Department of Transport

Commentary Document

Compact Roundabouts

in Rural High-Speed Environments

RDN 04-03

October 2021

Abstract

This Road Design Note (RDN) provides commentary to the compact roundabout development and design process.

Key Information

This RDN must be read in conjunction with Austroads Guide to Road Design (AGRD) Part 4B: Roundabouts and the Victorian Department of Transport (DoT) Supplement to AGRD Part 4B.

DoT encourages innovative approaches to improve road safety that come at a reduced cost or are more appropriate for the context needing to be considered at specific locations, including minimising environmental and cultural heritage impacts. Compact roundabouts for rural high-speed environments are a new form of treatment that present an opportunity to achieve high levels of safety at lower costs in certain contexts. As a result, definitive design standards and values have yet to be produced. To support innovation, help ensure consistency and assist in understanding emerging best practice, DoT should be provided with key design information during the development and design stages of compact roundabouts in high-speed settings (generally ≥ 80 km/h). This information will help inform more definitive design standards and values moving forward. As per all designs, decision making should be documented in an accompanying design report, required to be prepared for each location.

The information in this document focuses on aspects of compact roundabout development and design that vary from or add to the information in AGRD Part 4B and the DoT Supplement.

Purpose

This document has been produced to compile existing knowledge and learnings about compact roundabouts in rural high-speed environments from experience and activities within Victoria and from other jurisdictions. Most of this information has been collected from the experiences associated with the rural compact roundabout at the intersection of Korumburra – Wonthaggi Road and Glen Alvie Road, Lance Creek (referred to as “Lance Creek compact roundabout” in this document).

Compact roundabouts for rural high-speed environments are a new form of treatment and have not been widely implemented. While they show potential to achieve high safety benefit at generally lower cost than conventional roundabouts in many locations, further sites are needed to establish a body of evidence regarding their effectiveness and the design specifics that need to be considered for different environments and contexts. Accordingly, this document should be taken as broad guidance only, and additional site-specific investigations and principle-based decision making will need to be conducted for each new project. This document encourages practitioners to understand the principles of development and design of compact roundabouts and to make design decisions based on these principles and the site-specific characteristics.

The Lance Creek compact roundabout is used as a specific case study in this document. It includes known performance, benefits, and challenges faced throughout the project with particular focus on the justification for the design principles and criteria adopted. The Lance Creek project was subjected to design reviews, risk assessments, and evaluations to increase the level of confidence in the design treatment. The findings have been detailed in the case study and are intended to provide learnings for designers and road safety practitioners to inform future projects.

List of Abbreviations

AGRD – Austroads Guide to Road Design
BCR – Benefit Cost Ratio
CRF – Crash Reduction Factor
ESLS – Electronic Speed Limit Sign
FSI – Fatal and Serious Injury
LTR – Load Transfer Ratio
OD – Over-dimensional
RDN – Road Design Note
RSP – Raised Safety Platform
RD&SSE – (Department of Transport) Road Design and Safe System Engineering Team

Contents

1. Compact Roundabout Definition

A compact roundabout is a roundabout with a central island radius smaller than those noted in AGRD Part 4B. In a rural high-speed setting (generally ≥ 80 km/h), this treatment is typically comprised of:

- A non-mountable central island
- A mountable concrete apron
- Raised safety platforms, as an alternative to reverse curves, to manage entry speeds of vehicles to match the operating speed of the circulating carriageway.

The size of the central island is larger than that of a 'mini roundabout', which have a maximum central island diameter size of 4m and are used in low-speed environments. Figure 1 and Figure 2 depict important components of compact and conventional roundabouts that are referred to throughout this document.

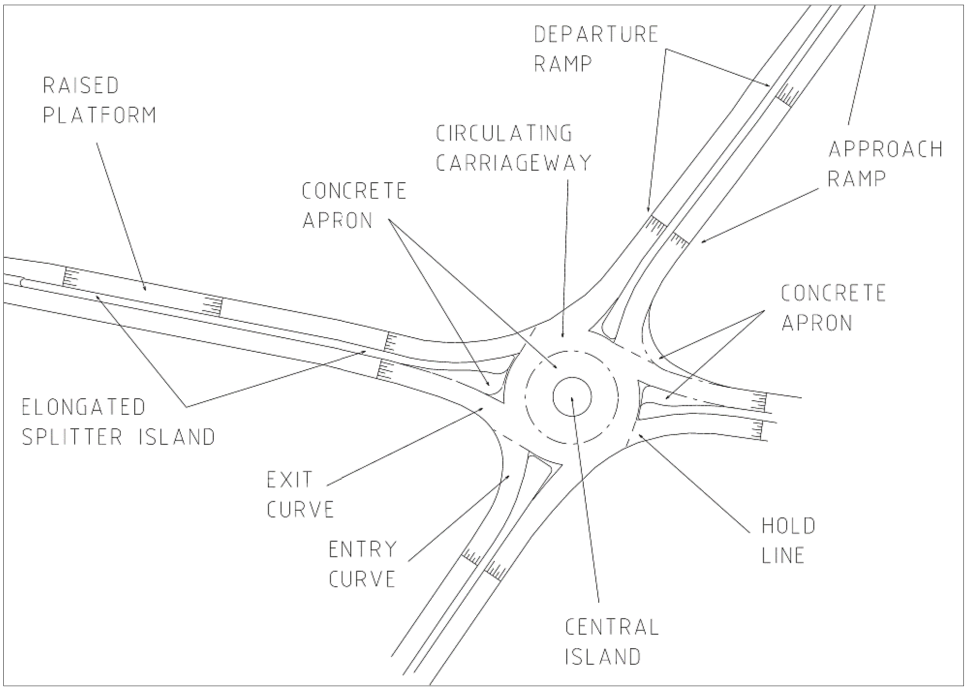


Figure 1: Important Components of Typical Compact Roundabouts

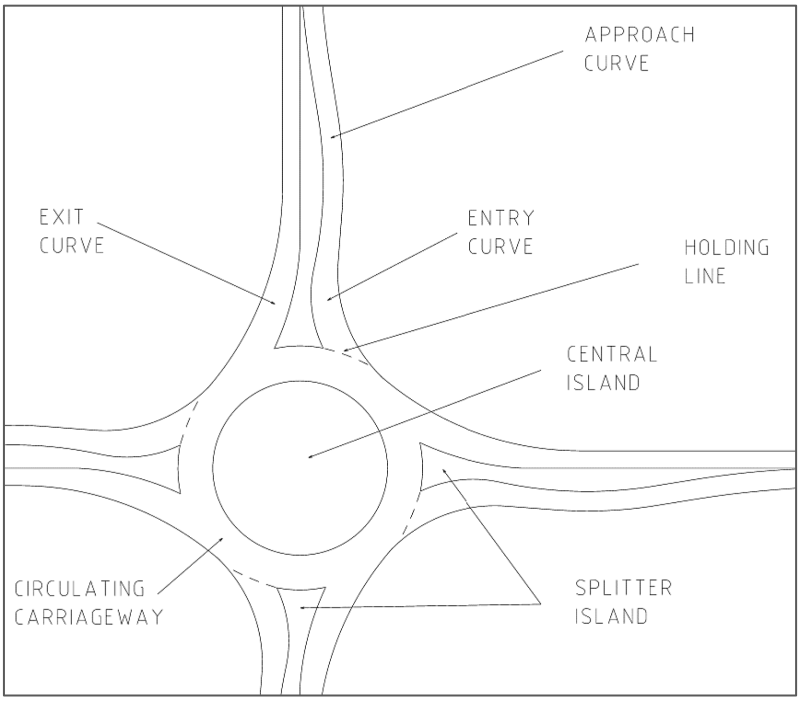
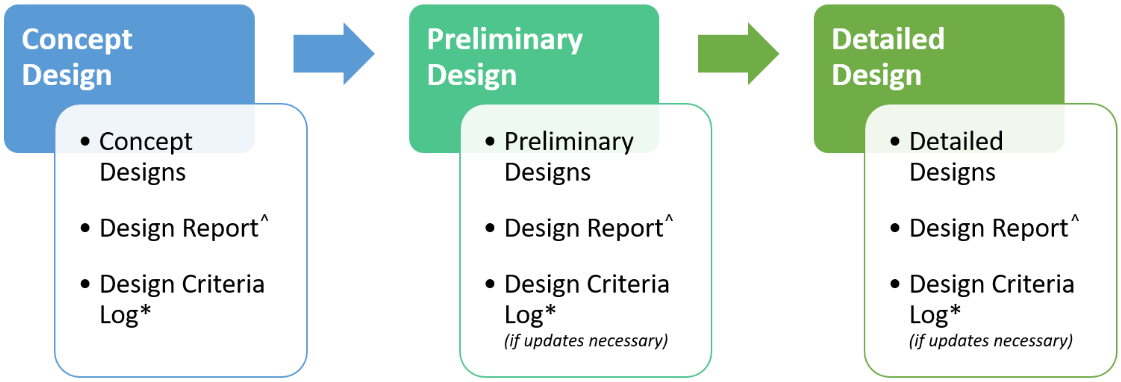


Figure 2: Important Components of Conventional Roundabouts

2. Evolving Best Practice

As compact roundabouts in rural high-speed environments are considered a new treatment within Victoria, it is essential that we learn from any future installations to better understand emerging best practice and inform more definitive design standards and values moving forward.

To help achieve this and ensure consistency in compact roundabout design, it is a requirement that key design information be shared with DoTs Road Design & Safe System Engineering (RD&SSE) team to add to the body of knowledge regarding their design, construction, and operation. Figure 3 details the information to be shared throughout the design process.



^ While a final version of a design report is not required during Concept and Preliminary stages of a project, relevant content should be captured throughout the evolution of a design and shared with RD&SSE.

* Refer **Appendix A** for further information regarding **Design Criteria Log**

Figure 3: Overview of design information to be shared with DoT throughout compact roundabout design process

Furthermore, it is recommended that associated design reports include a section focusing on roundabout design principles, established both within this RDN and AGRD Part 4B, to document how risk associated with an inability to meet any of these principles has been mitigated. An example Roundabout Design Principles checklist is provided in Appendix B.

Guidance on monitoring and evaluation, also key aspects of the knowledge capture process, is provided in Section 8 of this RDN.

3. Compact Roundabout Viability

Reducing crash risk at an intersection can be achieved with a variety of infrastructure countermeasures. The safety benefits of conventional roundabouts for passenger vehicle occupants are well known and universally accepted. Roundabouts are one of the few truly Safe System options for intersections, particularly on high-speed roads, but the costs associated are often prohibitive. This section considers different site conditions that may affect the decision to develop a compact roundabout treatment rather than a conventional roundabout.

3.1 Potential Cost Savings

Concept designs for conventional roundabouts have often been shown to be uneconomical and there has been a genuine desire by funders to find cheaper solutions. A compact roundabout offers such a solution by reducing the central island diameter and controlling speeds via means other than reverse curves, such as the use of raised safety platforms (RSPs) on the approaches. The reduction in the overall intersection footprint (when compared to a conventional roundabout) has the potential to reduce:

- the amount of land that needs to be acquired,
- impacts on vegetation,
- impacts on items with cultural heritage significance, and
- impacts on utilities.

If a compact roundabout cannot reduce some or all of these impacts, the relative cost savings are likely to be reduced and the decision to adopt a compact design in place of a conventional roundabout design should be revisited.

3.2 Considerations for adopting a roundabout

Before a compact roundabout design can be explored, thought must first be given to whether a roundabout is the right type of intersection form for the site in question. Aside from the safety benefits that a roundabout can provide, this will generally be based on the following considerations:

- **Network function.** *Will a roundabout cater to the needs of its road users?*
  Studies have shown that roundabouts more consistently perform closer to Safe System than conventional signalised and unsignalised intersections, making them a desirable road safety solution for many contexts. To achieve the best safety outcome for a roundabout, planners and designers must consider how a roundabout design will cater for the needs of all road users, and how this aligns with the desired function of the network. Metering or signalisation of roundabouts, the interaction of large vehicles and cyclists, and the provision of off-road facilities to cater for cyclists and pedestrian movements should be given due consideration.

- **Traffic performance.** *What is the target level of service at this intersection?*
  Where volumes on each leg are unbalanced, as often occurs at the intersection of busy arterial roads and local streets, delays on the minor legs can become excessive at roundabouts without additional treatments like metering signals on one or more approaches. This consideration is less important in rural areas, where volumes are usually low enough on the arterial road that they do not cause operational problems.

- **Vehicle types.** *What vehicles will be using this intersection and what are their requirements?*
  Where there are high volumes of large/heavy vehicles, such as on key freight or over-dimensional routes, roundabouts may not be suitable due to the difficulty for heavy vehicles to traverse the roundabout where gaps in the traffic flow on the circulating carriageway are short, or navigating the deflection associated with the circulating carriageway. Provision of a roundabout does provide priority for right turn movements once the (heavy) vehicle has entered the circulating carriageway which can aid those movements, however attention needs to be given to the crossfall on the circulating carriageway. Generally, when the central roundabout island is made smaller, the circulating carriageway needs to be wider to cater for the swept path of large vehicles. Balancing carriageway widths and central island size is explored throughout section 5 of this document.

3.3 Considerations for adopting a compact design

Once it has been established that a roundabout is the preferred intersection form, a decision on whether a compact design is suitable can be made. Beyond the considerations mentioned above, this decision will be influenced by several factors, which have been outlined below. While commonly considered when selecting any intersection form, these factors will generally hold a greater importance in determining the site suitability for a compact design.

- **The physical constraints at the site.** A constraints mapping exercise can help to determine the degree to which factors such as land acquisition, service relocation or environmental considerations will dictate the size of roundabout that can be provided.

- **The cost differential.** As mentioned in Section 3.1, the difference in cost between a conventional vs compact roundabout is dependent upon several factors. The decision to adopt a compact design should be made at the concept design stage after feasibility assessments and approximate costs for both conventional and compact design types have been determined. Understanding and balancing funding objectives in conjunction with established roundabout design principles is essential.

- **Topography.** Approach grades, crossfall and site topography will impact various roundabout design elements, including the slope of the circulating carriageway, size of the central island and, if adopted, RSP approach and departure ramp grades. While development of design solutions may be possible to overcome such challenges, these may come with an associated risk and/or additional financial cost to the project.

- **Number of lanes.** On multi-lane roads, multiple lanes will generally be required through the roundabout to retain the desired level of service on the road. There is currently no information available about the effectiveness of and the design approach required for a multi-lane compact roundabout, so the design and development of these facilities would require adoption of a principles-based design by a designer with strong roundabout design capability. This document does not cover those principles. Until such time that research and information on the performance of multi-lane compact roundabouts become available in high-speed environments, the use of single lane compact roundabouts is the only lane configuration accepted by DoT.
- **Noise.** Excess noise may be generated by vehicles traversing any vertical deflection associated with the compact roundabout (i.e. mounting/dismounting RSPs and rumble strips as required). When determining whether the location is appropriate for a compact roundabout, the acceptable level of noise generated by vehicles using the roundabout should be considered. This issue has the potential to generate significant community interest and should be a key consideration in the decision to adopt a compact design. Notwithstanding, results from the noise evaluation at the Lance Creek site have shown that excess noise has not been generated as a result of the project (see section 13).

Compact roundabouts may be suitable for use on high-speed (generally greater than 80 km/h) rural roads where it is not feasible to construct a conventional size roundabout in accordance with AGRD Part 4B, or where, following a risk assessment, a compact roundabout is considered to be a suitable alternative treatment to a conventional roundabout.

3.4 Undesirable characteristics

Compact roundabouts may not be suitable in the following circumstances:

- Where traffic modelling indicates that a roundabout will not perform satisfactorily or has the potential to divert traffic to less suitable routes.
- Where the design vehicle is particularly large, the size of the central island and/or circulating carriageway may need to be increased to meet operational requirements. The adoption of a smaller central island size has the potential to compromise the overall design and safety benefits of the treatment. Refer to section 5.3 for further information.
- On designated over-dimensional routes.
- Where the geometry adopted is likely to result in an unacceptable level of instability of heavy vehicles (including overturning).
- In extreme topography or where approach gradients are not suitable for RSPs.
- At sites with insufficient sight distance

4. Safety Implications

Provided compact roundabouts are designed to conform with overarching principles of roundabout design, they should theoretically provide comparable safety benefits. This has been the case for the Lance Creek Roundabout (see Lance Creek Case Study in Section 23). However, a larger body of evidence needs to be established to further quantify safety benefits and understand operational impacts on all road users, including heavy vehicles and motorcyclists.

From a Safe System principles perspective, both compact and conventional roundabouts should demonstrate a similar level of speed reduction and resulting operating speed at the roundabout hold line. The speed reduction method for conventional roundabouts in high-speed environments uses horizontal deflections on the approach to the roundabout that encourage the motorist to conform to a predetermined speed to navigate the intersection geometry. Compact roundabouts generally provide vertical deflections on the approach rather than horizontal deflections to achieve an equivalent outcome. Both forms of speed reduction are primary treatments within the Safe System Assessment framework.

The smaller central island associated with a compact roundabout can impact entry geometry (i.e. entry angles tend to be closer to 90 degrees), which can in turn lead to greater entering vehicle speeds than conventional roundabouts. This means that unless entry speeds are kept low, collisions may be more severe (both from speed and impact angle perspectives), and the need for effective speed control on the approaches becomes even more important. In addition, circulating speeds required for a vehicle turning at a compact roundabout are usually lower than those required at a conventional roundabout. Particular attention therefore needs to be given to achieve lower entry speeds to compact roundabouts in high-speed contexts.

At the time of publishing, due to the small number of these sites in Victoria, no formalised crash reduction factor (CRF) exists for compact roundabouts. Once enough sites have been built and a body of knowledge has been established, it will be possible to calculate a CRF. In the interim, it is recommended that the CRF for conventional roundabouts be used, noting that:

- The typically lower cost of compact roundabouts combined with the CRF of conventional roundabouts will generally produce a BCR in favour of compact roundabouts
- The general principles of roundabout design, as set out in AGRD Part 4B and in this document, must be followed to ensure that desired benefits are realised. Refer to Section 2 for recommended steps to help document project alignment with these principles
- The speed profiles on the approach legs at the Lance Creek site closely resemble those of a conventional roundabout.

5. Design Considerations

5.1 Approach Speed

5.1.1 General Principles of Conventional Roundabout Design

The approach and entry treatment are the most important geometric parameters to be designed at conventional roundabouts as they control the speed of entering traffic and consequently the safety performance of the roundabout. When aligned with Safe System principles, a well-designed conventional roundabout achieves lower relative speeds of vehicles primarily owing to the application of appropriate entry curvature, which limits the:

- speed on entry, which minimises the likelihood of rear-end type crashes;
- speed at which drivers can enter the circulating carriageway and the potential impact angle formed between entering and circulating vehicle paths. This reduces the severity and likelihood of side-impact crashes between these vehicle streams;
- speed achievable on the circulating carriageway. This minimises single vehicle crashes (loss of control) and the possibility of truck instability leading to overturning on the circulating carriageway or exit leg; and
- potential risk of a fatal or serious injury to pedestrians and cyclists in any potential impact/crash type (although the incidence of those crashes may increase).

These geometric elements, combined with the crossfall of the circulating carriageway, should all be considered together and assessed as to whether they will adequately accommodate turning manoeuvres, particularly for large and heavy vehicles. This is explored further in Section 5.1.2.3 (Entry Speed & Right-Turn Speed) and Section 5.3 (Central Island Size).

At conventional roundabouts, reverse curves are often used to gradually reduce the speed of vehicles in high-speed areas (≥ 80 km/h) and to improve approach alignment onto the roundabout. Each curve is designed to reduce approach speeds by around 20 km/h, with the final reduction to circulating speed occurring just prior to the holding line. Thus, in a 100 km/h zone, speeds reduce gradually from 100 km/h to 80 km/h, then 60 km/h, and finally to 40 km/h. It is this incremental reduction in approach speed that a compact roundabout seeks to replicate using methods other than reverse curves. Adoption of an appropriate entry curve radius approaching the roundabout is a critical component of ensuring effective speed management and impact angles at conflict points. This is illustrated in Figure 4 for both a conventional and a compact roundabout and discussed further in Section 5.1.2.3 (Entry Speed & Right-Turn Speed). Note that the first reduction in speed is achieved with a speed limit reduction from 100 km/h to 80 km/h.

The reduction in speed combined with the entry angle reduce kinetic energy such that vehicle occupants are better protected from injury in the event of a collision.

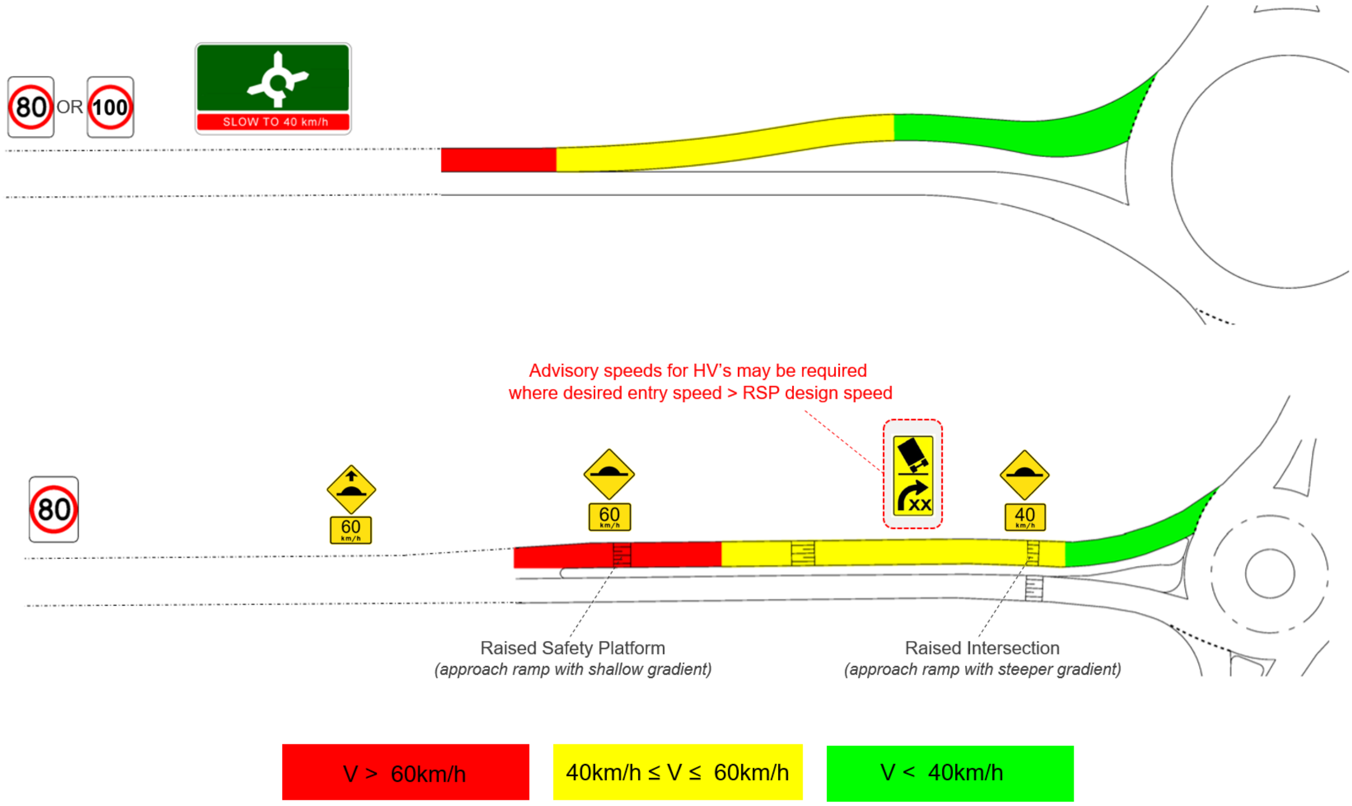


Figure 4: Visualisation of speed reduction logic on the approach to a conventional (top) and compact (bottom) roundabout (not to scale and not all signage shown)

Another important feature of approach geometry is that it informs the driver through a physical change in the road environment that they are approaching an intersection and therefore reducing the risk of an intersection crash. This aspect is common to both reverse curves and raised platform treatments.

5.1.2 Application at Compact Roundabouts

Aside from the use of reverse curves, a number of methods exist to reduce (or encourage drivers to reduce) approach speeds. These include:

- Raised safety platforms
- Extended median island kerb, combined with kerb on the left side of the approach lanes
- Rumble strips
- Perceptual line marking
- Advance warning signs
- Appropriate speed limit signs
- Lighting

At the time of writing, only RSPs provide a geometric solution to encourage vehicles to slow down and are therefore the only treatment that aligns with primary Safe System principles.

A number of platform configurations are possible on the approach to the compact roundabout. Two platforms are shown in Figure 5 and Figure 6. In Figure 5, the roundabout itself is raised and a platform is provided in advance to gradually reduce motorist speeds on the approach. In Figure 6, two separate RSPs are provided on the approach to the roundabout, which is at-grade. Further information about the RSPs is presented in Section 5.1.2.3.

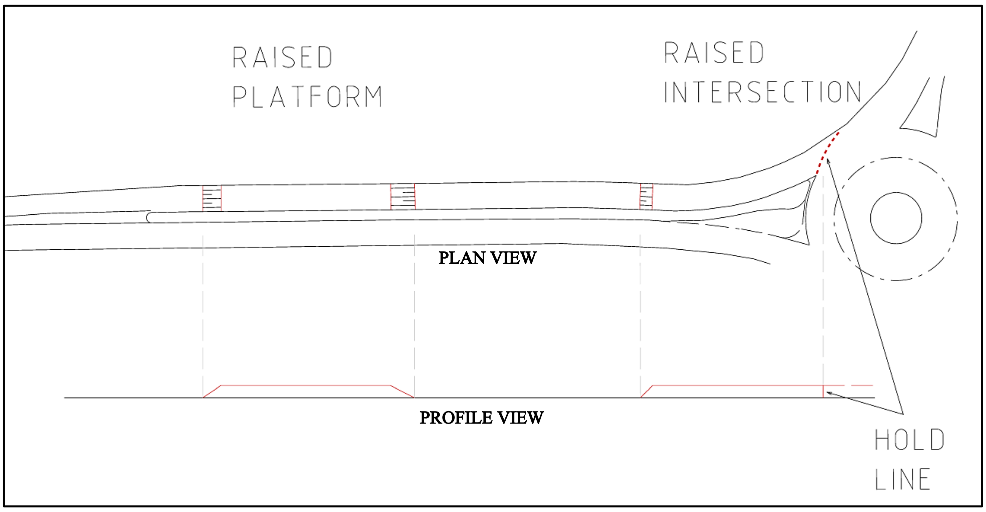


Figure 5: Profile of a compact roundabout with a raised intersection (not to scale)

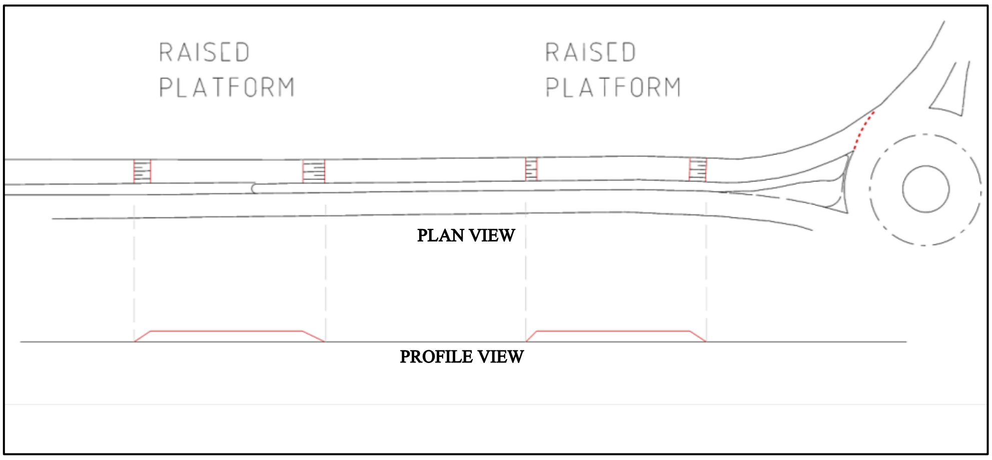


Figure 6: Profile of a compact roundabout without a raised intersection (not to scale)

5.1.2.1 Reverse Curves

There are several reasons why it may be less practical to provide reverse curves at a compact roundabout:

- The capital cost of the infrastructure, when the main aim of a compact roundabout is to reduce costs;
- The impact on the environment, cultural heritage, properties or utilities;
- The geometric relationship between the smaller central island diameter, the entry curve radius and the reverse curves compromises the ability to satisfy objectives for the design;
- The roundabout is located in a low posted speed environment.

Conventional roundabout design requires a correlation between the central island diameter, the entry curve radius, and the reverse curves on the approaches. The reduced central island diameter used at a compact roundabout does not allow for reverse curves to be designed to the desirable standards. Therefore, an equivalent speed reduction must be achieved on the approaches by other means to ensure that satisfactory safety performance is achieved at the intersection.

Note that speed reduction measures other than RSPs may be feasible, provided that comparable reductions in operating speeds are achieved (see section 5.1.2). If the volume of right turning traffic is significant, achieving speed reduction at the approach to the roundabout is particularly important due to the low turning speed required to ensure safe operation.

5.1.2.2 Entry Curve

The purpose of the entry curve of a compact roundabout is the same as that of a conventional roundabout in that it creates a horizontal deflection that:

- Modifies the angle of the vehicle entering the roundabout such that entry to the roundabout is tangential to the circulating carriageway;
- Provides the necessary horizontal deflection in combination with the central island that forces vehicles to slow down to the appropriate speed; and
- Controls the entry speed of vehicles into the roundabout to reduce the crash severity on vehicle occupants in the event of a crash and to facilitate safe speeds for traffic turning at the roundabout.

5.1.2.3 Entry Speed & Right-Turn Speed

As mentioned in Section 4, circulating speeds required to turn right at a compact roundabout will generally be lower than those required at a conventional roundabout. This is an important difference to consider, as it will have an impact upon the desired entry speed to ensure that such movements can be made safely.

It is therefore imperative that entry speeds be considered in combination with circulating speeds. As a roundabout design becomes more compact, the vehicle turning radii will be reduced and so too will the associated speeds at which these turns can be safely made. In some instances, this may result in design or check vehicle speeds as low as 5 to 15 km/h.

As per guidance provided in Table 4.1 of AGRD Part 4B, a decrease in speed between the entry curve and a right-turn on the circulating carriageway should be no greater than 20 km/h. Where speed differentials exceed 20 km/h, this has the potential to increase the number of single vehicle crashes on the circulating carriageway and/or adversely impact heavy vehicle stability. To address this, the following should be considered:

- Explore the potential of increasing the overall size of the roundabout to accommodate turning speeds within (or as close as possible to) the 20 km/h speed differential threshold between entry speeds and right-turn speeds.
- Adjust the proposed profiles of RSPs to achieve a lower entry speed. In some instances, this may result in a more severe ramp profile than those mentioned in Section 5.1.2.4 (Raised Safety Platforms) of this document.
- Provide advisory turning speed signs for heavy vehicles to advise operators of the reduced speed required to safely perform such movements.

5.1.2.4 Raised Safety Platforms

Road Design Note (RDN) 03-07 provides guidance on the use of RSPs and the application of appropriate profiles to achieve the intended speed reductions. Note that RDN03-07 provides guidance on the design of platforms being implemented on roads with speeds equal to or below 70 km/h. RDN03-07 (Section 6.1.7) suggests the use of multiple RSPs profiles on high-speed roads to allow motorists to shed speed incrementally. The important aspect of each design is that two approach ramps are provided ahead of the entry curve to the roundabout in high-speed areas (≥ 80 km/h).

The profile (slope) of the approach ramps depends on the target speed at the location being considered. Thus, the location of the platforms will also impact on the ramp profiles, as the slope must match the expected speed at that point.

RSPs also provide an early warning to motorists that there is an upcoming change in the conditions ahead. This makes motorists more alert and therefore less likely to be non-compliant or caught off-guard with the targeted speed at the roundabout. Appropriate sight distance should be provided to RSPs.

a. Platform Profile

The profile of RSPs should be in accordance with RDN03-07. Generally, ramp grades should be chosen such that a speed reduction of approximately 20 km/h is achieved by each platform. If speed reductions are too great, this may result in an increased risk of rear-end crashes (particularly on higher volume roads). If speed reductions are too small, this may result in an increase in ‘overshoot’ type crashes caused by entry speeds being too high, or possibly in run-off road type crashes resulting from high speeds through the roundabout. The plateau of the RSP should be long enough to allow the design vehicle to fully mount the platform before descending back to road level. For example, an approach that is designed to cater for B-doubles should ensure that the length of the plateau of the RSP is greater than 26m for straight approaches.

Assuming an upstream approach speed of 100 km/h, the ramp profiles shown in Table 1 are recommended. The design principles established in RDN03-07 can be used to tailor ramp profiles to achieve speed reductions in different contexts.

Table 1: Recommended ramp profiles for raised safety platforms

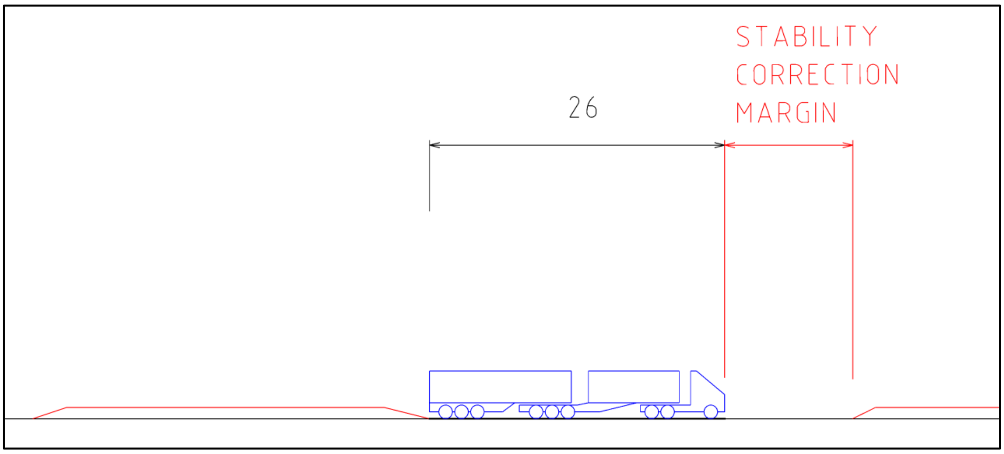
	Ideal Approach Speed	Ramp Slope		Comfortable Max. Speed
		Approach	Departure	
First Platform *(furthest from roundabout entry)*	80 km/h*	1:30 *(3.3%)*	1:35 *(2.9%)*	60 km/h
Second Platform *(closest to roundabout entry)*	60 km/h	1:20 *(5.0%)*	1:35^ *(2.9%)*	40 km/h

* Assumes a maximum posted speed limit of 80 km/h on approach, meaning compact roundabout designs in environments > 80 kmh/h will require a reduction in posted speed on approach. See Section 5.1.3 for further detail.

^ Where designs adopt a 'raised intersection', the departure ramp will be located at the exit of a roundabout. In these scenarios, consideration can be given to adopting departure ramp slopes > 1:35 *(2.9%)*.

b. Platform Location

The distance between the platforms must provide enough space for a check vehicle to completely dismount the first platform prior to mounting the second platform or ramp to the raised intersection. Some additional distance should also be provided to allow the vehicle to decelerate and stabilise prior to mounting the second platform as demonstrated in Figure 7. This stability correction margin allows for the vertical forces imposed upon vehicles (i.e. the discomfort experienced by motorists) to dissipate, thereby reducing the impact on vehicle stability. While this margin will vary depending on vehicle type and speed, data from recent RSP sites indicates that a distance of 12 m is appropriate for a bus with airbag suspension when traversing a platform at 60 km/h. As a guide, distance between the departure ramp of the first platform and the approach ramp of the second platform should approximate the locations of the reverse curves used at a conventional roundabout, thereby providing enough distance to comfortably decelerate to the speed of the next ramp.



*platform heights not to scale

Figure 7: Platform separation distance

For the positioning of the second ramp, vehicles should be able to yield at the hold line with the entering check vehicle resting on a level surface. This can be achieved by controlling the distance between the final ramp prior to the hold line, and the hold line itself. The distance between the final ramp and the hold line should be marginally greater than the length of the check vehicle. However, there are two requirements that supersede this:

- The final ramp prior to the hold line should not be placed within the entry curve as this may affect vehicle stability.
- A significantly large distance between the final ramp and the entry curve may encourage vehicles to accelerate on the approach to the roundabout.

5.1.2.5 Rumble Strips

Rumble strips (or sets of rumble strips) may be provided on the approach to the first RSP if it is thought that awareness may be low (e.g. after a long uninterrupted journey).

Note that rumble strips may not be suitable in noise sensitive environments such as residential areas.

5.1.2.6 Perceptual Line Marking

Perceptual line marking, such as dragon's teeth, are considered supporting treatments that can also be considered to alert drivers to the roundabout ahead. It is suggested that these be used instead of, and not in addition to, rumble strips.

5.1.3 Speed Limit

For approach roads with a speed limit above 80 km/h, and where raised platforms are used to aid speed reduction on the approach to a compact roundabout, a regulatory speed limit of 80 km/h should be implemented in advance of the first platform. This aids with increasing road user alertness and assists with the selection of ramp grades. The speed limit should be reduced far enough in advance of the first platform so that a motorist is travelling at 80 km/h by the time they see the platform and can adjust their speed. Appropriate sight distance shall be provided to RSP locations.

An appropriate amount of time should be factored into the project schedule to accommodate the approval process for speed limit changes.

5.2 Central Island Shape and Position

The provision of a circular central island allows entry speeds and angles to be approximately balanced on all approaches and allows for a consistent travel speed along the circulating carriageway.

While AGRD Part 4B allows the shape of the central island to be modified if required to suit unusual or constrained locations, this does introduce changes in radius within the circulating carriageway which may require speed reductions to navigate. For this reason, a circular central island is preferred for compact roundabouts to minimise the possibility of varying speeds within the circulating carriageway. Non-circular designs may increase the frequency of run-off-road or rollover crashes and are not desirable for compact roundabouts unless particularly complex approach geometry needs to be addressed in the design.

When designing for a four-leg roundabout, the central island should be positioned where it best promotes approach angles that are approximately even on all approaches.

5.3 Central Island Size

Compact roundabouts must be able to accommodate safe turning manoeuvres for both the design and check vehicle. The design vehicle is not necessarily the largest vehicle that will use the roundabout, but it generally represents the largest vehicle that will most frequently use the roundabout.

The check vehicle represents a larger vehicle that may infrequently use the roundabout. These vehicles may need to operate with reduced clearances or encroach into adjacent lanes, and while this may inconvenience some road users, the low frequency of such occurrences makes this acceptable. A guide to selecting the design and checking vehicles is provided in Table 4.2 of Austroads Design Vehicles and Turning Path Templates Guide (AP-G34-13) and should be supplemented with traffic surveys and local knowledge. Further design considerations for heavy vehicles can be found in RDN 04-01: Heavy Vehicle Network Access Considerations.

The size of the island and surrounding apron should accommodate a practical turning radius and speed of the design vehicle. If a movement is expected to be relatively rare, such as with the check vehicle, the absolute minimum turning speed can be adopted for the purposes of setting the island diameter. However, as implementation of compact roundabouts is still an evolving practice, the use of absolute minima is generally not recommended. Figure 8 illustrates how the turning radii of a design vehicle influences the size of both the central island and mountable area (or apron) of the roundabout. The more 'compact' the design, the tighter the turning radii required to accommodate the associated swept path. This not only influences the size of the central island but also the level of service for heavy vehicles, with tighter turning radii requiring lower speeds and greater swept path width than a conventional roundabout. As mentioned in Section 3 (Compact Roundabout Viability), these elements will influence traffic performance and need to be considered early in the development process.

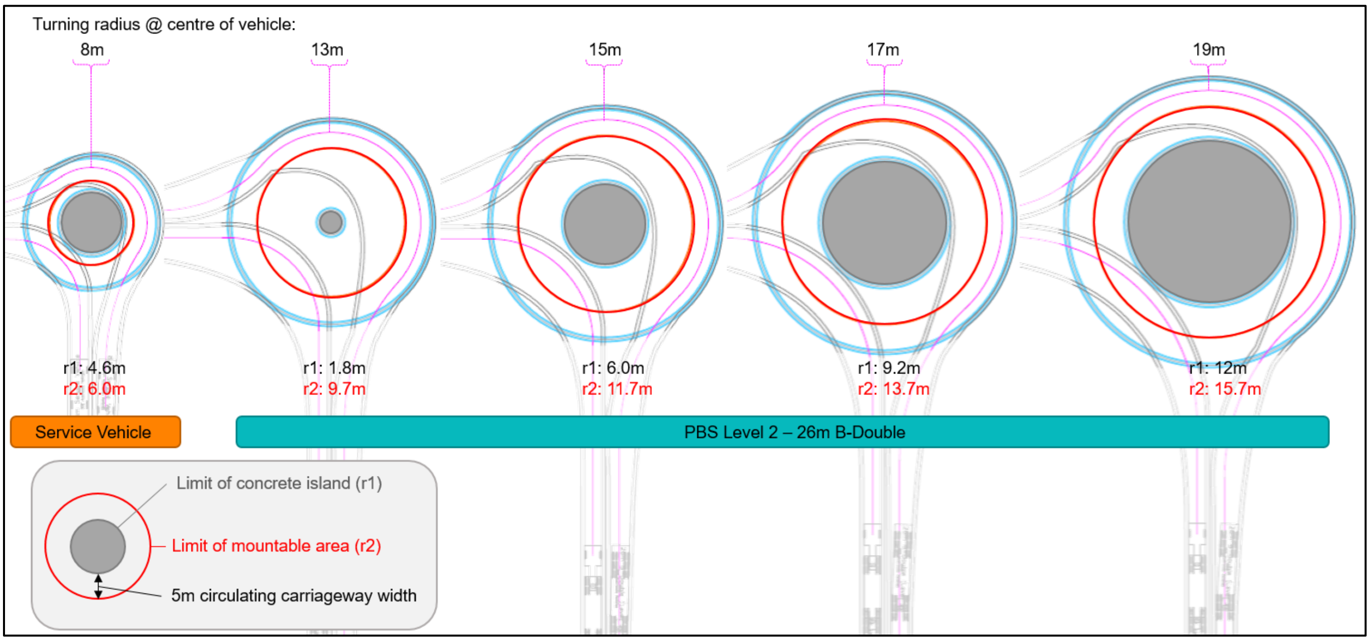


Figure 8: Impact of design vehicles turning radii upon size of concrete island & mountable area

The first step should therefore be to decide what the design and check vehicles are, along with the desirable turning radii and speeds. Refer to AP-G34-13 for further details.

The following principles should also be considered:

- The island should obstruct approaching drivers' view through the intersection and should be conspicuous to approaching vehicles. This provides a visual clue that a roundabout is ahead and that they must slow down. If the approach is particularly wide, the island will need to be larger to fully obstruct the view through the intersection.
- The size of the central island may need to be increased where there is a wide median on one or more approaches.
- The size and location of the central island may need to be adjusted based on the angle (or skew) between legs of the intersection. For example, if the angle between adjacent legs is acute, the island may need to be larger.

As depicted in Figure 9, adopting a smaller central island size whilst also catering for larger vehicles will inevitably result in large circulating carriageway widths. A wide circulating lane, however, would allow standard passenger vehicles to drive straight through the intersection with negligible deflection of their travel path. This would bring intersection impact angles close to perpendicular, which, in combination with higher speeds, would result in higher severity crashes. To overcome this, a concrete apron (or mountable area) is provided around the island to accommodate heavy vehicle movements while still guiding light vehicles on a deflected travel path through the roundabout (see Figure 9). See Section 5.10 (Kerbs) of this document and Section 4.6.3 of AGRD Part 4B for further details on concrete aprons including profile and kerb details. This is one of the key design principles of compact roundabouts and addresses one of the main challenges they face: that of providing for the access and movement of large vehicles.

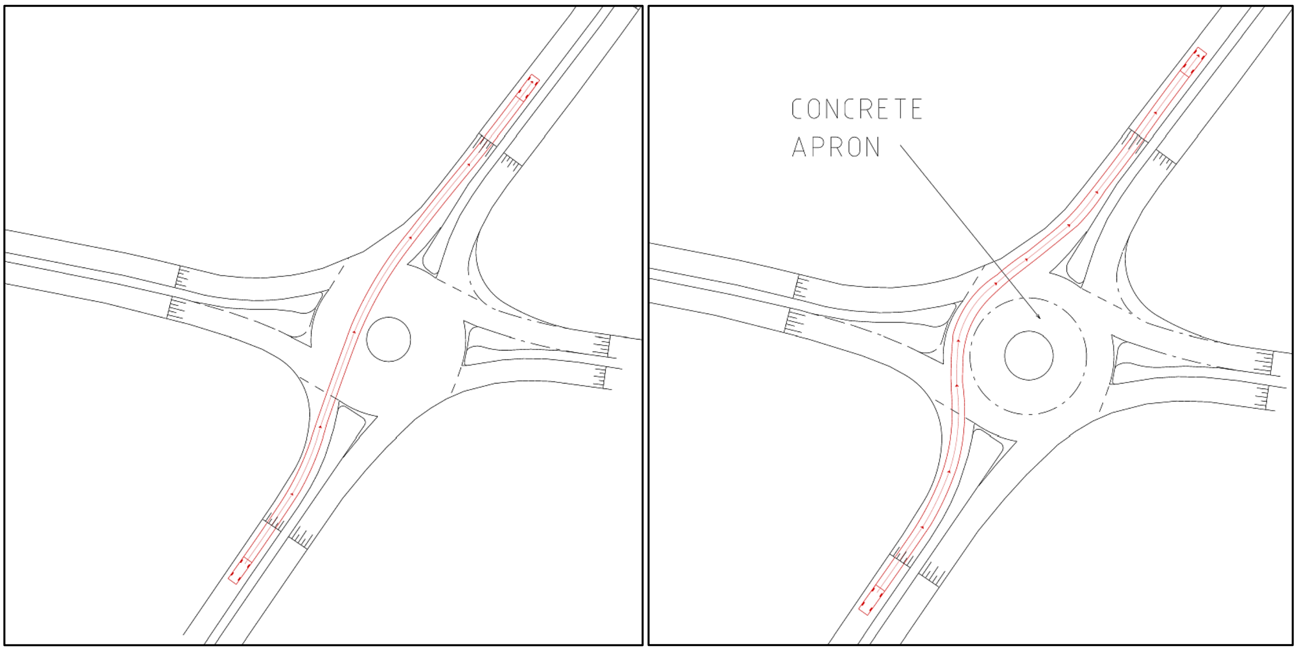


Figure 9: a. operation with wide carriageway, b. operation with concrete apron – movement deflection

The concrete apron also mitigates against vehicles entering the roundabout while other vehicles are still on the circulating carriageway. This issue is demonstrated in Figure 10.

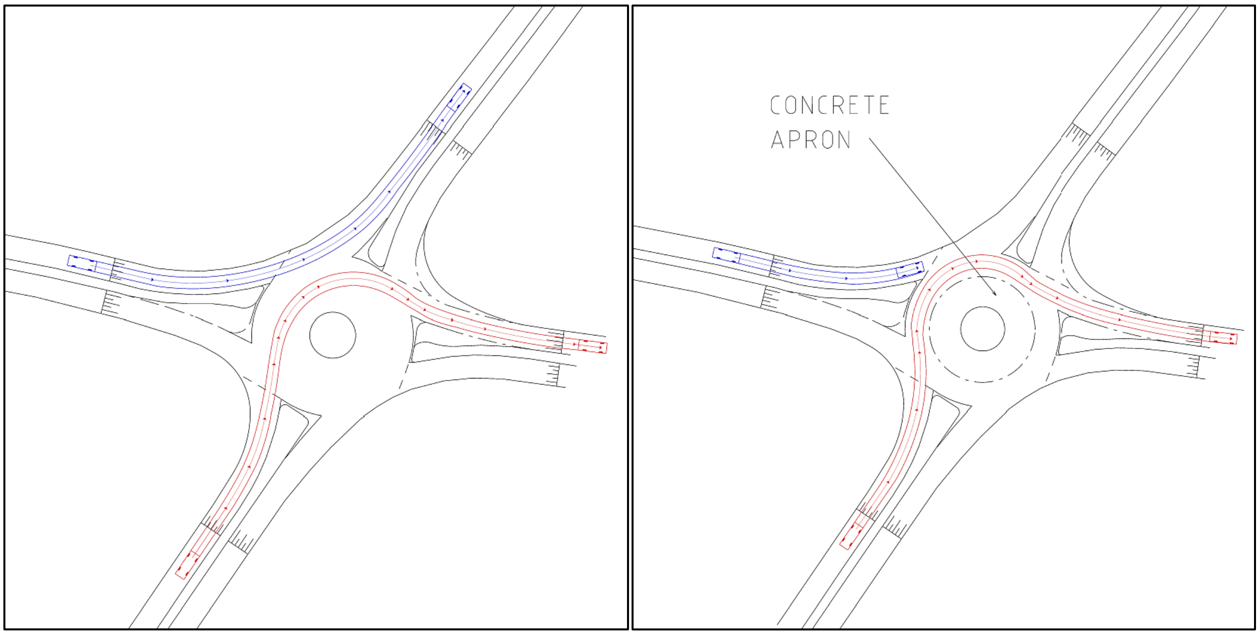


Figure 10: a. operation with wide carriageway, b. operation with concrete apron.

There is a risk that light vehicles with certain suspension configurations may encroach the concrete apron in an attempt to maintain a greater speed through the intersection. However, the level of risk associated with this is lower than the risk associated with the issues demonstrated above in Figure 9 & Figure 10 above.

5.4 Central Island Colour

It is essential that the central island is easily identifiable as an obstruction that impedes a straight-through movement at the intersection. The concrete apron should also contrast from the road pavement and ideally from the central island. For some projects, central islands may be concreted for maintenance purposes (e.g. where a particularly small radii is adopted). However, a concrete central island should still be distinguishable from the mountable apron and provide an appropriate difference in level between the apron and the central island.

5.5 Objects in the Central Island

It is not uncommon to see objects located in the central island of roundabouts. Such objects can include signs and other traffic guidance devices but can also include landscaping such as trees and bushes.

On larger roundabouts there may be sufficient sight distance between vehicles on the circulating carriageway and vehicles at the holding line that these objects do not compromise safety. However, on compact roundabouts it is likely that drivers at the holding line will need to be able to see across part of the central island when selecting gaps. Therefore, it is not recommended that objects be located in the central island apart from small signs that are deemed essential for guidance purposes.

5.6 Crossfall on the circulating carriageway

There are both advantages and disadvantages associated with adopting positive or adverse crossfall. For instance, a positive crossfall may better accommodate turning vehicles (e.g. tighter turning radii, higher turning speeds) and vehicle stability, but there are likely to be trade-offs from a constructability, maintenance and overall cost perspective due to the need to provide drainage within the centre of the roundabout. Generally, given the size of a compact roundabout, an adverse crossfall (that is, one that slopes from the centre to the outer edge of the roundabout) is likely to be more practical. Consideration may also be given to constructing the circulating carriageway on a plane whereby half the roundabout provides positive crossfall and the other half provides adverse crossfall. This approach may also suit the particular topography of the site more appropriately.

Due to the tighter turning radius associated with compact roundabouts and the presence of a concrete apron, there is an increased risk of heavy vehicle rollover. However, the lower operating speeds do mitigate against this risk. Vehicle stability must be considered when determining the horizontal geometry, approach speed reduction measures and any additional warning signs. Further detail on pavement crossfall and the stability of heavy vehicles in roundabouts is given in section 4.10 of AGRD Part 4B. For the majority of applications, the crossfall on the circulating carriageway should not exceed 2% and crossfall on the concrete apron (or mountable area) should not exceed 1%.

5.7 Approach gradient

Generally, it is desirable that the gradient on approaches to roundabouts be limited to 3 to 4% and should not exceed 6%. While the gradient may extend along part of the length of the entry curve it is essential that:

- On an uphill approach, a flat area (say 2–3% maximum) is provided on the immediate approach to the roundabout to accommodate the length of one design vehicle. This flat area will assist heavy vehicles to start up and move into gaps of traffic on the circulating carriageway, ensure that capacity is not unduly compromised, and also assist with ensuring appropriate sight distance is available.
- On a downhill approach, a sag curve will be required to match the higher gradient to the crossfall of the circulating carriageway (see section 5.6). Some thought will need to be given to drainage of sag curves and whether it is likely that surface water will be trapped in the sag if an overland discharge path is not available where underground drainage networks may be blocked.

Where there are RSPs on the approaches, the profile of the approach ramps must be adjusted to achieve an equivalent change in grade (i.e. the angle between the grade of the road surface and the platform ramp should be the same as if the ramp were on flat ground). See section 6.1.4 of RDN 03-07 for further details. It should be noted however, that while these adjustments will help to achieve the desired level of discomfort to motorists, heavy vehicle operators may still find it difficult to adequately shed speed on approaches with a significant down grade due to the momentum being carried (i.e. a significant grade combined with large vehicle mass will require a greater level of retardation to adequately reduce speed prior to the roundabout entry).

5.8 Traffic Volume

Compact roundabouts are suitable at intersections where traffic volumes on each leg are relatively low, or at least reasonably balanced. Care should be used when applying compact roundabouts on high-volume roads, as operational performance of the roundabout can be impacted.

As is the case with conventional roundabouts, compact roundabouts may become inefficient at providing traffic throughput if the traffic volumes on the approaches become largely unbalanced.

5.9 Splitter Islands

The use of splitter islands is essential at roundabouts as they:

- help define the alignment of the entry curve,
- separate entry and exit movements,
- physically delineate the outer edge of the circulating carriageway,
- provide advance warning to motorists that a roundabout is ahead, and
- split the carriageway and allow RSPs to be provided on the approach but not the departure

At compact roundabouts, the splitter island must extend far enough upstream of the roundabout to accommodate both approach RSPs (whether for two separate platforms, or one platform and a raised intersection). Additionally, the island should be extended as far back as is necessary to be visible (e.g. appropriate sight distance provided so that it is not hidden by a curve or crest).

Depending on the size of the roundabout and the angle (skew) of approach legs, sections of the splitter islands may need to:

- be driveable, or
- provide breaks to facilitate access to properties or other areas, or
- provide appropriate space for tracking of the check vehicle (generally large trucks).

Splitter islands must be wide enough to accommodate signs, light poles and their required clearances.

5.10 Kerbs

Kerbs have a number of functions at compact roundabouts:

- They form part of the drainage system by collecting stormwater and convey it to points of discharge
- They provide a visual cue that the road conditions are changing
- On the approaches, they appear to narrow the road, forming a physical restriction that slows drivers
- They provide delineation and direct traffic and guide it into the circulating carriageway

Except as noted below, all kerbs should be semi-mountable to minimise the potential for loss of control in the event of vehicle overrun. Further information on typical kerb profiles can be found within Standard Drawing 2001.

5.10.1 Approach kerbs

The approach treatment should include a median or splitter island and a kerb along the left side of the approach, which together with the entry curve geometry create a physical restriction which slows drivers. The kerb on the left should, as a minimum, be extended as far back as the nose of the splitter island. The starting location of the kerb is dictated by the location of the RSPs and visibility requirements (see section 5.9).

As kerbing will be provided on both the median and roadside, the lane width should be locally increased to 5m to allow vehicles to pass a broken-down vehicle.

5.10.2 Circulating carriageway

A kerb should be provided around the full exterior circumference of the circulating carriageway. An offset of 0.5 m should be provided between the kerb and body of the design vehicle in accordance with Section 4.6.2 of AGRD Part 4B.

5.10.3 Central island and apron

A kerb should be provided around the full circumference of the central island. At compact roundabouts, the central island will normally be surrounded by an apron (a depiction of which is in Figure 9 and Figure 10) that enables heavy vehicles to track while turning without overrunning the island itself. The kerb around the circumference of the apron should be *fully mountable* in profile (M1 - M6). The apron should be aggressive enough to discourage light vehicles from adopting a straight travel path through the roundabout. However, consideration should also be given to the rideability for motorcyclists, particularly on popular motorcycling routes, where a more forgiving profile (such as an M1 or M3) may be better suited.

Figure 11 shows the combination of kerb profiles adopted at the Lance Creek site (discussed further in Section 11), noting that mountable (M6) kerbing was provided at the extremities of the concrete apron. Section 4.6.3 of AGRD Part 4B can be used for further guidance on design considerations of concrete aprons.

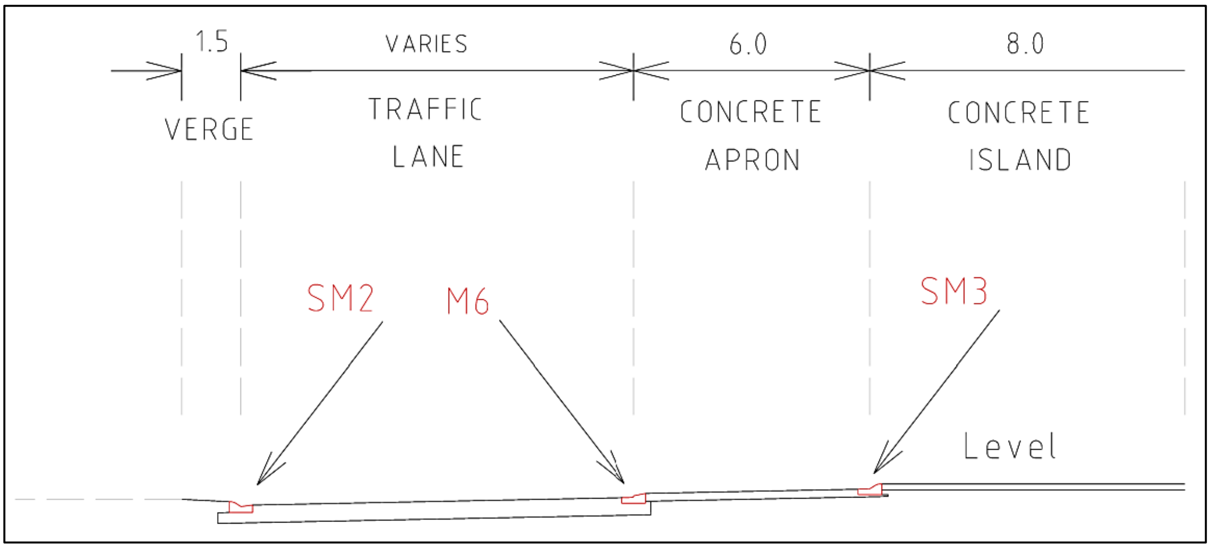


Figure 11: Kerbing adopted at the Lance Creek roundabout

As noted above, the splitter island forms the right side of each approach. It works in conjunction with the kerb along the left side of the approach to provide delineation and form a physical restriction which assists in slowing traffic and to guide motorists into the circulating carriageway.

In certain locations, splitter island kerbing may need to be mountable to accommodate the swept paths of design or check vehicles, particularly left turn movements. In these environments, a combination of semi-mountable (SM) and mountable (M) kerbing will be required.

5.10.4 Raised safety platforms

At RSP locations, a number of options are available to allow both drainage and platform functions to operate effectively.

Suitable arrangements include:

- Raising the kerb profile to follow that of the platform. This solution must ensure that the new kerb profile allows drainage to flow unimpeded at the ramps of the platform.
- Filling to the platform height across the kerb. This will result in the drainage being obstructed. A suitable alternative path must be provided for drainage. This can be achieved through the installation of a side entry pit immediately upstream of the platform.
- The sides of the platform may be tapered down to the lip of the kerb to allow unimpeded water flow along the kerb. This approach requires no additional works, provides a cost-effective solution, and is most easily retrofitted to existing sites. However, there are potential risks associated with taking this approach, such as:
  - it may impact vehicle stability
  - it may force cyclists to shift towards the centre of the lane to avoid this uneven surface
  - it may act as a wheel trap
  - it effectively narrows the lane for the length of the platform, it is generally considered unsuitable for sites with significant volumes of heavy vehicles or wide axle vehicles.

  This approach is also considered unsuitable at raised intersections, as vehicles may track near the edge of the platform while turning.

5.11 Heavy Vehicles

Consideration of heavy vehicles is especially important at compact roundabouts. As illustrated in Figure 8, the size of the central island, apron and circulating carriageway will all be determined based on the swept path and turning speed of the design and check vehicles. This is an iterative process using constraint points at the site to develop the design. Figure 12 provides an example of how these swept paths inform the dimensions of these elements of the roundabout during the design process.

A description of the design and check vehicles is provided in section 5.3 and a guide to their selection and turning speeds is provided in AP-G34-13. Typical design and check vehicle configurations are shown in VicRoads RDN04-

01. Often a compact roundabout design will adopt a smaller design vehicle than provided for in a conventional roundabout design (i.e. a single unit truck/bus or a service vehicle rather than a B-double truck). The concrete apron usually provides space for the swept path of a larger check vehicle. As such, when considering adopting a compact roundabout, it is important that the decision is informed by a good understanding of the type and number of vehicles that will be using the roundabout, including their OD patterns through the roundabout (i.e. turn volumes). These decisions should be documented early during the design process to ensure that the solution is fit for purpose.

The chosen design vehicle should be able to negotiate the intersection without encroaching onto areas behind the kerb or conflicting with other movements.

The check vehicle may have to negotiate the intersection in a less desirable way, such as at the absolute minimum speed (generally the stop condition) or by encroaching onto areas behind the kerb, such as concrete aprons. This is considered acceptable due to the infrequency of these movements. However, this may influence design elements including the location of signs and the provision of additional paved areas (e.g. behind kerbs, or aprons at the corners of the intersection to cater for left turn movements).

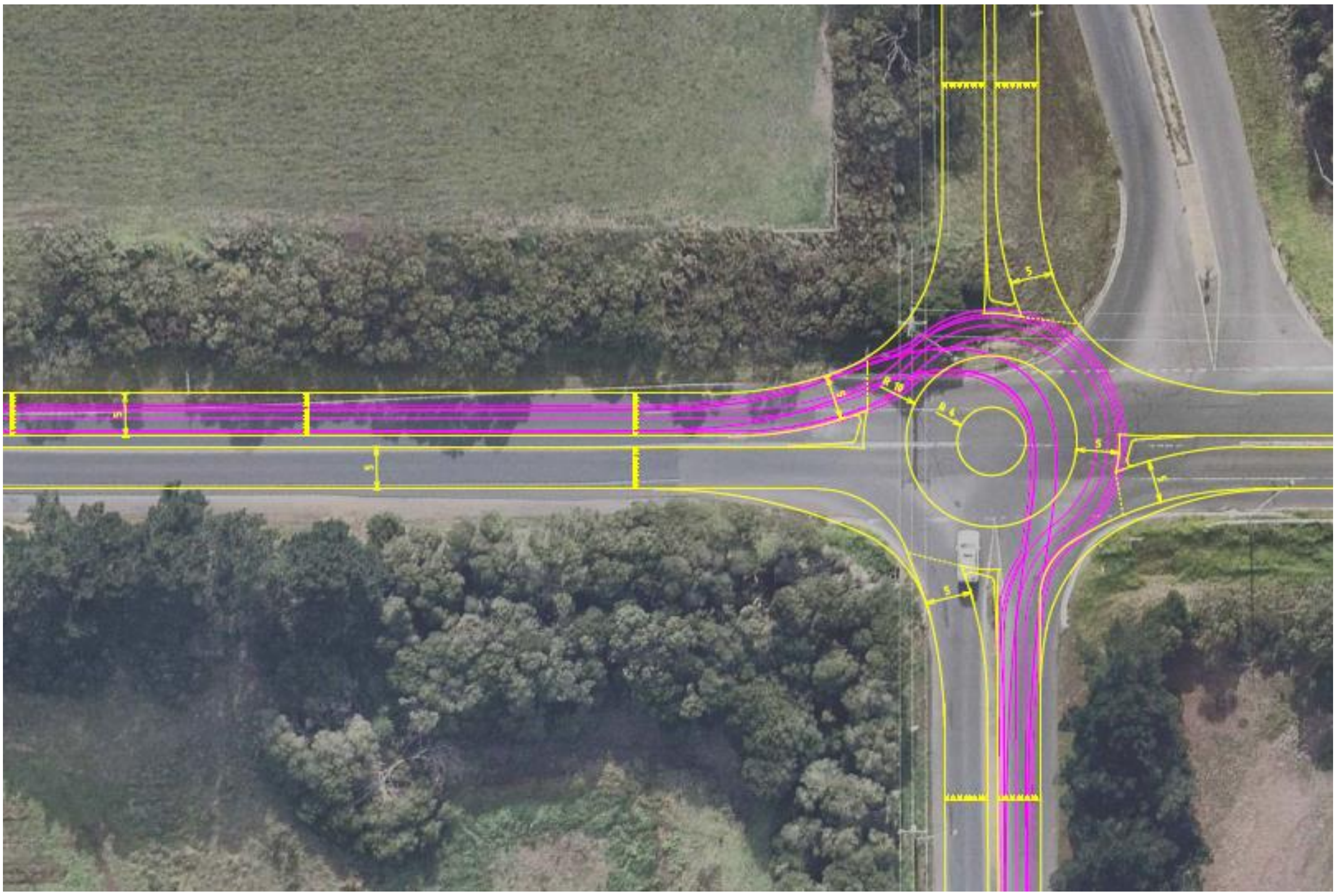


Figure 12: Swept path of a B-Double during the design of a compact roundabout

5.12 Signs and Line Marking

Compact roundabouts should adhere to the principles of signage arrangements for conventional roundabouts. However, the practical application of signage may differ at some locations on a case-by-case basis.

It should be noted that the turn envelope for both the design and check vehicles need to be free of signs. It is therefore important that sign placement is considered in the concept design phase to ensure that signs are positioned in effective locations (e.g. not obstructing sight lines).

5.13 Lighting

Lighting requirements for compact roundabouts are similar to lighting requirements at conventional roundabouts. However, additional lighting is required along the approaches to ensure that any RSPs are adequately lit in accordance with RDN03-07.

Ideally, lighting poles should be placed at the edge of the carriageway where they are exposed to less traffic and can be set back from the traffic lanes. However, this requires sufficient room behind the kerb. Alternatively, they can be located in the median/splitter island. It should be noted poles in the median will be exposed to more traffic (both directions) and even though a slip-base pole may protect the vehicle hitting it, the pole is likely to fall on a live carriageway where it may cause secondary collisions. The median/splitter island would also need to be wide enough to shelter the pole. Light poles should not be installed in the central island of compact roundabouts.

6. Land Acquisition

Compact roundabouts have a smaller footprint than conventional roundabouts. As a result, less land is required within the vicinity of the intersection. The advantages are especially evident where there is a constrained road reserve on the approaches to and/or at the intersection. See Figure 13 for an example land comparison.

Note that where approaches to a compact roundabout are narrow, widening may be required to accommodate elongated splitter islands. However, the associated impact of this is usually significantly less than that of reverse curves.

Figure 13: Example concept designs for a conventional and compact roundabout

7. Community Engagement

There are currently no indications that a compact roundabout is a compromise from a conventional roundabout in terms of safety or capacity when adopted in appropriate locations. The term “compact” refers to its physical size only and provides planners and engineers with an understanding of its design considerations (i.e., it will not conform to some design criteria for conventional roundabouts and decisions around design/check vehicle provision are often different). When used in public consultation, the term “compact” may result in unintended connotations of “sub-standard”. For this reason, the term “compact” should not be used at the forefront of public communications and compact roundabout should simply be referred to as a roundabout. There will, however, be a need to detail some of the features of the roundabout in communications – such as any RSPs or rumble strips.

The smaller footprint of a compact roundabout can be a significant advantage when engaging with the community. The reduction in land acquisition, vegetation removal and impact on the environment are all generally seen as positive outcomes by the community. Particular care is needed in consultation when addressing roundabouts that need to cater for significant demands for large vehicle access. Note that some rural locations may need to cater for OD size farm equipment which can be 6m wide. It is important that any OD needs are identified early in the design development process and that these requirements are reflected in the design solution.

8. Monitoring and Evaluation

Evaluation data from the Lance Creek site is very promising for compact roundabouts in rural high-speed environments, with the considerable efforts put into the planning, engineering, design, and delivery of this solution achieving intended outcomes.

Nevertheless, it is imperative that we learn from any future compact roundabout installations to:

- Ensure site specific objectives are achieved
- Build upon the current body of knowledge regarding their design, construction, and operation
- Better understand emerging best practice and how designs are tailored to a broader range of contexts
- Inform more definitive design standards and values moving forward.

To help achieve this, all future installations shall conduct extensive pre and post construction monitoring and evaluation. It is recommended that this form part of the foundation of future project scope, with an evaluation plan established within the development phase to allow sufficient time to collect any necessary pre-evaluation data.

Listed below are recommended aspects for monitoring and evaluation plans, noting of course that this will differ from site to site:

- Pre & post-crash data
- Speed profiles
- Control sites
- Noise testing
- Heavy vehicle stability
- Accelerometer data (where RSPs adopted)
- Community (sentiment)
- Other

For further guidance, please contact DoT Road Design & Safe System Engineering team.

Lance Creek Compact Roundabout Case Study

9. Introduction (Lance Creek)

This case study is intended to aid future compact roundabout projects by detailing the design considerations, process and issues faced during the development and design of the Lance Creek compact roundabout (intersection of Korumburra – Wonthaggi Road and Glen Alvie Road, Lance Creek, Victoria). Specifically, this case study focuses on how this design differed from conventional roundabouts, and any resulting challenges that were addressed.

Figure 14: Before and After aerial images of the intersection of Korumburra – Wonthaggi Road and Glen Alvie Road, Lance Creek

10. Safety Implications (Lance Creek)

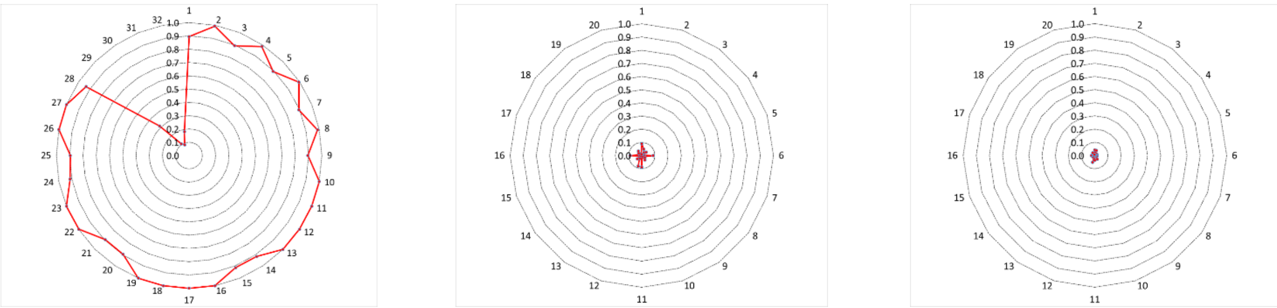
The compact roundabout at Lance Creek was installed in 2018. The extensive evaluation conducted at this site is primarily geared towards verifying the level of additional safety provided for road users and as a platform to improve future applications of compact roundabouts.

As of February 2021, no injury crashes have been recorded following the installation of the compact roundabout.

The number of community complaints regarding the intersection (pre roundabout construction) have diminished, and the community is satisfied with the level of safety when using the intersection. Routine surveillance of the site also indicates that vehicles are using the intersection as assumed in the design process.

An X-KEMM-X analysis was conducted for the Lance Creek roundabout design which demonstrated a significant reduction in the severity of all possible multi-vehicle crashes at the intersection. Results from the X-KEMM-X analysis are presented in Figure 15 and Table 2. The closer to the centre of the circle, the less the kinetic energy potential at the intersection.

Results from an X-KEMM-X analysis for a roundabout at the intersection of Paynesville Road and Forge Creek Road, which were conducted as a part of the same project, is also provided. Note that the Paynesville Road roundabout uses reverse curves. The X-KEMM-X results for the Paynesville Road roundabout therefore provides a comparison to the crash energies at a compact roundabout. It should be noted that the safety performance of the compact roundabout is due entirely to the application of the design principles outlined in this document. It is expected that performance would reduce if these principles were not adhered to.



(a) Original intersection (b) Compact roundabout (c) Conventional roundabout

Figure 15: a) FSI Probability - Original Intersection (100 km/h), b) FSI Probability - Compact Roundabout (80 km/h), c) FSI Probability - Conventional Roundabout at Paynesville Road (80 km/h)

Table 2: Probability of FSI crashes Summary Table

Intersection Type	Conflict point type	No. of Conflicts	Likelihood of FSI > 10%	Avg Likelihood of FSI	Max Likelihood of FSI
Original intersection (Lance Creek)	Vehicle-vehicle	32	31	0.86	1.00
Compact Roundabout (Lance Creek)	Vehicle-vehicle	20	0	0.04	0.09
Conventional Reverse Curve Roundabout (Paynesville)	Vehicle-vehicle	20	0	0.02	0.05

The compact roundabout at Lance Creek demonstrates remarkable improvements in safety performance in comparison to the priority controlled cross intersection previously in place that are generally only achievable with conventional roundabouts.

There is a need to evaluate the long-term safety benefits of compact roundabouts in comparison to conventional roundabouts. The Lance Creek compact roundabout has so far not experienced any crashes, and as a result, appears to provide an excellent crash reduction. The lack of crashes as of January 2021 is taken to be a positive indication of its likely longer-term safety performance.

11. Design Considerations (Lance Creek)

For the project delivered at the Lance Creek site, funding was competitive against other projects and was prioritised based on the project Benefit Cost Ratio (BCR). The safety benefit achieved per dollar invested was therefore the driving factor. Although land acquisition costs would have been relatively low at the rural site for a conventional roundabout, the presence of a Telstra exchange building at the corner of the existing intersection would have significantly increased costs due to the high price of service relocations.

The concept for a conventional roundabout at this site was therefore found to be uneconomical and there was a genuine desire by the project team to find a more viable solution. A compact roundabout provided such a solution by modifying the central island diameter and redesigning the approaches to replace reverse curve design with RSPs. These changes reduced the footprint of the proposed intersection, limiting impacts to the surrounding environment and services at the site. This created the opportunity to develop a roundabout solution while avoiding impact to the Telstra exchange building.

11.1 Approach Layout (Lance Creek)

In the design of the Lance Creek roundabout the decision was made to raise the intersection (as opposed to two distinct raise safety platforms). This was based on avoiding the need for additional widening along the approaches and the reduced length of the treatment.

11.2 Central Island Shape (Lance Creek)

A standard circular central island shape was used for the Lance Creek compact roundabout design. The kerbs used, and the gradient of the concrete apron, allowed the flat central island to sit above the level of the road surface improving its visibility while also facilitating the tracking of truck trailers when required. The grading of the roundabout cross section is demonstrated in Figure 16.

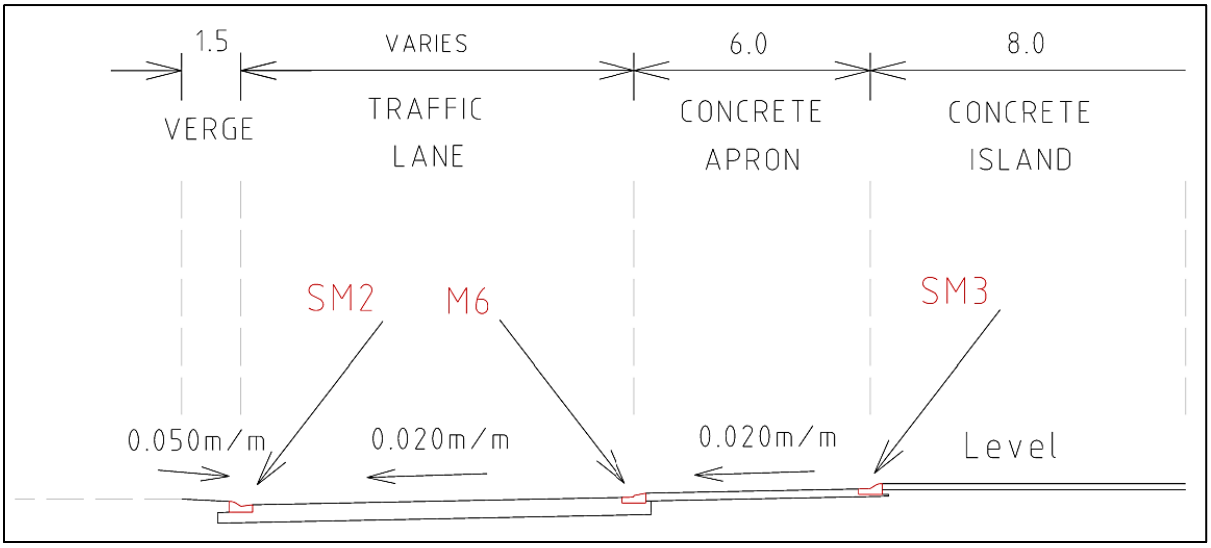


Figure 16: Grading of roundabout cross section

11.3 Central Island Size (Lance Creek)

The central island diameter (excluding apron) at Lance Creek is 8m. This allows the island to obstruct a view of continuous pavement when approaching the roundabout from any incoming lane, increasing the conspicuousness of the treatment and improving motorist awareness and responsiveness.

As kerbing is provided on both the median and roadside, the lane width is locally increased to 5m to allow vehicles to pass a broken down vehicle. An elongated median with a width of 1.2m is also provided along the approach.

The radii of the central island and concrete apron are also driven by the swept paths of vehicles using the roundabout, and not solely determined by obstructing the view of continuous pavement.

11.4 Central Island Colour (Lance Creek)

To assist in the identification of the central island, a standard pavement base was not used. A difference in colour and contrast between the pavement and the central island was provided, to reinforce the changed conditions to approaching motorists.

Figure 17 depicts the concrete apron and central island used at the Lance Creek site. Note that additional benefit may have been achieved by providing further contrast between the concrete apron and the central island. An improved arrangement may consist of a standard asphalt carriageway with a white concrete apron and a textured red central island.

Figure 17: Central Island at Lance Creek

11.5 Entry Curve (Lance Creek)

The design of the entry curve of the compact roundabout approximates the design of an entry curve of a conventional roundabout. See Figure 18.

Figure 18: Entry curves at Lance Creek

11.6 Raised Safety Platforms (Lance Creek)

11.6.1 General Information

The design and placement of the RSPs attempts to replicate the operating speed reductions that would be achieved through reverse curves in a conventional roundabout. For Lance Creek an approach raised platform and the raising of the intersection and extension of the platform achieved the desired operating speed reductions. Figure 19 shows the principles of moving vehicles from the default 100 km/h to a regulatory 80 km/h speed zone and then RSPs. It should be noted that the installation of a conventional roundabout at this location would have also required a speed reduction to 80 km/h along the approach to control speeds safely through the intersection through its geometric alignment.

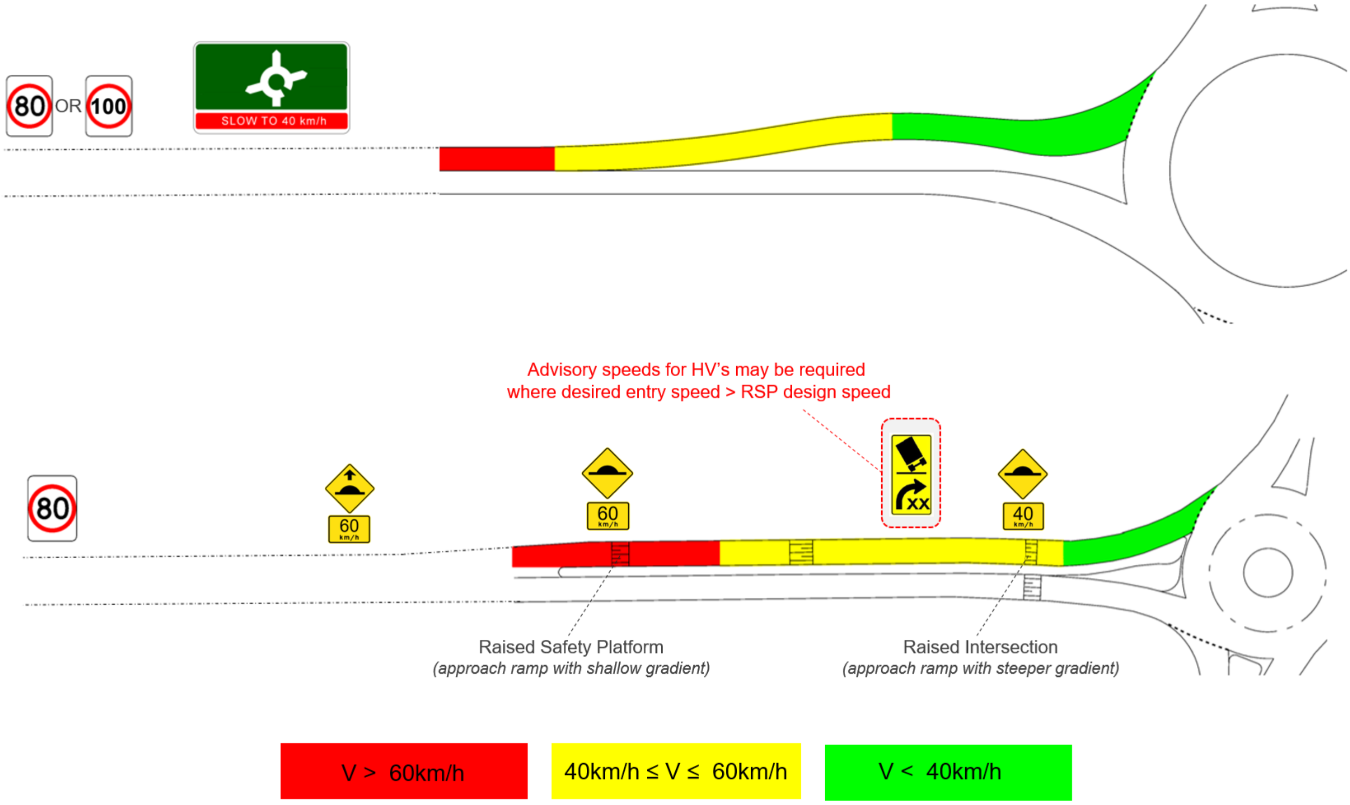


Figure 19: Visualisation of speed reduction on the approach to a compact (top) and conventional (bottom) roundabout (not to scale and not all signage shown)

Evaluation conducted for the Lance Creek roundabout has compared the differences in approach speed at various locations approaching the hold line. This information is presented in Figure 20 below. Note that the pattern of the speed reduction achieved with raised platforms (depicted in red) is comparable to the speed reduction pattern observed for a conventional roundabout with reverse curves, even though the initial speeds were higher.

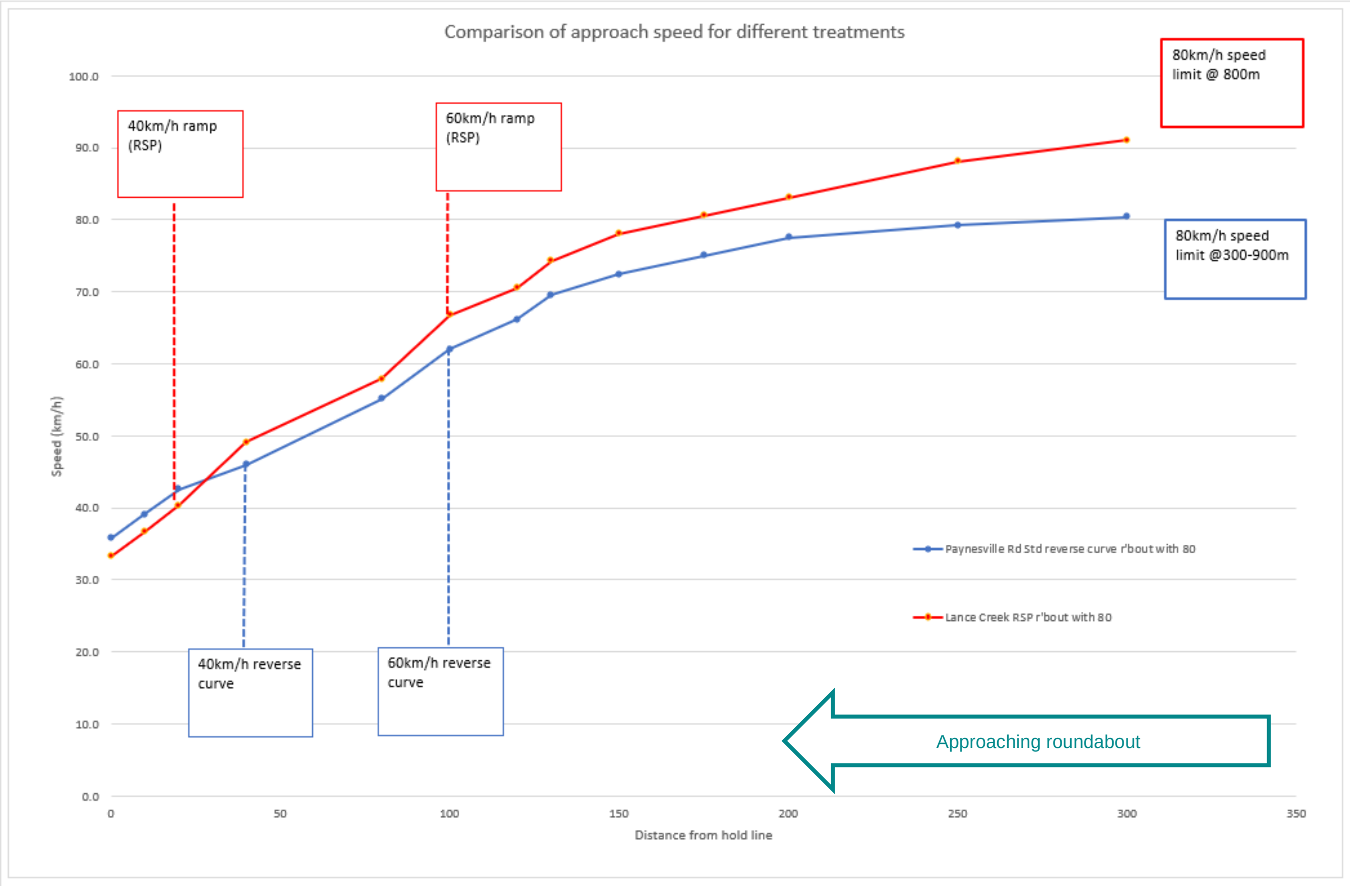


Figure 20: Comparison of approach speed by distance for reverse curve and raised safety platform

11.6.2 Platform Profile

Figure 21 shows the platform profiles used for Lance Creek.

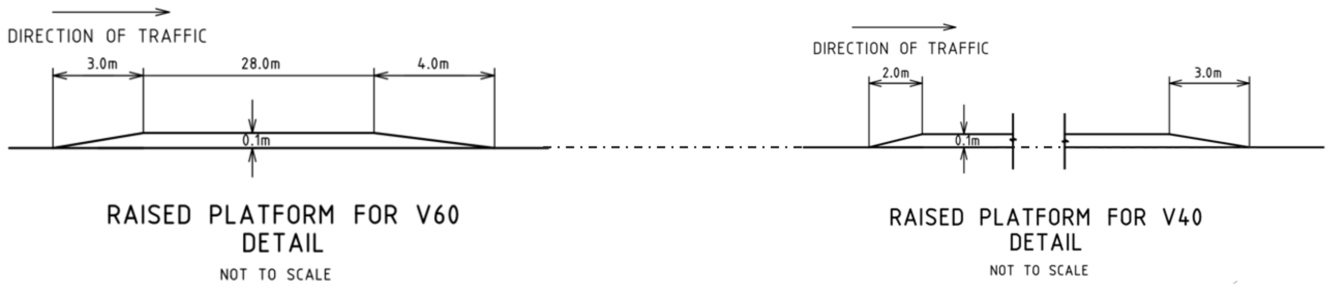


Figure 21: Lance Creek raised safety platform profiles

11.6.3 Platform Location

For the Lance Creek compact roundabout, the design vehicle was a 26m B-double, and a separation of 37m was provided between the platforms. Sufficient distance was created between the final ramp and the entry curve for a light vehicle to fully mount the final ramp before entering the curve. This principle is depicted in Figure 22. The distance between the two platforms ensured that vehicles were not able to accelerate between them.

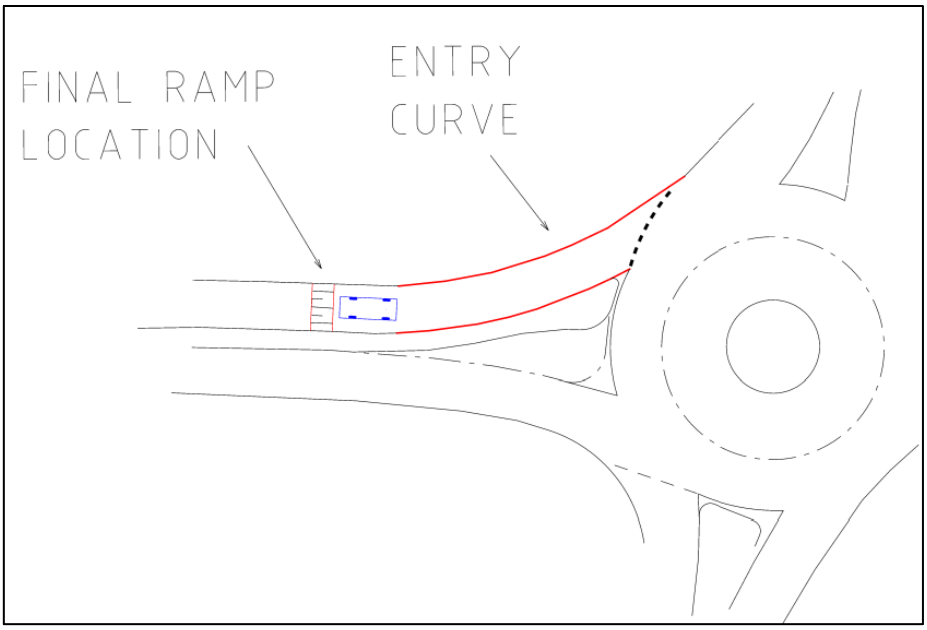


Figure 22: Design of final ramp location

11.7 Rumble Strips and Dragon's Teeth (Lance Creek)

As a previously trialled road safety measure, rumble strips were present at the Lance Creek intersection on the east and west approaches. Following the installation of the compact roundabout, additional sets of rumble strips were installed on the north and south approaches to reinforce awareness of the compact roundabout.

A single residence is adjacent to the Lance Creek compact roundabout. Noise testing conducted from within the property determined that differences in the noise generated at the residence after the treatments were installed were negligible.

11.8 Number of legs (Lance Creek)

The original site had five legs, but the Bird Road leg was realigned to enable a four-leg roundabout to be built. By restricting the compact roundabout to 4 legs, legs can be separated by angles of (or near to) 90 degrees. The inclusion of the additional Bird Lane leg would have created sharper turning movements at the roundabout that may not have been feasible for larger vehicles. This would have resulted in vast expanses of pavement when catering for such movements, which is undesirable, or alternatively would have required slip lanes to facilitate certain turning movements.

11.9 Speed Limit (Lance Creek)

The speed limit at the original site was 100 km/h, which is not compatible with current RSP profiles. Therefore, the speed limit was reduced to 80 km/h sufficiently far in advance of the first platform to ensure that vehicles did not mount the platform at excessive speed.

A speed limit reduction was key to the success of the project, as RSPs are currently not permitted in 100 km/h speed zones.

11.10 Operational Performance (Lance Creek)

The results of the SIDRA analysis conducted on the impact of traffic volumes on vehicle delays is presented in Figure 23. For comparison, delays caused by conventional roundabouts are also shown. The findings suggest that compact roundabouts can provide an adequate solution with minimal impact to traffic delays for intersection volumes upwards of 500 vehicles per hour (or approximately 5000 vehicles per day).

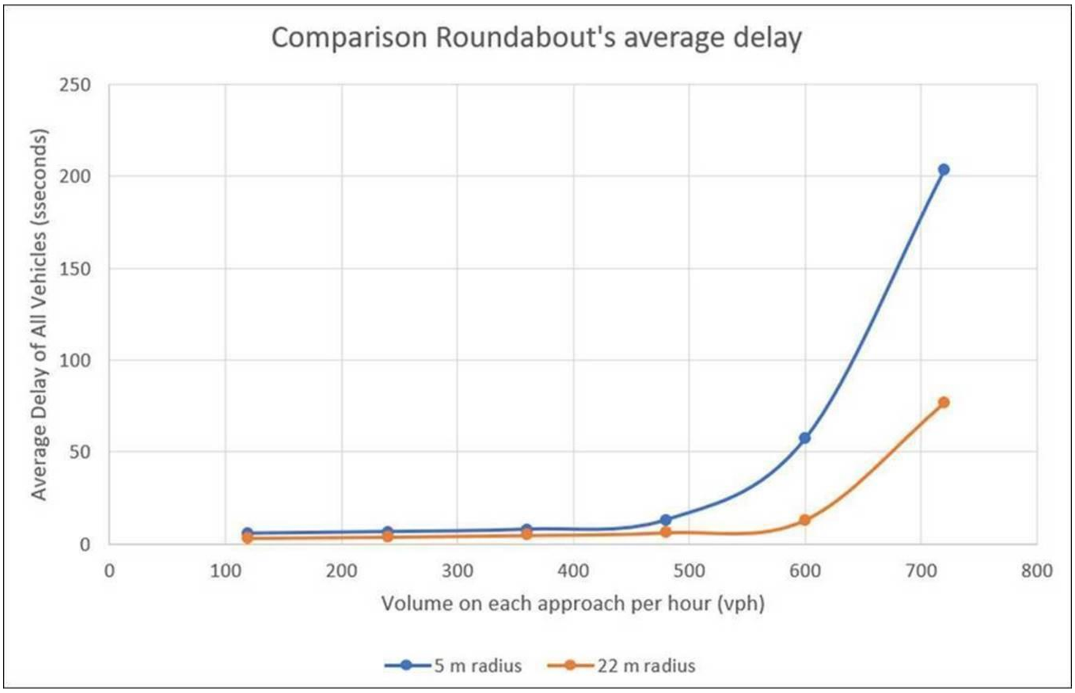


Figure 23: Delays caused by compact and conventional roundabouts

11.11 Splitter Islands (Lance Creek)

For the compact roundabout, the splitter islands were elongated to allow RSPs to be restricted to the approach lane only. The elongated splitter islands also alert motorists of the upcoming treatment in addition to the signage and line marking provided. This was especially important at Lance Creek in order to compensate for its position atop a crest which obstructed visibility of the intersection treatment and the hold line.

Figure 24: Lance Creek elongated splitter islands

In addition to being elongated, sections of the splitter island were made drivable to ensure that they could accommodate all movements (including into and out of property accesses and tracking of large vehicles (as seen in pink in Figure 25).

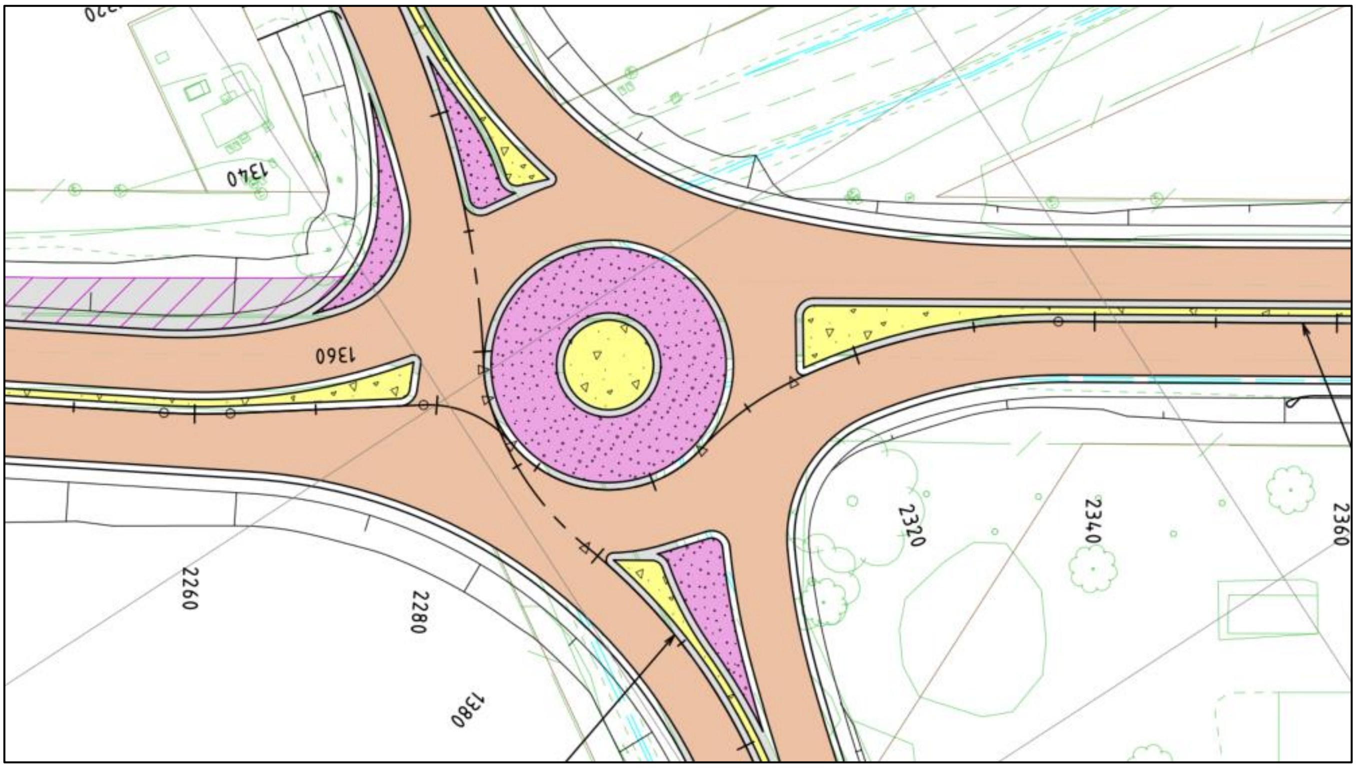


Figure 25: Lance creek mountable splitter island sections (pink)

As the elongated splitter islands support the placement of RSPs on the approach lanes only (rather than across the entire carriageway), costs were reduced. However, the use of extended splitter islands also impacted the pavement width available for traffic lanes. This resulted in the need for pavement widening which added to project costs.

Splitter island widths were made sufficient to accommodate signs and light poles, along with the associated clearances required for each.

11.12 Kerb (Lance Creek)

Kerb was provided along the approach to delineate the edge of the traffic lane. Used in conjunction with the elongated splitter islands, a perceptual narrowing was created, further reinforcing the speed reduction measures for approaching vehicles.

11.13 Heavy Vehicles/ Design Vehicle (Lance Creek)

Analysis was conducted of the stability of turning vehicles at the Lance Creek Roundabout using the 'TruckSIM' heavy vehicle simulation software. The critical (worst-case) vehicle was a 4.6m high stock crate (single articulated) vehicle. The stability of this critical vehicle is extremely low in comparison to almost all other heavy vehicles operating in Victoria.

The risk threshold used allowed for a certain amount of disparity in the vehicle's load sharing between the left and right sets of tyres, referred to as the Load Transfer Ratio (LTR). The LTR is zero when the load is evenly shared and 1 when all the weight is carried by tyres on a single side of the vehicle. The LTR tolerance was set to a conservative maximum value of 0.6. Note that rollover is not possible provided that this value remains below 1.

The analysis evaluated the stability of the critical vehicle for the highest risk turning movements through the roundabout based on swept path characteristics, horizontal and vertical alignment, and crossfalls. The analysis concluded that the critical vehicle could negotiate the highest risk turns at the roundabout with a speed of 16km/h before the conservative LTR of 0.6 was reached. Typical heavy vehicles would be able to travel significantly faster before reaching the threshold, reaching speeds well above 20 km/h before an LTR of 0.6 is reached.

In order to further reduce the likelihood of heavy vehicles destabilising due to the turning movements, W1-8(R) signs (tilting truck) were provided for all right turning movements with an advisory speed of 15km/h, which is below the critical turning speed for trucks.

Separate data on heavy vehicle speeds at the hold line are not available. Traffic surveys conducted at the site observed an average vehicle speed 26.5km within the roundabout and a minimum speed of 10.4km/h. Although the 85th percentile speed is 32km/h, it is expected that heavy vehicle speeds are skewed towards the slower end of the spectrum. Ongoing monitoring of the site has not observed any truck stability issues, and no complaints have been received. This suggests that the treatment, in combination with the provided warning signage, is operating to a satisfactory level of safety.

The findings from the Lance Creek roundabout evaluation suggest that the tighter annulus of compact roundabouts still provide sufficient space for heavy vehicles to safely perform turning movements when provided in conjunction with the warning signage.

11.14 Signs and Line Marking (Lance Creek)

Dragon’s teeth line marking was applied on the approaches to the RSP as a supplement to the use of rumble strips. The benefit of using dragon’s teeth line marking is that they do not generate any noise. However, it should be noted that dragon’s teeth are a perceptual countermeasure only and have been known to lose their effectiveness for regular users of an intersection. As such, their successful operation is dependent upon the behaviour of motorists.

The compact roundabout adhered to the principles behind signage arrangements for conventional roundabouts as far as possible, however, the following changes were made:

- Elongated splitter islands were sufficiently wide to be able to shelter keep left signage, and this signage was repeated where gaps have been provided for property access.
- Heavy vehicle tilting advisory speed signs for right turning movements were also provided on all approaches.

Aside from these modifications, all other standard roundabout signage and line marking were provided for the intersection in accordance with AGRD 4B. Additionally, all standard signage and line marking for the RSPs and raised intersection were provided in accordance with RDN 03-07.

11.15 Lighting (Lance Creek)

At the Lance Creek compact roundabout, the central island (of diameter 8m) was insufficient to accommodate a light pole. Lighting was instead provided by five light poles located around the outside of the circulating carriageway. In doing so, care was taken to position light poles in locations that would minimise the possibility of impact by errant vehicles.

12. Cost Implications (Lance Creek)

Prior to the implementation of the Lance Creek compact roundabout, a conventional roundabout design was developed and costed. The cost of the compact roundabout was approximately half the estimated cost of a regular roundabout at this site, costing $3.4M as opposed to an estimated $6.0M for a conventional roundabout.

The Benefit Cost Ratio (BCR) for the Lance Creek project was determined to be 1.7 using a Crash Reduction Factor (CRF) of 0.7. The BCR for the conventional roundabout was determined to be 1.9 using a CRF of 0.9.

13. Noise (Lance Creek)

Noise testing was conducted for the Lance Creek compact roundabout to evaluate the level of noise generated by the RSPs. The results showed a decrease in the level of noise generated when compared to existing conditions (i.e. the pre-roundabout intersection form). When interpreting these results, it should be noted that other works that were part of the roundabout construction, such as the rehabilitated pavement, have had an influence on the results. Nevertheless, the results indicate that the RSPs do not generate a sufficient amount of noise to consider them unsuitable due to noise.

At the time of writing, no noise complaints have been noted at the Lance Creek compact roundabout.

14. Community Engagement (Lance Creek)

The Lance Creek compact roundabout project was initiated by community concerns regarding safety at the intersection. The community had requested a small roundabout during the engagement process – which in their words was a ‘pizza roundabout’. Minimal concerns have been raised since its construction with it now operating as normal within the community. The community consultation was therefore very positive, and the project was well received.

15. Monitoring and Evaluation (Lance Creek)

As the first treatment of its kind in Victoria, the Lance Creek compact roundabout is being regularly monitored by a surveillance officer. Additionally, crash information from the intersection (or the lack thereof) is used as a measurement of the safety performance of the intersection. In addition to this, the following evaluations have been conducted for the compact roundabout:

- Noise Evaluation
- Truck Stability Assessment
- Speed evaluation
- Traffic Capacity Assessment (SIDRA)
- X-KEMM-X analysis

16. References

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17. Appendices

APPENDIX A	Design Criteria Log
APPENDIX B	Roundabout Design Principles Checklist

18.Revision History

Version	Date	Clause	Description of Change
1.0	October 2021	All	First version
No additional notes			

19. Contact Details

Road Design and Safe System Engineering

Department of Transport
60 Denmark St, Kew Vic 3101

Email: safesystemdesign@roads.vic.gov.au

Appendix A: Design Criteria Log

The designer/project officer is required to submit a completed version of the following table to allow DoT Road & Traffic Engineering to compile important design content at a glance. This will help to ensure consistency across sites and assist in formalising design guidance. For a softcopy of the associated Excel sheet, please email DoT Safe System Engineering (SafeSystemEngineering@roads.vic.gov.au).

Compact Roundabout Design Criteria Log (PROJECT-SPECIFIC)

Intersecting Road Names:	
Locality:	

Existing conditions				
Traffic Volumes	Leg #1*	Leg #2	Leg #3	Leg #4
Through movement (AADT)	-	-	-	-
% Heavy Vehicles (% / AADT)	-	-	-	-
Right turn movement (AADT)	-	-	-	-
% Heavy Vehicles (% / AADT)	-	-	-	-
Posted Speeds (km/h)	-	-	-	-

*Take leg #1 as the northernmost leg, with subsequent legs taken clockwise from this point

Roundabout Design				
Shape	-			
Central island inner radius *(i.e. Concrete Island only)*	-			
Central island outter radius *(i.e. Concrete Apron + Concrete Island)*	-			
Circulating carriageway width	-			
Crossfall adopted *(e.g. 2% / 0.020m/m)*	-			
Consideration of right turners	Leg #1	Leg #2	Leg #3	Leg #4
Design vehicle type *(e.g. PBS Level 2 - 26m B-Double)*	-	-	-	-
Design vehicle swept path speed	-	-	-	-
Check vehicle type	-	-	-	-
Check vehicle swept path speed (km/h)	-	-	-	-
Entry curves	Leg #1	Leg #2	Leg #3	Leg #4
Width (m)	-	-	-	-
Desired vehicle speed at entry to roundabout (km/h)	-	-	-	-
Speed differentials	Leg #1	Leg #2	Leg #3	Leg #4
Posted speed to roundabout entry speed (km/h)	-	-	-	-
Roundabout entry speed to right turn speed (km/h)	-	-	-	-

Raised Safety Platform Design				
Speed differntials	Leg #1	Leg #2	Leg #3	Leg #4
Posted speed to roundabout entry speed (km/h)	-	-	-	-
If ≤ 20km/h, recommend single approach RSP be considered *If > 20km/h & ≤ 40km/h, recommend two approach RSPs required be considered* *If > 40km/h, permanent speed reduction & two approach RSPs required*				
PRIMARY Profile (i.e. positioned **closest** to the roundabout)				
Approach ramp grade (e.g. 1:25)	-	-	-	-
Flat-top length (m)	-	-	-	-
Departure ramp grade (e.g. 1:35)	-	-	-	-
SECONDARY Profile (i.e. positioned **furthest** to the roundabout)				
Approach ramp grade (e.g. 1:25)	-	-	-	-
Flat-top length (m)	-	-	-	-
Departure ramp grade (e.g. 1:35)	-	-	-	-
Placement				
Offset of primary RSP to roundabout entry (m)	-	-	-	-
Offset of secondary RSP to primary RSP (m)	-	-	-	-
Logic around speed retention between RSPs				

Note: Please note fields as "N/A" where a primary or secondary RSP is not being adopted.

Appendix B: Roundabout Design Principles Checklist

It is recommended that the following table be included within design reports accompanying compact roundabout designs in high-speed rural environments. These principles should be applied to achieve a safe and efficient roundabout design.

Table 3: Roundabout Design Principles

Principle	**Met** (Yes / No)	**Risk mitigation** *(i.e. if principle not met)*
the roundabout should be clearly visible from the approach sight distance at the road operating speed in advance of the roundabout approach		*(Reference relevant section of Design Report where this is documented)*
the number of legs should desirably be limited to four (although up to six may be used at an appropriately designed single-lane roundabout)		
legs should desirably intersect at approximately 90°, especially for multi-lane roundabouts		
it is essential that appropriate entry curvature is used to limit the entry speed		
exits should be designed to enable vehicles to depart efficiently		
the periphery of the roundabout (inscribed circle diameter) must be large enough to accommodate all entries and exits to an appropriate standard without them overlapping		
the circulating roadway should be wide enough to accommodate the swept paths of the design vehicle/s plus clearance to kerbs for both through movements and right-turn movements		
entering drivers must be able to see both circulating traffic and potentially conflicting traffic from other approaches early enough to safely enter the roundabout		
sufficient entry, circulating and exit lanes should be provided to ensure that the roundabout operates at an appropriate level of service		

Note: While best practice in compact roundabout design is evolving, there will inevitably be elements of a design that have well established parameters or principles that need to be achieved.

For instance, an inability to achieve relevant sight distance requirements at a compact roundabout site should be treated as a design exception, documented accordingly and relevant approval sought. Substituting reverse curves for RSPs and adopting a central island radius below those noted in AGRD 4B does not provide a blanket exemption to other aspects of best practice in road design.