1.4 million people. Pedestrian and rear-end crashes associated with pedestrian crossing facilities were evaluated (note: none of these locations had crossing facilities over more than two traffic lanes in each direction), and several sites were chosen for closer evaluation via video observation of pedestrian and driver behaviour. Reported pedestrian crashes for the ten years from 1999 – 2008 were analysed for each of the eleven roundabouts, and individual police Traffic Crash Reports (TCR’s) for these incidents were also reviewed.

Zebra Crossings

In New Zealand, zebra crossings are a form of pedestrian crossing facility where pedestrians have priority of way over drivers, and these are legally required to be marked out with striped paint marking across the roadway. In general the zebra crossings studied did not demonstrate any significant pedestrian safety problems that could not be addressed. Summary of the crash types is shown in Table 1 below.

Based on the analysis, the following observations were made:

- Zebra crossings on dual-lane roundabout entries located 20 m (65 ft) or closer to circulating lanes experience far fewer pedestrian crashes than those further away, with a total of just three reported pedestrian injury crashes at eleven crossings over a period of five years. A separation of one to two vehicles from circulating lanes appears to be the optimum location. Sixteen (84%) of the 19 reported crashes on dual-lane entries occurred at five zebra crossings located 25 m (82 ft) or further from roundabout circulating lanes. This corresponds to an average pedestrian crash rate of some 3.2 crashes per site every five years, which is considerably higher than for crossings located closer to the roundabout. Twelve of these 16 crashes involved collisions with pedestrians crossing in traffic queues – highlighting that this is the main safety issue being experienced by pedestrians at multi-lane crossings (i.e. vehicles overtaking). Arrow markings on roundabout approaches which cause uneven queuing can further exacerbate this.
- Single lane crossings appear to operate reasonably safely, but inadequate speed control through the roundabout can still have an adverse effect on pedestrian safety.
- Additional measures to improve safety at multi-lane or higher speed locations (such as at crossings > 20m or 65 ft from a roundabout) could include flashing signs, flashing road studs, raised platforms and high friction surfacing.

TABLE 1: Table showing reported pedestrian injury crashes from 1999-2008 at zebra crossing facilities for the eleven roundabouts studied in Auckland. NB: F = Fatal, S = Serious Injury, M = Minor Injury

ZEBRA CROSSINGS SUMMARY			
	Single-lane Exit	**Double-lane Exit**	**Double-lane Entry**
Pedestrian Injury Crashes	2S, 5M @ 15 crossings = 0.46/site/5 yrs	7M @ 5 crossings = 1.5 /site/5 yrs	1F, 3S, 15 = total 19 ped injury @ 16 crossings = 1.19/site/5 yrs
Crashes involving overtaking in traffic queues	N/A	4M or 57% of total. Three occurred at Royal Oak crossing 30m from rbt.	Twelve (11M & 1F) or 63% of total. All 12 occurred at crossings > 25m from rbt
Comments	One crossing had 2 injury crashes, the remaining 14 crossings had 4 injury crashes combined.	Two crossings had 3 injury crashes each, the remaining 3 crossings had just 1 injury crash combined.	Sixteen of the 19 ped injury occurred at 5 crossings, all located 25m or more from roundabout = 3.2/site/5yrs Just 3 ped injury occurred for the 11 crossings located 20m or less from rbt = 0.27/ site/5 yrs

Pedestrian Signals

In general the pedestrian signal sites did not demonstrate any significant safety issues that could not be addressed. Note: in New Zealand only set-time signal arrangements are used, the use of flashing displays such as by ‘Hawk’ or “Pelican’ crossings are currently illegal.

Of the seven reported pedestrian incidents between1999-2008 at the four signalised crossing sites, three involved red-light running with the remaining four being pedestrians crossing heedless of the traffic signal. Therefore in order to improve safety at these locations:

- Visibility of signal displays to approaching drivers is an important consideration for reducing red-light running crashes. Overhead signal displays are recommended in multi-lane situations.
- Pedestrian wait times should desirably be set at not greater than around 30 seconds each crossing stage, in order to reduce the jaywalking which can potentially adversely affect safety statistics. Anticipatory call-up of opposite cross phases at staggered island layouts is also recommended practice to reduce walker delay.
- All-red times could be increased to reduce the chance of late-runners hitting pedestrians. This is more viable for staggered island crossings where driver delays are lesser in any case.

In addition, it is suggested that active advance warning measures such as flashing road studs or signs could potentially assist drivers perceiving there is a red display ahead.

2.4 Conclusions of Pedestrian Crossing Facilities

Well designed multi-lane roundabouts are able to safely accommodate pedestrians, and should certainly at the very least be a viable alternative to a traffic signalised intersection for these users. Further research is desirable to definitively distinguish the difference in safety performance between traffic signalised intersections and roundabouts.

Zebra crossing facilities offer the greatest mobility to able-bodied pedestrians, although they can have some disadvantages to visually impaired users. A review of zebra crossings at multi-lane crossing points in Auckland, New Zealand demonstrated that they can be relatively safe if located less than 20 m (65 ft) from the roundabout, mainly due to the lower approach vehicle speeds near circulating lanes. Note this finding seems to be affirmed by design guidelines in the UK which recommend zebra crossings are not to be located between 20 – 60 m (65 – 197 ft) from roundabout limit lines (Department for Transport 2007a). However, zebra crossings at multi-lane locations where vehicle speeds are higher (such as greater than 20 m or 65 ft from the roundabout) can invariably experience safety problems and additional measures or even alternative crossing facilities may be desirable. This is particularly relevant at locations where vehicle queues from the roundabout regularly extend through the crossing. Appropriate speed control at the roundabout is a most important consideration, and active warning devices such as flashing signs or flashing road studs, staggered island arrangements or raised pedestrian platforms will also improve pedestrian safety at crossing facilities.

Pedestrian signals near roundabouts are a viable alternative to zebra crossings, but pedestrian wait times need to be set low enough to reduce the ‘jaywalking’ that may otherwise occur which in turn can compromise pedestrian safety. Staggered signalised crossing arrangements can reduce disruption to vehicles as crossing times are shorter for each direction. Overseas ‘Hawk’ or ‘Pelican’ crossings are simple signalised crossing alternatives that can reduce disruption to traffic flow with no apparent significant compromise to pedestrian safety. Pedestrian detection technology as used with ‘Puffin’ crossings in the UK could feasibly achieve a similar objective to these, although their practicality needs to be better proven for New Zealand conditions at least.

Finally, lane arrow markings can cause uneven vehicle queuing which has safety implications to all types of multi-lane pedestrian crossing facilities on roundabout approaches, so should be applied with due caution.

3.0 Vertical Deflection Devices at Main Road Roundabouts

3.1 Background

Vertical deflection devices are an effective means of vehicle speed control and potentially are viable for use in the proximity of roundabouts for the benefit of cyclists and pedestrians in particular. Previous research undertaken in New Zealand (NZTA 2005) identified that the reduction of vehicle speeds on roundabout approaches is a principle objective in reducing cyclist crashes at roundabouts. Vertical deflection devices (speed humps, speed tables or speed cushions) offer one of the most economic methods of retro-fitting existing roundabouts to achieve this aim, and can also be used at pedestrian crossing facilities where safety is a concern.

However outside the context of shopping centres with large volumes of pedestrians, the use of vertical deflection devices on main roads is not considered to be appropriate by many road controlling authorities in New Zealand. Primary objections generally relate to: adverse effects to emergency vehicles; increased noise adjacent to the device (particularly from heavy vehicles i.e. trucks, trailers and buses); wear and tear on vehicle suspension (especially heavy vehicles); potential traffic diversion; and general annoyance and discomfort to the public, especially bus passengers. The main objective of this part of the project was to comprehensively examine these issues and develop a preliminary guideline for application if possible.

3.2 Effects on Vehicle Occupants, Emergency and Bus Service Operators

There is anecdotal evidence available on the internet from the UK and USA of occasional spinal injuries to bus passengers and fire fighters when their vehicles have traversed speed hump type devices at inappropriately high speeds, and also of the impediment they can present to people with existing severe spinal conditions. However these reports tend to refer to entire street networks areas treated with such devices, rather than isolated examples such as at an intersection. Overall safety benefits of a particular application (such as at a roundabout for the purpose of speed control) should be able to be objectively weighed up against these potential dis-benefits.

A UK study entitled “Impact of Road Humps on Vehicles and their Occupants” examined this topic in some detail (Kennedy et al 2004), and was motivated by the aforementioned public concerns. It was generally concluded that levels of discomfort were generally acceptable if devices were traversed at appropriate speeds of around 24 – 32 km/h (15 – 20 mph). Passengers in the rear of vehicles such as taxis, ambulances or buses are likely to suffer the most discomfort, but this is substantially mitigated if drivers are duly aware and reduce speed accordingly. It was considered that vehicle occupants are very unlikely to be injured as a result of single or repeated traversing of road humps, the exceptions being people with severe back conditions who could be more susceptible. For major bus or ambulance routes speed cushions were recommended as the preferred treatment if vertical deflection devices are to be used. Careful attention to signing and marking of the devices is also recommended in order to encourage drivers to slow down in good time for them, especially at night.

A recent guideline for traffic calming measures in the UK (Department for Transport 2007b) is a useful document for reference, and does include a comprehensive evaluation of different types of devices. Vertical deflection devices are deemed acceptable for bus routes provided they are under

75mm (3 in) high and preferably not installed in great numbers. Flat-top platforms with 1 in 15 approach ramps are deemed to be an acceptable compromise between speed reduction and driver comfort, with a plateau length to match wheelbase of buses that use the route (around 6m or 25 ft for standard buses, and up to 12.5m or 41 ft for articulated buses). Shallower off-ramps of some 1 in 20 are recommended for one-way streets. Traffic calming guidelines for the cities of London and Manchester do not accept round-top humps for bus routes because of the double ‘bump’ they give passengers.

3.3 Heavy Vehicles

It has been concluded from this research that adding speed humps or platforms to main road roundabout entrances should have no measurable effect on heavy vehicle chassis or suspension wear, and should in fact have a positive safety effect by controlling truck traversing speeds.

However, some increased noise may be generated by some lightly-laden heavy vehicles with mechanical leaf-spring suspension as they traverse a vertical deflection device - particularly those with three axles or more, or with two axles if driven at excessive speed. In New Zealand, air suspension is becoming more widely adopted for three-axle vehicles and trailers (with the current exception of tipper and concrete trucks), so this may not be a significant issue for many situations. Any acceleration/deceleration noise from heavy vehicles would depend upon the particular device and proximity to the roundabout. If residential or similarly sensitive activities are in very close proximity, then truck volumes by type and time of day could be reviewed as a means of assessing the potential for adverse noise effects.

Some research was undertaken in the UK following some public concerns being expressed relating to damage to buildings in close proximity to speed hump type devices as a result of vibrations from heavy vehicles. In summary, it was found that although vibrations could be felt up to 76m (250 ft) away, noticeable damage to buildings would only occur if they were less than 4m (13 ft) away at most (Watts et al 1997).

3.4 Roundabouts in Malmo, Sweden

The Swedish city of Malmo has in recent years constructed several multi-lane roundabouts with raised platform type treatments for pedestrian and/or cyclist crossing points. An interesting difference here though, is that they have used short ramps on the approach direction to each crossing point, and for the departure direction the platform is ramped off at a slight gradient as shown in Figure 2. This method of construction achieves a similar effect to that of a raised intersection treatment, in that it minimises the discomfort to road users (particularly bus passengers) whilst still maintaining a measure of speed control. This concept is considered to hold great potential for application elsewhere.

Road controlling authorities in Malmo were contacted, and they graciously forwarded some of their design plans for referral. The approach ramps they use are 100mm (3.9 in) high with a 1 in 13 gradient (or typically 6 - 8%). This ramp profile is considered to achieve good vehicle speed reduction without any potential adverse health effects to bus drivers who repetitively traverse them. Length of departure ramps are variable, but are generally in the order of 5 m (16 ft) to achieve a gradient in the order of 1 in 50 (2%). Note that a median island of some length is required to allow for differing carriageway levels in each direction.

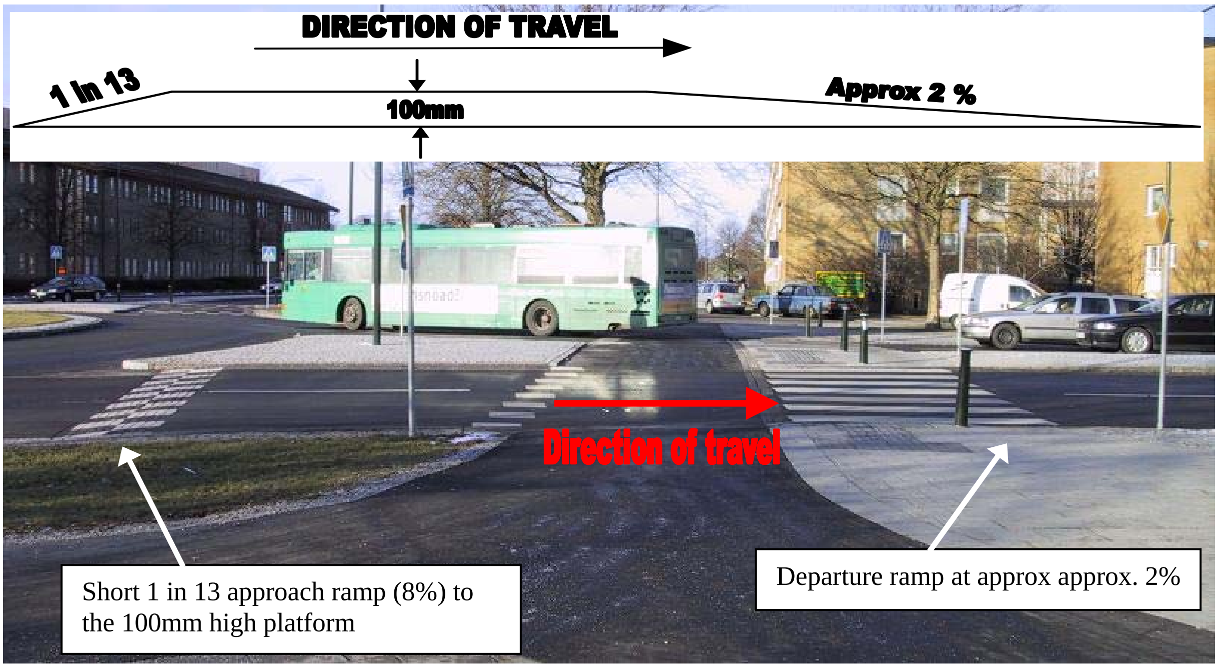

FIGURE 2: Side view of a platform from the Swedish city of Malmo with roundabout exit lanes in the foreground (photo provided by Transport Department, City of Malmo).

3.5 Conclusions of Vertical Deflection Devices

The premise for this research was that given vertical deflection devices at roundabouts are beneficial for pedestrian and cyclist safety, there should be some justification why they are not used more often on main road roundabouts worldwide. In some cities such as Malmo, Sweden they are more often being used for this purpose.

This research has identified that the most likely adverse effect of any significance would be some additional noise generated from some heavy vehicles as they traverse the device – lightly laden trucks with three axles or more and mechanical leaf-spring suspension, or two axle trucks if driven at excessive speed. Although there are other potentially adverse effects including delays to emergency vehicles, vehicle occupant discomfort (particularly bus passengers), fatigue damage to heavy vehicles, traffic diversion and vibration damage to adjacent buildings or structures - all of these were found to be usually of minor nature and therefore of minor significance. Hence for any proposed installation, the safety benefits of a vertical deflection device should be objectively weighed up against these potential adverse effects. For example, noise effects could feasibly be assessed by a review of truck volumes by type, time of day and proximity to sensitive land use activities.

Options include raised speed platforms, speed humps and speed cushions, and in general the higher profile the vertical deflection device the greater the speed reduction effect. If it is anticipated that vertical deflection devices might be used more often in the vicinity of noise-sensitive areas such as residential streets, one possibility is that national legislation that requires or encourages the more widespread use of less noisy alternatives to mechanical suspension on larger heavy vehicles (such as air suspension) could be introduced.

The use of vertical deflection devices at roundabouts need not be limited to only pedestrian and cyclist safety considerations. They do offer an economic alternative to geometric means of vehicle speed control at roundabouts which can otherwise be costly in terms of land-take (for example refer to Figure 3 below).

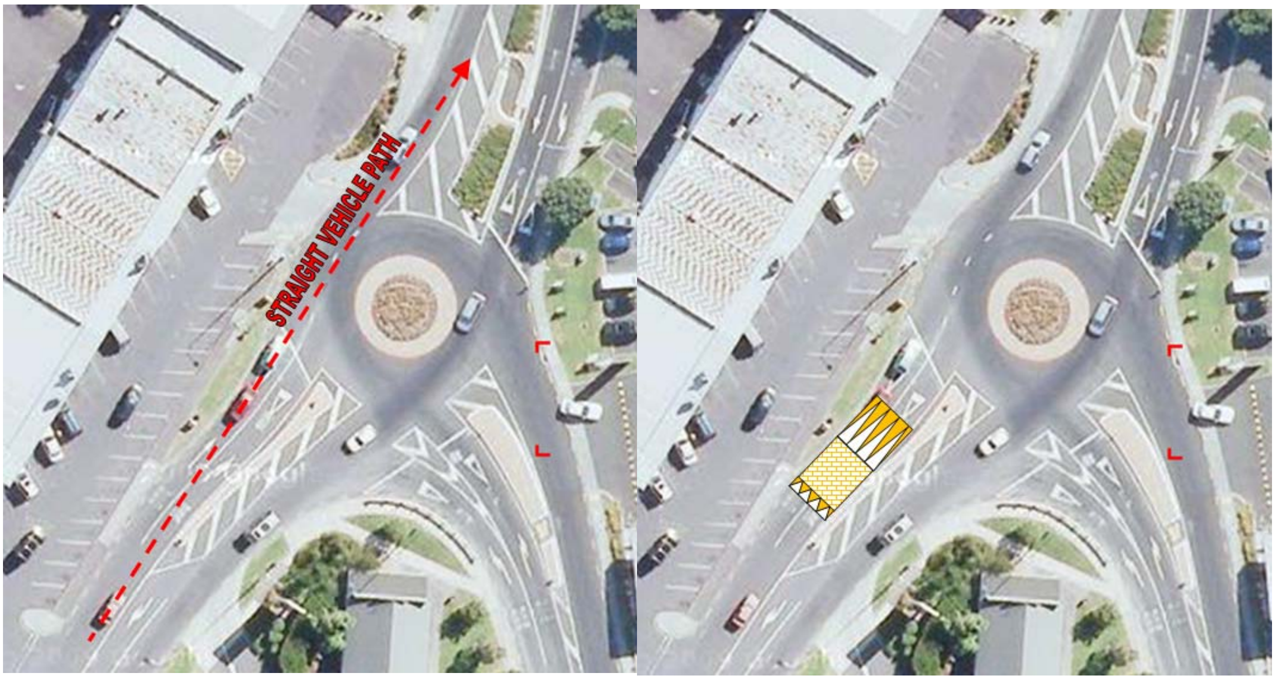

FIGURE 3: Example installation of a Swedish style platform at an existing roundabout which has inadequate speed control in the northbound direction as shown on left.

4.0 Use of Sightline Restrictions to Improve Safety at Roundabouts

4.1 Introduction

Conventional traffic safety wisdom is that the greater visibility of oncoming vehicles a driver is provided with, the safer a junction will be. However a relationship between excessive sightlines at higher-speed rural roundabouts and loss-of-control crashes was demonstrated in the UK in the 1980's (Maycock & Hall 1984), and more recently barrier screens are being successfully installed in the UK to restrict visibility of circulating traffic and address rear-end crash patterns associated with drivers entering the roundabout at excessive speeds (refer Figure 4 below where a rear-end crash pattern was addressed). However, close evaluation of a roundabout in Auckland, New Zealand demonstrated that entering vehicle versus circulating vehicle crashes can increase if sightlines are restricted too much.

The principle objective of this study was to attain a better understanding of how sightlines can affect driver speed and roundabout crash statistics, and to produce a preliminary guideline for application if possible. It was concluded that sightline restrictions can potentially be very useful as a means of reducing driver approach speed to a roundabout, but they do need to be applied with due caution.

FIGURE 4: Photo taken in 2008 of a 2.5m (8 ft) high visibility screen installed on the approach to a roundabout at the intersection of the A50/A511 and Junction 22 of the M1 motorway in Markfield, Leicestershire County Council, UK.

4.2 Close evaluation of the Church St / Avenue Rd roundabout in Otahuhu, Auckland.

The Church Street / Avenue Road roundabout in Otahuhu, Auckland is in a 50 km/h (31 mph) residential area, and was selected for evaluation as part of this research project for the following reasons:

- It has an unusual combination of sightline constraints (refer Figure 5), with three of the four approaches being restricted by corner boundary fences (shown as approaches B – D), and the fourth having almost unimpeded visibility across a sports field (shown as approach A).
- It has previously been identified as a site with an unusual crash pattern (refer Figure 6) which appeared to be related to these sightline constraints. All the reported crashes involved straight-through versus straight-through vehicles, and 13 of these 16 crashes (or 81%) involved vehicles from approach A. Higher vehicle speeds through the roundabout from the Church Street southern approach A appeared to be a major factor in the crash pattern here. Traffic volumes are reasonably comparable for each of the four approaches, and certainly not reflective of this crash pattern.

After close analysis it was concluded that the restricted visibility of oncoming vehicles from approach A is a major reason why more crashes with vehicles entering from approach B.

FIGURE 5: Example photo taken 10 m (33 ft) back from the limit line on approach D to the small Church Street / Avenue Road roundabout in Otahuhu, Auckland. Sightline restrictions are almost identical for approaches B-D, whilst approach A has virtually unimpeded visibility due to the presence of a field on the right.

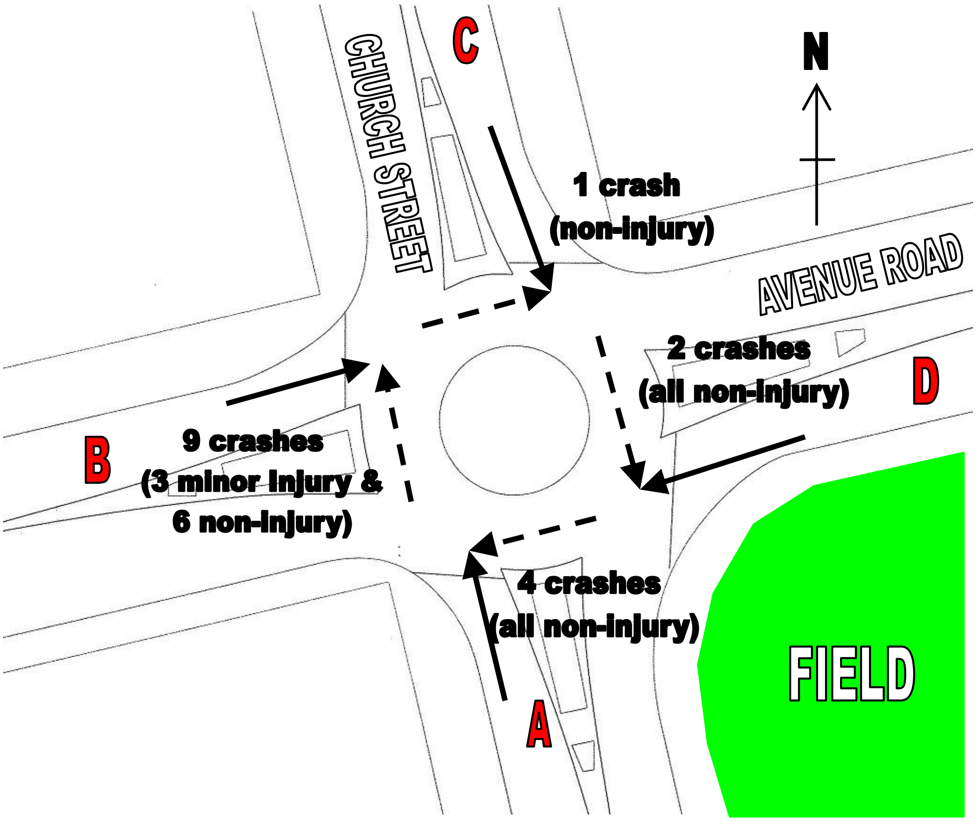

FIGURE 6: Diagram showing reported entering vehicle versus circulating vehicle crashes for the nine-year period 2000 – 2008.

Speed measurements

On-site measurements of unopposed straight-through vehicle speeds through the roundabout were undertaken via a video camera survey, and demonstrated 85% vehicle speeds for approaches B, C & D of 30 – 31 km/h (18 -19 mph) compared to 37 km/h (23 mph) for approach D. Although vehicle deflection through the roundabout does vary for each approach, these showed little relationship to these straight-through speeds. Pneumatic tube counters placed 10 m (33 ft) in advance of limit lines were also installed for a period of one week, and just 20 vehicles for each approach B, C & D were recorded as travelling >40 km/h (25 mph) compared to over 200 vehicles from approach A.

Discussion

The significant majority of reported crashes at the Church Street / Avenue Road roundabout involve entering vehicles from approach B colliding with straight-through vehicles from approach A. The most critical sight-line scenario is the B approach - sight distance is the most restricted and straight-through vehicle speeds from adjacent approach A the highest. For example, if a vehicle from approach B entered the roundabout at 30 km/h (19 mph), it would only just clear the conflict point (taking into account the length of the vehicle) before a vehicle from approach A travelled past at 40 km/h (25 mph) without slowing. This vehicle from approach A also has marginal distance to react and come to an emergency stop. The historical crash pattern here confirms this is a safety problem, and would appear to demonstrate the adverse effects of too high vehicle speeds for approaching drivers to adequately stop in time for opposing traffic should they suddenly come into view

The reason that approaches C and D are experiencing much less significant reported crashes than approach B appears to be largely due to the lower vehicle speeds of straight through opposing vehicles coming from their right. Although approach speeds for C and D are similar to that of approach B, even if a vehicle does suddenly come into view then a collision is more likely to be averted here simply because the oncoming vehicle would not reach the conflict point in time. Hence if sightlines to the right for approach A were restricted similarly to that of the other three approaches, it is expected that approach A driver speeds would be reduced to around 30 km/h and the crash patterns involving these vehicles be effectively eliminated.

Note that for sightlines to the right at roundabouts, UK guidelines only discuss visibility of the adjacent road limit line rather than upstream on the approach (Department for Transport 2007a). However, the above example clearly demonstrates that sightlines of adjacent approaches can also be an important consideration.

From this analysis, it is concluded that a roundabout should be able to operate safely enough with sightline restrictions (perhaps even in lieu of geometric means of speed control), but only if approaching vehicles are travelling slowly enough to still comfortably stop in time for opposing vehicles at speed. Given that sightline restrictions can have a significant influence on roundabout safety and feasibly be a very cost effective means of reducing vehicle approach speed, it is strongly recommended that this concept be developed through further research.

4.3 Proposed sightline analysis procedure

The following analysis of speeds and sightlines can be undertaken at a roundabout, either for a proposed installation or as part of a crash pattern investigation. A conflict diagram can be drawn for each approach as shown in Figure 7 - this speed/sightline analysis can be done for each one in turn. Preliminary analysis can be undertaken using the parameters given below:

- Estimate or measure 85% speeds of straight-through unimpeded vehicles A & B (i.e. drivers travelling through without having to give way to opposing traffic). Preferably this can also be done at an exact location in advance of the Conflict Point (e.g. 10 m or 33 ft before the Limit Line is suggested).

- Assume reaction time of 0.7 – 1.0 second for an alert driver approaching the roundabout who is aware of the possibility that braking will be necessary (Transportation Human Factors 2000).
- Assume a comfortable vehicle deceleration rate of some 3.5 m/s^2.

If Vehicle B is travelling fast enough that they will reach the conflict point before Vehicle A can stop in time, then there is the possibility of a collision. The probability of crashes occurring at a particular location will depend upon the number of vehicles from each approach that are travelling at the higher speeds. For example a driver travelling at 30 km/h (19 mph) requires some 10 m (33 ft) to stop if decelerating at 3.5m/s^2 excluding reaction time. Even if already decelerating in preparation to stop for opposing vehicles, drivers travelling in excess of 30 km/h (19 mph) at 10 m (33 ft) back from the Limit Line may have to decelerate uncomfortably hard in order to prevent a collision. If there are numbers of two-wheeled users (cyclists or motorbikes) then slower vehicle speeds are particularly desirable as these users can be more difficult for drivers to discern.

Figure 8 shows an example where such a screen could potentially be retro-fitted to a two-lane roundabout where existing speed control is inadequate.

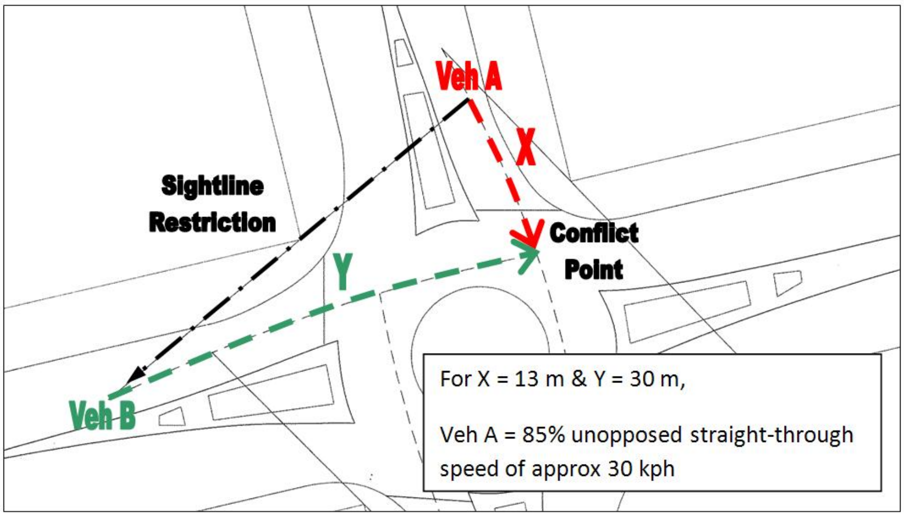

FIGURE 7: Speed / sightline relationship gathered from analysis of the Church Street / Avenue Road roundabout in Otahuhu.

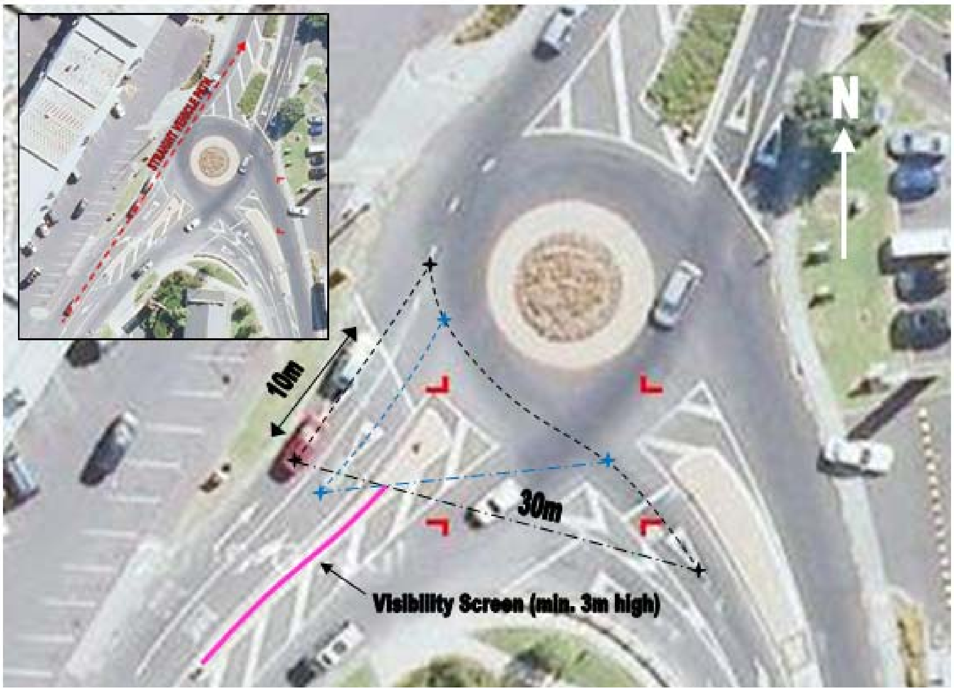

FIGURE 8: Example installation of a visibility screen at the same roundabout shown in Figure 3 which has inadequate speed control in the northbound direction as shown.

5.0 SUMMARY

A major finding of this research project has been that multi-lane roundabouts should be able to be designed to safely cater for pedestrians for most situations, although due care is still required on behalf of the designers to ensure there is adequate vehicle speed control and also to select appropriate crossing facilities. Multi-lane pedestrian crossing facilities where vehicle speeds are higher (such as at locations greater than 20 m or 65 ft from the roundabout) will in particular require consideration for additional safety features such flashing signs or flashing road studs, staggered island arrangements, raised pedestrian platforms, or signalised crossings.

Vertical deflection devices are an option that could be more widely used for main road roundabouts, both for pedestrian crossing facilities and for speed control on roundabout entries which can improve cyclist safety in particular. In general the only potentially adverse effect of any significance was found to be noise from some trailer and heavy vehicle types as they traverse the devices. These noise effects could feasibly be assessed beforehand, and will also depend upon adjacent land uses e.g. residential areas may be more sensitive.

Sightlines of opposing vehicles can affect driver approach speed to a roundabout, and the use of screens or similar to restrict sightlines can be used as a tool for the purpose of reducing these speeds. However, due care is required on behalf of designers to ensure that additional crashes won’t result when circulating vehicle speeds are too high. Development of this concept is recommended through further research.

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