Accidents at Roundabouts in New South Wales

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Abstract

A significant proportion of reported 2-party casualty accidents at roundabouts in New Wouth Wales (NSW) — 66% of severe or fatal accidents and 50% of all injury accidents — involved a pedestrian, cyclist or motorcyclist. More than 70% of these 2-party accidents to cyclists or motorcyclists involved circulating riders hit by entering motorists or riders hit from behind. Single vehicle accidents accounted for 40% of all severe/fatal accidents and 23% of all accidents at roundabouts.

The high proportion of single vehicle accidents and predominance of entering motorist/circulating rider accidents together suggest that excessive vehicle speeds, especially on the approaches, is a major contributory factor to accidents at roundabouts in NSW. Safety measures should therefore be directed at preventing these most common accidents types, e.g. by reducing speeds of those drivers who tend to approach at unsafe speeds. Also, motorists could be encouraged to take special care in looking out for cyclists when entering a roundabout and cyclists could be encouraged to position themselves where motorists are most likely to be looking, i.e. exactly where a car would be — in the middle of the circulating lane.

Over-representation of cyclists in accidents at roundabouts is indicated by the fact that only 6% of those injured at cross intersections in NSW were cyclists, compared with 18% at roundabouts. Motorcyclists were also over-represented in accidents at roundabouts. In non-metropolitan areas where cycling is more popular, 32% of those injured in 2-party accidents at roundabouts were cyclists. Furthermore, only 16% of reported accidents at roundabouts appear to be the fault of the cyclist. Safety of cyclists should therefore be an important consideration in the decision to design and build new roundabouts. Treatments other than a roundabout might be advised for intersections used by greater than average numbers of cyclists. In particular, for intersections with a history of accidents in which drivers have had difficulty realising they should give way, improved road markings might be considered.

Lane change accidents accounted for only 9% of accidents to cyclists at roundabouts, probably because the vast majority of roundabouts in NSW are single-lane. Therefore, the data analysed here do not invalidate overseas research that indicates multi-lane roundabouts are especially difficult and dangerous for cyclists.

Refereed Paper

This paper has been critically reviewed by at least two recognised experts in the field.

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Roundabouts are becoming increasingly popular as traffic control devices in Australia and other countries. Concerns have, however, been expressed about the safety of cyclists and pedestrians. In a literature review of cyclist safety at roundabouts in the United Kingdom (UK) , Allott & Lomax (1991) found the accident involvement rate of cyclists was 14 to 16 times greater than that of car occupants, and indeed the figure would be substantially higher if unreported accidents were taken into account.

In Australia, an investigation into accidents in a small country town — Armidale, New South Wales (NSW) — found clusters of cyclists' accidents at several roundabouts, but no other locations. A comparison of reported accidents to cyclists where medical attention was required, in approximately equal periods of time before and after construction of roundabouts at 4 central locations, found an increase from 1 in 12.0 intersection-years to 7 in 14.2 intersection-years. Furthermore, at all roundabouts in Armidale from 1989 to 1994, 57% of reported 2-party accidents requiring medical attention involved a cyclist and 79% involved a cyclist, pedestrian or motorcyclist.

The number of roundabouts in Armidale increased from 6 in 1990 to 9 in 1993, less than 2% of the 500 grade intersections. Despite this small proportion, 47% of all reported injury accidents to adult cyclists from 1990 to 1993 happened at roundabouts, compared with 12% for motorcyclists and 0.7% for other road users. Another 9 roundabouts have subsequently been constructed or are planned in Armidale, the majority being located near the CBD, a popular destination for cyclists, and a hub of pedestrian activities.

This note reports an investigation of injury accidents at all roundabouts in NSW to determine the proportion involving cyclists and other vulnerable road users and what attention needs to be focussed on the safety of cyclists and others at roundabouts, especially if cycling in NSW does indeed become more popular, or roundabouts continue to be built in ever increasing numbers.

REPORTED ACCIDENTS AT ALL ROUNDABOUTS IN NSW

The numbers of accidents at roundabouts in NSW from 1990 to 1994 are given in *Table 1*, together with percentages involving injury. The accidents listed (henceforth called 'reported accidents') are those which happened on public roads, were reported to police and involved injury or a vehicle being towed away (RTA 1994). The data show no obvious trends in severity or type of accidents, or type of road users involved. The increase in numbers of accidents over time is probably due to construction of new roundabouts.

Single vehicle accidents

A significant proportion of accidents involved only a single vehicle. This was especially true of the more severe accidents (see *Table 2*). For example, 40% of severe (hospital admission required) or fatal accidents at roundabouts happened when a vehicle failed to stay on course, either running off the road or into a parked car or other object, without any other road users recorded as involved. This suggests a significant cause of serious accidents at roundabouts is excessive approach speed. Loss of control on a roundabout will result in a single vehicle accident only if no other road users are in the way. Substantially more than just the 40% of severe/fatal accidents and 23% of all accidents may therefore have been caused by excessive speed.

This strongly suggests one way of reducing accidents at roundabouts is to reduce approach speeds. For existing roundabouts, one option might be to introduce 40 or 30 km/h speed limits for a certain distance before the roundabout and enforce the limit by speed cameras if necessary. For new roundabouts, design criteria such as deflection angle and

Table 1

Numbers of reported accidents at all roundabouts in NSW and percentage involving injury

Year	1990	1991	1992	1993	1994	All
Number of accidents	833	908	936	1060	1144	4881
Percentage involving injury	41	33	37	34	35	35.9

Table 2

Characteristics of single vehicle accidents at roundabouts in NSW

Degree of accident	Severe/Fatal	Any Injury	All accidents
% involving only 1 vehicle	40.0	24.5	22.7

circulating lane width may also help achieve reductions in approach speeds.

Table 3 shows a breakdown of single vehicle accidents by severity of accident and road user type.

Two-party accidents

Table 4 gives the percentages of cyclists, pedestrians and motorcyclists involved in 2-party accidents (i.e. those involving 2 or more road users) at roundabouts, and for all reported accidents in NSW. Cyclists were significantly over-represented in injury accidents at roundabouts (22% vs 7%). Motorcyclists were also over-represented. The proportion involving pedestrians, though relatively high, was no greater than for all roads in NSW. This suggests that, though not particularly bad for pedestrians, roundabouts are not particularly beneficial either, casting doubt on their use to improve safety in areas of high pedestrian activity. Overall, half of all 2-party injury accidents at roundabouts involved a cyclist, motorcyclist or pedestrian, as did 66% of severe/fatal accidents.

Metropolitan vs country urban and rural areas

One possible explanation for the over-representation of cyclists at roundabouts might simply be a tendency to install roundabouts in urban areas where there are more cyclists. The lack of over-representation for pedestrians suggests this is probably not the case. However, to confirm that location and consequent variation in cycling activity was not unduly influencing the comparison, the proportion of injury accidents at roundabouts involving cyclists was calculated separately for the Sydney metropolitan region, other urban areas of NSW (roads with speed limit known to be ≤ 80 km/h) and other areas. Reported accidents to cyclists generally involve another road user, so results are given both for all 2-party injury accidents and all injury accidents (see *Table 5*). For comparison, *Table 5* also shows cyclists as a percentage of total road casualties by area from a limited dataset for the period January to September 1995.

Consistent with census figures showing a lower proportion of people cycled to work in Sydney, *Table 5* shows that injury accidents in the Sydney metropolitan region involve a lower percentage of cyclists than in the rest of NSW. However, cyclists were over-represented 2–3 fold in accidents at roundabouts both in Sydney and in other urban areas. Indeed, at roundabouts in urban areas excluding Sydney, cyclists accounted for almost a third of 2-party injury accidents and 57% involved a cyclist, motorcyclist or pedestrian, as did 71% of all 2-party serious injury accidents.

Another way of assessing the relative dangers is to compare the percentages of accidents at roundabouts which involved cyclists with percentages for other types of intersections, roads or road features (see *Table 6*). Of all road features or intersection treatments, roundabouts stand out clearly and significantly with the highest percentage of injury accidents involving cyclists (18.3%; $\chi^2 = 300.8$; $P < 0.0001$). Altogether, 51% of cyclists' accidents were at intersections, and another 9% at driveways. The other most common other identifying feature was a steep grade or crest (21% of cyclist accidents). Only

Table 3

Road users involved in single vehicle accidents at roundabouts (%) by severity of accident

	Car	Motorbike	Truck	Bicycle	Other
All accidents	74.1	13.0	8.6	1.9	2.4
All Injury accidents	50.6	32.4	8.3	5.0	3.8
Severe/Fatal accidents	52.3	34.6	9.3	1.9	1.9

Table 4

Percentage of accidents involving a cyclist, pedestrian or motorcyclist in NSW

	Bicycle	Pedestrian	Motorbike	Any of these
2-party accidents at roundabouts[1];				
All accidents	7.9	4.1	6.6	18.4
Injury accidents	22.3	11.5	16.6	50.0
Severe/fatal accidents	22.6	20.2	25.6	66.1
All reported accidents in NSW, 1992–94:				
All accidents	2.7	6.4	3.9	13.0
Injury accidents	6.8	16.3	9.8	32.9
Severe/Fatal accidents	4.9	20.6	11.9	37.4

[1]Bike/Pedestrian, Bike/Motorbike and Motorbike/Pedestrian accidents represented 0.02%, 0.02% and 0.08% of accidents at roundabouts, i.e. essentially negligible.

Table 5

Percentage of injuries and injury accidents at roundabouts and throughout NSW involving pedal cyclists by area and accident severity — severe or fatal (S/F) or all injury accidents (A.Inj)

	% of injury accidents at roundabouts[1] involving cyclists				% of all injury accidents in NSW[2] involving cyclists			
	% 2-party inj. accs		% All injury accs		% inj. accidents[3]		% of casualties	
Area	S/F	A.Inj	S/F	A.Inj	S/F	A.Inj	S/F	A.Inj
Sydney Metropolitan	16.7	18.0	10.6	14.8	4.1	5.6	3.3	4.1
Other urban	31.9	29.1	20.5	23.2	6.0	10.0	4.9	7.4
Non urban/Unknown	0.0[4]	30.0[4]	0.0[4]	28.6[4]	0.8	1.2	0.6	0.9
Total	22.6	22.3	14.6	18.1	3.7	6.0	3.0	4.5

[1]Jan 1990-Dec 1994. [2]Jan-Sept 1995. [3]Estimated from numbers of casualties using 1992–94 averages of 1.34 casualties per injury accident and 1.23 severe/fatal casualties per severe/fatal accident and 1 cyclist injured per cyclist injury accident. [4]Unreliable figure - only 21 accidents were recorded at roundabouts in non urban/unspecified areas.

0.3% of accidents to cyclists happened on 1-way roads, so while they may cause more problems for cyclists than other road users, the overall risk of 1-way roads is still relatively small.

Roundabouts accounted for 9% of cyclist intersection accidents. While this may not seem a high proportion, roundabouts are not yet particularly common. Armidale, where a little under 2% of intersections are roundabouts, may be typical or even above average. However, almost as many roundabouts are proposed for Armidale as currently constructed. Given the increased accident rate relative to other intersection treatments, the risk will increase as construction continues, unless modifications can be made to improve safety for cyclists.

Nature of accidents at roundabouts

Road user movement (RUM) codes and directions of travel were investigated to determine the nature of vehicle/cyclist accidents. One party is labelled a key vehicle, described in the Roads and Traffic Authority (RTA) coding handbook as 'that vehicle considered to have played the major role in the accident'. The key vehicle in a give-way intersection accident is therefore the one which was on the minor road and should have given way. At roundabouts, the same rules do not apply, so, as in other special cases, the key vehicle will not always be responsible for the accident. An example is code 21 (right thru) where the key vehicle is circulating to turn right but has priority over entering traffic.

Table 6

Percentages of severe/fatal (S/F) and all injury (A.Inj) accidents involving cyclists, Jan 1990 – Sept 1995, by intersection type or road feature

Accidents at intersections			Not at intersections			Identifying features of accident		
	S/F	A.Inj		S/F	A.Inj		S/F	A.Inj
Roundabout	14.1	18.3	1-way road	14.5	10.8	Bridge/causeway	2.4	3.2
Cross	5.3	6.4	2-wy undivided	4.0	6.0	Steep grade/crest	5.4	6.7
T	7.6	8.7	Divided freeway	1.8	2.0	Drivewy/entrance	10.5	11.8
Other	9.9	9.7	Other divided	4.9	7.2	Poor surface	5.4	6.8
All intersections	6.9	8.1	All non intersectns	4.0	6.1	Other/No feature	4.6	6.8

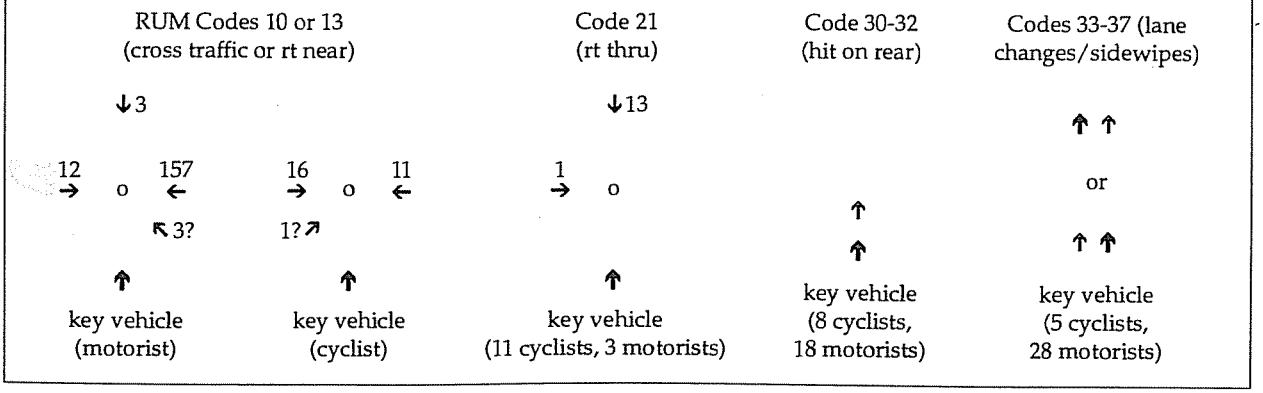
Two-thirds (68%) of 2-party accidents to cyclists at roundabouts were code 10 (cross traffic) accidents, one of a series of codes for traffic travelling from adjacent directions (i.e. at right angles). A further 2%, coded 13 (right near), appeared similar to code 10 accidents, except that the entering (i.e. key) vehicle probably intended to turn right, but for the collision. *Diagram 1* illustrates travel directions relative to the key vehicle. The motorist was the key vehicle in 86% of cases, and 90% of these would appear to be straightforward cases of entering vehicles hitting circulating cyclists. In three cases, the cyclist was listed as going in the same direction as the motorist (e.g. both going north or both west), but on a different road. Such accidents may have happened at 5- or 6-arm roundabouts, for which directions (given only as 4 points of the compass) cannot be resolved accurately. *Diagram 1* therefore shows the most likely scenario — that the cyclist entered from a road on the motorist's right going in a similar direction to the motorist's road.

Diagram 1 also illustrates the other main codes — lane change sideswipes, rear end collisions and right turn accidents. The small number of cross traffic accidents in which the cyclist was the key vehicle follow a different pattern to those with a motorist key vehicle. In the majority of cases, the motorist comes from the cyclist's left. It is not known whether these were entering/circulating accidents where the motorist was actually responsible or whether the accidents happened on circulating/exiting and the cyclist was considered responsible. Coding of lane change accidents (defined in relation to vehicles travelling in the same direction) may cause some confusion in the case of roundabouts where vehicles were travelling in different directions before the roundabout! However, such accidents represent a relatively small proportion of total bike/motorist accidents.

Of the 93% of bike/vehicle accidents shown in *Diagram 1*, cyclists were apparently responsible for

Diagram 1

Numbers of bike/motorist accidents at roundabouts by direction of key (bold arrow) and other vehicle and road user movement (RUM) code (most frequent codes only, 93% of total).



44/276 (16%) compared with 84% for motorists. The most frequent types were circulating cyclist/entering motorist accidents (157 accidents coded 10 and 13; 11 coded 21), lane changes or sideswipes by motorists (28 accidents) and cyclists hit by motorists from behind (18), which together comprise 72% of all bike/motorist accidents at roundabouts. The high proportion of entering motorist/circulating cyclist or rear end accidents (62% of all bike/motorist accidents), in conjunction with the relatively high percentage of single vehicle accidents noted earlier, suggests excessive approach speeds are a significant cause of accidents and that a proportion of motorists are tending to approach roundabouts too fast to see and safely give way to circulating cyclists.

A similar picture emerges for 2-party accidents to motorcyclists (see *Diagram 2*). Some motorcyclists may also approach roundabouts too fast, as is clear from the fact that 38% of motorcyclist accidents at roundabouts involve only the motorcyclist and equally many rear end accidents were caused by the motorcyclist as the other motorist. In total, 77% of the 2-party accidents to motorcyclists in *Diagram 2* seem to have been caused mainly by the other motorists, the most significant proportion involving circulating motorcyclists and entering cars.

For all 2-vehicle accidents, the picture is again similar (see *Diagram 3*). Those considered as above to be mainly entering/circulating accidents represented 60% of all 2-party accidents, followed by accidents that involved hitting the rear of another vehicle (15%). Lane changes, sideswipes or overtaking accidents amounted to 8% of 2-party accidents. All the above suggest lane change accidents may not be as important as entering/circulating accidents and the main thrust of road safety measures should be directed at slowing down those motorists who tend to approach and travel through roundabouts at unsafe speeds.

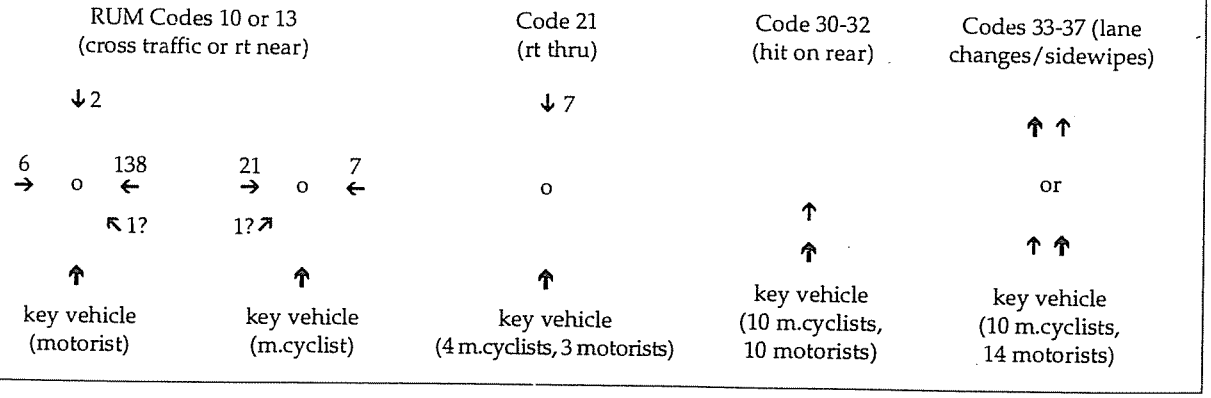
Small-scale before/after comparison

Table 7 shows a comparison of accidents to cyclists and other road users at 4 give-way intersections in a small country town (i.e. Armidale, NSW) when roundabouts were constructed. Accidents involving cyclists increased from 1 in 12 intersection-years to 7 in 14.2 intersection-years. In all but one accident, circulating cyclists were hit by entering motorists. Over the same period, total reported accidents requiring medical attention fell from 23 to 11. However, the vast majority (16/23) of 'before' accidents occurred in the year or so prior to construction. The decision to build a roundabout may well have been influenced by the immediately preceding accident rate. After adjusting for these 'regression to mean' effects, the 'before' rate of approximately 1 injury per intersection-year is only a little higher than after roundabouts were constructed.

Another confounding factor is that the reporting rate for cyclist injury accidents is only a sixth of that for other road users, according to local hospital records (GHD, 1996). Indeed, casual conversations revealed 3 unreported cyclists' injury accidents to

Diagram 2

Motorbike/other motorist accidents at roundabouts by direction of key vehicle (bold arrow) and road user movement (RUM) code (most frequent codes only, 95% of motorbike/motorist accidents. Includes one rear end accident involving two motorcyclists.)



add to the 'post-roundabout' periods in *Table 7*. After accounting for differences in reporting rates of cyclist and motorist injury accidents, it is therefore possible that construction of roundabouts actually increased injury accidents. However, before construction only 4% of those injured at the intersections were cyclists, compared with at least 64% afterwards. Accidents to cyclists at roundabouts have continued. For example, in 1995, 3 out of 5 reported injury accidents, for which motorists appeared responsible, were at roundabouts.

Note the roundabouts in question are small radius single-lane roundabouts. Allott & Lomax (1991) reported these were safer for cyclists than conventional roundabouts. However, small-radius, single-lane roundabouts in the UK are often of a special type known as a mini roundabout. Such roundabouts are installed only on roads with speed limits of 30 mph (48 km/h) and drivers may slow well below this limit to ensure they can see and give way to circulating traffic. In contrast, it is not uncommon to observe drivers in Armidale approach roundabouts at speeds in excess of 50 km/h. The critical aspect for safety may therefore relate less to roundabout size than actual approach speeds of drivers.

DISCUSSION

The relatively high proportion of accidents at roundabouts in NSW which involve cyclists, compared with other intersection types, and the nature of these accidents — mainly entering motorist/circulating riders, suggest that roundabouts, especially those with high approach speeds, can be a problem for cyclists. The critical effect of low vehicle speeds for improving safety, was highlighted by a study in the UK of 23 roundabouts where the size of the central island was reduced to provide greater circulating capacity. A resulting 91% increase in casualty accidents was attributed to higher vehicle speeds (Austroads 1993). High vehicle speeds were also considered by Wisdom (1992) as a major contributor to problems

Table 7

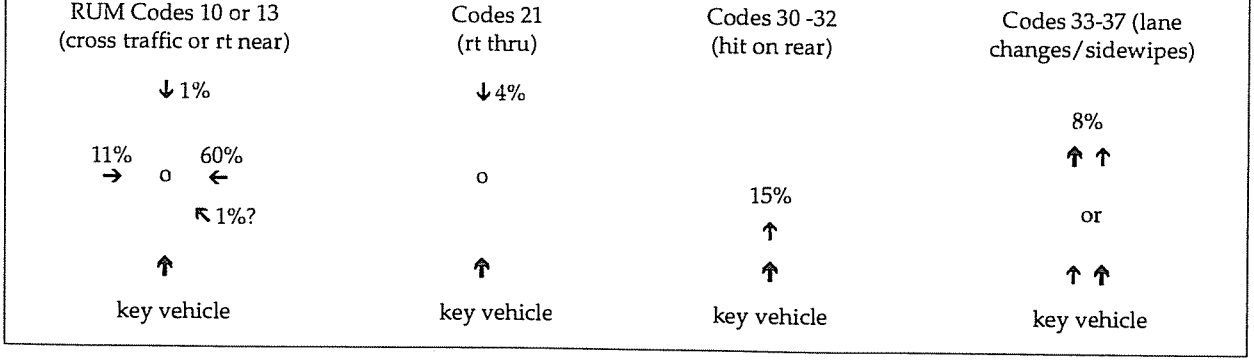
Accidents requiring medical attention before and after construction of roundabouts at 4 central intersections, Armidale, NSW

Inter-section	Date r'bout constructed	No. of Years		Cyclist injury accs		All Injury accs	
		Before	After	Before	After	Before	After
NDo	6/89	3.5	3.5	1	2	6	3
MDu	6/89	3.5	3.5	0	2	9	2
MR	5/88	2.4	4.6	0	2	5	3
MDo	5/91	2.6	2.6	0	1	3	3
Total		12.0	14.2	1	7 (10)[1]	23	11 (14)[1]

[1]Figures in brackets include known, but unreported injury accidents.

Diagram 3

All 2-vehicle accidents at roundabouts by direction of key (bold arrow) and other vehicle and road user movement (RUM) code (% of most frequent codes only, equalling 92% of 2-vehicle accidents).



for cyclists at roundabouts, with strong relationships noted between bicycle accident rates and roundabout geometry. Wisdom adds: 'At existing roundabouts, installation of speed reduction devices such as speed humps on the approaches may reduce vehicle speeds (and so improve cyclist safety) without unduly affecting capacity.'

Lane change accidents were not a particularly high proportion of total accidents to cyclists at roundabouts in NSW. This may simply be a consequence of the numbers of single- and multi-lane roundabouts in the State, rather than relative dangers. However, unless prohibited by congestion, approach speeds, as well as circulation and exit speeds, are likely to be higher on multi-lane roundabouts. Allott and Lomax (1991) reported that multi-lane roundabouts are generally the most feared and avoided by cyclists. A specific investigation of multi-lane roundabouts in NSW would reveal whether the main dangers are caused by higher vehicle entry speeds or because cyclists also experience difficulties changing lanes in fast moving traffic.

Until more is known, cyclists (and perhaps all traffic) might be permitted to make use of the outermost lane of a roundabout, even when turning right. Vehicles changing lanes on roundabouts might be required to give way to vehicles continuing in the same lane. Because of the additional threat posed to cyclists, pedestrians and motorcyclists, who suffer half of all 2-party injury accidents and 66% of 2-party severe/fatal accidents, double-lane roundabouts, which encourage higher entry and circulating speeds, should be considered only when there is a clear need for additional capacity.

Perhaps the greatest problem for cyclists in NSW, exacerbated by high approach speeds, was the risk of being hit by entering motorists. Therefore, the greater the distance cyclists are able to leave between themselves and entering motorists, the safer they are likely to be. Allott & Lomax (1991) commented:

> *Experience in Hertfordshire (UK) indicated the edge 1.5 metres of a roundabout can be the most dangerous area for cyclists, as drivers entering the roundabout do not readily perceive movement in this areas. Accordingly, this area was hatched as an experiment at a large roundabout in Hertfordshire in order to push cyclists into the line of vision of drivers entering the roundabout. Early results indicate a decline in accidents, including those involving cyclists.*

Conversely, advisory cycle lanes on the perimeter of a roundabout may have the opposite effect of encouraging cyclists to ride closer to entering motorists, reducing the margin for error if drivers approach too fast and also positioning cyclists where they are less likely to be seen by drivers looking only in the area where they expect to see other motorists. Wallace (1992) reported one scheme in Cambridge, UK, involving 'an on-highway circumferential advisory cycle lane round the perimeter of a large roundabout ... the accidents involving cyclists *increased* fairly dramatically after a short period and the scheme was taken out'. This research suggests trialling layouts to direct cyclists away from the outer edge of roundabouts to ascertain whether such a treatment might be helpful in reducing the entering vehicle/circulating cyclist conflict.

In Australia, many towns have streets laid out in a grid arrangement. The need to give way is indicated on the minor road by a triangular 'give way' sign on a pole often at the end of a row of street trees and an (often faded) dashed line across the road. Therefore, the primary problem is often the difficulty in realising which road has priority. Construction of a roundabout with its inherent much greater visibility is thus bound to reduce accidents caused by failure to perceive which road has priority. However, other solutions may also be effective. One method, similar to the way a roundabout sign is duplicated on a splitter island, is to duplicate the 'give way' sign on a specially constructed median island. This treatment has generally been found to reduce accidents, often substantially. A problem is that drivers tend to scan the carriageway immediately ahead of the road and there is evidence that even this treatment may not be sufficient to convey the correct message to inattentive drivers. Observation of a problem intersection in Armidale, NSW, already furnished with a second 'give way' sign on a splitter island, found 14% of drivers passing through the intersection either did not slow at all or slowed only minimally, indicating some drivers still had problems perceiving the need to give way (Witherby 1994). A study of police P4 collision reports of all accidents at this intersection found that injury accidents almost invariably happened when drivers from one direction on the non-priority road hit vehicles on the priority road at speeds of 30 km/h or above (Robinson 1995). If such accidents were eliminated by improving drivers' perception of the need to give way, remaining injury accidents would have been lower than expected with a roundabout, which was proposed at an

estimated cost of $250,000 (Robinson 1995). One suggestion adopted in the UK is a white triangle marked on the carriageway (see *Figure 1*). A high-visibility paved threshold entry treatment across the minor road might be used to similar effect. These may be effective low-cost solutions for intersections where the accident history, or observation of driver behaviour, indicates drivers have difficulty realising they have to give way. They probably represent safer solutions for cyclists and motorcyclists, and might be considered in locations where cyclists or motorcyclists are expected to represent a significant proportion of casualties if a roundabout is constructed.

The use of roundabouts on low-traffic streets, especially those used by greater than average numbers of cyclists, is also questionable. A study of roundabouts constructed in Stirling, Western Australia, found that at low-volume sites, or where there is an imbalance of traffic flow and average of one accident per year, there was no probability of accident reduction and a possibility of increased accidents (Austroads 1993). This suggests roundabouts installed as traffic calming devices may not be particularly effective and use of other devices which lower vehicle speeds without increasing risk to cyclists may be preferable.

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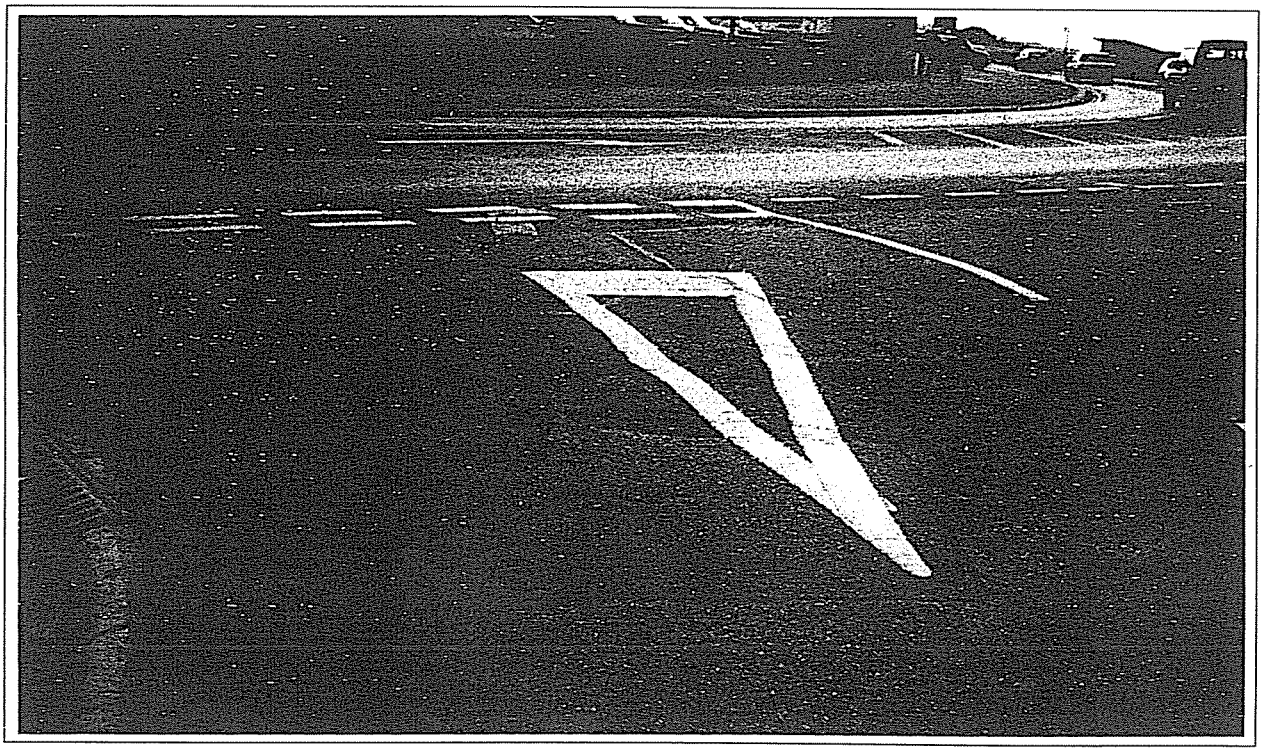

Figure 1
Highly visible intersection marking used in the UK to tell drivers to give way

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