Improved Multi-lane Roundabout Designs for Cyclists

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Abstract

In 2004 GHD Ltd was engaged by Land Transport New Zealand to improve multi-lane roundabout designs for cyclists, as part of their 2004/5 research programme. This paper is a summary of this project. Duncan Campbell (GHD Ltd) also completed a Masters thesis that included further work on this subject.

Multi-lane roundabouts are generally viewed by experienced cyclists as a reasonably hazardous element of the road network to be avoided if conveniently possible. Literature review, analysis of crash statistics in Auckland and a survey of cyclists confirmed the original focus of this research, which was to design a low-speed multi-lane roundabout for on-road cyclists. This should substantially treat the critical 'entering vehicle versus circulating cyclist' crash type, and is anticipated will also address roundabout exits which is the other main safety issue of concern to bike riders. Good streetlighting is also imperative, as night-time crashes comprise a significant proportion of Auckland cyclist crashes at these types of junctions.

The design of a roundabout that reduces maximum car speeds to 30 kph rather than the conventional 50 kph requires a confined geometry. The outcome of this research project is the Cyclist Roundabout, or "C" Roundabout, which requires a narrow roundabout entry that relies on larger vehicles to straddle both entry lanes.

An alternative measure is the use of vertical deflection devices on roundabout approaches. Although these have implications for bus passenger comfort, emergency and heavy vehicles, they are an economic form of speed reduction for roundabout entries compared to substantial roundabout redesign.

The "C" Roundabout as shown in this report is a design that may not be suitable for every intersection situation. Rather it is hoped that the design concept demonstrated here, will be taken into consideration alongside other options for any new junction designs or improvements. In the context of improving the road network for cyclists, the "C" Roundabout is just another tool at the traffic engineer's disposal.

1. Introduction and Background

Multi-lane roundabouts are typically viewed by cyclists as one of the more hazardous type of intersections to negotiate, and Police crash statistics bear this out. For the purposes of this research, the definition of a 'multi-lane roundabout' is that of a roundabout that accommodates more than one lane of traffic on the circulating carriageway.

In 2003 City Design Ltd (now GHD Ltd) undertook scheme investigation for two new cycle routes in Manukau City, Auckland. These routes were 8km and 11km long and included eight multi-lane roundabouts. Hence there was a need to cater for cyclists at these types of intersections. Available Austroads design guides (Austroads 1993, 1999) only provide for off-road facilities and no on-road alternatives are offered. This led to the research presented here.

Off-road bypasses for roundabouts are already well documented in various guidelines including Austroads (1999) Part 14 “Bicycles”, and have been shown by some studies to reduce cyclist crash numbers (Swedish National Road and Research Institute 2000). However unless they are grade separated from the circulating carriageway (a personal security issue in itself and often very expensive), additional delays and inconvenience to cyclists are inevitable, and are a deterrent to their use. Generally speaking, only low numbers of cyclists are likely to use off-road facilities provided at roundabouts (Sharples 1999). They are in the main more appropriate for younger cyclists and novices.

There is no adequate on-road design available for cyclists to ride through roundabouts, and this seems to be a deficiency in design standards. The purpose of this research was to come up with an on-road design that is both safe as well as attractive to cyclists, which ideally will have benefits to other roundabout users as well. To achieve the above, the improved design needs to reduce vehicle speeds and hopefully not adversely affect junction capacity. The intention of the design was to:

1. Achieve a low speed environment (particularly vehicle entering speeds) of around 30 kph or less that is amenable to on-road cyclists mixing with circulating traffic;

2. Improve visibility of circulating cyclists, by way of radial approaches and lower vehicle approach speeds that will improve driver perception of bike users;

3. Potentially reduce number and severity of crashes by all roundabout users, by way of this reduced speed environment; and

4. Potentially will have little or no effect on capacity of these junctions. Lower user speed may enable drivers to accept gaps easier, which means that capacity of the junction could increase. This was investigated this further.

The result of this work is the “C” Roundabout, a new concept in roundabout design.

2. Literature Review

A literature review was undertaken that included sources from New Zealand, Australia, the UK, the USA, and several other European countries including The Netherlands and Finland. Major topics investigated were:

- Cyclist crashes at roundabouts
- Vehicle speed and crash statistics
- Vehicle speed and comprehension of cyclists
- Cyclist numbers and crash statistics
- Capacity implications of low speed roundabout designs

- Sideswipe crashes
- On-road design solutions used overseas

Roundabouts are generally safer for cyclists than priority junctions (Schoon and Van Minnen 1994). However, multi-lane types are considered to be relatively hazardous for cyclists compared to traffic signals (Allott and Lomax 1991, Campbell 2005), and are of sufficient concern to cyclists to justify improvements. There appears to be no satisfactory design solution that is available overseas.

There are indicators that a roundabout design which reduces the speed differential between cyclists and car traffic will improve cyclist safety. Lower vehicle speeds have the potential to reduce both numbers and severity of all user crashes (C.R.O.W. 1993, Davies et al 1997, Department For Transport UK 2003, Swedish National Road and Transport Research Institute 2000), will improve driver recognition of cyclists (Rasanen and Summala 2000, Summala et al 1996), and should also assist cyclists to undertake their manoeuvres by enabling them to better establish their road presence.

The predominant cyclist crash pattern at roundabouts in New Zealand and overseas is the 'entering vehicle versus circulating cyclist' type (Allott and Lomax 1991, Harper and Dunn 2003). At sites with higher numbers of cyclists, drivers are more likely to be careful and cyclist crash rates have been shown to be lower (Beca 2005, Davies et al 1997, Department For Transport UK 2003).

A UK design guide has indicated that excessive visibility can result in higher approach and entry speeds than desirable for junction geometry (The Highways Agency 2005), and recommends limiting visibility on approach roads to no further back than 15m from roundabout limit lines. However, this is contrary to Austroads (1993) recommendations that recommend a desirable visibility from 40m back (equivalent to the stopping sight distance for a car travelling at 50 kph), and this topic therefore justifies further research.

The 'turbo-roundabout' from The Netherlands is a potential alternative treatment for multi-lane roundabouts at main-road junctions with lower-volume roads (Fortuijn 2003), but further research is recommended before application in New Zealand. It includes the use of an off-road facility that can give priority to cyclists at road crossing points, which is of interest and also deserves further attention.

3. Crash Analysis in Auckland

Bicycle crashes at multi-lane roundabouts in the Auckland region were reviewed – in Auckland City, Waitakere City, Manukau City and North Shore City. A total of 59 Police Crash Reports for the ten-year period 1995 to 2004 at 58 sites were reviewed. Of these some 39 involved injury to the cyclist. Figure 3.1 shows a summary diagram of all crashes.

The crash type most reported to police is the 'entering vehicle vs. circulating cyclist', which comprises some 68% of total crashes and 69% of all injury crashes at multi-lane roundabouts in Auckland. The only other common type of crash that features with respect to injuries are the ‘exiting vehicle versus circulating cyclist’ and ‘sideswipe circulating vehicles versus circulating cyclist’.

Night-time accidents are an issue for cyclists due as they are less visible - some 25% of the cyclist crashes at Auckland multi-lane roundabouts occurred in dark conditions. This highlights the importance of good streetlighting at these locations, and for cyclists to use correct night-time equipment.

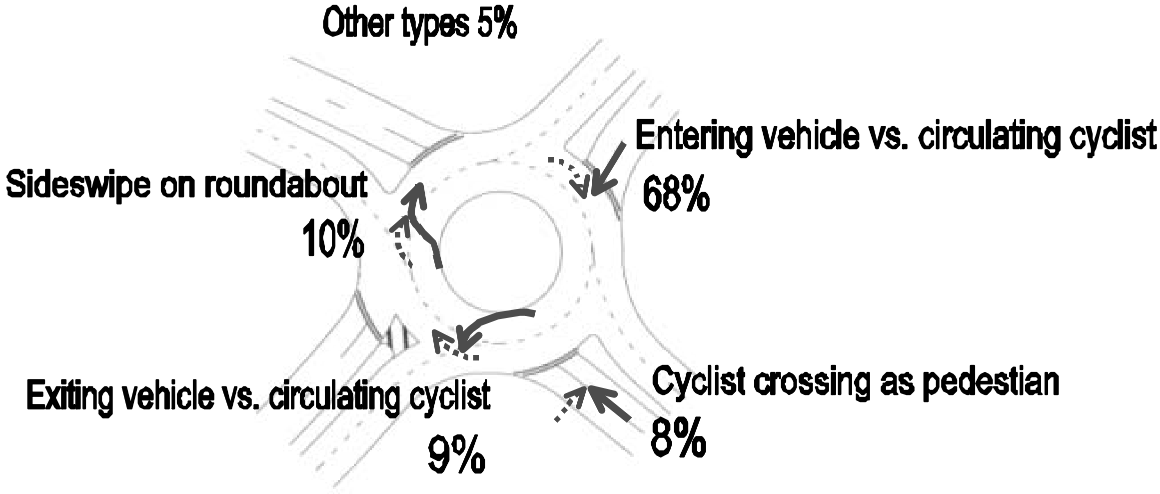

Figure 3.1 Summary Diagram of crash data for cyclists at multi-lane roundabouts in the four Auckland cities (non-injury and injury) 1995 to 2004.

4. Cyclist Survey

A survey was undertaken to assess the level of concern cyclists have with multi-lane roundabouts, identify their main perceived safety issues, and get some preliminary feedback on the concept of low-speed designs. In summary, overwhelming support was received for the latter.

A survey form was drafted in Excel format and distributed via email as well as a downloadable website link, to cyclist organisations and retail outlets in the Auckland Region. A total of 195 responses were received.

Based on the above survey, the following conclusions have been made:

- Experienced cyclists predominantly responded to the survey, and they generally view multi-lane roundabouts as a reasonably significant obstacle that is to be avoided if conveniently possible.

- The most important safety issues as perceived and experienced by cyclists relate to ‘entering motorist versus circulating cyclist’, ‘exiting motorist versus circulating cyclist’, and ‘cyclists entering the roundabout’. Figure 4.1 shows a summary of the incidents reported by cyclist.

- Education for cyclists making right-turns at multi-lane roundabouts is recommended. A significant proportion of cyclists would use the kerbside approach lane when making a right turn, which is not advisable. They are either unaware that it is best practise for them to use the right-hand lane (Franklin 1997), or are wary of doing so. Roundabout designs that reduce traffic speeds should be more conducive to this aim.

- The overwhelming majority of experienced cyclists (85%) prefer to use the road rather than use at-grade bypasses (with zebra crossings) if provided.

- About 87% of respondents agreed that a multi-lane roundabout design that reduces maximum vehicle speeds to around 30 kph is the most desirable on-road outcome for cyclists. This confirms the aim of this research.

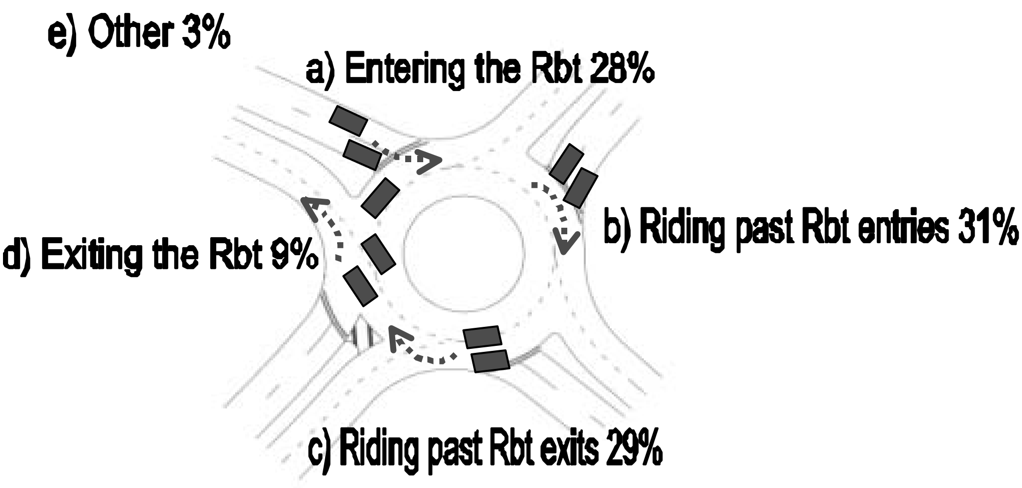

Figure 4.1 Summary diagram of incidents as reported by cyclists in the survey.

5. Low Speed Design Options

Identified design options to achieve a reduction in roundabout traffic speed include:

- The application of confined roundabout geometry and thermoplastic roadmarking. The research undertaken in this report (described further in Section 6) indicates that maximum path radii in the order of 30 to 40m is required for the desired 30 kph environment.

- Vertical deflection devices on roundabout approaches. Although an economic alternative to roundabout redesign, these are potentially contentious to install on bus routes and there are some issues with emergency and heavy vehicles.

- The 'turbo-roundabout' as used in The Netherlands (Fortuijn 2003). The layout assumes two opposing single-lane exits, and it includes mountable lane dividers that are an uncertain element with respect to the safety of two-wheeled road users.

As the second two options had limitations of some sort, the focus of this research was directed towards the first approach. In practice it was difficult to achieve confined geometry and still allow for larger vehicles to enter alongside other traffic, and this led to the “C” Roundabout concept.

6. Negotiation Speed and Geometric Design

6.1 Summary

The aim of this project was to design a roundabout configuration that reduces the speed differential between cyclists and cars. This will enable cyclists to take up full lanes and safely mix with vehicle traffic without holding up traffic, and in order to do this requires these users be travelling at similar speeds. This reduction of vehicle speed at roundabout entries is also expected to improve driver recognition of cyclists (see Section 2), which is particularly important given the prevalence of entering vehicle versus circulating cyclist type injury crashes.

For an assumed average cyclist speed of around 20 kph (from the author’s own riding experience), vehicle speeds of around 30 kph are estimated to be acceptable for them to competently mix with traffic. In addition, at this speed any injuries incurred from a collision are expected to be coincidentally reduced.

The target of this study is the *85th percentile speed of unimpeded car drivers entering the roundabout,* i.e. those not having to give way to circulating vehicles already on the roundabout, or held up for any other reason such as queued or turning vehicles. It is supposed that it is predominantly this group of drivers that is more likely to collide with circulating cyclists on the roundabout. This lower entry speed will assist in recognition of cyclists on the roundabout, which in turn reduces the chance of a conflict (see Section 2).

A brief review of overseas literature was undertaken along with some field surveys of roundabouts in Waitakere and Auckland City. These indicated that for roundabout design a maximum vehicle path radius in the order of 30 to 40 metres would achieve the desired lower speed environment for cyclists.

6.2 Maximum Path Radius

Maximum path radius is a critical factor for geometric design of roundabouts. This is the maximum radius a car can track between kerbs, and relates to expected vehicle speed. If radii are reduced it can have significant consequences on the roundabout configuration and larger vehicle tracking. Therefore deciding upon an acceptable range of maximum path radii is important so as to retain the 30 kph speed concept without making inappropriate compromises.

In order to identify an appropriate radius that will achieve the 30 kph 85th percentile speed as described above, further investigation was required. Some overseas literature was reviewed, and though helpful did not decisively answer this question. Some observations of existing roundabouts in Auckland were therefore undertaken in order to give a more definitive recommendation.

6.3 Field Research – Waitakere and Auckland City Roundabouts

Additional research was undertaken at six multi-lane roundabouts in Waitakere and Auckland City. These roundabouts had individual approaches with maximum path radii between 30 to 50m, and were used as 'simulators' for the proposed final design.

A sample of approximately 100 unimpeded through vehicles were taken at each site. Speeds were assessed by timing vehicles between the limit line and a point approximately 20m downstream.

From these observations it was concluded that:

- Provision of a 30m maximum path radius approximately achieves the desired 30 kph speed environment. This is particularly relevant for left-turning vehicles, as these usually have positive superelevation (i.e. sloping towards the centre of the turn radius) and are effectively a single negotiation radius.

- A 40m maximum path radius achieves a marginally higher speed environment than desirable. However, it is surmised that if drivers have to undertake "S" manoeuvres to achieve this then vehicle speeds may be acceptable (such as for straight-through alignments). This tendency is best understood when considered from a driver comfort point of view. Undertaking two opposing turns of the wheel in quick succession is more demanding (and uncomfortable) than what might otherwise be simply the negotiation of a single radius curve. Figure 1 in the Appendix demonstrates this for the straight-through vehicle path.

- Larger maximum path radii than the above do not achieve the low speed environment that is desired for cyclists.

7. Frost Road / Carr Road Intersection

The single-lane Frost Road / Car Road roundabout in an industrial area of Mt Roskill in Auckland was redesigned in 1999 to improve its capacity. One of its approaches was amended to provide for two entry lanes of reduced width (5.3m kerb to kerb), which large trucks straddle rather than travel alongside other vehicles (see Figures 7.1 and 7.2). This approach is marked for two lanes some 100m upstream of the roundabout. From observations as well as a review of the site's crash history, it has shown to be a practical concept and is the basis for the "C" Roundabout design.

Although there have been some reported non-injury sideswipe crashes between car traffic when entering the roundabout, it is expected that new roadmarking on the confined circulating carriageway will address this. It is proposed to confirm this with a 'before' and 'after' conflict study before the "C" Roundabout is implemented.

Figure 7.1 Semi-trailer straddling both entry lanes while entering the Frost Road / Carr Road roundabout from the Carr Road approach.

Figure 7.2 Views of smaller vehicles approaching the roundabout from Carr Road.

8. The “C” Roundabout

A generic design has been prepared for roundabout design at a typical four-way cross intersection in an urban area - the Cyclist Roundabout or “C” Roundabout. A preliminary design guide is attached in the Appendix.

In order to achieve the 30 kph speed environment, the roundabout entry width is narrowed to 5.4m so that larger vehicles do not attempt to enter alongside other vehicles (see Figure 8.1). These narrow lanes also encourage cyclists to travel in the centre of the lane, which is desirable for their safety and amenity. In turn, circulating carriageway width can be reduced which helps to facilitate an overall speed reduction on the roundabout.

The design process was an iterative one involving differing combinations of central island diameters and approach angles for side roads. The 20m central island diameter as shown in Figure 1 of the Appendix was chosen because, for a four-way junction, it provides an optimum configuration for the desired maximum path radii as recommended in Section 6.3. This being for around 30m for left-turn movements, and 40m for straight-through movements with an “S” type alignment.

The “C” Roundabout now needs to be trialled and proven in practice. Scheme plans have been prepared for two sites in Manukau City (Bader Drive / Robertson Road and Lambie Avenue / Cavendish Drive) that include two options for each site. One option at the Bader Drive / Robertson Road location retains the existing large central island (see Figure 8.2). An option at the Lambie Avenue / Cavendish Road site includes both dual lane approaches as well as additional left-turn slip lanes for improved capacity (see Figure 8.3)

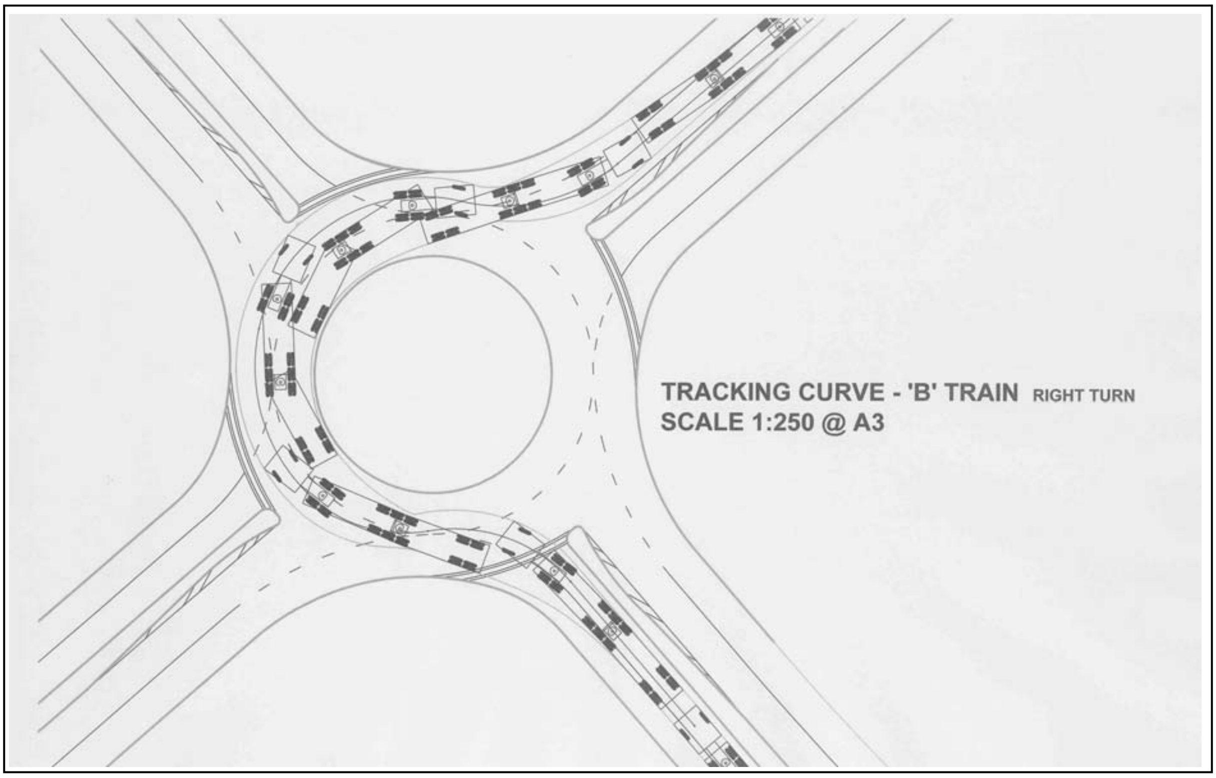

Figure 8.1 “B” train undertaking a right-turn at the “C” Roundabout.

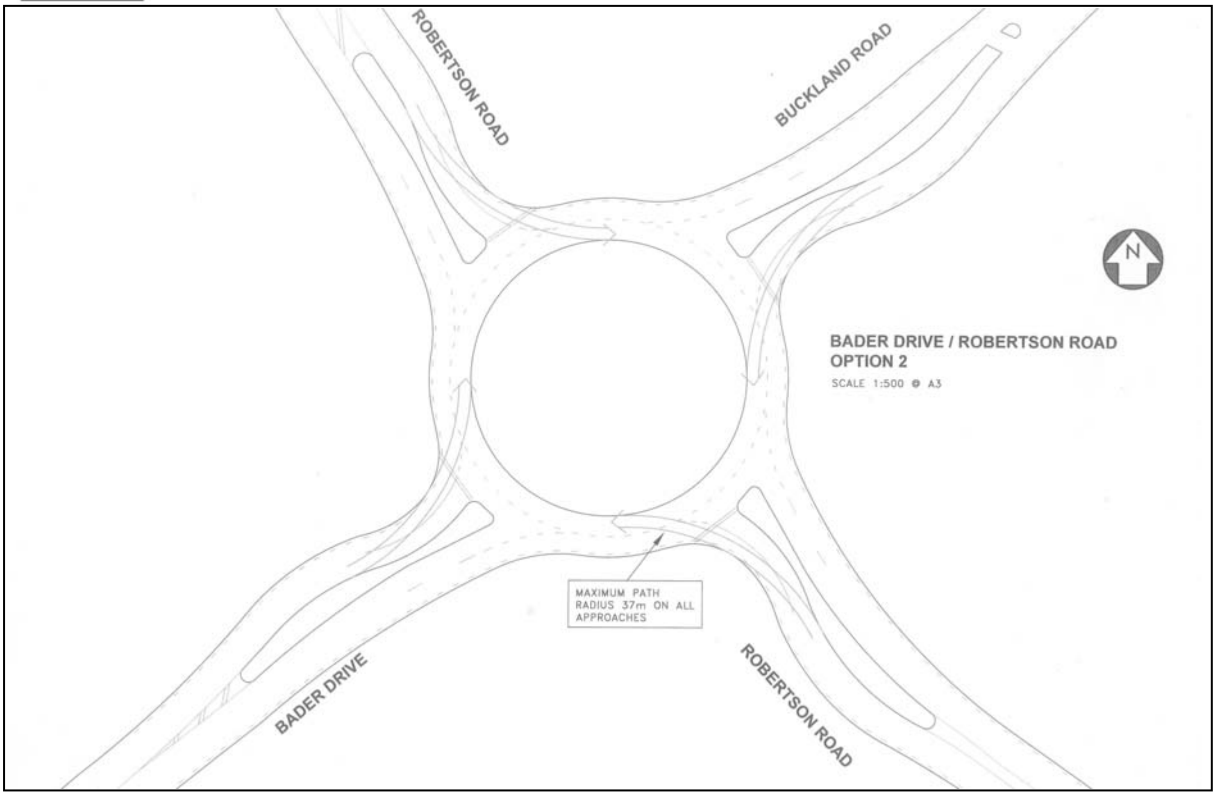

Figure 8.2 Alternative Design at Bader Drive / Robertson Road in Manukau City that retains the existing 45m diameter central island.

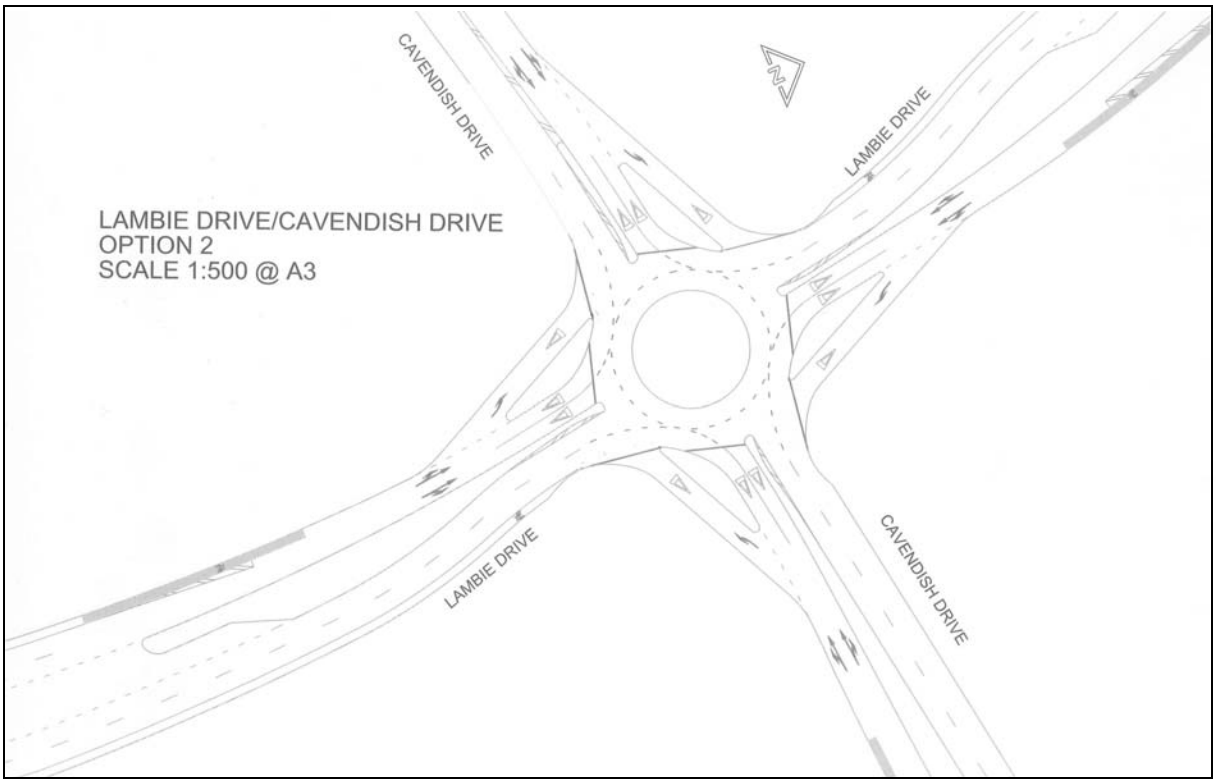

Figure 8.3 Option for Lambie Drive / Cavendish Drive in Manukau City that includes left-turn slip-lanes for additional roundabout capacity. Note some approaches are dual-lane and are shown with merge areas upstream of roundabout entries.

9. Roundabout Capacity Study

To assess impact on roundabout capacity, it was initially proposed to compare gap acceptance behaviour at two roundabouts of differing geometries. If critical gaps or follow-up headways were predicted to be lower for the "C" Roundabout, then it was assumed that capacity would be increased and vice versa.

Two roundabouts with similar separation between roundabout legs were chosen for comparison. The first (the 'higher speed' design) has a standard configuration with 100m maximum path radii. The second (the 'lower speed' design) has maximum path radii similar to the "C" roundabout of around 30 to 40m. The expectation was that during capacity conditions, operating speeds at the lower speed roundabout would be less than the higher speed design, and that this might relate to differing gap acceptance behaviours by drivers entering the roundabout. However, field surveys were undertaken and they showed peak hour operating speeds were very similar for the two roundabouts, and therefore gap acceptance behaviour would not be affected.

The narrow entry width of a "C" Roundabout allows only a single large vehicle through at a time. However, unless heavy vehicles numbers are substantial which is usually not the case, the impact on capacity would not need to be considered.

10. Recommendations

The main recommendations of this research are:

1/ That the "C" Roundabout be installed and trialled at the two sites in Manukau City.

2/ That further research on the use of vertical deflection devices, visibility guidelines at roundabouts, cyclist priority laws in The Netherlands, and a review of the 'turbo-roundabout' from The Netherlands be undertaken.

References

Allott and Lomax (1991). *Cyclists and Roundabouts: A review of literature*. Cyclists' Touring Club. Technical Report. Godalming: Cyclist's Touring Club. 32pp.

Austroads (1993). *Guide to Traffic Engineering Practice, Part 6 - Roundabouts*. Austroads, Sydney, NSW. 86pp.

Austroads (1999). *Guide to Traffic Engineering Practice, Part 14 - Bicycles*. Austroads, Sydney, NSW. 154pp.

Beca Carter Hollings and Ferner Ltd (2005). Predicting Accident Rates for Cyclists and Pedestrians (Draft copy supplied by principal author Shane Turner February 2005). Land Transport New Zealand Research Report (unpublished to date). 141pp.

Campbell D R (2005). *Improved Multi-lane Roundabout Design for Cyclists*. Submitted Masters thesis, Auckland University. 84pp.

C.R.O.W. (1993). *Sign up for the Bike: Design Manual for a cycle – friendly infrastructure*. Record 10. Centre for Research and Contract Standardisation, Ede, The Netherlands. 325pp.

Davies D G, Taylor M C, Ryley T J, Halliday M E (1997). Cyclists at roundabouts – the effects of 'continental ' design on predicted safety and capacity. *Transport Research Laboratory, TRL Report 285.* 31pp.

Department For Transport United Kingdom (2003). *Cyclists at Roundabouts: Continental Design Geometry*. Downloaded from internet December 2004. 4pp.

Fortuijn L G H (2003). *Pedestrian and Bicycle-Friendly Roundabouts: Dilemma of Comfort and Safety*. University of Technology, The Netherlands. 20pp.

Franklin J (1997). *Cyclecraft – Skilled Cycling Techniques for Adults*. The Stationary Office, United Kingdom. 200pp.

Harper N J and Dunn R C M (2003). *Accident Prediction at Urban Roundabouts in New Zealand – Some Initial Results.* 26th Australasian Transport Research Forum, Wellington, Proceedings CD ROM, paper 53, October 2003. 15pp.

Rasanen M and Summala H (2000). *Car Drivers Adjustments to Cyclists at Roundabouts*. Traffic Research Unit, Department of Psychology, University of Helsinki. Downloaded from internet, October 2004. 15pp.

Schoon C and Van Minnen J (1994). The Safety of Roundabouts in The Netherlands. SWOV Institute for Road Safety Research, *Traffic Engineering and Control, March 1994: 142-148pp.*

Sharples R (1999). The Use of Main Roads by Utility Cyclists in Urban Areas. *Traffic Engineering and Control, January 1999: 18-22pp.*

Summala H, Pasanen E, Rasanen M, Sievanen J (1996). *Bicycle Accidents and Drivers Visual Search at Left and Right Turns.* Traffic Research Unit, Department of Psychology, University of Helsinki. Downloaded from the internet, October 2004. 7pp.

Swedish National Road and Research Institute (2000). What Roundabout Design Provides the Highest Possible Safety? *Nordic Road and Transport Research, No. 2*. 9pp.

The Highways Agency (2005). *Design Manual for Roads and Bridges: Volume 6.* Downloaded from internet June 2005. 20pp.

Appendix

PRELIMINARY DESIGN GUIDE FOR THE "C" ROUNDABOUT

1.0 Design Philosophy

The principle of the "C" Roundabout, is for unimpeded through-car speeds to be reduced to around 30 kph, a speed amenable to cyclists mixing with vehicle traffic. The geometric layout of kerblines is critical to this aim, and appropriate roadmarking and signage will assist in the operation of the "C" Roundabout.

2.0 General Principles

The "C" Roundabout design concept is for a confined geometry for all movements, but still with some acceptable allowances for driver manoeuvring within lanes. Generous widths on the roundabout circulating carriageway and exits will achieve this.

Entries should be wide enough to accommodate two large cars with adequate clearance, but sufficiently narrow to dissuade cars from attempting to pass heavy vehicles. Narrow lanes also encourage cyclists to travel in the centre of the lane, which is desirable.

The circulating carriageway should accommodate two large cars with comfortable clearances. It also should be wide enough for a single bus or preferably a "B" Train with adequate clearances from all kerbs.

3.0 Roundabout Entry Width

Entry width between kerbs should be 5.4m. This is to prevent cars attempting to enter adjacent to heavy vehicles, but also give minimum acceptable clearance between larger cars that enter side by side.

4.0 Vehicle Deflection Through the Roundabout

Desirably, a maximum path radius of 30m to 40m will be achieved for all movements including left and right turns and straight-through vehicles. This maximum path radius is of particular importance at the roundabout entry, as the majority of cyclist crashes occur here.

A typical layout as shown in Figure 1 with a 20m diameter central island and a 7m wide circulating carriageway, achieves a 40m path radius for through movements and 33.5m path radius for left-turns, and also accommodates a "B" Train with 0.5m clearances from kerbs.

5.0 Mountable Areas for Heavy Traffic

The central island should desirably have a strengthened kerb of up to around 0.5m wide that allows for some margin of error by heavy vehicle drivers. A kerb height of 150mm is recommended.

It is recommended that the kerbs on the roundabout approaches, including median islands, be constructed to allow for the occasional heavy vehicle infringement. If desired bollards can be installed to prevent this practice.

6.0 Road Marking and Signage

Roadmarking and signage for the "C" Roundabout are shown in Figure 2. They include a supplementary PW-25 '30' sign attached to the PW-8 'Rotary Junction Ahead' sign. Note however, attaching PW-25 to PW-8 signs is not currently permitted under the Manual of Traffic Signs and Markings (Transit NZ 1998)

Advance Direction Signage (ADS) on approaches, and prominent Intersection Direction Signage (IDS) at the roundabout are also recommended to avoid driver distraction.

Modified Alberta markings with additional markings on entries are recommended on roundabout entries to avoid sideswipe crashes relating to the confined geometry. Note that lane arrows are now required under Land Transport Rule: Traffic Control Devices 2004.

It is recommended that all kerbs within 30m of the roundabout be painted reflectorised white for improved conspicuity at night.

7.0 Other Design Issues

7.1 Cyclist Access to Head of Queues during Congested Periods

It is recommended that bypass paths for cyclists be considered to assist them get to the head of traffic queues in congested conditions. This path should take into account adjacent development and pedestrian activity. Exit and entry ramps for these are discussed in detail in Austroads (1999) Guide to Traffic Engineering Practice, Part 14 "Bicycles" Section 4.5.3. If there is reasonable pedestrian activity, then a separated path facility for cyclists may be desirable.

7.2 Roundabout Carriageway Crossfall

A crossfall of around 2% sloping towards the outside of the roundabout is recommended.

7.3 Service Covers

Service covers on the circulating carriageway are to be avoided where two-wheeled users are expected to track over them. If absolutely necessary then they should have treated surfaces for improved friction in wet conditions. Kerbside stormwater catchpits should be 'cyclist-friendly'.

7.4 Lighting

Given the relative low visibility of cyclists, a satisfactory level of lighting at the roundabout is important. Illumination should at least comply with Australian / New Zealand Standard 1158.1.1 (1997), and use of metal halide fittings is recommended for increased conspicuity of cyclists and pedestrians.

7.5 Sight Distance

Sight distance requirements as per Austroads (1993) Guide to Traffic Engineering Practice, Part 6 "Roundabouts" Section 4.2.7 should be provided, taking into consideration the lower speed environment of the "C" Roundabout.

7.6 Roundabout Approaches with Two Upstream Traffic Lanes

For entries with two approach lanes upstream, a merge area prior to the roundabout entry is required. This is to avoid larger vehicles entering the "C" Roundabout adjacent to other vehicles. This is described in more detail in the Land Transport New Zealand 2005 report "Improved Multi-lane Roundabout Design for Cyclists" (Campbell et al 2005)

References

Australian / New Zealand Standard 1158.1.1 (1997). *Road Lighting Part 1.1: Vehicular traffic (Category V) lighting – Performance and installation design requirements*. Standards Australia. 36pp.

Austroads (1993). *Guide to Traffic Engineering Practice, Part 6 - Roundabouts*. Austroads, Sydney, NSW. 86pp.

Austroads (1999). *Guide to Traffic Engineering Practice, Part 14 - Bicycles*. Austroads, Sydney, NSW. 154pp.

Campbell D R, Jurisich I, Dunn R C M (2005). Improved Multi-lane Roundabout Design for Cyclists (provisional title). Land Transport New Zealand Research Report (unpublished to date).

Transit New Zealand (1998). *Manual of Traffic Signs and Markings, Part I: Traffic Signs*. Transit New Zealand, Wellington.

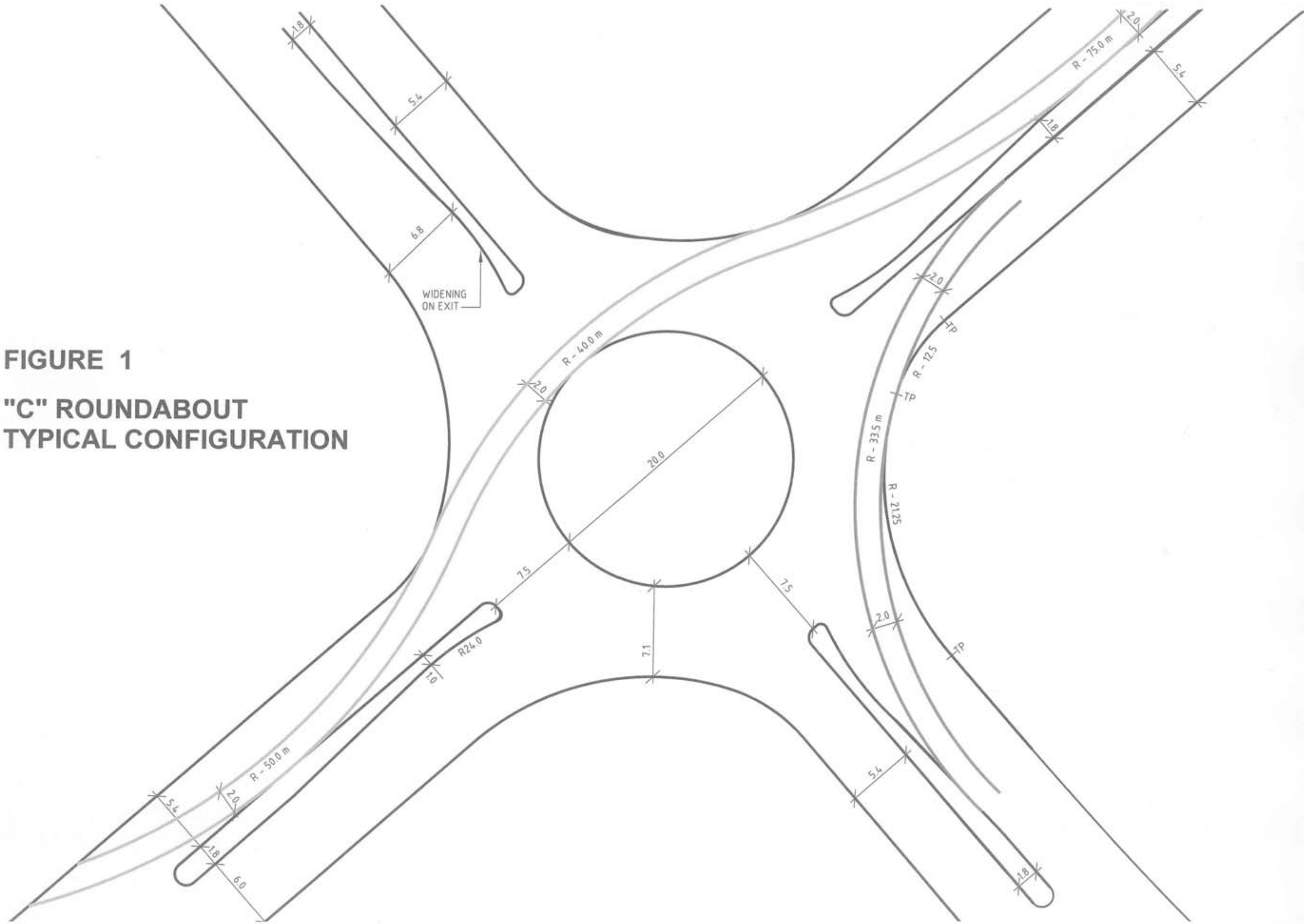

FIGURE 1

"C" ROUNDABOUT
TYPICAL CONFIGURATION

FIGURE 2

"C" ROUNDABOUT
ROADMARKING AND SIGNS DRAWING