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Section 1
Introduction

Evaluate: Applying the railway crossing cause consequence bow tie models is a reference tool to assist planners to manage risks at railway crossings (RCs). The guideline explains how to use the cause consequence bow tie models to clearly define a risk and to identify safety management measures and post-incident management measures for different risk types.

1.1 Purpose

This document assists planners to:

1. Analyse the mechanisms of crash causation at an RC.
2. Select safety management measures that are appropriate for the risk and minimise that risk, so far as is reasonably practicable.

Please note that the cause consequence bow tie models presented in this document have been developed from the RTA’s standpoint as the agency responsible for managing road use at an RC on a State road.

1.2 Background

The RTA has as a matter of policy, determined to enter into, or be a party to a safety management plan for every RC on State roads. In addition, the RTA should generally be a party to a safety management plan where an RC is connected to traffic control signals or a railway crossing not on a State road affects safety or the operation of a State road.

A railway crossing that is not on a State road but has infrastructure on a State road provides additional challenges for the parties responsible for safety at the railway crossing. In the spirit of cooperation and collaboration promoted in the Rail Safety Act, the RTA may choose to be involved in the safety management plan for the RC, or may provide acknowledgement to the parties responsible that the RTA will maintain traffic control devices on the State road to the standards required in the Australian Standard AS1742.7.

The RTA’s intention is to enhance the cause consequence bow tie models for RCs as further research is completed in this area.
Section 2

What is a railway crossing cause consequence bow tie model?

A ‘bow tie’ model is a qualitative risk assessment technique. These models can be used as a simple tool for the communication of how crashes occur, how they can escalate and how they can be managed.

The cause consequence bow tie models used in this guideline is specifically adapted to the management of road users and the road environment in an RC context. A detailed explanation of a cause consequence bow tie model is provided in Appendix 1 on page 15.

A conceptual diagram of the cause consequence bow tie model is provided below in Figure 1, and an example of how risk is translated through the model is presented in Figure 2 on page 5.

**FIGURE 1: CONCEPTUAL DIAGRAM OF THE CAUSE CONSEQUENCE BOW TIE MODEL**

A detailed description of each phase of the model is provided below.

2.1 Risks at a railway crossing

2.1.1 Risk categories

Risks that occur at RCs can be classified into various groups according to the behaviour of a road user as they traverse an RC. These groups are called ‘risk categories’. The following risk categories have been adopted for an RC:

- Road user fails to stop while a train is approaching.
- Road user fails to keep clear while a train is approaching.
- Road user fails to stay within travel lane, carriageway or path.
- Failure of traffic control signals or active control.
- Road user fails to observe other road user during operation of the RC.

2.1.2 Risk types

As they stand, these risk categories are too broad to be applied in the risk assessment of a specific RC, because the controls and other characteristics of RCs vary.

Therefore, to enable planners to identify and evaluate risks at specific RCs, design and operation ‘risk types’ have been developed. These risk types are more specific than risk categories in that they consider both driver behaviour and the control, design and operational elements at an RC. These risk types are detailed in Appendix 2.

2.1.3 Hazards and hazardous events

The presence of a hazard or hazardous event at an RC will result in a ‘risk type’. Identify: The railway crossing safety hazard checklist is a reference tool to assist planners in identifying hazards and hazardous events at an RC.

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1 The RTA has adopted the term ‘risk category’ in place of the term ‘hazard’, as outlined in the explanation of the cause consequence bow tie model in Appendix 1.
2.1.4 Correlation of risk categories, risk types and hazards or hazardous events

The following table (Table 1 on page 6) illustrates the interrelationships between risk categories, risk types and potential hazards or hazardous events. To understand how to use Table 1 the following example is provided:

**Example of how to use Table 1**

During a site inspection, a planner has identified that active control with boom gates is implemented at an RC. In addition, the planner has noted that since the road runs east–west, there is a risk that sunrise and sunset may impact on the driver’s ability to see the RC controls as they approach the RC. In this scenario the sunrise and sunset are classified as ‘potential hazardous events’. Figure 2 shows how this risk is translated through the bow tie model.

A range of consequences is provided in the figure to demonstrate the potential impacts of an incident on RTA objectives; however the intent of the NSW Rail Safety Act 2008 is to focus on the safety of road and rail users and these are the most important consequences to consider when looking at risk at a railway crossing.

**FIGURE 2: HOW RISK IS TRANSLATED THROUGH THE BOW TIE MODEL**

Based on this information the 'risk type' that the planner would use is:

*Road user fails to observe traffic control device at RC.*

As the above example illustrates, the risk type can only be identified once the safety implications of a potential hazard or hazardous event are assessed at an RC.

Note that if the same scenario occurred at a passive controlled RC, the risk type would remain the same. Similarly, this risk type is applicable to pedestrians.

Note also that the risk types presented in the bow tie models are broad in nature to allow for their flexible application in multiple control, design and hazard or hazardous event circumstances. In situations where the existing risk types are inadequate and the planner deems it necessary to generate a new risk type, the Policy Manager, Road User Priority and Access should be contacted to develop the risk type in collaboration with the planner.
<table>
<thead>
<tr>
<th>Risk categories</th>
<th>Risk types</th>
<th>Hazards or hazardous events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Road user fails to stop while a train is approaching.</td>
<td>1.1 Road user fails to observe traffic control device at RC.</td>
<td>• Road/path alignment, cross section and pavement.</td>
</tr>
<tr>
<td></td>
<td>1.2 Road user fails to respond to traffic control device at RC.</td>
<td>• Road/path layout and controls.</td>
</tr>
<tr>
<td></td>
<td>1.3 Road user does not see train at, or approaching, the RC.</td>
<td>• Traffic/pedestrian signals and road/path signs.</td>
</tr>
<tr>
<td></td>
<td>1.4 Deliberate action by road user to beat train to RC.</td>
<td>• Road/path pavement marking and delineation.</td>
</tr>
<tr>
<td></td>
<td>1.5 Road user does not allow for increased stopping distance on slippery or unsealed road or path.</td>
<td>• Road related area.</td>
</tr>
<tr>
<td></td>
<td>1.6 Road user travelling too fast on approach to RC.</td>
<td>• Railway crossing signals and boom barriers.</td>
</tr>
<tr>
<td></td>
<td>• Road/path layout and controls.</td>
<td>• Restricted Access Vehicles (RAVs).</td>
</tr>
<tr>
<td></td>
<td>• Road/path pavement marking and delineation.</td>
<td>• Non-motorised traffic.</td>
</tr>
<tr>
<td></td>
<td>• Road related area.</td>
<td>• Climatic events.</td>
</tr>
<tr>
<td>2. Road user fails to keep clear while a train is approaching.</td>
<td>2.1 Road user stranded/crashed on an RC.</td>
<td>• Road/path layout and controls.</td>
</tr>
<tr>
<td></td>
<td>2.2 Road vehicles queue across RC.</td>
<td>• Road/path pavement marking and delineation.</td>
</tr>
<tr>
<td></td>
<td>2.3 Insufficient storage length for heavy/long vehicles.</td>
<td>• Railway crossing signals and boom barriers.</td>
</tr>
<tr>
<td></td>
<td>2.4 Road user slow to clear RC.</td>
<td>• Traffic operations.</td>
</tr>
<tr>
<td></td>
<td>2.5 Road user does not see a second train coming.</td>
<td>• Restricted Access Vehicles (RAVs).</td>
</tr>
<tr>
<td></td>
<td>2.6 Deliberate action by road user to beat a train to RC.</td>
<td>• Non-motorised traffic.</td>
</tr>
<tr>
<td>3. Road user fails to stay within travel lane, carriageway or path.</td>
<td>3.1 Road vehicle leaves travel lane into oncoming traffic.</td>
<td>• Road/path alignment, cross section, pavement and edge drop-off.</td>
</tr>
<tr>
<td></td>
<td>3.2 Road vehicle leaves carriageway.</td>
<td>• Railway crossing signals and boom barriers.</td>
</tr>
<tr>
<td></td>
<td>3.3 Road vehicle loses control.</td>
<td>• Restricted Access Vehicles (RAVs).</td>
</tr>
<tr>
<td></td>
<td>3.4 Pedestrian/cyclist leaves path.</td>
<td></td>
</tr>
<tr>
<td>4. Failure of traffic control signals or active control.</td>
<td>4.1 Power failure.</td>
<td>• Communication breakdown.</td>
</tr>
<tr>
<td></td>
<td>4.2 Lantern defect.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3 Damaged infrastructure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.4 Failure or inappropriate coordination of TCS and RC signals</td>
<td></td>
</tr>
<tr>
<td>5 Road user fails to observe other road user during operation of railway crossing.</td>
<td>5.1 Road user fails to observe and react to stationary or slow road users.</td>
<td>• Road related area.</td>
</tr>
<tr>
<td></td>
<td>5.2 Road user fails to comply with traffic control device.</td>
<td>• Restricted Access Vehicles (RAVs).</td>
</tr>
<tr>
<td></td>
<td>5.3 Damaged infrastructure.</td>
<td>• Road/path alignment, cross section.</td>
</tr>
<tr>
<td></td>
<td>• Road/path layout and controls.</td>
<td></td>
</tr>
</tbody>
</table>

2 Refer to the Identify: The railway crossing safety hazard checklist.
2.2 Safety management measures

A safety management measure\(^1\) is any initiative that aims to prevent, or mitigate the negative outcomes of, a risk type. Safety management measures that can be implemented at RCs include:

- Legislative measures such as road rules.
- The closure of an RC.
- Engineering treatments, such as traffic control and traffic management measures at an RC and within the road reserve.
- Changes to maintenance or operational practices.
- Administrative changes, such as enforcement activities.
- Campaigns to educate drivers, pedestrians, cyclists or train operators in order to positively influence behaviour and raise awareness of the risks at an RC.

Safety management measures may also be implemented by the rail infrastructure manager to enhance safety. However, as the roads authority does not have power to compel action by the rail infrastructure manager, such measures should be discussed and negotiated as part of the risk assessment, and during the development of the safety management plan.

When undertaking a risk assessment, planners should consider the relative applicability and effectiveness of the various safety management measure options outlined in this guideline.

It may be necessary to implement multiple control measures to reduce a safety risk to an acceptable level.

It is the planner’s aim to minimise the likelihood, exposure and consequence of risks to safety arising from the existence and operation of a railway crossing, whether they arise at, or on the approaches to, the railway crossing.

2.3 Incidents (resulting from a breakdown in safety management measures)

The term ‘incident’ describes the event that occurs as a result of the breakdown of the safety management measures. Incidents may involve a crash between road and rail users, road users, or a road user and infrastructure. Consequences arising from an incident may vary from no impact at all (commonly referred to as a ‘near miss’), through minor injuries to multiple fatalities.

An RC risk type can lead to one of the following incidents:

- Crash between road user and train at RC.
- Crash between road user and RC related infrastructure.
- Crash between road users.

\(^1\) The RTA has adopted the term ‘safety management measure’ in place of the term ‘barriers’ (or ‘control measures’), as outlined in the explanation of the cause consequence bow tie model in Appendix 1.
2.4 Post-incident management measures

A post-incident management measure is reactive in nature, and is any initiative that may:

- Limit the consequence (or severity) of an incident once it has occurred.
- Reduce the likelihood of a second incident eventuating as a result of the incident.

Post-incident management measures include:

- Engineering treatments, such as frangible posts and closed circuit television cameras (CCTV).
- Operational practices, such as emergency response plans and procedures carried out by the Transport Management Centre (TMC).

2.5 Consequences

Incidents have consequences. Safety management measures aim to reduce the occurrence of incidents (that is, they are preventive measures), and post-incident management measures aim to reduce the severity of the consequences of incidents (that is, they are reactive measures). Where an incident does occur, the consequences may include:

- Fatalities and injuries to road and/or rail users.
- Delay to road users and freight.
- Delay to rail users and freight.
- Damage to property and the environment.
- Secondary incidents.
Section 3
When to use the cause consequence bow tie models

Identify: The railway crossing safety hazard checklist provides planners with information to refer to when they are undertaking a risk assessment or planning for infrastructure upgrades at an RC on the State road network.

The cause consequence bow tie models should be used in the following situations:

• During the risk identification, analysis and evaluation stages of an RC safety management plan. Here planners should transfer information from the relevant bow tie model to the RTA Risk Assessment Tool, which has been specifically developed for use as part of the RTA’s risk assessment procedure.

• During the identification of safety management measure options when planning for infrastructure upgrades.
Section 4
How to use the cause consequence bow tie models to assist with risk assessment

The cause consequence bow tie models must be used when completing the risk assessment procedure for a railway crossing (RC). The following sections explain how the model should be applied during the various stages of the risk assessment procedure. For an overview of the risk assessment procedure see Appendix A of the RTA’s Plan: Establishing a railway crossing safety management plan.

4.1 Determine the specific risk type applicable to the hazard or hazardous event being investigated

During Step 2 (Identify railway crossing hazards, hazardous events and safety risks) of the RC risk assessment procedure, planners should review the hazard or hazardous event. At this point planners must use Table 1 in this document (see page 6) to determine the most appropriate risk type.

Once the planner has identified the most appropriate risk type they must transfer the description of the risk type from Table 1 to the RTA Risk Assessment Tool, under the section titled ‘Risk’.

4.2 Identify the safety management measures that are used to prevent the risk eventuating at a railway crossing

During Step 3 (Analyse existing railway crossing risks) of the RC risk assessment procedure, planners must analyse the applicability and effectiveness of existing measures in minimising risks to safety. At this point planners should refer to the bow tie models (see Appendix 2, pages 18–22), where the safety management measures for each risk type are outlined.

The information in Appendix 2 of this document will help planners to apply the bow tie models for each risk type. Planners should therefore review this section.

The bow tie models have been specifically designed so that incremental safety improvements can be introduced in order to minimise risk, so far as is reasonably practicable.

Note that in some cases planners may choose to introduce a safety management measure that is not the next measure specified by the bow tie model. In such cases the planner should clearly document their decision making process so as to justify the need for that measure. The planner should also detail the additional safety benefits provided by the safety management measure.

The planner should then place the information sourced from the model into the RTA Risk Assessment Tool, under the section titled ‘Existing management measures/mitigations’.

Planners must also refer to the safety management measures presented in the bow tie models (in Appendix 2, pages 18–22) during Step 4 (Evaluate railway crossing safety management measures) of the RC risk assessment procedure to determine the applicability and effectiveness of measures when evaluating RC risks rated Medium, High or Extreme. The information sourced from the bow tie models should then be transferred to the RTA Risk Assessment Tool, under the section titled ‘Additional management measures/mitigations proposed’.
4.3 Identify the incidents for the risk at a railway crossing

Once planners have identified an incident for a particular risk, they should transfer the information about the incident from the bow tie model into the RTA Risk Assessment Tool, under the section titled ‘Potential incident’.

4.4 Identify the post-incident management measures for the risk at a railway crossing

The bow tie models outline a range of post-incident management measures. This information is provided to help planners assess the applicability and effectiveness of existing safety management measures in minimising risks to safety following an incident.

The planner should place the information sourced from the model into the RTA Risk Assessment Tool, under the section titled ‘Existing controls, mitigations, and post-incident management measures’.

Planners can also refer to the post-incident management measures presented in the model when identifying additional management measures during the evaluation of RC risks rated Medium, High or Extreme (Step 4 of the Railway crossing risk assessment procedure – Evaluate railway crossing safety management measures). The information sourced from the bow tie models should then be transferred to the RTA Risk Assessment Tool, under the section titled ‘Additional controls, mitigations, and post-incident management measures proposed’.
Section 5
How to use the cause consequence bow tie models during the planning for a road infrastructure upgrade

When planners consider the various infrastructure improvement options for an existing RC during the planning for a road infrastructure upgrade, they should use the safety management measures outlined in the bow tie models as guidance.

The information in Appendix 1 of this document (page 15) will help planners to apply the bow tie models for each risk type. Planners should therefore review this section.

The bow tie models have been specifically designed so that incremental safety improvements can be introduced in order to minimise risk, so far as is reasonably practicable.

**Note** that in some cases planners may choose to introduce a safety management measure that is not the next measure specified by the bow tie model. In such cases, the planner should clearly document their decision making process so as to justify the need for that measure. The planner should also detail the additional safety benefits provided by the safety management measure.
Section 6
References

- ITSR Level Crossing Cause Consequence Bow Tie Model 2010.
- RTA Plan: Establishing a railway crossing safety management plan (policy number PN240G).
- RTA Identify: The railway crossing safety hazard checklist (policy number PN241G).
- RTA Assess: Applying risk tolerance and risk assessment criteria to railway crossings (policy number PN238G).
- RTA Railway Crossing Risk Assessment Tool.
Appendices
Please note that the terminology used below is ITSR standard and does not accord with the RTA terminology used in this document. See Table 2: Alignment of terminology between ITSR and RTA bow tie models on page 17.

Bow tie diagrams are a qualitative risk assessment technique that encourages workforce involvement in analysing the mechanisms of crash causation. These diagrams provide a simple tool for the straightforward communication of how unwanted events occur, how they can escalate, and how they are managed.

The logic model that forms the basis of the bow tie model is the so-called ‘defence in depth’ model. Crash causation can be considered as a combination of hazardous occurrences and failure of defences, as shown below.

**FIGURE 3: THE RELATIONSHIP BETWEEN HAZARDS, DEFENCES AND LOSSES**

![Diagram](image)

The basic ‘defence in depth’ model can be extended to introduce the idea of preventative defences (preventing the initial event) and mitigative defences (limiting the impacts of the event). The inclusion of preventative and mitigative defences allows for the results of a hazard analysis and evaluation to be represented in a manner that is readily understood by all levels within an organisation. The extended model is illustrated on page 16.

In the bow tie model, unwanted events, such as crashes or precursors to crashes, are portrayed as the centre of the bow tie. In the model, this ‘central event’ represents the loss of control of the hazard. For example, where an approaching train is identified as the hazard, the failure of a road vehicle to stop at an RC is defined as the ‘loss of control event’. In the model, a ‘threat’ is the release mechanism, i.e. the cause of the central unwanted event. The central event may be the first in a chain of events that escalate to the ultimate outcome, or consequence. For example, the chain of consequences of a vehicle failing to stop at an RC could include fires, derailments and/or subsequent collisions.

For each threat, one or several ‘barriers’ (control measures) can be specified to prevent the release of the hazard (that is, to prevent the threat mechanism leading to the central event). These controls, or barriers, are shown on the left side of the bow tie and can be either items of equipment or actions taken in accordance with rules and procedures. Examples for RCs are equipment such as booms and flashing lights and rules and procedures such as road rules.

* Illustration based on Reason JT (1997) Managing the Risks of Organisational Accidents
Should the central event (loss of control) occur, further controls or ‘recovery measures’ can be implemented to interrupt the escalation of the scenario and mitigate the consequences.

When setting the level of detail in the bow tie model, individual controls and recovery measures should be independent from each other. Dependent controls should not be artificially represented as separate boxes on the diagram.

For any barrier there may be internal or external ‘escalation’ factors that influence its effectiveness. These factors can be controlled by ‘secondary barriers’. Any threat should have a sufficient number of primary and secondary barriers to ensure the integrity of the system. For example, if a primary barrier of ‘active control of the RC through installation of flashing lights and bells’ is weakened by a lack of testing of the active equipment, a secondary barrier of ‘scheduled testing’ is present to ensure the integrity of the system – that is, to ensure that the primary barrier operates as expected.

In order to provide assurance that the hazard will continue to be managed effectively, it is necessary to identify any tasks that are carried out as part of the workforce’s day-to-day duties and which support and maintain the identified barriers, recovery measures and escalation factor controls. These critical tasks ensure that the control measures will continue to function in the future and are therefore essential to ongoing management of the hazard. Critical tasks can be design activities, operations and maintenance activities, or management/administration type activities.

Source: ITSR Level Crossing Cause Consequence Bow Tie Model 2010.
While bow tie models in general may be applicable to all types of risk assessment throughout an organisation (such as safety, financial and reputation), the RTA’s Evaluate: Applying the railway crossing cause consequence bow tie models is designed specifically to address safety risk management. Therefore the terminology in the RTA model is safety focused. The following table aligns terminology in the two models.

**TABLE 2: ALIGNMENT OF TERMINOLOGY BETWEEN THE ITSR AND RTA BOW TIE MODELS**

<table>
<thead>
<tr>
<th>ITSR bow tie model terminology</th>
<th>RTA bow tie model terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard</td>
<td>Risk category</td>
</tr>
<tr>
<td>Threat</td>
<td>Risk type</td>
</tr>
<tr>
<td>Barrier</td>
<td>Safety management measure</td>
</tr>
<tr>
<td>Initiating Event</td>
<td>Incident</td>
</tr>
<tr>
<td>Recovery Measure</td>
<td>Post-incident management measure</td>
</tr>
<tr>
<td>Consequence</td>
<td>Consequence</td>
</tr>
</tbody>
</table>
Appendix 2: Cause consequence bow tie models for the risk categories

**RISK CATEGORY: Road user fails to stop while a train is approaching**

**INCIDENT:** Crash between road user and train at railway crossing

**POST INCIDENT MANAGEMENT MEASURES**
- CCTV cameras at RC
- Advance warning signs for approaching train
- Road speed limit appropriate for conditions
- Active control of RC / boom gates
- Active advance warning signs
- Road lighting in urban areas and at passive control sites
- Education campaigns that inform drivers of statutory requirements

**SAFETY MANAGEMENT MEASURES**
- Road user travelling too fast on approach to RC
- Road user does not see train at approach to RC
- Road user fails to comply with AS 1742.7
- Road user fails to respond to traffic control device
- Road user fails to observe traffic control device

**CONSEQUENCES**
- Fatalities and injuries
- Delays to road users and freight
- Damage to property / environment
- Secondary crash

**Notes:**
1. The safety management measures’ and post incident response measures provided are a guide, other measures may be applicable.
2. Road user may include: vehicle driver / passenger, motorcycle rider / passenger, pedestrian, cyclist, animal rider or draw vehicle, or toy vehicle.

---

**RISK TYPE:**
- Type 1.1: Road user travels too fast on approach to RC
- Type 1.2: Road user does not see train at approach to RC
- Type 1.3: Road user does not see train at approach to RC
- Type 1.4: Deliberate action by road user to beat train to RC
- Type 1.5: Road user does not observe traffic control device
- Type 1.6: Road user travelling too fast on approach to RC
Type 2.1 Road user stranded/crashed on RC

Type 2.2 Road vehicles queue across RC

Type 2.3 Insufficient storage length for RAV

Type 2.4 Road user slow to clear RC

Type 2.5 Road user does not see a second train coming

Type 2.6 Deliberate action by road user to beat train to RC

SAFETY MANAGEMENT MEASURES

RISK CATEGORY

RISK TYPE

SAFETY MANAGEMENT MEASURES

POST INCIDENT MANAGEMENT MEASURES

CONSEQUENCES

2 Road user FAILS TO KEEP CLEAR while a train is approaching

Road user stranded/crashed on RC

Road vehicles queue across RC

Insufficient storage length for RAV

Road user slow to clear RC

Road user does not see a second train coming

Deliberate action by road user to beat train to RC

Crash between road user and train at railway crossing

Notes:
1. The 'safety management measures' and 'post incident response measures' provided are a guide, other measures may be applicable.
2. Road user may include: Vehicle driver / passenger; motorcycle rider / passengers; pedestrian; cyclist; animal rider or drawn vehicle, or toy vehicle.
Consequences

Post Incident Management Measures

Fatalities and Injuries

Delays to road users and freight

Delays to trains and passengers

Damage to property/environment

Secondary crash

Consequences

- Fatalities and injuries
- Delays to road users and freight
- Delays to trains and passengers
- Damage to property/environment
- Secondary crash

Post incident Management Measures

- Consequences
- Safety Management Measures
- Emergency response
- Traffic management plan
- CCTV cameras at RC
- Road vehicle leaves travel lane into oncoming traffic
- Road vehicle loses control
- Pedestrian / cyclist leaves path

Safety Management Measures

- Pavement line marking and delineation to AS 1742
- NSW Road Rules 2008
- RRPMs and CAMs
- Pedestrian lighting to AS 1158
- Audio-tactile linemarking
- Realign road / railway

Risk Category

Type 3.1
- Road vehicle leaves carriageway
- Pedestrian and cyclist

Type 3.2
- Road vehicle leaves carriageway
- Pedestrian and cyclist

Type 3.3
- Road vehicle loses control
- Pedestrian and cyclist

Type 3.4
- Pedestrian / cyclist leaves path

Notes:

1. The safety management measures and post incident response measures provided are guidelines, other measures may be applicable.

2. Road user may include: vehicle driver / passenger, motorcycle rider / passenger, pedestrian, cyclist, animal rider or drawn vehicle or toy vehicle.

“EVALUATE” APPLYING THE RAILWAY CROSSING CAUSE CONSEQUENCE BOW TIE MODEL

Section 7
Consequences

Post incident management measures

Safety management measures

Risk category

Failure of traffic control signals or active control

Incident

Crash between road user and train at railway crossing

Notes:
1. The safety management measures and post incident response measures provided are guides, other measures may be applicable.
2. Road user may include: vehicle driver / passenger, motorcycle rider / passenger, pedestrian, cyclist, animal rider or drawn vehicle, or toy vehicle.

Risk type

Type 4.1: Power failure

Type 4.2: Lantern defect

Type 4.3: Damaged infrastructure

Type 4.4: Failure or inappropriate operation of TCS and PC signal

Failure category

Type 4.1

Type 4.2

Type 4.3

Type 4.4

Evaluation: Applying the Railway Crossing Cause Consequence Bow Tie Model

Section 7
Road user fails to observe other road user during operation of railway crossing

**SAFETY MANAGEMENT MEASURES**

- Type 5.1: Road user fails to observe and react to stationary or slow vehicles
  - CCTV & SCATS monitoring
  - Road lighting
  - Road markings
  - Road signage
  - Road lighting in urban areas
  - Maintenance of traffic control signals
  - Maintenance of equipment
  - Active advance warning signs
  - NSW Road Rules 2008
  - NSW Police

- Type 5.2: Road user fails to comply with traffic control device
  - CCTV & SCATS monitoring
  - Road lighting
  - Road markings
  - Road signage
  - NSW Police

- Type 5.3: Damaged infrastructure
  - CCTV & SCATS monitoring
  - Road lighting
  - Road markings
  - Road signage
  - NSW Police

**POST INCIDENT MANAGEMENT MEASURES**

- Fatalities and injuries
  - Emergency response by TMC, police, local council, and rail authority
  - CCTV cameras at RC
  - Traffic management plan
  - Frangible roadside furniture
  - Clear zone free of hazards

- Delays to road users and freight
  - Emergency response by TMC, police, local council
  - CCTV cameras at RC
  - Traffic management plan
  - Frangible roadside furniture
  - No unnecessary infrastructure at RC

- Delays to trains and passengers
  - Emergency response by TMC, police, local council
  - CCTV cameras at RC
  - Traffic management plan
  - Frangible roadside furniture
  - No unnecessary infrastructure at RC

- Damage to property / environment
  - Emergency response by TMC, police, local council
  - CCTV cameras at RC
  - Traffic management plan
  - Frangible roadside furniture
  - No unnecessary infrastructure at RC

- Secondary crash
  - Emergency response by TMC, police, local council
  - CCTV cameras at RC
  - Traffic management plan
  - Frangible roadside furniture
  - No unnecessary infrastructure at RC

**NOTES:**

1. The ‘safety management measures’ and ‘post incident response measures’ provided are a guide, other measures may be applicable.
2. Road user may include: vehicle driver / passenger, motorcycle rider / passengers, pedestrian, cyclist, animal rider or drawn vehicle, or toy vehicle.
Section 8
Glossary

- **Active advance warning sign**: a sign that provides advance warning of the impending or current operation of flashing signals at a railway crossing through the use of flashing yellow signals within the advance warning sign. These comprise the RX-11 assembly provided in AS 1742.7.

- **Active control**: controlling the movement of vehicular or pedestrian traffic across a railway crossing using devices such as flashing signals, gates or barriers (or a combination of these), where the device is activated prior to, and during, the passage of a train through the crossing. These comprise the RX1, RX2 and RX5 assemblies as defined in AS 1742.7. See also the glossary entry for ‘passive control’.


- **Barrier**: an alternative term for a safety management measure.

- **Bow tie model**: a qualitative risk assessment technique that ‘links’ the relationships between the causes of crashes (‘risks’), the initiatives or controls designed to mitigate the potential for a crash (‘safety management measures’), the crashes (‘incidents’), the initiatives or controls designed to reduce the negative outcomes of an incident (‘post-incident management measures’), and the outcome of an incident despite the initiatives and controls (‘consequences’). The bow tie model is an integral part of the RTA railway crossing risk assessment and management procedure.

- **Broadly acceptable**: a level of risk deemed to be Low or Negligible and, when considered in the context of all risks being managed by the organisation, requiring no further action to comply with the ‘so far as is reasonably practicable’ principle.

- **Clear zone**: the area adjacent to the traffic lane that should be kept free from features that would potentially be hazardous to errant vehicles. The decision of whether or not to include a clear zone is based on the consideration of the recovery area for every errant vehicle, the cost of providing that area, and the probability of an errant vehicle encountering a hazard. The clear zone should be kept free of non-frangible hazards where economically and environmentally possible. Alternatively, hazards within the clear zone should be treated to make them safe or be shielded by a safety barrier (Austroads, 2008).

- **Consequence**: the outcome of an incident that has arisen from a risk. In the context of a railway crossing, a consequence may involve the injury and/or death of road or rail users, delays to people and freight on the road or rail networks, and property and environmental damage. Note that:
  - There can be more than one consequence from one incident.
  - Consequences can be expressed qualitatively or quantitatively.
  - Consequences are considered in relation to the achievement of RTA objectives, especially those related to road safety.

- **Coordination provisions of the NSW Rail Safety Act 2008**: the purpose of these provisions is to ensure that rail infrastructure managers and roads authorities identify risks to safety arising from rail or road crossings, so far as is reasonably practicable, determine measures to manage, so far as is reasonably practicable, those risks, and seek to enter into agreements to manage those risks.

  The provisions are intended to ensure that risks arising from rail or road crossings are identified and that the accountabilities for risk control measures are clearly articulated.
• Crash: see the glossary entry for ‘incident’.

• Design for safety: design that uses a safe systems approach. See also the glossary entry for ‘safe systems approach’.

• Frangible: Roadside furniture designed to collapse on impact. The severity of potential injuries to the occupants of an impacting vehicle is reduced, compared to those that could occur if the furniture was unyielding.

• GIS database: see the glossary entry for ‘Railway crossing GIS database’.

• Hazard or hazardous event: a source of potential harm or a situation with a potential to cause harm (as defined in AS 4360: 2004). A hazard is anything that may cause a risk – here ‘risk’ includes physical risks (eg, objects), environmental conditions (eg, fog) and road user behaviour (eg, crossing the centre line). See also the glossary entry for ‘risk’.

• Hazard identification: the process of identifying and characterising hazards that exist or potentially exist.

• Hierarchy of control: a legal and logical preference of treating or controlling risk. For example, using the principles of SFAIRP and incremental road safety to spread limited resources across many demands.

• Incident: a crash at, or as a result of the operation of, a railway crossing. Incidents occur where safety management measures either fail, or are not present, when required. Incidents can include: a vehicle or pedestrian being struck by a train; a vehicle or pedestrian being struck by a vehicle; and railway crossing infrastructure being struck by a vehicle.

• Infrastructure: the network and devices used to carry or display the information, services and equipment required for the operation of railway and road systems. These include railway crossing control systems and equipment, such as flashing lights, boom gates, signal huts or culverts to clear stormwater.

• Interface agreement: an agreement in writing regarding the management of risks to safety that are identified and managed under Division 3 of the NSW Rail Safety Act 2008. An interface agreement includes provision for:
  - The implementation and maintenance of measures to manage those risks.
  - The evaluation, testing and (if appropriate) revision of those measures.
  - The respective roles and responsibilities of each party to the agreement in relation to these measures.
  - A process for reviewing and revising the agreement.


• Level crossing: the area where a road and a railway meet at substantially the same level. Please note, however, that a level crossing does not include the road related area, such as the road shoulder; the dividing strip and pedestrian paths (see Rule 120 of the NSW Road Rules 2008). ‘Level crossing’ is used colloquially as an alternative term for a railway crossing.

• Likelihood: a general description of probability or frequency. In the context of a railway crossing, likelihood refers to the probability of an incident occurring.

• Local road: an administrative category of roads in NSW. Local roads are under the care, control and funding of local governments. See www.rta.nsw.gov.au/doingbusinesswithus/downloads/ldr/reg_table_for_internet_31jan11.pdf for a list of roads classified as regional or State (local roads can be identified as those not appearing on the list).

• May: ‘may’ is used in this document to make recommendations of good practice.

• Must: ‘must’ is used in this document to give mandatory directives.

• Near miss: a failure by a safety management measure that does not result in a crash. In the operation of a railway crossing, the Independent Transport Safety Regulator defines a near miss as ‘Any occurrence where the driver of a moving train takes emergency action, or would have if there was sufficient time, to avoid impact with a person, vehicle or other obstruction, and no collision occurred. Emergency action includes continuous audible warning and/or brake application.’

Source: www.rsrp.asn.au/files/publications/12_30..pdf
Operational issues: events or potential events that may impact upon the safe and efficient movement of road or rail traffic.

Over Size Over Mass: a category of heavy vehicle which includes vehicles that, either on their own or with their loads included, exceed a relevant mass or dimension limit of the Road Transport (Vehicle Registration) Regulation 2007 or Road Transport (Mass, Loading and Access) Regulation 2005. Examples include special purpose vehicles (eg, mobile cranes), vehicles carrying an indivisible load (eg, a wind power generator blade), and agricultural vehicles (eg, tractors and airseeders). In such cases, authority to travel is provided by a vehicle permit system (see www.rta.nsw.gov.au/heavyvehicles/oversizeovermass/index.html or www.rta.nsw.gov.au/heavyvehicles/downloads/operating_conditions-oversize_overmass.pdf).

Passive control: controls the movement of vehicular or pedestrian traffic across a railway crossing using signs or devices which rely on the road user detecting the approach or presence of a train by direct observation. In other words, in passive control the signs and devices are not activated during the approach or passage of a train. For definitions of crossing control types see page 15 of ITSR www.rsrp.asn.au/files/publications/12_30..pdf.

Person: refers to a natural person, or a company, partnership, joint venture, the association or corporation of another body corporate, or any governmental authority.

Planner: the officer responsible for the planning and management of a safety management plan at a railway crossing. The planner is normally appointed by the directorate delegated to deliver the project on behalf of the project sponsor; but in some cases the planner is appointed by the project sponsor.

Policy Manager, Road User Priority and Access: the position responsible for the policy, strategy and program management of railway crossings in the RTA’s Traffic Management Branch, Network Services Directorate.

Post-incident management measure: any measure which aims to:
- Limit the severity of an incident (crash) once it has occurred.
- Reduce the likelihood of consequences (that is, injuries and fatalities to road and rail users) of that incident.
- Reduce the likelihood of a secondary incident occurring (that is, a subsequent crash) as a result of the initial incident.
- Reduce the likelihood of consequences occurring as a result of a secondary incident, should it occur.

Project Manager (railway crossings): the RTA’s Infrastructure Services, Road Safety and Traffic Management section officer responsible for the day-to-day management of railway crossings in their region.

Public road: any road that is opened or dedicated as a public road, whether under the Roads Act 1993 or any other law; and any road that is declared to be a public road for the purposes of the Roads Act 1993 but does not include a Crown road.

Rail infrastructure manager: the person who has effective management and control of the rail infrastructure of a railway, whether or not the person owns the rail infrastructure, or has a statutory or contractual right to use the rail infrastructure or to control and/or provide, access to it. In NSW rail infrastructure managers include:
- The Australian Rail Track Corporation (ARTC).
- The Rail Corporation New South Wales (RailCorp).
- The Country Rail Infrastructure Authority (CRIA).
- The Transport Infrastructure Development Corporation (TIDC).
- Rail infrastructure managers of isolated lines and private sidings.
(Source: Section 4 of the NSW Rail Safety Act 2008.)

Rail transport operator: may be a rail infrastructure manager, or a rolling stock (train) operator, or a person who is both (NSW Rail Safety Act 2008). Typically, the term ‘rail transport operator’ is used to refer to any person who operates rolling stock on the railway.

Rail reserve: the land dedicated for the operation of a railway.
• **Railway**: a guided system designed for the movement of rolling stock, which has the capability to transport passengers or freight on a railway track together with its infrastructure and rolling stock.

• **Railway crossing**: the area where a road and a railway cross at substantially the same level. This includes the land, features and infrastructure bounded by the rail reserve and prolongation of the road boundary.

• **Railway crossing area of influence**: in the roads authority context, this includes the railway crossing and an agreed distance along the approach roads that are considered to be essential to ensure the safe operation of both the railway crossing and the traffic which is affected by the operation of the railway crossing. The length of road agreed upon typically relates to the provision of traffic control devices such as warning signs. However, the area of influence may extend further along the road, as the length of vehicle queues may influence road safety further than the warning signs. For instance, a crash at the back of the queue of traffic might be associated with the operation of the railway crossing.

• **Railway crossing GIS database**: a spatial database used to store information regarding railway crossings. Among its uses is the mapping of railway crossings with other spatial information such as road crashes. This database is managed by the RTA’s Road Information and Asset Management Technology section.

• **RC**: railway crossing.

• **RC Risk Register**: a list of those sites where risk is deemed to be above a ‘broadly acceptable’ level. These sites are prioritised for treatment when funds are available. The register is held by the Policy Manager, Road User Priority and Access, Traffic Management Branch. See also the glossary entry for ‘broadly acceptable’.

• **Recovery measure**: another term for a post-incident management measure.

• **Regional road**: an administrative category for roads in New South Wales. Regional roads are roads under the care and control of local governments, with funding provided by local government and supplemented by the RTA under the ‘block grant agreement’. For information on the block grant agreement see www.rta.nsw.gov.au/doingbusinesswithus/lgr/index.html. For a list of classified roads, including their administrative category, see www.rta.nsw.gov.au/doingbusinesswithus/downloads/lgr/reg_table_for_internet_31jan11.pdf.

• **RAV**: Restricted Access Vehicle. A vehicle that is larger than a general access vehicle, as defined in the *Road Transport (Mass, Loading and Access) Regulation 2005*. These vehicles are restricted to travel on specified (gazetted) routes in New South Wales. Common configurations include B Double and Road Trains. See also the glossary entry for ‘Over Size Over Mass Vehicle’ for another category of vehicle/load that is larger than the general access limits.

• **Risk**: the chance of something happening that will have an impact on RTA road safety objectives. A risk is:
  - Often specified in terms of an event or circumstance and the consequence that may flow from it.
  - Measured in terms of a combination of the consequences, their likelihood and exposure.

• **Risk analysis**: the assessment of the risks presented by an RC in terms of the likelihood and consequences of incidents that might arise from these risks, taking into account the existing safety management measures at that railway crossing.

• **Risk assessment**: the overall process of identifying, analysing and evaluating risks, hazards and hazardous events at a railway crossing. See also the glossary entries for ‘risk analysis’ and ‘risk evaluation’.

• **Risk assessment criteria**: standards for the comparison and evaluation of risks at railway crossings. See Assess: *Applying risk tolerance and risk assessment criteria to railway crossings*, Section 5, for a discussion of these criteria.

• **Risk assessment procedure**: a five-step procedure used to identify, assess, evaluate and manage safety risks and safety management measures at railway crossings. This five step procedure is detailed in Appendix A of Plan: *Establishing a railway crossing safety management plan.*

• **Risk category**: a way in which risks at a railway crossing are grouped according to the different types of road user behaviour from which they arise. See Evaluate: *Applying the railway crossing cause consequence bow tie models*, Section 2.1.
• **Risk control**: the part of risk management that involves the implementation of policies, standards, procedures and physical changes to eliminate or minimise adverse risks (AS 4360).

• **Risk evaluation**: the process of comparing the existing level of risk at a railway crossing with the new level of risk that would eventuate from the implementation of changes to risk management, should any be deemed necessary, arising from the risk analysis process. Risk evaluation therefore often involves a comparison of the effects of existing safety management measures with the effects of revisions to the existing safety management measures. Often a number of alternative revisions are considered during risk evaluation.

• **Risk level**: a qualitative measure that brings together the likelihood and consequence of a risk, on a scale from Negligible to Extreme, to allow the ranking of risks and the prioritising of mitigation or safety management measures where the level of risk is above the ‘broadly acceptable’ threshold. See also the glossary entry for ‘broadly acceptable’.

• **Risk evaluation**: the process of comparing the existing level of risk at a railway crossing with the new level of risk that would eventuate from the implementation of changes to risk management, should any be deemed necessary, arising from the risk analysis process. Risk evaluation therefore often involves a comparison of the effects of existing safety management measures with the effects of revisions to the existing safety management measures. Often a number of alternative revisions are considered during risk evaluation.

• **Risk level**: this is determined taking into account the risk assessment criteria of likelihood and consequence, and assigned through use of the risk level matrix. See [Assess: Applying risk tolerance and risk assessment criteria to railway crossings], Section 5.

• **Risk level matrix**: a matrix which uses the risk assessment criteria as they apply to a particular railway crossing to generate a risk level for that particular risk. See [Assess: Applying risk tolerance and risk assessment criteria to railway crossings], Section 5.5.

• **Risk management**: an overall process of hazard identification, risk assessment and risk management, which includes the implementation, and active monitoring and review, of controls, policies, procedures and practises, to manage those risks, so that they are maintained at a level that is as low as is reasonably practicable.

• **Risk ranking**: An output of ALCA which sorts the relative safety of public railway crossings throughout NSW from greatest risk to lowest. A railway crossing ranked ‘one’ is judged to have the highest risk.

• **Risk rating**: the overall risk level of a railway crossing.

• **Risk tolerance**: the amount of risk that the RTA is prepared to accept, tolerate, or be exposed to, before it judges that action is necessary to reduce or eliminate that risk. Decisions regarding risk tolerance take into account all the risks to the RTA in the context of exhaustible resources. Risk tolerance is a function of ranking a risk against all other assessed risks and determining at what risk level risk mitigation action should be taken, SFAIRP. For the purposes of railway crossing risk assessments, levels of Negligible and Low are considered to be broadly acceptable.

• **Risk type**: a way in which risks at a railway crossing are grouped which takes into consideration both road user behaviour and the control, design and operational elements at a railway crossing. Risk types are organised as sub-categories of risk categories. See [Evaluate: Applying the railway crossing cause consequence bow tie models], Section 2.1.

• **Road carriageway**: the portion of a road or a bridge devoted particularly to the use of vehicles, inclusive of shoulders and auxiliary lanes (Austroads Glossary of Terms 2010).

• **Road project**: a project funded or commissioned by the RTA that results in a new road or new traffic management infrastructure, or a physical change to the infrastructure of an existing road which, subsequent to this change, will become part of the State road network in NSW. Examples of road projects include:
  - A new motorway or improvement to an existing motorway.
  - A new arterial road or an upgrade to an existing freeway or arterial road, including road widening, traffic control signals, intelligent transport systems and traffic control facilities.
  - An enhancement to the road-based public transport network, such as a transitway or bus priority measure on an existing freeway or arterial road.

• **Road Safety Audit policy**: released as a Technical Direction by the NSW Centre for Road Safety TD 2003/R03, Version 2 in August 2005. This provides an imperative to conduct road safety audits. See [www.rta.nsw.gov.au/roadsafety/downloads/tds/td2003rs03-aug05.pdf].
• **Road Safety Audit process**: a formal examination of an existing road, or a future road or traffic project, in which an independent qualified team looks at the project’s potential crash and safety performance. The process may be applied to an existing road network, to concept or detail designs prior to road construction, during road construction or before opening the road to traffic.

• **Road**: a private road or a public road that has, as one of its main uses, the driving or riding of motor vehicles, and includes any relevant road-related area within the meaning of the *NSW Road Rules 2008*.

• **Road user**: a driver, rider, passenger or pedestrian (*NSW Road Rules 2008*).

• **RTA**: the Roads and Traffic Authority of New South Wales.

• **Safe systems approach**: an approach that provides for safety to be considered throughout all phases of a road project, as all phases can be seen as contributing to the provision of a safer system. For example, a safe systems approach to a road project would include the following: designing the road, roadside areas and traffic management measures to provide a forgiving environment for all road users (safer roads); public education (safer people); and, vehicle safety standards (safer vehicles).

• **Safety control measure**: an alternative term for a safety management measure. See also the glossary entry for ‘safety management measure’.

• **Safety management measure**: any measure (including legal measures, physical actions, engineering measures, educational measures and so on) that aims to prevent or mitigate an incident.

• **Safety management plan**: a railway crossing safety management plan is a contract between the RTA and other relevant parties which details how safety risks, safety management measures and post-incident management measures will be managed at a railway crossing, so far as is reasonably practicable.

• **Safety risk**: another term for ‘risk’. See also the glossary entry for ‘risk’.

• **SFAIRP**: see the glossary entry for ‘so far as is reasonably practicable’.

• **Shall**: ‘shall’ is used in this document to give mandatory directives.

• **Should**: ‘should’ is used in this document to make recommendations of good practice.

• **So far as is reasonably practicable**: what is (or was at a particular time) reasonably practicable in relation to ensuring safety with regard to risk, taking into account:
  - The likelihood of a risk eventuating.
  - The degree of harm that would result if a risk eventuated.
  - What the person concerned knows, or ought reasonably to know, about a risk and any ways of eliminating or reducing a risk.
  - The availability and suitability of ways to eliminate or reduce risk.
  - The cost of reducing or eliminating a risk.

  *(Source: Section 6 (2), *NSW Rail Safety Act 2008*)

• **State road**: an administrative category for roads in NSW. The RTA takes responsibility for managing the primary traffic function of State roads, including funding and determining priorities. The RTA also regulates the activities of third parties – including local councils and contractors – on the road. This is to ensure that road safety and traffic efficiency are promoted and consistently applied across the major traffic routes throughout the State, and that the road asset is protected. Activities that are located outside of the primary traffic area do not relate to traffic control, such as footpaths, are generally the responsibility of local councils. See [www.rta.nsw.gov.au/doingbusinesswithus/downloads/lgf/reg_table_for_internet_31jan11.pdf](http://www.rta.nsw.gov.au/doingbusinesswithus/downloads/lgf/reg_table_for_internet_31jan11.pdf) for a list of roads classified as State roads.

• **Unincorporated area**: the area in the far west of NSW that does not have a local government. The *Western Lands Act 1901* established the position of the Western Lands Commissioner who is responsible for administering the Act, subject to the control and direction of the Minister for Lands. The Unincorporated Area is managed by the NSW Department of Lands under direction of the Western Lands Commissioner. See [www.edo.org.au/edonsw/site/factsfs/fs02_6.php](http://www.edo.org.au/edonsw/site/factsfs/fs02_6.php).
This document is part of the Railway Crossing Safety Series 2011, the documents that make up the series are:

- Plan: Establishing a railway crossing safety management plan (policy number PN239G)
- Identify: The railway crossing safety hazard checklist (policy number PN241G)
- Assess: Applying risk tolerance and risk assessment criteria to railway crossings (policy number PN238G)
- Evaluate: Applying the railway crossing cause consequence bow tie models (policy number PN240G)