

A

MEMBER

THE

GROUP

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PREFACE

Transfund New Zealand commissioned Traffic Design Group of Lower Hutt to prepare this report.

One of the benefits claimed for safety audits is that it increases the awareness of safe design practices. The findings of individual safety audits are not usually published. Thus the mechanism for raising this awareness is slow. Therefore Transfund has commissioned reviews of audit reports to disseminate their main findings to the profession. The most recent review, undertaken by Traffic Design Group, was of audits of roundabouts. The report of their review was published as Transfund Report RA96/559S "Review of Safety Audits of Roundabouts".

Practitioners involved in the design of roundabouts said that the information contained in Report RA96/559S should be supplemented by giving practical examples of problems and solutions.

Traffic Design Group have selected examples from 50 audit reports. These examples are typical but cannot claim to cover the full range of issues identified in the audit reports. So readers are urged to seek specific advice on particular matters and not rely solely on this report.

While every effort has been made to ensure the accuracy of this report, it is made available strictly on the basis that anyone relying on it does so at his/her own risk without any liability to Transfund New Zealand or Traffic Design Group.

Further information may be obtained from:



Ian Appleton
Safety Audit Manager
Transfund New Zealand
P O Box 233 1
Wellington
New Zealand
Ph +64 4 495 3271
Fax +64 4 499 0733
Email ian.appleton@transfund.govt.nz



Gary Clark
Traffic Engineer
Traffic Design Group
P O Box 30-72 1
Lower Hutt
New Zealand
Ph +64 4 569 8497
Fax +64 4 569 2398

INTRODUCTION

The purpose of this booklet is to draw attention to those elements of the design and construction of roundabouts which safety auditors have frequently found to be deficient

This publication was commissioned following a review of 50 safety audit reports of New Zealand Roundabouts, the results of which were presented at the 1998 Traffic Management Workshop in Hamilton.

It summarises the results of this review, highlighting the key issues raised by the reports and providing auditors' comments alongside examples of good design.

The purpose of this booklet is to draw attention to those elements of the design and construction of roundabouts which safety auditors have frequently found to be deficient, and to present some solutions commonly applied to address these reported deficiencies. While key issues are highlighted, this document should not be treated as a design guide.

Appropriate standards and guidelines are already in place to assist designers and other professionals in providing safe and comprehensive designs. However, the users of these design guidelines must understand the basic concepts that are needed to ensure road users' safety. Guidelines, standards and research data such as AUSTRoads, Transport Research Limited and other similar publications provide a useful tool for practitioners but are often referred to only after things go wrong.

ROAD SAFETY AUDITS

Road Safety Audits were introduced to address safety issues resulting from poor design, lack of resources, and land constraints. The task of an auditor is to methodically assess the design of a project, highlighting potential problems and identifying possible mitigation measures to address the identified problems.

Audits are carried out at various phases of the design process and at the end of the construction phase so as to ensure that the final project provides a safe and efficient addition to the road network. There are five stages at which an audit may usefully be undertaken, as follows:

Stage One – Feasibility Phase

Stage Two – Assessment Phase

Stage Three – Final Design Phase

Stage Four – Pre-opening Phase

Stage Five – Post-opening Phase

An audit is not necessarily undertaken at every stage, particularly for a relatively low cost project such as a roundabout.

As part of the audit process, the auditor's comments and recommendations are passed to the road controlling authority, which is then responsible for reviewing the matters raised by the audit and implementing any safety improvements considered necessary. The audit process then intends that the roading authority respond to the auditor as to how or whether the identified problems have been addressed. In practice, however, this final phase of the audit process often appears to be overlooked.

The audit process provides useful feedback to practitioners and improves their skills for other projects. Most importantly, the audit process highlights areas requiring attention so as to reduce accidents and provide a safer roading environment for all users.

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LIST OF COMMON ROAD SAFETY PROBLEMS AT ROUNDABOUTS

The results listed below were obtained from a previous report produced by Transfund and Traffic Design Group which detailed the most common problem areas identified by road safety auditors during the various audit stages.

PROBLEM	PERCENTAGE
Signs	15%
New Markings	9%
Cyclists	7%
Inadequate Deflection	7%
Delineation	6%
Lane Configuration	6%
Pedestrians	6%
Visibility	6%
Sight Lines	6%
Pole Location	5%
Lighting	5%

The most common problems with roundabouts were identified by safety auditors as relating to the location, appropriateness, size and quantity of signs. Poor signage can lead to a variety of road safety problems, including poor driver guidance, high approach speeds and poor driver recognition of intersection control.

The next most common problem area identified by the auditors was the issue of road markings. Typically, the plans provided insufficient or incorrect markings, and in as-built situations, markings were frequently confused by underlying old markings which had not been properly removed.

Other key issues raised by the auditors included lack of proper consideration for cyclists and inadequate deflection as motorists approach the intersection.

The most common problems with roundabouts were relating to the location, appropriateness, size and quantity of signs.



COMMONLY IDENTIFIED DESIGN PROBLEMS

The use of detailed checklists is an integral part of the road safety audit procedure. This ensures a methodical and consistent approach is taken for every project. During the audit process, members of the team are expected to imagine what it is like to drive, ride and walk as they approach, negotiate and leave the roundabout intersection.

This section of the booklet illustrates these common problems from a user's viewpoint and suggests possible remedies as recommended by safety auditors.

Signs

- Advance Direction Signs
- Recognition of Central Island

Pedestrians

- Inadequate Provision
- Poorly Located

Road Markings

- Poor Lane Markings
- Old Road Markings

Cyclists

- Location of Services

Inadequate Deflection

- Insufficient Approach Deflection
- Poor Median Island Alignment

Delineation

- Poor Lighting

Visibility

- Visibility Restricted by Vegetation

ROUNABOUT ACCIDENTS

Road User Type

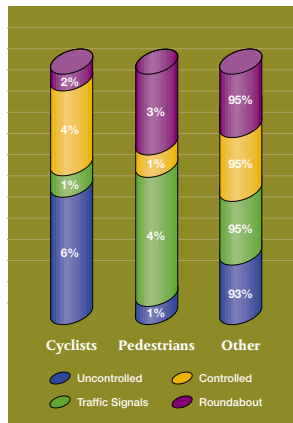
Recent times have seen the introduction of roundabouts as the preferred intersection treatment for existing uncontrolled, controlled and traffic signal junctions because of the possible capacity and safety benefits that can be achieved.

Some road users however are disadvantaged by the introduction of roundabouts because of their free flowing design and operating characteristics. Pedestrians and cyclists are usually the most affected by the introduction of a roundabout and careful consideration must be given to ensure potential safety reductions anticipated for vehicles are not lost with increases in accidents for other road users.

A search was made of the Land Transport Safety Authority accident database to identify the types of controlled intersections including roundabouts, traffic signals and priority control for the years 1994 to 1998.

Accidents were then grouped into three road user types: cyclists, pedestrians, and other (cars, trucks etc).

The results of this search have been graphed below:



As shown, cyclists account for 6% of accidents at roundabouts, 1% at traffic signals and 4% at priority controlled intersections, further highlighting the need for special consideration for cyclists at roundabouts.

ACCIDENTS INVOLVING VULNERABLE USERS

However, pedestrian volumes at signalised intersections would probably be higher than at roundabouts, therefore giving an artificial result.

The following table gives further details about accidents, and their severity for each of the intersection types.

	Roundabout			Traffic Signals		
	Cyclist	Ped	Other	Cyclist	Ped	Other
Fatal	9%	18%	73%	7%	28%	65%
Serious	29%	13%	58%	7%	23%	70%
Minor	22%	6%	73%	0%	12%	88%
Non Inj.	2%	0%	98%	1%	0%	99%
TOTAL	6%	1%	93%	1%	4%	95%

	Controlled			Uncontrolled		
	Cyclist	Ped	Other	Cyclist	Ped	Other
Fatal	5%	5%	90%	2%	14%	84%
Serious	12%	6%	82%	5%	13%	82%
Minor	12%	4%	85%	6%	9%	85%
Non Inj.	1%	0%	99%	0%	0%	100%
TOTAL	4%	1%	95%	2%	3%	95%

As shown, accidents involving road users other than cyclists and pedestrians are around 95% for each of the junction types. As one would expect, reported non-injury accidents for cyclists and pedestrians are noticeably fewer in number than for other road users.

PEDESTRIANS

Inadequate provision for pedestrians

Roundabout junctions tend to be unfriendly to pedestrians because of their free flowing nature and the fact that crossing points generally need to be further from the intersection than for conventional intersections.

Providing adequate facilities for pedestrians at roundabout junctions requires careful attention to the needs of all road users. Facilities must be provided as close as possible to the desired pedestrian paths to ensure their effectiveness.

Safety Issues

Inadequate pedestrian provisions at roundabouts can lead to:

- Rear end accidents resulting from poorly sited crossing locations.
- Severance of existing pedestrian routes without making suitable alternative provision.



Pedestrian ramps leading nowhere

Solutions

- Clear, safe guidance of pedestrian to appropriately located facilities.
- Provision of guard fences and hand-rails to control pedestrian movements.
- Locating pedestrian facilities as far from the roundabout as possible without reducing the attractiveness of facility.



Good pedestrian design with linking paths and clear visibility

PEDESTRIANS

Poorly located pedestrian facilities

Consideration of pedestrian needs should always be an integral part of the design process for a roundabout. Because it is generally unsafe to cross directly across the circulating roadway, or directly across the entry or exit points, the safest locations for pedestrians to cross may not be on their natural “desire lines”.

Pedestrian provisions at all locations including roundabouts should avoid creating problems for people with disabilities.

Safety Issues

Poorly designed pedestrian facilities can lead to:

- Poor intervisibility with approaching drivers.
- Inadequate stopping sight distance for motorists.
- Crossing points not being located on pedestrian desired routes.
- Poor design or lack of provision of drop-crossings.



Shadow across crossing and vegetation hiding pedestrian

Solutions

- Always ensure adequate intervisibility between drivers and pedestrian facilities.
- Realign adjacent footpaths to guide pedestrians to crossing locations.
- Judicious planting/street furniture/fences to discourage pedestrians from crossing at hazardous locations.
- Ensure that all pedestrian crossing points have smooth kerb ramps.



Good clear sight lines with pedestrian and motorist

DEFLECTION

Inadequate deflection of roundabout approaches

A properly designed roundabout can provide safe and efficient movement of vehicles. When replacing traffic signals, uncontrolled or controlled intersections with a roundabout, generally a reduction in accidents occurs.

Established practice, supported by the recognised Design Guidelines has shown that vehicles travelling through the roundabout should not travel a path greater than 100 metres radius. The tighter the radius, the slower the vehicle will enter the roundabout.

Safety Issues

Inadequate deflection on approaches will result in higher approach speeds and this may lead to:

- Failure to give way to vehicles already on the roundabout.
- Rear end collisions when vehicles brake suddenly.
- Loss of control accidents within the area of the roundabout.



No deflection for straight through traffic

Solutions

Depending upon when this deficiency is identified, the most satisfactory solution will be to redesign the roundabout so as to meet established guidelines. This may include:

- Moving the centre of the roundabout.
- Increasing the diameter of the central island.
- Modifying the approach geometry .
- Increasing the deflection by realignment of the approach kerblines or splitter islands.
- Greater use of roadmarkings, including raised reflective pavement markers.



Deflection provided

DEFLECTION

Poor splitter island alignment

The splitter islands on the roundabout approaches provide important cues to the driver as to the angle and/or radius of approach on entry to the roundabout, which the driver is then able to relate to the speed at which the entry to the roundabout can be negotiated.

Safety Issues

Poorly designed and/or located splitter islands may lead to:

- Loss of control accidents.
- Drivers incorrectly assessing appropriate approach paths.
- Failure to give way accidents.



*Badly aligned median with sharp transition.
Roadmarking needs to be altered*

Solutions

- Ensure drivers are guided around the roundabout and not through it.
- Smooth transitions must be provided along edge of the splitter island to ensure approach speeds are reduced gradually (ie avoid abrupt deflection at entry to the roundabout).



*Good deflection of median further
highlighted by roadmarking*

ROADMARKINGS

Poor lane marking configuration

Motorists and other road users require clear, unambiguous guidance as to the correct travel path for each road user and who has priority when the travel paths of various road users intersect. Although signage is important, properly designed roadmarkings should provide the primary means of guidance.

Poor or insufficient roadmarkings can confuse road users and provide little guidance for the driver approaching and travelling through the roundabout. One of the most common problems occurs at multi-lane roundabouts where no guidance is provided within the circulating roadway.

Safety Issues

Inadequate or poor roadmarkings can:

- Lead motorists into unsafe situations and confuse motorists.
- Reduce the capacity of the roundabout to handle the intended traffic volumes.
- Increase speeds through the roundabout.
- Lead to unexpected weaving manoeuvres through the roundabout or on the approaches.



Multi-lane roundabout providing no guidance to motorists in the circulating roadway

Solutions

- Ensure roadmarkings provide a clear indication of what is expected of the driver and other users of the roundabout.
- Remove old roadmarkings to avoid confusion.
- Provide roadmarkings within the circulating roadway.
- Adopt a consistent marking style with nearby roundabouts.



Good clear roadmarkings provide motorists with clear instructions

ROADMARKINGS

Old road markings

Motorists require good clear signage and markings to ensure correct decisions are made when approaching, entering and exiting any intersection. The removal of old signs and markings is important and will reduce any possible confusion about what is expected of the motorist at these junctions.

Safety Issues

Old signs and markings need to be removed otherwise motorists are not provided with correct information:

- Old markings can lead motorists into the path of an oncoming vehicle, particularly at night.
- Old signs may incorrectly inform motorists.



Old markings confuse pedestrians and motorists. Redundant reflective markers misguide motorists

Solutions

- Permanently remove all old markings.
- Remove all redundant signs.



Good clear roadmarkings

SIGNAGE

Poor destination signing for drivers

Motorists unfamiliar with the area require good advance signing and guidance to their destination. This is particularly important on both urban and rural arterials.

The provision of good signage allows motorists to plan their route in advance of the roundabout, adjust their speed, and select the appropriate lane from which to enter the roundabout.

Safety Issues

Inadequate or inappropriately located advance warning and directional signage can lead to:

- Confusion for unfamiliar drivers seeking a particular location.
- The inability of the motorists to anticipate the type of junction ahead.
- Reduced driver's vision.
- Last-minute or unexpected lane changing when destination information is provided too late.



Destination signs hide approaching vehicles

Solutions

- Provide larger warning signs on high speed approaches to a roundabout and/or increase the number of warning signs; ie one on each side of the roundabout approaches.
- Install large advance directional signs for major urban and rural roundabout junctions especially at high speed locations.
- Ensure signs do not obstruct critical sight lines.



Good clear directions given to motorists in advance of the roundabout

SIGNAGE

Recognition of central island

Motorists unfamiliar with the intersection require appropriate information and guidance to enable the correct vehicle paths to be taken. Results from audits have shown that the central island within a roundabout should be carefully signed so as to improve its visibility.

Poor central island recognition may lead to motorists colliding with or driving through the central island.

Safety Issues

Lack of central island recognition can lead to:

- Motorists losing control because of failure to see central island.
- Vehicles driving through central island.
- Rear-end accidents due to sudden braking
- Inability to determine appropriate roundabout speeds leading in turn to accidents resulting from failure to give way.



Poor central island design leading to a lack of island recognition

Solutions

- Raising central island to improve its visibility.
- Chevron signing to highlight central island radius.
- Lighting of central island at night.
- Design of splitter islands to guide motorists around central island.



Raised central island improves the intersection control and its recognition

VISIBILITY

Visibility Restricted by vegetation

The design of approach lanes must be such that the available visibility is sufficient to allow approaching vehicles, cyclists or pedestrians to be clearly seen and in adequate time for appropriate decisions to be made. The safe and efficient movement of traffic relies on good unobstructed lines of sight. Likewise, pedestrians also need clear lines of sight to approaching traffic. Appropriate types of vegetation need to be used which will not intrude on sight-lines, and should be regularly maintained so as to ensure adequate sight-lines are available at all times.

Safety Issues

Inadequate or obstructed lines of sight can result in motorists being unable to identify hazards as they approach and enter the roundabout:

- View is obstructed by signs/vegetation creating blind spots for drivers.
- Efficiency of the roundabout is affected because of extra delays associated with poor visibility.
- Signs and vegetation hide smaller and/or slower moving road-users such as pedestrians or cyclists.



Approaching vehicles are hidden by vegetation

Solutions

- Ensure a regular maintenance programme is in place such that the height of any vegetation does not intrude on sight lines.
- In critical areas provide hard surfaces rather than planting.
- Relocate vegetation away from critical line of sight triangles.
- Remove inappropriate vegetation and plant low ground cover plants.



Excellent visibility provided for motorists

DELINEATION

Poor lighting

Lighting of the roundabout junction was also high on many auditors' lists of matters requiring more attention to detail. All too often the lighting of the roundabout is designed at the last minute or in some cases, completely overlooked.

Safety Issues

Poor or inappropriate lighting of a roundabout junction can lead to motorists entering the intersection with inadequate information which can lead to:

- Confusion, causing emergency braking and/or collision
- Loss of control night-time accidents
- Delays due to poor guidance to motorist



Streetlights lead motorists straight through the roundabout

Solutions

- Consider more lanterns and/or greater luminance.
- Consider central island lighting column.
- Use of reflectorised paint on kerbs and install reflective markers around islands.
- Ensure that all physical elements including splitter islands are clearly lit.
- Adjust lighting on approaches, as necessary to ensure that the junction is recognised.



Street lighting highlighting roundabout and its approaches

CYCLISTS

Poor facilities

Cyclists are generally poorly catered for at roundabouts, and poor design can force riders into kerbs or service covers.

Safety Issues

- Stormwater grates, particularly where the grates are orientated parallel to the roadway, are a real hazard for cyclists.
- Cycle lanes, where they are provided along a route typically stop short of roundabouts.
- Large roundabouts with higher circulating speeds create difficulties for cyclists.
- Inadequate lane widths, particularly on circulating roadways shared with heavy commercial traffic.



End of spitter island is beyond sump forcing rider to the left and onto stormwater grate

Solutions

- Avoid use of stormwater grate patterns which are parallel to the direction of travel.
- Avoid locating any service covers within the travelled way.
- Provide adequate clearances to heavy vehicle tracking paths in the design phase.
- Provide adequate circulating lane widths to properly accommodate cyclists.



Typical cycle treatments used overseas

STREET FURNITURE LOCATION

Poor location of lighting poles, signs and other fixed obstructions

The redevelopment of an existing intersection to form a new roundabout can often mean that existing service poles and/or trees, while not on the carriageway itself, are located much closer than previously and may either provide a hazard to errant vehicles and/or restrict lines of sight on the roundabout approach.

Safety Issues

Poor location of street furniture can lead to:

- Motorists hitting obstructions.
- Poor intervisibility with other road users.



Poor location of solid concrete lamp-post on approach

Solutions

- Move lighting columns to back of footpath and use frangible poles
- Ensure signage is kept clear of sight lines.



Street lighting poles located well clear of kerbs

SUMMARY

In summary, this booklet endeavours to raise designers' awareness of some issues in need of particular attention when constructing or altering roundabouts.

Some of the identified problems highlighted by safety audits can easily be modified during the design process. If poor design is left unchanged, the necessary alterations to rectify the roundabout design could be costly.

Therefore when designing roundabouts, engineers should use all the resources available such as guidelines, standards and technical publications. A safety audit and/or review should always be considered.

Ian Appleton

Safety Audit Manager

Transfund New Zealand

P O Box 2331

Wellington

New Zealand

Ph +64 4 495 3271

Fax +64 4 499 0733

Email ian.appleton@transfund.govt.nz

Gary Clark

Traffic Engineer

Traffic Design Group

P O Box 30-721

Lower Hutt

New Zealand

Ph +64 4 569 8497

Fax +64 4 569 2398

Email gpc@tdg.co.nz

