Road Design Note

Guidelines for the protection of gantry and cantilever sign supports

RDN 06-13

January 2019

1. Purpose

The purpose of this Road Design Note (RDN) is to provide additional guidance to designers when considering the protection of gantry and cantilever sign supports located in close proximity to traffic lanes.

Gantry and cantilever signs not only pose a roadside risk to errant vehicle occupants, but also to other road users should they collapse following impact. Therefore, unlike other roadside hazards, the potential risk of collapse and additional risk to third party road users, means designers need to consider whether a higher level of protection is required to mitigate the risk.

This RDN must be read in conjunction with the Austroads Guide to Road Design (AGRD) and VicRoads supplements (VRS). The information provided is intended to complement other guidelines hence VicRoads should be sought for clarification, regarding any unusual discrepancies.

This RDN does not apply to the protection of bridge piers, approach barriers or on bridges. In these cases, AS 5100 and relevant VicRoads Bridge Technical Notes must be used.

2. Background

This RDN has been issued in response to an increasing demand for gantry and cantilever structures on which static route information signs, Variable Message Signs, Lane Use Management Signs and Intelligent Transport Systems are provided.

It is necessary that designers understand and consider the additional risks specific to gantry and cantilever supports. Designers should consider the protection of errant vehicle occupants and a potential third-party road user when determining the most appropriate protection.

While current guidelines, such as AGRD Part 6 and VicRoads supplements, assist designers to assess and treat the risk of vehicle-to-hazard impacts, the consideration of third-party risk and consequence is not yet provided.

3. Safe system

VicRoads adopts a Safe System approach of shared responsibility, which means designers need to recognise that humans, as road users are fallible and will continue to make mistakes on the road. In a Safe System, roads would also be designed to reduce the severity of crashes when they inevitably occur.

Forgiving treatments which reduce the severity of an injury, such as Wire Rope Safety Barrier (WRSB), are preferred over less forgiving (more rigid) systems and should be used where they meet the objectives of the site.

For Gantry and Cantilever protection, barrier combinations should be considered to provide both a forgiving and higher containment barrier to reduce the likelihood of a vehicle occupant injury and structure collapse.

4. Additional risk

Gantry and cantilever sign supports are a potentially greater hazard than other roadside hazards (e.g. tree or batter) given their value to the network and consequence (or severity) in the event of a collapse.

In addition to AGRD Part 6 and VRS, Gantry and Cantilever supports should be designed with consideration of additional risks to a potential third party in accordance with this RDN.

Additional risks, specific to Gantry and Cantilever supports, should include the following:

- Consequence of a collapse. (4.1)
- Provision of a safe workplace. (4.2)
- Potential disruption to the network due to a collapse. (4.3)
- Asset value / repair cost (4.4)

4.1. Consequence of a collapse

This additional risk considers the likelihood that a collapse will occur, and the potential consequence to a third party in the event of a collapse (e.g. a collapsed structure impacting a vehicle).

4.1.1. Likelihood of a collapse

The likelihood of collapse is a function of '**impact frequency**' and '**structural capacity to resist an impact**'. In other words, the probability that an errant vehicle will impact the support with enough energy to cause a collapse.

Initially gantry and cantilever supports are not designed to withstand impacts from vehicles, the same way that supporting bridge piers are, and will collapse as a result of any impact.

The likely frequency that an errant vehicle may impact the support will depend on traffic exposure (volume) and can be determined with quantitative analysis methods, such as those specified in AGRD Part 6, Section 4.5 and 4.6 (e.g. RASPv3[9]).

Where a safety barrier is provided, the likelihood of impact and collapse will be reduced to include only vehicles that penetrate or vault the selected barrier. Higher barrier containment levels will reduce the risk of penetration further, while specific barrier types can be used to provide a more consistent mechanism of failure. See Section 6.4.

If gantry and cantilever supports can be designed to withstand a vehicle impact (see Section 7.3), the likelihood of a collapse can be further calibrated to vehicles with an impact energy that exceeds capacity. Collision protection is often combined with barrier protection to mitigate the risk further.

Hazard risk assessment tools, such as the Roadside Safety Analysis Program (RSAPv3[9]), can be used to assess the likelihood of hazard penetration and collapse, however, these results rely on the quality of input data and should only be used in conjunction with road design guidance, sound engineering judgment and informed decision making.

The 'likelihood of a collapse' may differ between two supports of the same structure, depending on the location and ability to withstand an impact. For example, a median overhead gantry support will typically have twice the traffic exposure to a verge support, increasing the likelihood of collapse.

4.1.2. Consequence to a third party

To assess the additional risk to a third party, designers should consider the probable outcome in the event of a collapse.

The primary factors that require consideration include:

- Number of trafficked lanes affected by a collapse;
- Probability that a vehicle is present during a collapse (e.g. traffic volume);
- Speed, sight lines and stopping distance provided for approaching vehicles.

Where gantry supports are shown to collapse in a predictable, uniform manner and a vehicle can be expected to avoid the hazard, the risk of third-party incident may be reduced.

4.2. Provision of a safe workplace

Gantry and Cantilever structures can be designed for easy access and maintenance under live traffic. Where a gantry or cantilever structure is intended as a workplace for maintenance personnel, the following must apply:

Section 28 of the Victorian OHS Act 2004, states that "a person who designs a structure, who knows that the structure is to be used as a workplace, must ensure that it is designed to be safe and without risks to the health of persons using it as a workplace for a purpose for which it was designed." [20]

The designer of a workplace gantry should therefore consider the need of a higher barrier containment level based on the frequency of maintenance, the routine tasks undertaken and the program to coordinate additional safety controls during work hours, such as a temporary speed reduction or adjacent lane closure during access.

4.3. Disruption to the network

Gantry and Cantilever supports are typically located on high speed, high volume roads and are used to house vital network infrastructure. Designers should recognise that in the event of a collapse, there could be a direct and/or indirect effect on the network operation.

The primary network disruption factors that require consideration include:

- Number of trafficked lanes affected by a collapse;
- Potential to detour traffic;
- Direct and in-direct network disruption;
- Removal and replacement disruption.

Direct network disruption includes delays to occupants on the affected road and connecting roads. Indirect network disruption includes resultant congestion and increased safety risk from detoured traffic using smaller arterial and local roads.

4.4. Asset value / repair cost

The asset owner is required to consider the value of the asset over its lifetime and potential repair costs in the event of an impact.

Where an increased cost to protect the asset is offset by a lower lifecycle repair cost from vehicle impact damage, this treatment should be considered.

This is primarily a cost-based decision and applies only to the protection of assets, not the vehicle occupant. As such, higher protection is only required near to the support and a more forgiving barrier system should be adopted on the approach to support safe system principles.

5. Risk categorisation

To assist designers and Projects in quantifying the additional risk for typical gantry and cantilever supports, four risk categories (1-4) have been provided, each with a minimum risk scenario and barrier criteria.

Where gantry and cantilever supports can be classified into one of these four categories, the protection should meet the minimum barrier criteria provided.

Risk categorisation should be undertaken on each support as the risk may differ between two supports of the same structure.

These risk categories have been provided as guidance for designers, on what is considered to be a complex problem, and must be used in conjunction with sound engineering judgment.

The classification process must consider all relevant additional risks mentioned in Section 4. Risk category examples below do not consider the whole of life asset value / cost.

5.1. Risk Category 1

The following is considered to be Risk Category 1: Minimum Scenario:

- A gantry or cantilever support that satisfies one or more of the following,
  - it cannot feasibly be impacted,
  - is designed to withstand all impact forces of an errant vehicle, or
  - it does not have the potential for additional risk e.g. does not project over a trafficked lane and is improbable to cause third party incidents.

Risk Category 1 supports demonstrate similar risk to other roadside hazards, and the additional risk of the structure is considered very low to none.

Category 1 Example Scenario

This cantilever support has a low probability of collapse given the elevated location and 60km/h likely impact speed. In this case, there is a very low chance for collapse or fatal and serious injuries.

Category 1: Minimum barrier criteria

Risk category 1 supports do not require consideration of additional risk in this RDN and should be treated as a hazard in accordance with AGRD Part 6 and VicRoads supplementary guidance (e.g. safety barrier).

NB: Safe system principles note that even hazards located outside the clear zone can still cause injury when impacted and should be treated to reduce the likelihood and severity.

Road safety barriers must be selected in accordance with RDN 06-04 and rated to the design speed of the road and expected vehicle class.

5.2. Risk Category 2

The following is considered to be Risk Category 2: Minimum Scenario:

- A gantry or cantilever support that satisfies all the following:
  - the likelihood of collapse is considered “low”, such as when the operating speed is less than 80km/h, or the support is sufficiently set back from the traffic lane on a straight section of road and away from diverge or merge points (e.g. outside clear zone);
  - the percentage of vehicles greater than <u>2T</u> (e.g. pick-up truck) is less than 15% or CV <u><8%</u> (Appendix B);

    AND the road has an AADT of less than 60,000 at 100km/h and less than 80,000 at 80km/h (Appendix E).
  - the structure does not provide access for maintenance workers during live traffic;
  - the possible network disruption from a collapse can be reasonably managed. e.g. collapsed structure is unlikely to block all lanes.

Risk category 2 supports recognise additional risk, but are very unlikely to be impacted as a result of a barrier penetration, do not provide access for maintenance workers and are considered manageable to the operation of the network in the event of a collapse. See the Category 2 Example Scenario below.

Supports with a greater additional risk, e.g. less offset, higher design speed or increased percentage of CV%, should be considered for Category 3 or above.

Category 2 Example Scenario

This cantilever support projects over a single on-ramp traffic lane. Thriebeam is TL-4 and is unlikely to be penetrated. In the event of a collapse, vehicles are unlikely to be impacted and the structure would have minor disruption to the network until repaired.

Category 2: Minimum barrier criteria

Risk category 2 supports must be treated with a road safety barrier rated Test Level 3 (TL-3) or higher and designed to 100km/h regardless of operating speed.

Road safety barriers must be designed in accordance with AGRD Part 6 and Section 6 of this RDN. Where a concrete barrier type is required, the barrier is to be designed in accordance with VicRoads Standard Drawings and AS 5100.

5.3. Risk Category 3

The following is considered to be Risk Category 3: Minimum Scenario:

- A gantry or cantilever support that satisfies all the following:
  - the support is located such that a desirable road geometry and barrier design (e.g. working width) is achieved;
  - the percentage of vehicles greater than 8T (e.g. moving van) is less than 15% or CV < 21% (Appendix B);

    AND the road has an AADT of less than 20,000 at 100km/h and less than 30,000 at 80km/h (Appendix E).
  - the structure does not provide access for maintenance workers or risks are mitigated with additional control measures (e.g. lane closure and/or speed reduction);
  - the possible network disruption from a collapse is critical but manageable (e.g. it projects over a single direction carriageway/ramp or contraflow is possible).

Risk Category 3 supports recognise a higher probability of collapse than Category 2, but the probable frequency of an impact is low and the asset value does not warrant a higher barrier containment level. See the Category 3 Example Scenario below.

Supports with greater additional risk, including when a working platform or vital piece of infrastructure is attached, should be considered for Category 4.

Category 3 Example Scenario

This cantilever support projects over a single traffic lane.

Straight road alignment with 15% CV. Barrier offset 3m from traffic lane.

Asset value likely warrants greater protection than TL-3 as shown in photo. Maintenance must be completed with a temporary speed reduction.

Category 3: Minimum barrier criteria

Risk category 3 supports must be treated with a road safety barrier rated and designed to Test Level 4 (TL-4) or higher regardless of operating speed.

Road safety barriers must be designed in accordance with AGRD Part 6 and Section 6 of this RDN. Where a concrete barrier type is required, the barrier must be in accordance with VicRoads Standard Drawings and AS 5100.

5.4. Risk Category 4

The following are considered to be Risk Category 4: Minimum Scenario:

- A gantry or cantilever support with a high risk of collapse. This will typically include a combination of either minimum road geometry, high speed, high volume and increased CV%;
- A gantry or cantilever with access for maintenance workers under high speed live traffic;
- A gantry or cantilever that will have detrimental consequences to the road network in the event of a collapse. e.g. spans an entire road carriageway.
- A gantry or cantilever that houses valuable network assets and warrants the use of a higher barrier containment level and barrier confidence.

Risk category 4 supports recognise that one or more additional risks may be detrimental to the safety of road users or the operation of the road network in the event of an impact.

These gantries will typically include working platforms & access ladders, valuable infrastructure and/or have a high likelihood of collapse or consequence.

Category 4 Example Scenario

This gantry projects over the entire carriageway.
Maintenance to be completed during controlled traffic management.
Gantry support houses vital network assets.

Medium minimum: Medium recommended

Category 4: Minimum barrier criteria

Category 4 supports should be treated in accordance with AS 5100: Bridge design. Safety barriers must be CONCRETE, and the minimum barrier containment level must be 'Medium' or higher as determined by a risk assessment.

This risk assessment must evaluate all additional risks of the support and conclude the containment level required considering the methodology detailed in *AS5100.1 Appendix B: Road Barrier Performance Level Selection Method*[5] or an approved alternative.

Road safety barrier layouts should be designed in accordance with AGRD Part 6 and Section 6 below. It is noted that at the time of writing this RDN, a 'Medium' performance barrier or higher has not been accepted in RDN 06-04, therefore all concrete barriers must be engineered and designed in accordance with SD 3901, AS 5100 and Bridge Technical Notes.

6. Road Safety Barrier Design

Gantry and cantilever supports that have additional risk (i.e. Risk Category 2 to 4) must be treated with a road safety barrier that is designed in accordance with AGRD Part 6, relevant VicRoads supplements and this document.

The following section is structured as per the road safety barrier design process detailed in AGRD Part 6, Figure 6.1.

A modified version of the barrier design process (Figure 6.1) has been provided in Appendix F to include the guidance within this document. This process may be used by designers.

6.1. Collect information about site and barrier objective (B1 & B2)

The objective of gantry and cantilever protection is to;

- protect road users from impacting the support, and
- shield the support from impact, to protect the asset and mitigate the potential of collapse and consequence to third parties.

To assess the relevant additional risk, designers must understand the expected mode of transport of the site (e.g. vehicle types & distribution), the possible impact conditions and intended use of the structure. Site context is critical to ensure the barrier is designed for the expected road user and the potential for a barrier penetration is understood.

6.2. Determine the lateral offset of the barrier (B3 & B4)

Gantry and cantilever supports are typically located close to the road where a desirable barrier offset of 3-4m cannot be achieved. While desirable barrier offsets are still preferred, other objectives must be balanced such as the management of internal stresses (maximum span) in cantilever gantries.

Findings from an Austroads (2012)[8] report indicate that most vehicles recover within the first 2.0m of sealed shoulder. As such, where 3.0m cannot be achieved, a short length of barrier offset at 2.0-2.5m from the traffic lane may be adopted in front of the support without approval. This offset aims to:

- reduce nuisance impacts on the barrier and the overall time the barrier remains damaged,
- minimise the potential for vehicles to impact the barrier at high angles, and
- minimise maintenance costs over the life of the barrier.

Where a reduced barrier offset is required and the support cannot be relocated, the barrier should be able to withstand nuisance impacts to minimise repair costs and mitigate the risk of a damaged barrier not performing as intended.

Barrier offsets less than desirable should be limited to locally in front of the support and a flare rate should be adopted in accordance with AGRD Part 6 to reduce perception effects for motorists (e.g. shy away effects) and opportunity for stopping.

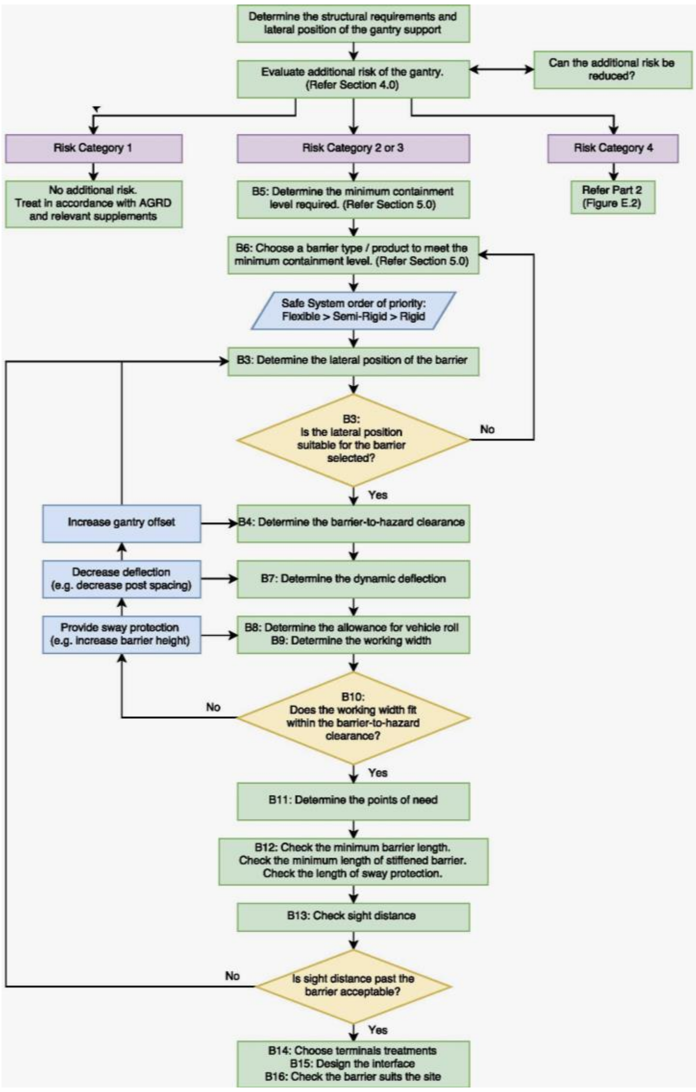

Figure 6.1: Road Safety Design Process (Modified) (Source: Appendix E, Figure E1)

6.3. Determine the containment level required (B5)

VicRoads does not provide objective warrants for the use of higher containment roadside barriers outside of this RDN, and site-specific factors are often required to be considered such as percentage of heavy vehicles, road geometry or severe consequences associated with a penetration.

AGRD Part 6 states that if the run-off-road risk associated with heavy vehicles is particularly high or the consequence of a run-off-road would be catastrophic, a barrier meeting TL-5 or TL-6 may be considered being largely based on consideration of additional risk and consequence of a heavy vehicle impacting the support.

Supports classified as risk category 2-3 should be protected with a safety barrier rated to the minimum test level specified in Section 5. Higher containment levels should be considered where the risk is greater than the minimum scenario, e.g. when traffic has a high percentage of heavy vehicles.

Test Level	Vehicle (kg)	Speed (km/h)	Angle	Impact Severity (kJ)	Vehicle (kg)	Speed (km/h)	Angle	Impact Severity (kJ)
	NCHRP Report 350				MASH			
1	2,000	50	25°	34.5	2,270	50	25°	39.1
2	2,000	70	25°	67.5	2,270	70	25°	76.6
3	2,000	100	25°	138	2,270	100	25°	156.4
4	8,000	80	15°	138	10,000	90	15°	209.3
5	36,000	80	15°	595	36,000	80	15°	595
6	36,000	80	15°	595	36,000	80	15°	595
Special[1]	44,000	100	15	1137				

Table 6.1: Test level conditions and impact severities

Source: AS/NZS 3845.1 Road Safety Barriers[4]. Not all impact conditions are included.
Note 1: Special performance as outlined in AS 5100.2:2017 Appendix A – Design loads for special performance level barriers[6].

To assess the risk and conclude a barrier containment level, designers should understand the criteria to which road safety barriers are tested, and be able to compare a potential vehicle impact with the crash tested capacity.

For example, Test Level 4 (NCHRP350) barriers are tested to capacity with an 8,000kg truck impacting at 80km/h and 15 degrees. See Table 6.1. Impacts from heavier vehicles with a greater energy are more likely to breach the barrier.

As a recommended guide, a higher containment barrier should be considered when more than 15% (85th percentile) of vehicles are heavier than capacity, e.g. where 15% of vehicles are greater than 8,000kg, a TL-5 barrier should be considered. See methodology in Appendix B for guidance.

Supports classified as risk category 4 must be protected with a <u>CONCRETE</u> safety barrier rated to a performance level determined via AS 5100.1 Appendix A.

While ‘Medium’ performance should be the minimum level required, the barrier performance level selection method in Appendix A of AS 5100.1 should be completed to determine if a higher performance level (‘High’, ‘Special’) should be adopted. If an alternative methodology is proposed (e.g. RASPv3[9]), it must be agreed by the Superintendent and Manager Safe System Engineering in writing.

6.4. Choose the barrier type (B6)

This section does not apply to category 4 supports which must be protected with a <u>CONCRETE</u> safety barrier.

The type of barrier (flexible, semi-rigid or rigid) chosen for risk category 2 & 3 supports should be based on relevant guidance, site constraints and product specific performance.

Figure 6.2 shows an example of how the support offset can influence barrier type, based on TL-4 containment level, a straight alignment and 100km/h design speed.

6.4.1. General

As per AGRD Part 6, Section 6.2 and Section 6.3.14, the key parameters to consider when selecting a barrier type include; Performance, Deflection, Site Conditions, Compatibility, Cost and Maintenance.

In reality, the potential impact conditions and distribution of vehicle types on a section of road are broader than those used during crash testing. Designers must recognise the mode of transport that can impact the barrier and select the performance level required to meet objectives.

For details on the performance of specific barrier types, refer supplementary guidance such as RDN 06-02, RDN 06-04, RDN 06-08 and Detail Sheets on the VicRoads website.

6.4.2. Capacity for heavy vehicles

To date, the capacity for a barrier to contain and redirect a heavy vehicle has been largely based on impact conditions; e.g. whether the impact energy is less than the barrier capacity and the barrier engages with the vehicle.

In fact, exceeding the energy capacity of a barrier does not necessarily mean the barrier is totally compromised, but rather it begins a failure process that depends on many variables including barrier type and method of failure (e.g. rollover, structural failure or vaulting) -NCHRP 2013[9].

The choice of barrier type should consider the traffic distribution and if required, the ability to contain a heavy vehicle. Certain barrier types may require greater deflection area, a vehicle roll allowance (Section 6.6) or the addition of sway protection (Section 6.6.2).

Detailed guidance on the “capacity for heavy vehicles” is not always readily available and engineering judgment is critical.

6.4.3. Barrier performance confidence

Where barrier protection is critical to mitigate the additional risks of a support, the confidence in which a barrier is likely to contain a vehicle should be considered.

Barrier types with a uniform dynamic deflection, additional capacity, or predictable failure mechanism can provide greater confidence and mitigation of risk than barriers with multiple performance variables.

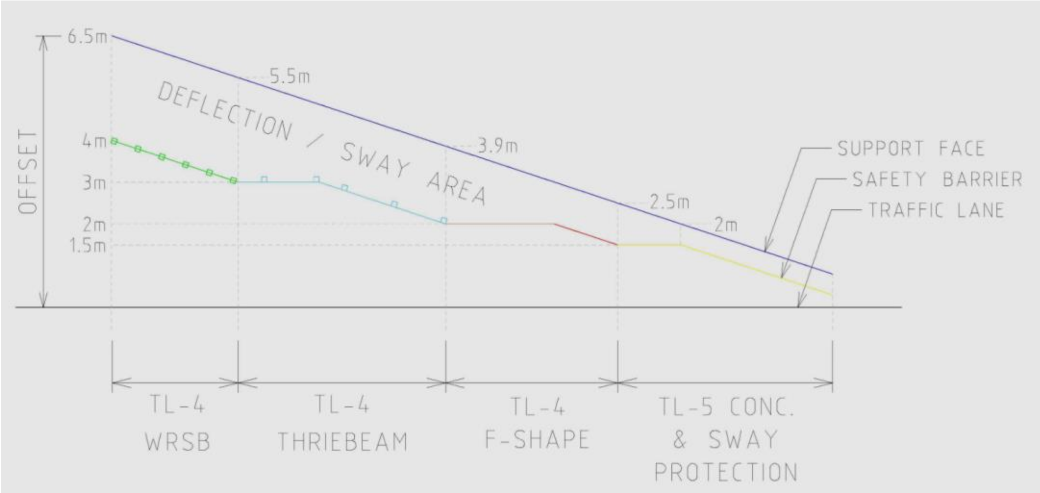

Figure 6.2: Example of TL-4 barrier type vs. offset

For example, concrete barriers are designed for limited and sometimes zero deflection (excluding vehicle roll allowance) when the impact energy is less than capacity. In the event of a greater vehicle impact, concrete barriers have shown to absorb energy during failure or cause the vehicle to roll over the barrier. This can provide a high level of protection confidence even for impacts with high angles or unconventional vehicle shapes.

In comparison, semi-rigid and flexible systems rely more on barrier-vehicle engagement. While crash testing demonstrates a 'worst practical case', these barrier types possess a risk of penetration from unconventional impact conditions (e.g. increased deflection).

Gantry and cantilever signs that provide maintenance access under live traffic should adopt a high level of performance confidence, such as concrete barrier.

Software such as RSAPv3[9] or computer simulation techniques may be used to assess the risk of barrier penetration for several impact scenarios including vehicle roll, structural fail or vaulting.

6.4.4. Maintenance and Repair

Key maintenance factors for barrier selection include:

- Routine and Periodic maintenance
- Collision repair (cost and frequency)
- Safety risk / exposure from a damaged barrier

While these parameters are typically regarded as cost factors, (e.g. repair cost and frequency) designers should consider the potential safety consequence where these tasks are not undertaken.

For example, WRSB must be periodically maintained to meet consistent barrier performance compared to concrete barriers which require no routine maintenance. Concrete barriers can also withstand greater impacts without damage, thereby increasing the overall time that a barrier is effective.

6.4.5. Vulnerable road users

Where the gantry or cantilever support is located in a high-risk area for vulnerable road users, consideration must be given to tested barrier types with protection for vulnerable road users.

For example, motorcyclists are more likely to lose control on the outside of tight curves and the barrier type in this location should allow for motorcyclist protective treatments, such as the use of continuous motorcyclist protection.

If a barrier treatment cannot provide the minimum containment level and protection for high risk vulnerable road users, the support location should be reconsidered.

6.5. Determine dynamic deflection (B7)

The likelihood of replicating a tested dynamic deflection value on-site will rely on the potential weight, speed and angle of an impacting vehicle.

Risk Category 2, 3 and 4 barriers must be designed for a 100km/h deflection regardless of design speed.

Where the percentage of heavy vehicles is high, an additional safety factor should be built into the design, such as a greater deflection area or vehicle roll allowance (Section 6.6).

Product specific dynamic deflection is documented in relevant VicRoads Road Design Notes, Detail Sheets and Supplier design manuals.

It is important for designers to note that although dynamic deflection is a key consideration of safety barrier design, the barrier should achieve a positive life-cycle benefit/cost, including safety, maintenance and other ongoing considerations. Decreasing deflection will increase the stiffness and severity of the barrier for impacting vehicle occupants.

6.6. Determine vehicle roll allowance (B8)

Vehicle roll allowance, also known as Working Width, must be considered and provided for all gantry and cantilever protection, in accordance with this section.

6.6.1. General

Vehicle roll allowance provides additional clearance behind the barrier for taller vehicles that may roll beyond the barrier during redirection. This may include heavy vehicles with an impact energy less than capacity.

The concept of vehicle roll is depicted with an indicative line of roll experienced by an impacting vehicle. See Figure 6.3.

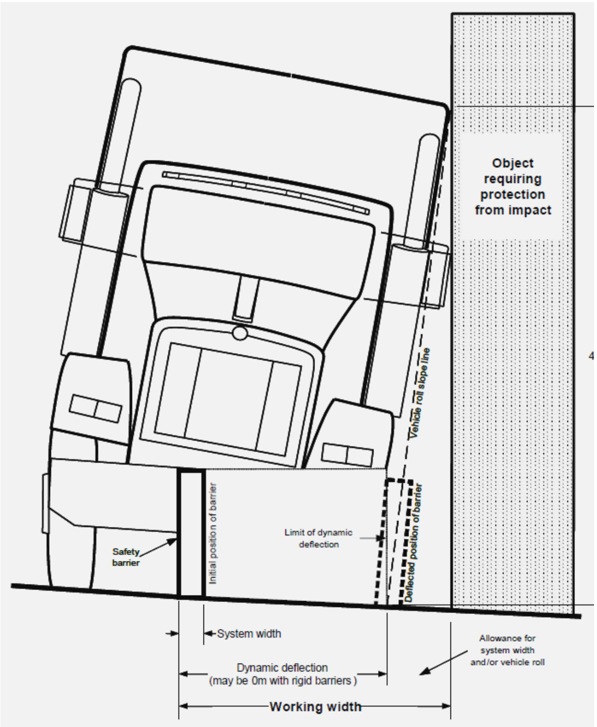

Figure 6.3: Working Width

Barrier suppliers are required to document working width (roll allowance) during crash testing, which is typically observed only with larger test vehicles such as the TL-4 (8T-10T) truck and above. Refer relevant Detail Sheets, Product Manuals or Road Design Notes for barriers with working width values.

6.6.2. Methods of vehicle roll allowance

Where working width values are not provided for a barrier product, the vehicle roll allowance must be determined using the following:

- Austroads Guide to Road Design Part 6, Table 6.8 should be used for rigid and semi-rigid barriers approximately 800mm high;
- The barrier "point of contact method" should be used for rigid barriers greater than 800mm high, typically TL-4 concrete barriers adopted for Risk Category 3 & 4 supports. The point of contact method adopts a projected vehicle roll line that contacts the face of the barrier and is extended to a height of 4.6m above the pavement surface. See Figure 6.4.

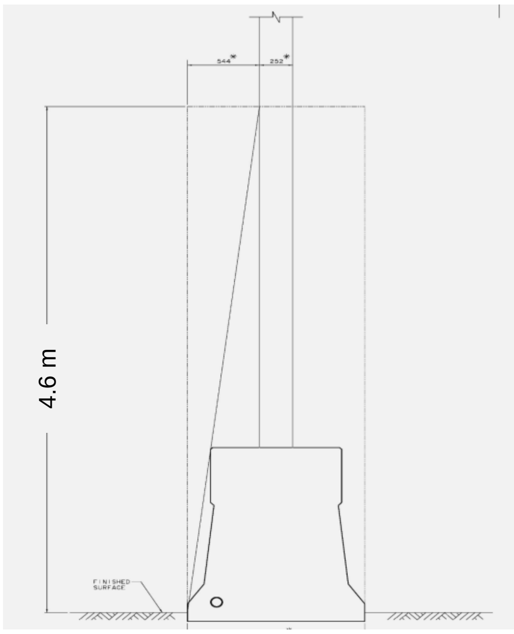

Figure 6.4: Point of contact method

6.7. Check that working width is less than the barrier-to-hazard clearance (B10)

Gantry and cantilever supports must be located outside the barrier working width (deflection + roll allowance). If impracticable, the support must only be located within the working width where all risks have been evaluated and the following order of precedence has been documented:

- alternate barrier type and design (6.4),
- provision of barrier sway protection (6.7.1);
- higher containment level (6.3) or,
- collision protection for the support (7.3).

Where a Risk Category 4 support is still located within the working width of the barrier, the barrier must have sway protection (Section 6.7.1), a minimum effective height of 1500mm (Special T44[5]) above pavement level and the support must be designed for a minimum collision load of 200kN (Medium Performance Level longitudinal load[5]) applied 1m above the top of barrier. This ensures the risk has been mitigated as far as practicable.

6.7.1. Sway protection

Sway protection for concrete barriers can be used to reduce the amount of vehicle roll above and beyond the barrier that would otherwise impact the support.

Sway protection is not necessarily intended to increase the containment level of the barrier, but can be used in the vicinity of a support for additional risk mitigation. Sway protection can be used to protect both the asset and vehicle occupant of a heavy vehicle. This is effective where the percentage of heavy vehicles is high enough to warrant protection from the gantry.

Sway protection is a modification to barrier profile and should be used only when necessary. All modifications to profile should retain smooth vehicle redirection and limit snagging; excessive protrusions with the sole intent of satisfying vehicle roll allowance is prohibited and can be unsafe.

Concrete barriers with sway protection must retain the F-Shape profile in accordance with SD 3901 to an effective height of 920mm above pavement level. An example of a concrete barrier with sway protection has been detailed in Figure 6.5.

Figure 6.5: Sway protection example

6.8. Determine barrier points of need (B11)

The barrier points of need should be determined in accordance with the 'Run-out Length Method' specified in AGRD Part 6 and VicRoads supplements. VicRoads standard drawing SD 3521 adopts this method for a range of hazard & barrier offsets.

The minimum barrier containment level and type determined must extend between the vehicle run-out-lines to adequately protect the support.

Outside the length of need, the barrier may be terminated or transitioned in accordance with VicRoads guidelines. Flaring the safety barrier may be adopted in accordance with AGRD Part 6 to reduce the length of barrier required.

Where sway protection or reduced deflection is required locally in front of the support, the minimum length should be based on performance requirements of the barrier variant. For example, the length of reduced post spacing for a WRSB must extend either side of the support to ensure a reduced deflection at the support.

Case Study: gantry protection barriers for the M80 adopted a concrete barrier length of 36m, 24m before and 12m after the support to provide enough contact length for the redirection of heavy vehicles in front of the support. This was in addition to guard fence that extended to the barrier point of need.

6.8.1. Points of need for two-stage protection

If a two-stage protection system (Section 7.1) has been adopted, the barrier points of need may differ for each system.

The 'run-out-length method' must be applied to the primary (front) barrier intended to protect road users. This is the minimum length of barrier to address run-off-road risk. The secondary (back) barrier however, if intended to only prevent heavy vehicle collision with the gantry support, may consider a 15° departure angle as the run-off line for a heavy vehicle. See Figure 6.6.

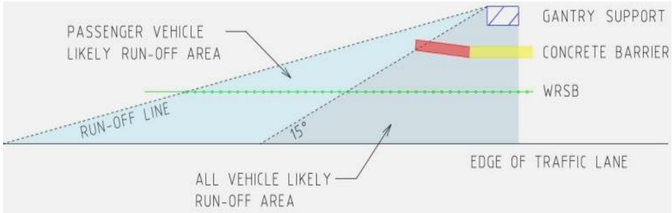

Figure 6.6: Two-stage protection points of need

6.9. Choose terminal treatments (B14)

Terminal treatments are designed to protect the end of a longitudinal barrier. As such, any additional risks considered for the gantry or cantilever support do not apply to the barrier terminal. The containment level of the terminal should meet the design speed of the road. Refer RDN 06-04 for accepted terminal treatments.

6.10. Design the transitions between barriers (B15)

Transitions between concrete barrier containment levels should be done in accordance with VicRoads Bridge Technical Notes and must transition consecutively in performance level.

The transition length between two containment levels is considered at the lower barrier containment level and should be situated outside the minimum length of need required.

Transitions in barrier height must be done at a maximum rate of 1:10.

Transitions that require a change in barrier offset to the traffic lane must refer AGRD Part 6, Section 6.3.5: Step B3.

7. Other design considerations

7.1. Location of gantry and cantilever supports

The effective location and spacing of gantry and cantilever structures should be designed in relation to certain road features in accordance with *VicRoads Traffic Engineering Manual* and *Freeway Ramp Signals Handbook*.

Where flexibility is available from a traffic engineering perspective, the location of supports (chainage and offset) should be in conjunction with barrier design to balance multiple objectives.

To lower the additional risk of a support and resultant level of protection required, gantry and cantilever supports should be located in areas with a low likelihood of vehicle impact.

Supports should be sufficiently offset from the traffic lane to accommodate the installation of more forgiving barrier systems such as WRSB or flexible GF.

Where a certain barrier type is preferred, e.g. motorcyclists have been identified and a motorcycle friendly barrier is desirable, supports should be located to accommodate suitable barrier designs.

7.2. Two-stage protection

Where adequate offset is available from the traffic lane, the use of a two-stage protection system can provide a forgiving barrier system for the safety of passenger vehicle occupants, and a high containment barrier for the mitigation of additional risks. Flexible barrier systems are preferred to reduce impact severity of vehicle occupants.

Two-stage protection will require supports to be offset further from the road and is not always beneficial unless the additional risk of the structure is considered high.

An example of a two-stage protection is shown in Figure 7.1; a rigid concrete barrier rated to the required containment level is offset 1.9-2.3m behind a WRSB (working width) which is offset 3.0m from the traffic lane. The extent of concrete barrier is enough to capture potential heavy vehicles that may cause collapse, and the extent of WRSB is enough to reduce impact severity for vehicle occupants. See also AGRD Part 6, Section 6.3.14.

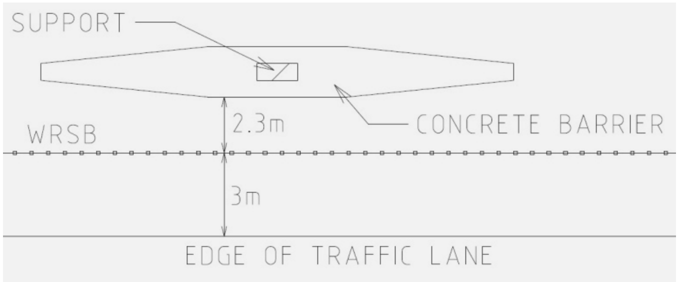

Figure 7.1: Example of two-stage protection

At the time of writing, the effect of a two-stage protection when determining the barrier containment level has not been quantified. While errant heavy vehicles are less likely to penetrate two safety barrier systems compared to one, the precise interaction and benefit is unknown therefore the containment level should be selected in accordance with Section 6.3.

It is noted that computer simulation is becoming increasingly common and as more expertise is developed worldwide, the use of simulation techniques is strongly recommended to support complex decision making in constrained locations, especially when a reduced containment level is proposed.

7.3. Gantry leg collision protection

To minimise the level of additional risk, gantry and cantilever supports can be designed to resist the collision load of an impacting vehicle.

While collision protection may be used to mitigate additional risk of a collapse, a barrier combination should be provided to protect the occupants of passing traffic from impacting the support.

Collision loads from road traffic

AS 5100.2:2017 states that where supports are located within the clear zone, and not located behind an appropriate protective barrier, they shall be designed to resist a minimum equivalent static load of 2700 kN acting in any direction in a horizontal plane, applied 1.2 m above ground level.

Assuming an impact deformation of 0.3m, this 2700 kN collision force equates to a 4,500kg vehicle impacting at 60km/h and does not represent the maximum force generated in a collision. AS 5100.2:2005 commentary states that for high speed roadways (>60km/h), a higher collision load should be investigated.

In theory, the collision load adopted should be based on the maximum vehicle impact on-site to eliminate additional risk. In practice, designing solely for collision protection is not ideal and a combination of protection that can redirect most errant vehicles away from the gantry and resist the collision loads from a barrier penetration is more cost effective.

Where a Risk Category 4 support is located within the working width of the barrier, refer Section 6.7.

7.4. Light poles, light mast and power pole protection

Light poles, light masts and power poles are not required to be protected in accordance with this Road Design Note.

It is however recommended that the design and protection of structures such as these, considers any relevant additional risks detailed in Section 4, and are protected in accordance with relevant guidelines and engineering judgement.

Refer to Bridge Technical Note 014 – Sign gantries and lighting masts.

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5. Australian Standard, 2017, AS 5100.1: 2017 Bridge Design, Part 1: General Principles;
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18. VicRoads, 2018, Standard drawings for roadworks;
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21. VicRoads, 2018, Bridge Technical Note 014: Sign gantries and lighting masts;

Appendices

APPENDIX A: Summary of concrete barrier guidelines

APPENDIX B: Containment of heavy vehicles

APPENDIX C: Worked Example – Risk Category 3 (seeking examples)

APPENDIX D: Worked Example – Risk Category 4 (seeking examples)

APPENDIX E: Modified Road Safety Barrier Design Process

APPENDIX F: Risk profile comparison with AS5100.1:2017

APPENDIX G: Risk Category – Summary Table

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Road Design Note 06-13 – Revision Summary

Issue	Approved	Date	Amendment
v1.0	M-SSD	Feb2018	First edition
v1.1	M-SSD	Jan2019	Revisions related to AS5100 and similar references. Editorial changes.

Appendix A – Summary of concrete barrier guidelines

This appendix summarises current safety barrier requirements and the design of rigid concrete barriers. Content in this Appendix is informative only.

AS/NZS 3845: 2015 – Road safety barriers

AS/NZS 3845 sets out the requirements for both permanent and temporary road safety barrier systems, including testing methods, the evaluation process, manufacturing, installation and maintenance.

In simplest terms, it informs road authorities on how safety barriers should be tested and evaluated for suitability.

It details the preferred crash testing required to establish a system's suitability, the material specifications and the accompanying documentation. It is intended that Road Authorities review the information in this Standard to meet a duty of care for barrier systems on the network.

For rigid barriers, where the installed configuration (e.g. foundation) is different to a crash tested configuration, it must be of sufficient strength to assist the barrier to resist the lateral loads and effective load height specified in AS 5100.2 for the dynamic forces applied by the design performance crash test with minimal if any resulting deflection or deformation.

AS 5100: 2017 – Bridge design

AS 5100 is intended for the design of rigid barriers on new and existing bridges, and through reference in AS/NZS 3845 is also relevant where roadside concrete barriers cannot be installed as they were crash tested. AS 5100 provides the criteria to design the anchorage, footing, foundation, and material (including reinforcement) of concrete barriers.

In simplest terms, it details how rigid concrete barriers should be designed to resist impact forces from heavy vehicles and built to provide a long-term maintainable asset.

Ultimate design loads in AS 5100 have been chosen to align with values in AASHTO LRFD Specifications, to allow for barriers crash tested in accordance with NCHRP Report 350 and MASH to be adopted. Equations for the analysis of stresses have been provided in AASHTO LRFD (2012).

AGRD Part 6 – Roadside design, safety and barriers (2010)

Austroads Guide to Road Design part 6 provides guidelines for hazard identification, mitigation and a clearly defined process for designing roads for safety.

In simplest terms, it tells designers and Road Authorities what is considered a hazard/risk and how to best mitigate that hazard/risk considering all road users.

Hazards and barriers are assessed based on impact severity, while guidance on barrier products or minimum containment level is left to the designer and guidance from Road Authorities.

As such this RDN should be used to supplement the AGRD Part 6 and ensure designers consider the additional risk and severity of a gantry or cantilever support.

At the time of writing this RDN, AGRD Part 6 is being updated to consider the principles of safe system to advise Road Authorities and designers on the preferred methodology to protect hazards.

VicRoads safety barrier requirements (2017)

In Victoria, crash testing criteria from AS/NZS 3845.1 has been adopted as the minimum for all roadside safety barriers. Safety barriers are subject to a matrix of impacts using a described vehicle, speed and angle while meeting a set of criteria that is based on factors of structural adequacy, occupant risk and vehicle trajectory.

Safety barrier products that have been evaluated and accepted by VicRoads are listed in Road Design Note 06-04 – Accepted safety barrier products.

Safety barriers should be designed in accordance with AGRD Part 6 and VicRoads supplements to ensure the barrier will mitigate the risk. Where hazards have additional risk to 3rd parties, then guidance such as this RDN must be sought.

Barriers products selected for site (e.g. Conc., GF, or WRSB), must also be designed in accordance with product specific requirements to ensure the barrier performs as designed.

NCHRP Report 350 vs MASH

MASH (Manual for Assessing Safety Hardware) is the new set of guidelines for crash testing safety devices and will replace the previous testing standard: NCHRP Report 350.

AS 5100:2017 uses MASH as the basis for design loads.

VicRoads accepts both MASH and NCHRP 350 roadside safety barriers and is currently transitioning to MASH only.

VicRoads concrete barrier requirements (2017)

In Victoria, F-Shape is the preferred concrete barrier profile for its superior small car performance. Standard profile dimensions and concrete barrier requirements are provided in Standard Drawing SD 3901.

Roadside concrete barriers (Test Level) must be designed, built and installed in accordance with the suite of standard drawings. Performance Level concrete barriers (e.g. used on structures and the approach) must be in accordance with AS5100.

The manufacture and installation of concrete barrier will depend on the Test Level or Performance Level required.

Concrete barriers with sway protection are often required to modify the F-shape profile or height. To minimise the potential for snagging or small car de-stabilisation, the profile shown in SD 3901 must be used.

Concrete barriers with steel rails must be designed in accordance with AS 5100.

Appendix B – Containment of heavy vehicles

Barrier containment level should be selected based on the specific weight distribution of passing traffic. Unfortunately, detailed traffic information is not always readily available and the CV% is often used to make decisions.

This appendix discusses containment of heavy vehicles and provides designers with a general guide to protect heavy vehicles based on CV%.

This guidance uses network wide assumptions and does not preclude the importance or need to consider site specific context. Refer Assumptions, notes and other considerations.

Heavy vehicle vs. commercial vehicle

'Commercial vehicle' is a term typically used within traffic volumes and includes non-passenger vehicles from small trucks (4.5T GVM) and towing (car + caravan) to large trucks.

This can differ to the term 'Heavy vehicle' which may refer to a vehicle of greater mass than the capacity vehicle used during barrier crash testing. Including:

- TL-3: 2,000kg Pick-up,
- TL-4: 8,000kg Truck, and
- TL-5: 36,000kg Articulated Van.
- TL-6: 36,000kg Tanker

Relationships between heavy and commercial vehicles

The following guidance uses data from a 2015 study of the entire Victorian registered vehicle fleet and documented vehicle weight / type.

The general weight distribution of registered vehicles at September 2015 on the network can be seen in Figure B.1. The weight gap between 3000kg-4500kg is due to the record change from Tare to GVM.

Using this distribution, the percentage of vehicles can be grouped by weight into the barrier test levels, and an approximate relationship between Commercial Vehicles and Heavy Vehicles can be predicted.

This can be converted into the following relationships;

- % vehicles: 820-2000 kg = 92 x (1-CV%)
- % vehicles: 2000-8000 kg = 8 + (22 x CV%)
- % vehicles: 8000-16500 kg = 42 x CV%
- % vehicles: 16500-36000 kg = 24 x CV%
- % vehicles: > 36000 kg = 4 x CV%

Note: CV% to be written as a decimal.

Figure B.1, for example, shows that 8% of non-CV's and 30% of CV's generally weigh between 2000-8000kg.

	Weight Range (kg)	Non-CV Cumulative percentage	Total	CV Cumulative percentage	Total
Test Level 3	< 800	0.7		-	
	800-1100	16		-	
	1101-1400	49	92 %	-	-
	1401-1700	82		-	
	1700-2000	92		-	
Test Level 4	2001-2300	98		-	
	2301-2600	99		-	
	2601-2900	>99	8 %	-	30 %
	4501-6000	-		6	
	6000-8000	-		30	
Test Level 5	8000-10000	-		38	
	10000-12000	-	-	51	42 %
	12000-16500	-		72	
	16500-20000	-	-	76	24 %
	20000-36000	-		96	
	> 36000	-	-	>99	4 %

Figure B.1: Registered vehicle weight distribution (2015)

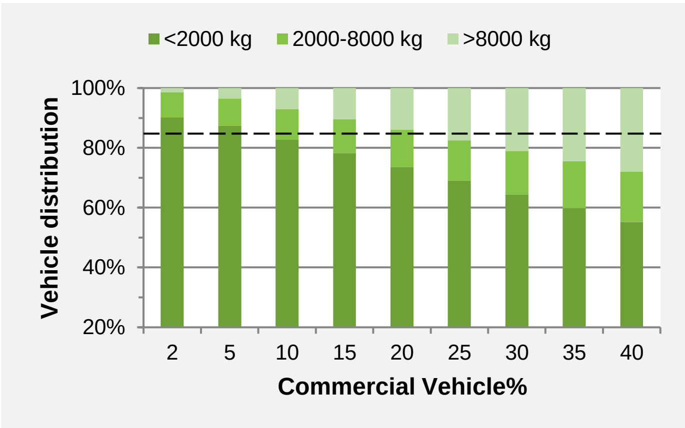


Figure B.2: Vehicle weight distribution vs. CV%

Containment of heavy vehicles

As a general minimum, the 85th percentile of passing traffic should be contained by a road safety barrier.

Figure B.2 uses the relationships determined to graph the calculated weight distribution based on CV%.

Summary:

- The percentage of vehicles larger than 2,000kg will exceed 15% when the percentage of CV exceeds 7.6%.
- The percentage of vehicles larger than 8,000kg will exceed 15% when the percentage of CV exceeds 21%.

As such, a TL-4 and TL-5 safety barrier should be considered when the CV% exceeds 7.6% and 21% respectively.

Assumptions, notes & other considerations

- This method assumes that the traffic distribution for the road is similar to the entire network. In practice, certain vehicle types may be more common depending on the local area which should be considered. E.g. Tourist roads with low traffic count but carrying significant numbers of buses should consider a higher containment level.
- Vehicle weight distribution data (2014) does not include special vehicles such as Busses, Service or Emergency, given the ratio would be quite low compared to all vehicles.
- This section provides general guidance on when to increase the minimum barrier level based on vehicle weight. It does not recognise high risk locations or very low volume roads where the exposure is low.
- This method does not include the likely impact speeds and angles on-site. This would require further analysis to demonstrate that a vehicle is more or less likely to penetrate a barrier at various speeds and angles.
- AS 5100.1:2017 Table A2 shows a different vehicle mix to be used for benefit cost analysis; the original data could not be located for comparison. It is however expected that differences in the classification may make an accurate comparison difficult and given that both methods are general, rather than site specific, such a comparison would not be overly valuable. Refer Figure F1.
- Other Australian Road Authorities may develop methods to determine containment level based on vehicle mix and distribution. The methods may be considered when they become available.

Appendix C – Worked example: Risk Category 3

We are seeking opportunities for a worked example. If you have any comments or suggestions, please contact the author noted on the last page for consideration in the next revision.

Appendix D – Worked example: Risk Category 4

We are seeking opportunities for a worked example. If you have any comments or suggestions, please contact the author noted on the last page for consideration in the next revision.

Appendix E: Modified road safety barrier design process

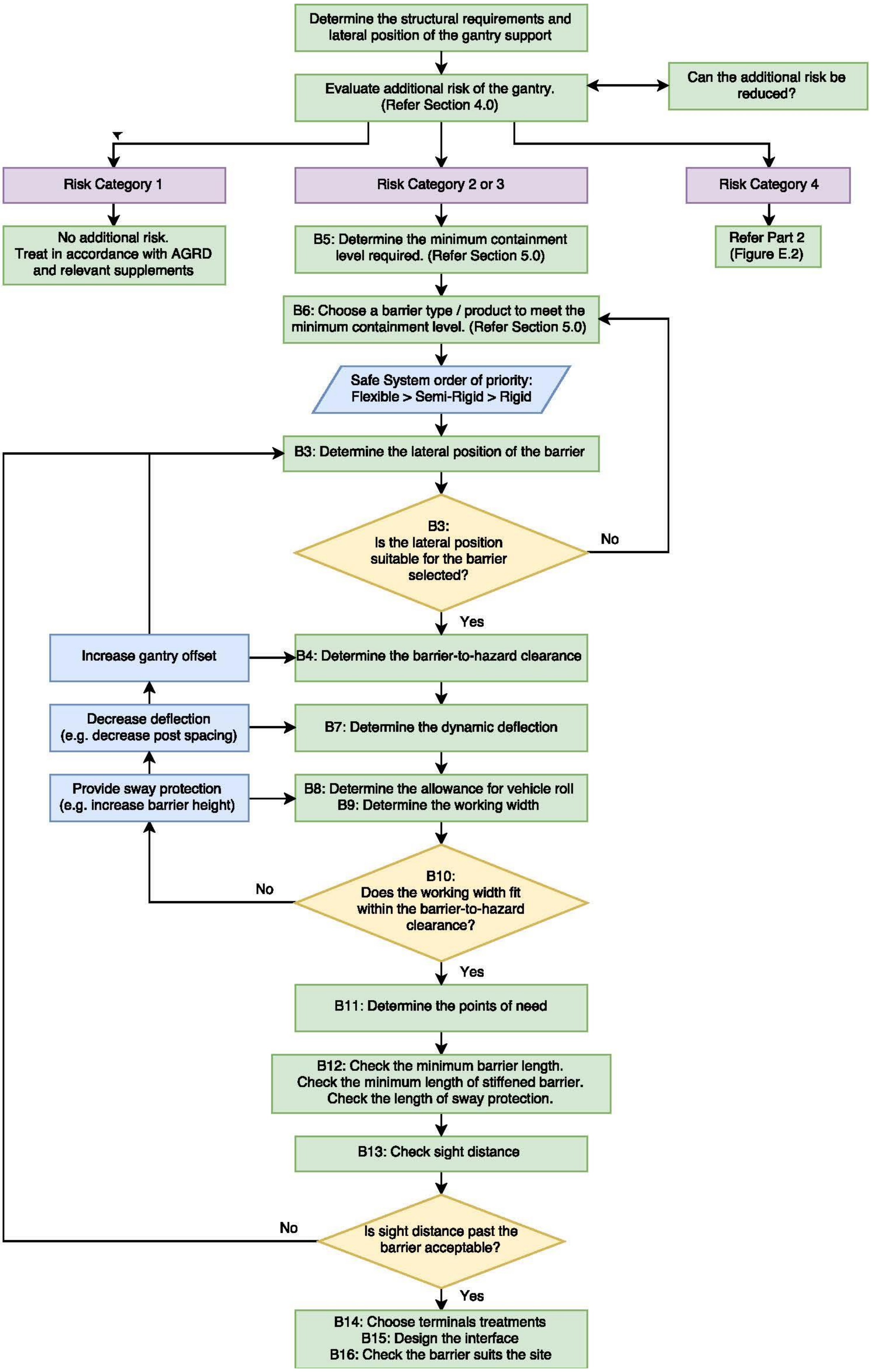


Figure F.1: Modified road safety barrier design process for the protection of gantry and cantilever sign supports (Part 1)
(Original Source: Source: AGRD Part 6, Figure 6.1)

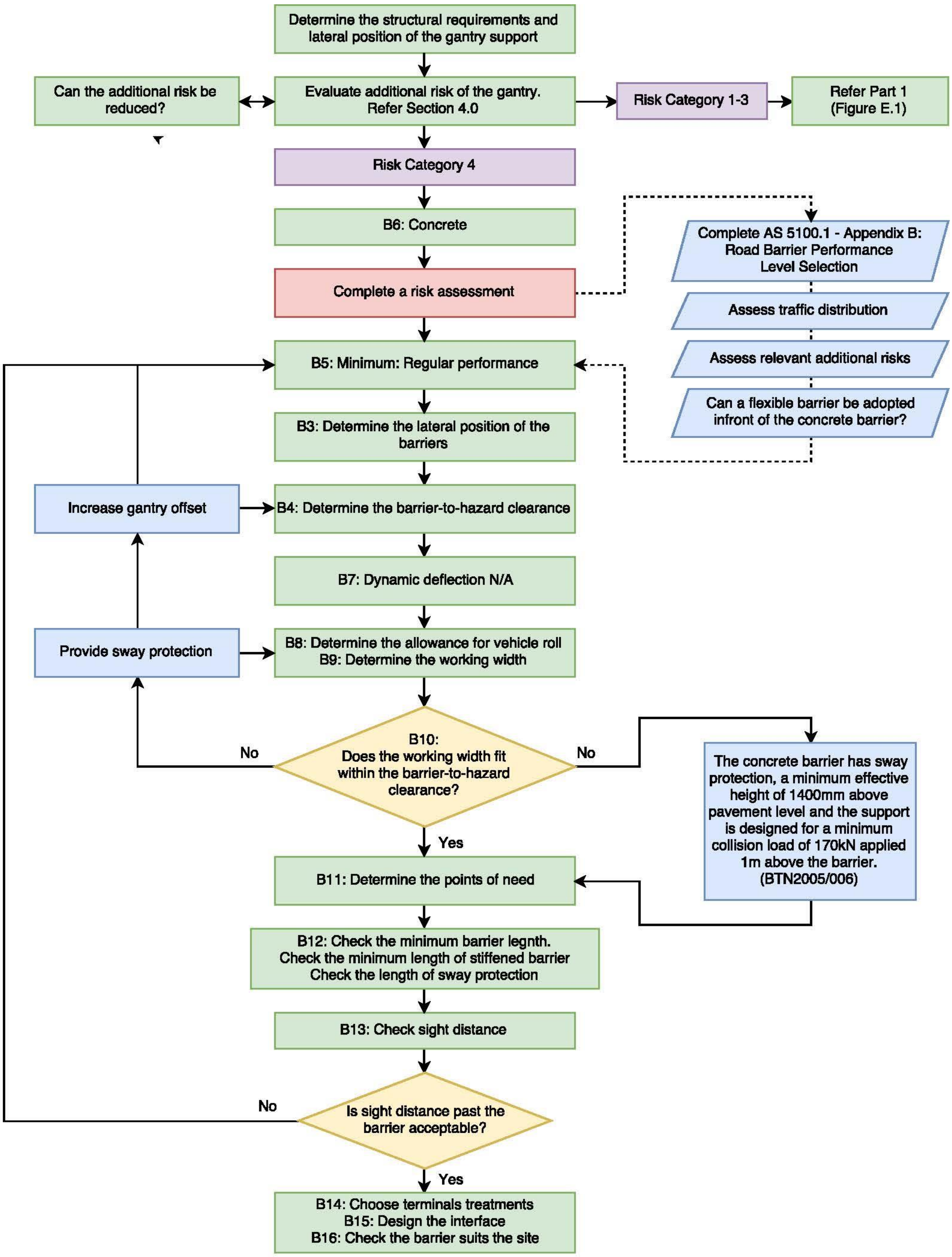


Figure F.2: Modified road safety barrier design process for the protection of gantry and cantilever sign supports (Part 2) (Original Source: Source: AGRD Part 6, Figure 6.1)

Appendix F: Comparison of risk profiles with AS5100:2017

AS 5100.1:2017, Appendix A; provides a selection method for barrier performance levels on bridges. Risk categorisation within this RDN has been provided as roadside guidance for designers, on what is a complex problem. The information provided is intended to compliment the risk profile in AS5100:2017 for roadside use and VicRoads should be notified or sought regarding any unusual discrepancies for a response.

For reference, a comparison of risk profiles between this RDN and AS5100:2017, Appendix A: Road barrier performance level selection method, has been provided below.

TABLE A2

VEHICLE MIX BASED ON PERCENT COMMERCIAL VEHICLES OR TRUCKS

Vehicle class	Cars	Vans/pickups	Rigid vehicles	Articulated vehicles
Commercial vehicles %	Percent of traffic mix			
10	63	27	4	6
20	56	24	4	16
30	49	21	4	26

Commercial vehicles %	Cars and Vans/pickups (<8000kg)	Rigid and Articulated vehicles (>8000kg)
10	93	7
20	86	14
30	70	30

Figure F1: Comparison of vehicle mix in AS5100 (top) and RDN 06-13 (bottom)

Comments:

1. ‘Commercial vehicle’ is a term typically used within traffic volumes and includes non-passenger vehicles from small trucks (4.5T GVM) and towing (car + caravan) to large trucks.
2. Refer Appendix B for assumptions, notes & other considerations.

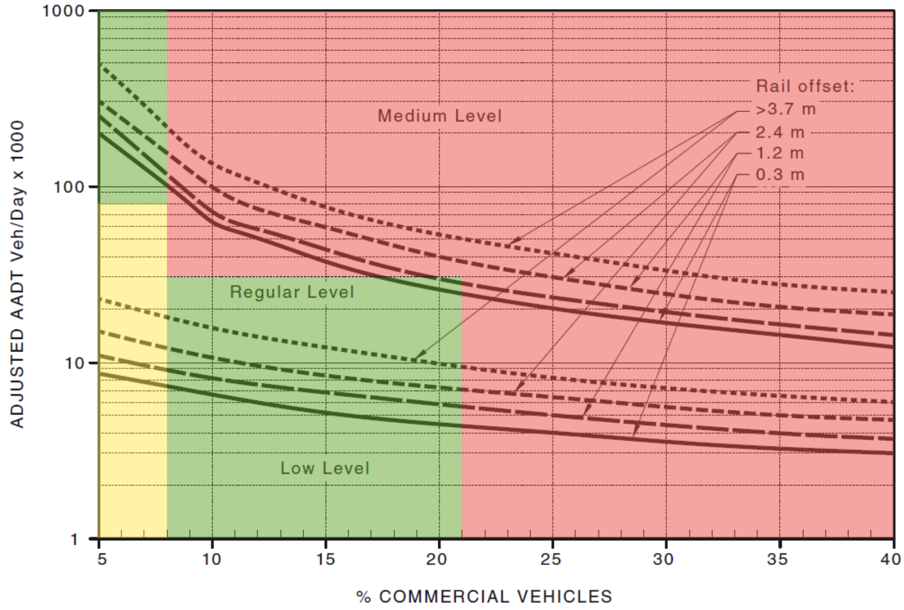
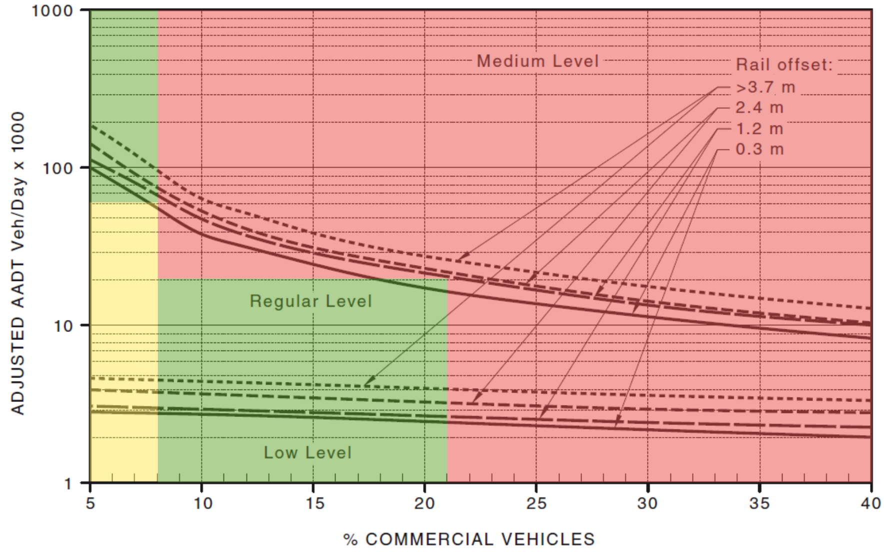


FIGURE A6 THRESHOLD LIMITS, 80 km/h



Example:
For an adjusted AADT of 20 000 vpd, 100 km/h speed, 16% commercial vehicles and 1.2 m barrier offset. The selected barrier level is the regular performance level.

FIGURE A7 THRESHOLD LIMITS, 100 km/h

Figure F1: Comparison of performance level in AS5100 and RDN 06-13

Comments:

1. Risk Category 2 (TL-3) = Yellow. Risk Category 3 (TL-4) = Green. Risk Category 4 (AS5100) = Red
2. In accordance with AS5100.1:2004 Table 10.4; Low is similar to Rigid TL2, Regular is similar to Rigid TL-4 and Medium is similar to Rigid TL-5.

Appendix G: Risk Categorisation – Summary Table

This table is a summary of the information provided in Section 5. As such, should only be used after reading the entire document to understand the issue and guidance included.

Risk categorisation should be undertaken on each support as the risks may differ between two supports of the same structure. These risk categories have been provided as guidance for designers, on what is considered to be a complex problem, and must be used in conjunction with sound engineering judgment.

Risk Cat.	Scenario	Minimum barrier	Example
1	It cannot feasibly be impacted, <u>or</u> it is designed to withstand impact forces of an errant vehicle, <u>or</u> it does not have the potential for additional risk e.g. does not project over a trafficked lane and is improbable to cause third party incidents.	Treated as a hazard in accordance with AGRD Part 6 and VicRoads supplementary guidance e.g. typical safety barrier	
2	The likelihood of collapse is considered "low", e.g. the operating speed is < 80km/h, or the support is sufficiently set back from the traffic lane on a straight section of road and away from diverge or merge points; <u>and</u> AADT less than 60,000 at 100km/h AADT less than 80,000 at 80km/h; <u>and</u> CV < 8% or 2T < 85^{th} percentile); <u>and</u> no access for maintenance workers during live traffic; <u>and</u> network disruption from a collapse can be reasonably managed. e.g. collapsed structure is unlikely to block all lanes.	Road safety barrier rated to Test Level 3 (TL-3) or higher; and designed to 100km/h regardless of operating speed. e.g. flexible guard fence	
3	The support is located such that a desirable road geometry and barrier design (e.g. working width) is achieved; <u>and</u> AADT less than 20,000 at 100km/h AADT less than 30,000 at 80km/h; <u>and</u> CV < 21% or 8T < 85^{th} percentile); <u>and</u> no access for maintenance workers or risks have been mitigated with additional control measures (e.g. lane closure and/or speed reduction); <u>and</u> the possible network disruption from a collapse is manageable (e.g. it projects over a single direction carriageway or ramp).	Road safety barrier rated to Test Level 4 (TL-4) or higher; and designed to 100km/h regardless of operating speed. e.g. Thriebeam guard fence	
4	A gantry or cantilever support with a high risk of collapse. E.g. a combination of road geometry, high speed, high volume and increased CV%; <u>or</u> A gantry or cantilever with access for maintenance workers under high speed live traffic; <u>or</u> A gantry or cantilever that will have detrimental consequences to the road network in the event of a collapse. e.g. spans an entire road carriageway; <u>or</u> A gantry or cantilever that houses valuable network assets and warrants the use of a higher barrier containment level and barrier confidence.	Adopt AS 5100: Bridge design. CONCRETE road safety barrier, containment level of 'Medium' or higher as determined by a risk assessment. A risk assessment must evaluate all additional risks of the structure and conclude the containment level, including the methodology detailed in AS5100.1 Appendix B or an approved alternative.