Final Report

Rail Safety Investigation

QT2459

Fatal Collision between the Cairns Tilt Train and B-Double Truck
Rungoo Level Crossing, Queensland
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Queensland Government

Department of Transport and Main Roads, *Rail Safety Investigation QT2459*, 2009

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Executive summary

At 1447:13[1] on Thursday 27 November 2008, the northbound Cairns Tilt Train (CTT) collided with a loaded B-double truck[2] at the Rungoo level crossing, about 19.5 km north of the township of Ingham in north Queensland. On board the CTT were 81 passengers and seven train crew. The truck driver was the sole occupant of the B-double truck. The maximum permitted speed for road vehicles at the Rungoo level crossing was 100 km/h and the maximum speed for trains was 60 km/h.

The two train drivers were fatally injured as a result of the collision. The truck driver incurred moderate injuries that consisted of abrasions and grazes to his hands and chest wall and cervical pain. He was airlifted to the Cairns Base Hospital at 1730. In addition, injuries were incurred by nine passengers; these consisted of chest pain, shortness of breath, back pain, soft tissue injury and anxiety. The nine passengers were treated on board the CTT at the crash site and later transferred by ambulance to Ingham for further assessment.

The gross weight of the B-double truck was estimated at about 56 t; the gross weight of the CTT was 448 t. At impact the B-double truck was travelling at an angle of about 97 degrees to the train at an estimated speed of 75 km/h. The CTT data event recorder logged the train's speed at the time of collision as 57 km/h.

The front of the CTT impacted the leading trailer of the B-double truck about eight metres from the truck's front bull-bar. The angle of the collision and the speed and weight of the B-double truck imparted very high lateral forces on the driver's cabin of the CTT. This caused the driver's cabin to lozenge[3] which, in turn, reduced the amount of survivable space afforded to the train's two drivers. In essence, the lead power car and, in particular, the driver's cabin of the CTT, bore the brunt of the force of the collision. This was evidenced by the fact that the power car was rotated about 135 degrees in an anti-clockwise direction and that the driver's cabin sheared to the left while the rest of the train's nine carriages remained relatively undamaged.[4]

The B-double truck driver said he saw the flashing light assemblies at the Rungoo level crossing but they were not illuminated. Consequently, he did not slow from his estimated approach speed of 90 km/h until he saw the CTT when the truck was about 150 m away from the level crossing. Two witnesses travelling in a vehicle following the B-double truck said they saw the lights flashing. Two witnesses in a second vehicle following the B-double truck said they did not see the lights working however, the driver could not recollect whether he looked at the level crossing flashing light assembly before or after the collision. The

1 The 24 hour clock is used in this report to describe the local time of day. The time of 1447:13 is calculated from the data event logger on the CTT.

2 A B-double truck means a combination consisting of a prime-mover towing two semi-trailers where the first semi-trailer is connected to the prime-mover by a fifth wheel coupling and the second semi-trailer is connected to the first semi-trailer by a fifth wheel coupling.

3 Lozenge – Four sided planar figure with a diamond shape; a rhombus that is not a square.

4 The luggage car immediately behind the lead power car was derailed all wheels but, apart from bogie and lead coupler damage, was essentially intact and remained upright.

passenger in this vehicle said he did not see the train before the collision or notice if the lights were working.

The investigation examined data from the CTT data event recorder[5], the CTT data logger[6] and the level crossing Remote Monitoring Unit. The investigation concluded that the level crossing lights were operating normally for 26 seconds before the CTT entered the level crossing. The investigation also concluded that the train speed at impact was 57 km/h, within the permitted speed of 60 km/h, the train horn was sounded twice on the approach to the level crossing and the headlight was illuminated. Also, an emergency brake application was made by the train driver about two seconds before impact.

The investigation examined the layout of the level crossing advance warning signs and pavement markings, the conspicuity of these devices and the flashing light signal assembly. The Rungoo level crossing was found to be generally compliant with the relevant level crossing standards. The focus of the flashing lights was also determined to be in accordance with the locality plan.

An extensive examination of the standards to which the CTT was designed and constructed was conducted in order to determine the crashworthiness of the driver's cabin. This examination included a comparison between the Australian standards and overseas standards at the time of design (circa 1999) and a comparison between contemporary Australian and overseas standards at the time of the investigation.

The findings are that the CTT was constructed in accordance with the QR crashworthiness standards and that the standards at the time of design and at the time of the investigation were (and are) consistent with their European and American counterparts in terms of crashworthiness. Of note is that no former or contemporary Australian or international rollingstock standard takes into account high levels of lateral loading in their crashworthiness requirements.

The emergency response measures enacted by the CTT on-board train staff and the emergency response agencies of the Queensland Police Service, the Queensland Ambulance Service and the Queensland Fire and Rescue Service were found to have been of a very high calibre.

The investigation has made recommendations in regard to:

- Locomotive standards and the ability of rolling stock to withstand high levels of lateral loading;
- Communication from an accident site;
- The use of medically qualified persons during an emergency;
- Information contained in passenger train manifests;
- Testing for illicit drugs;
- Differing standards of safety systems in the road transport industry; and
- Continued investigation into remote monitoring of heavy vehicles.

5 Data Event Recorder – A recorder that records data whenever an event occurs.

6 Data Logger – A recorder that records data at set time intervals.

Terms of reference

In pursuance of the powers given to me under Section 216 of the *Transport Infrastructure Act 1994*, I hereby amend my directive issued on 2 January 2009 requiring you to investigate the circumstances and causes of the fatal occurrences involving firstly the collision between the diesel tilt train and semi trailer on the Bruce Highway level crossing at Rungoo on 27 November 2008 and secondly the collision between a diesel Sunlander train and a truck which occurred at Mundoo on 1 January 2009.

In pursuance of the powers given to me under Section 216 of the *Transport Infrastructure Act 1994*, I hereby require you to chair an independent investigation into:

- The circumstance and causes of the fatal occurrence involving the collision between a diesel tilt train and semi trailer on the Bruce Highway level crossing at Rungoo on 27 November 2008; and
- The circumstance and causes of the fatal occurrence involving the collision between a diesel Sunlander train and a truck which occurred at the Aerodrome Road level crossing at Mundoo near Innisfail on 1 January 2009.

Reports of your findings and recommendations in relation to these incidents are required in writing to the Director-General, Department of Transport and Main Roads by 1 November 2009.

Should the final report for either incident be unable to be provided by these dates then an interim report must be submitted.

The investigation will:

- Clearly establish the factual circumstances of both occurrences;
- Identify the direct cause or causes of these occurrences and any other contributing factors;
- Assess human factors to identify any underlying matters which may have caused or contributed to the occurrences;
- Clearly identify any systemic issues; and
- If necessary make appropriate recommendations designed to reduce the likelihood of a re-occurrence.

The investigation report should be based on a systematic style investigation approach and should not be written in a manner that apportions blame.

The investigation panel will be comprised of two Queensland Transport Rail Safety Officers and an independent chair.

Dated this 19 June 2009

Dave Stewart
Director-General
Department of Transport and Main Roads

Investigation methodology

The purpose of this investigation is to enhance rail safety by determining the sequence of events that led to the fatal collision between the Cairns Tilt Train (CTT) and a B-double truck at the Rungoo level crossing on Thursday 27 November 2008 and to then determine why those events occurred. The investigation has endeavoured to identify the factors, both latent and active, that contributed to the collision with the intent of identifying risks that may have the potential to adversely affect rail and road safety at level crossings. Where considered necessary, recommendations to this effect have been made.

The investigation was conducted by Queensland Transport[7] (QT) as an independent accident investigation with the Australian Transport Safety Bureau (ATSB) acting as the chair and providing resources as necessary. The investigation was conducted in accordance with the legal framework as defined in Queensland's *Transport Infrastructure Act 1994*.

During the investigation information was obtained and analysed from many sources. Without being limited, this included:

- Interviews with persons directly and indirectly involved with the accident:
    - The B-double truck driver;
    - Witnesses to the collision;
    - Passenger services staff who were on the CTT at the time of the collision; and
    - Various management and safety staff from road and rail disciplines.
- Evidence and technical information:
    - Visits to the crash site and collection of relevant perishable and retrievable evidence;
    - Examination of the CTT data logs and level crossing data logs;
    - Examination of relevant safety management system documentation;
    - Examination of the design and construction of the CTT power car and a comparison with examples of 'best practice' to determine the adequacy of the existing crashworthiness standard; and
    - Research into human behaviour applicable at level crossings.

The conclusions of the investigation are based on the data available to the investigation team at the time of finalising this report.

The investigation team acknowledges the cooperation received from all parties to this investigation, both individuals and organisations.

7 Queensland Transport and the Department of Main Roads amalgamated on 26 March 2009 and became the Department of Transport and Main Roads. Throughout the report, Queensland Transport will be referred to as QT and the Department of Main Roads will be referred to as MR. Recommended Safety Actions for QT and MR will be referenced to the Department of Transport and Main Roads as the responsible body.

1 Factual information

1.1 Overview

1.1.1 Occurrence location

The Rungoo level crossing is located 19.5 km by rail north of Ingham. Ingham is a provincial town with a population of about 6000 people in the State of Queensland, about 110 km north of Townsville and about 230 km south of Cairns. The Rungoo level crossing is a road/rail interface between the main north coast rail line to Cairns and the Bruce Highway.

Figure 1: *Occurrence location*

Map – Geoscience Australia. Crown Copyright ©

The Bruce Highway is the main vehicular route between Brisbane and Cairns. It is a B-double 'higher mass limit' route meaning that B-double combinations of up to 26 m in length and 68 t gross weight can travel this route. As at December 2008 the two way vehicular count traversing the Rungoo level crossing was estimated to be 2360 per day.

The rail line between Townsville and Cairns is the northern component of the Brisbane to Cairns main line. The daily operational management of this corridor is vested in the managers and train controllers at the Townsville Network Control Centre. Weekly, there are 41 timetabled trains which traverse the Rungoo level crossing. Of these, 12 are passenger trains that consist of three return Sunlander and three return Cairns Tilt Train (CTT) services. On average, about six trains traverse the Rungoo level crossing on a daily basis in either direction.

The passage of road traffic across the Rungoo level crossing is controlled by signs that provide advance warning (passive) of the presence of the level crossing and flashing lights that are designed to activate when rail traffic is approaching. Road users are required to stop at the level crossing when these lights are activated.[8]

1.1.2 Road and rail layout

Road approach (southbound)

The Bruce Highway traverses the Conn level crossing 8.36 km to the north of the Rungoo level crossing. Between these two points the road is predominantly level with sweeping/wide radius curves to the left and right. The countryside is heavily timbered, generally up to the boundaries of the road corridor, about 15 to 20 m from the edge of the bitumen (figure 2). There are no 'major' side roads that join the Bruce Highway between these two level crossings.

Figure 2: *Typical countryside north of the Rungoo level crossing*

8 The Rungoo level crossing was upgraded to active protection (flashing lights) in August 1978.

The immediate southbound approach to the Rungoo level crossing is similar (level with timbered countryside) although it is on a gradual right-hand curve that restricts the view of a 'northbound' train from a 'southbound' motorist until about 100 to 150 m from the Rungoo level crossing. The Bruce Highway remains level as the rail line is crossed and then straightens out as it continues in a southerly direction before commencing to climb the Cardwell Range about 850 m south of the Rungoo level crossing. At the time of the collision the speed limit for road traffic was 100 km/h throughout.

Figure 3: ***Approach to the level crossing from the north***

Rail approach (northbound)

The Hinchinbrook crossing loop is located a little over two kilometres to the south of the Rungoo level crossing, about 16 km (by rail) north of Ingham. The rail track between the Hinchinbrook crossing loop and the Rungoo level crossing is undulating with 'gentle' wide radius curves. Within about 500 m of the level crossing the track is almost level (a slightly falling grade of 1:165).

The surrounding countryside between the Hinchinbrook crossing loop and the Rungoo level crossing is heavily timbered up to the boundaries of the rail corridor; about 20 m from the rail line. Within about 100 m of the Rungoo level crossing the land on the 'south-western' side of the rail corridor is cleared of timber, thereby allowing a good view of road traffic approaching from the left (south). To the right (north) though, the timber remains thick until the boundary of the Bruce Highway corridor is encountered about 40 m from the level crossing.

The section of track between the Hinchinbrook crossing loop and the Rungoo level crossing has a maximum speed of 80 km/h. However, a temporary 60 km/h speed restriction has been in place for several years for north and southbound rail traffic traversing the Rungoo level crossing. This speed restriction was initially applied by QR for operational reasons[9] and then extended when the level crossing upgrade at Rungoo was announced.

1.1.3 Train and crew information

The Cairns Tilt Train

QR Passenger Pty Ltd, a subsidiary of QR, is an accredited operator of passenger rail transport services in Queensland. QR Passenger Pty Ltd operates the CTT between Brisbane and Cairns three times a week. Two identical tilt train sets are used for this service.

The CTT's were built by EDI Rail, Maryborough, Queensland and started service in June 2003. These trains are operated as a push-pull configuration with a diesel power car at the front and rear of the train and seven air-conditioned trailer cars in between. Each train is 197 m long[10], has a gross weight of 448 t and a capacity of 173 passengers (167 seated, six wheel-chairs). The maximum speeds permitted are 160 km/h between Brisbane and Rockhampton, 100 km/h between Rockhampton and Townsville and 80 km/h between Townsville and Cairns.

Figure 4: *CTT at Townsville*

Photograph - G. Watkins Copyright ©

9 Due to high humidity and rainfall, stainless steel welds were applied at the level crossing track circuits to assist with train detection. It was then found that these welds were causing wheel damage at the formerly permitted speed of 80 km/h.

10 This length includes 800 mm between cars (not shown in table 1).

Table 1: *The CTT consist (train number VCQ5) Thursday 27 November 2008*

Car	Type	Number	Passenger Capacity	Tare Weight	Length
Power Car		DTD 5403	Nil	67 t	20.1 m
A	Luggage	DTB 7401	Nil	43 t	21.5 m
B	Sitter	DTL 7402	39	45 t	21.5 m
C	Sitter	DTL 7403	39	45 t	21.5 m
D	Sitter	DTL 7404	39	45 t	21.5 m
E	Club Car	DTC 7405	N/A	45 t	21.5 m
F	Sitter	DTP 7406	28	46 t	21.5 m
G	Sitter	DTP 7407	28	46 t	21.5 m
Power Car		DTD 5402	Nil	67 t	20.1 m

Pre-trip inspection

The CTT is regularly inspected in accordance with a hierarchy of maintenance schedules at varying intervals. These inspections range from major work such as overhaul/component change-out, to trip inspections that are conducted on completion of each return Brisbane to Cairns journey where the electrical and mechanical systems of the CTT are inspected. Trip inspections encompass traction, pneumatic, brakes, wheels, under-frame and galley systems. In addition, ultrasonic inspections are carried out on wheel-sets when scheduled. The last trip inspection conducted on the CTT involved in the collision at Rungoo was on Monday 24 November 2008.

In addition to the trip inspection, the CTT is certified as fit for service by a preparation driver before entry into traffic. At these inspections the preparation driver certifies that the trip inspection has been completed and that systems such as traction, brakes, event recorder, vigilance control, lighting, radios, horn and speedometer are operational. The CTT involved in the collision was inspected in this manner before departure from Brisbane on Wednesday 26 November 2008.

No faults were found in either inspection that would have placed the CTT outside of required mechanical or operational parameters.

Train drivers

The CTT is crewed by two drivers who operate the train from the leading power car. In addition to the actual operation of the CTT, the drivers are responsible for the adherence to all safeworking requirements associated with the passage of the train and other operational aspects such as en-route fault rectification of the CTT train or the operation of way-side equipment in accordance with the competencies they hold.

The two drivers of the CTT on Thursday 27 November 2008 were male, aged 53 and 54. One driver had nearly 30 years experience and the other nearly ten years experience in train operations respectively. Both drivers were based in Townsville where they had signed on duty at 1130 to work train VCQ5 to Cairns. At Cairns they were rostered to sign off and rest in motel accommodation before signing on again at 0705 on Friday 28 November 2008 to work the southbound CTT back to Townsville.

Both drivers held appropriate qualifications for the operation of the CTT between Townsville and Cairns and both were classed as medically fit for duty in accordance with the criteria prescribed in the *National Standard for Health Assessment of Rail Safety Workers*. A review of personnel records revealed that both train drivers had a good work history with no employment or safety related infringements during the four years preceding the collision.

On-board train staff

The CTT has a complement of five on-board staff whose duties broadly encompass attending to passenger requirements, train servicing, cleaning, security and, if the need should arise, emergency response.

The senior member of the on-board train staff is the Passenger Services Supervisor (PSS). This position is responsible for the overall management of the 'on-board' train crew. Assisting the PSS is a Passenger Attendant (PA). In addition to the PSS and PA, there are three catering staff that provide meal and drink services throughout the train.

On-board train staff are provided with emergency response training that places particular emphasis on the development of skills required to respond to an emergency evacuation of passengers. Facets of emergency response such as securing the site, assisting with train protection, leadership, communication and use of emergency equipment are all dealt within this training. Also, 'hands on' role-play exercises that test the application of the framework and course learning are undertaken.

The on-board train staff were also based in Townsville and were rostered to lay-over at Cairns in the same manner as the two drivers. They all held current certification for all aspects of their respective duties.

Communication

CTT train drivers are able to contact train control, way-side personnel, the PSS and other on-board staff by radio or telephone. There are also hand-held radios and a satellite telephone that enable communication if the train drivers need to vacate the driving cabin.

The PSS has a workstation located in Car A. At this workstation there is communication equipment that allows the PSS to communicate to external parties such as train control and internally to the passengers via the passenger address system, other on-board train staff or the train drivers. From this workstation the PSS is also able to monitor much of the auxiliary on-train equipment such as air-conditioning, refrigerator temperatures, the entertainment system and alternator outputs.

The CTT is equipped with an emergency position indicating radio beacon (EPIRB). Once activated, an EPIRB emits an internationally recognised distress signal on a frequency monitored by the COSPAS-SARSAT satellite system.[11] The EPIRB is a backup to the other communication systems if these systems are unavailable for any reason and is intended to provide an immediate indication of distress.

1.1.4 Road transport company, truck and driver information

Company and B-double truck

MFT Transport Pty Ltd was a Brisbane based road transport company that operated about 15 trucks of varying combinations on a lease/buy contractual arrangement.[12] The company engaged in general haulage with some long term contracts. The truck and trailer combination involved in the collision consisted of a 2002 Freightliner C620 class prime-mover hauling two Maxi-CUBE tri-axle trailers. The tare weight of the B-double combination was 28.2 t. This comprised the prime-mover at 8.6 t and the two trailers at 9.5 and 10.1 t respectively. Both trailers were certified to a maximum design gross weight of 35 t. At the time of the collision the truck was carrying about 28 t of empty pallets, meaning that the gross weight of the B-double combination was about 56 tonnes.

An inspection of the prime-mover and two trailers at Townsville by an officer from the Queensland Police Service (QPS) Mechanical Inspection Unit revealed that the B-double combination was in good condition. No non-conformances in regard to roadworthiness issues were identified.

B-double driver information

The B-double truck driver was a 63 year old male who had driven trucks for over 40 years. He had travelled the section of road where the collision occurred for several years including three return trips in the three weeks preceding the collision.

At the time of the collision he was appropriately licensed to drive B-double trucks as he held a current MC(0) class heavy vehicle licence. However, a review of his driving record for the past four years revealed a poor driving history. Since August 2004 his driving licence had been suspended twice due to an accumulation of demerit points that related to, amongst other issues, exceeding the speed limit, logbook irregularities and possession of an incomplete, false or misleading driving record. The most recent suspension of his licence was for three months between 28 May 2008 and 28 August 2008.

11 A global search and rescue service using geostationary and polar orbiting satellites.

12 MFT Transport Pty Ltd was placed in the hands of receivers and ceased trading in early 2009.

1.1.5 Environmental conditions

The closest weather observation station to the Rungoo level crossing is at Ingham. At 1500 on Thursday 27 November 2008, the weather observation station at Ingham recorded the following information:

Table 2:

Local time	Wind direction	Wind speed	Temperature	Relative humidity	Rainfall since 0900
1500	NNE	6 km/h	26.7 Celsius	88 percent	9.0mm

Information from witnesses indicates that the weather at the time of the collision at the Rungoo level crossing was similar to that recorded by the weather observation station at Ingham. That is, reports of predominantly fine weather with showers about the tops of the hills in the vicinity with an overcast sky.

1.2 Sequence of Events

1.2.1 Train journey from Townsville

The northbound CTT departed Townsville two minutes behind schedule at 1207 on Thursday 27 November 2008. On board were 81 passengers and a Townsville based crew of two train drivers and five on-board staff, the standard crew arrangement for the CTT.

Between Townsville and Purono[13], 35 minutes of timetable time was lost due to problems with loose ballast (at Bohle) and points (at Garbutt). Three minutes of the lost time was then made up during the 81 km between Purono and Ingham where the CTT arrived 32 minutes late at 1417. At Ingham the southbound Sunlander, another Cairns to Brisbane passenger train, was crossed. The CTT then departed Ingham 40 minutes behind schedule at 1430. The collision at the Rungoo level crossing occurred some 17 minutes later, at 1447:13.[14]

1.2.2 Truck journey

The truck driver and the B-double truck involved in the collision left Brisbane with a load for Tully on Tuesday 25 November 2008. The truck driver said that arrival at Tully was on the evening of Wednesday 26 November 2008 whereupon he spent the night in the sleeping cabin of the prime-mover. He said that the sleep he had was “as good as you’re going to get in a truck cabin” as it was hot and stuffy and that he had to start the truck engine a couple of times to run the air-conditioner. Nevertheless, he said he felt well when he arose at about 0500 on Thursday 27 November 2008. After having a light breakfast he unloaded the truck and at about 0700 he proceeded empty along the Bruce Highway to Cairns to pick up a load of pallets for Ayr. Ayr is about 320 km south of Cairns (or 88 km south of Townsville).

13 Purono is about 27 km north of Townsville.

14 Time obtained from the data logger of train VQC5.

The truck driver said he left Cairns at about 1100 and proceeded south along the Bruce Highway as far as Innisfail (about 90 km) where he had a sandwich and a soft drink for lunch. The truck driver estimated that he departed Innisfail at about 1300 and then continued south along the Bruce Highway. The journey was uneventful until he encountered a level crossing south of Cardwell (Conn) where the level crossing flashing lights were operating but no trains could be seen. A truck and a number of other vehicles were also stopped ahead of him at the level crossing. After a short time, presumably upon realising that no trains were approaching, these vehicles moved across the rail line. The truck driver said that, after stopping and having a look each way along the rail line, he did likewise.

He estimated that about seven or eight miles (about 12 km) further south, he encountered another level crossing. By this time he was the leading vehicle as the truck he had been following had pulled over at a rest area and the other vehicles were further along the highway to the south. He said that the flashing lights at this level crossing were not illuminated and, as such, he continued at an estimated 90 km/h around the sweeping right-hand bend on the approach to the level crossing. At an estimated 150 m from the level crossing, he saw a train approaching from his left at about a 45 degree angle and realised it was moving. He said he applied the brakes hard momentarily but then, realising he would not be able to stop, applied power to get as far across the level crossing as he could in order to try and get the prime-mover clear of the impact point. The truck driver said he could not turn right due to the acute angle of the rail line to the road and, if he turned left, he probably would have rolled the truck into the side of the train.

Within moments the collision occurred and the truck driver felt the prime-mover being violently thrown about before coming to a rest on the side of the road in an upright position. The truck driver then alighted from the truck to assess the situation.

The truck driver said that at the time of the collision the air-conditioning was on, the windows were wound up and both the radio and the CB radio were turned off. He also said that he did not notice any of the advance level crossing warning signs, he only saw the flashing light assembly at the level crossing and they (the lights) were not illuminated.

1.2.3 Witness accounts

External witnesses

The driver of a vehicle immediately behind the B-double truck involved in the collision, a Nissan Patrol, said that he had followed the truck for some distance and had pulled up behind it at the previous level crossing where the lights were flashing continuously. He said that when the truck continued across the level crossing he, after looking for approaching trains, did likewise. He then remained behind the B-double truck all the way to the second (collision) level crossing. He said that both vehicles were travelling between 90 and 95 km/h during this time. On the approach to the collision level crossing, as he encountered the sweeping right-hand bend, he saw that the level crossing lights were flashing. He said he then saw the brake lights of the B-double truck flash momentarily and then black smoke from the truck's exhaust. At this time he heard a horn sounding until impact; he said he was sure it was the train horn. He said the train then passed through the truck's lead trailer and the leading vehicle of the train (the power car) then 'flipped up' into the air. His sister-in-law, who was seated in the third row of seats in the Nissan Patrol, then called the emergency services via the triple-zero number on her mobile telephone.[15]

His sister-in-law had also witnessed the events. Although seated towards the rear of the vehicle, she said that her view was not significantly impeded as this seat was 'built up' higher than the seats in front. She saw the brake lights of the B-double truck come on momentarily and heard a horn sounding before she saw the train appear from behind the line of trees to the left of the level crossing. She also said that as they came around the right-hand bend towards the level crossing she saw that the level crossing lights were flashing.

Both witnesses were asked a number of questions in regard to the flashing lights at the level crossing, both were adamant that the lights were working and clearly visible. They also said that the windows of the Nissan Patrol were wound down because the air-conditioning was not working.

Two people were travelling in a white Mercedes delivery van behind the Nissan Patrol. They were travelling from Cardwell to Townsville for work related activities. At the first level crossing south of Cardwell the level crossing lights were flashing but no train appeared to be in the vicinity. At these lights there was a B-double truck (the collision vehicle) and a four wheel drive vehicle in front of them. After a short while these two vehicles proceeded through the level crossing and, after checking for trains, they followed. Once underway, both estimated that they and the two vehicles in front were travelling at between 80 and 90 km/h.

By this time the driver of the delivery van was engaged in a conversation with a work colleague on his hands free mobile telephone. Some minutes later the person in the passenger seat also received a work related call on his mobile telephone; the delivery van driver then slowed the vehicle slightly so as to reduce road noise. Both were still engaged in their respective conversations when the collision between the B-double truck and the train occurred. The delivery van driver said that he saw a train come from his left out of the corner of his left eye and collide with the truck at the level crossing. At impact he said he saw the engine of the train (the power car) 'fly straight up into the air'. After stopping the vehicle, the driver called the emergency services and told them what had happened. He said he 'did not see the flashing lights working' but was not sure whether he looked or noted this before or after the collision.

15 The Australian Communications and Media Authority (ACMA) regulates and monitors the emergency call services. The emergency call service is an operator-assisted service that connects the caller to the relevant emergency service organisation (police, fire or ambulance).

The person in the passenger seat estimated that they were about 150 m from the level crossing when he saw a train collide with the B-double truck. By this time he said that they and the vehicles in front had slowed to somewhere between 60 and 80 km/h. The person in the passenger seat said that he did not see if the flashing lights were working, nor did he see the train before the collision.

Three persons not in the immediate vicinity when the collision occurred were also interviewed. The first were residents who lived on the hill beside the Bruce Highway south of the Rungoo level crossing. They said that on a number of occasions previously they have had to call the emergency services upon hearing the noise of crashes on the Bruce Highway below. In this instance both were in the living room of their house with all windows open; the living room faces the direction of the Bruce Highway. They said that they heard the train horn sound for about two seconds and then a very loud 'bang'. The nature of the noise seemed to indicate a very solid impact and there was no 'scraping' noise as is often heard with road crashes.

The third person interviewed was a semi-trailer driver who had traversed the Rungoo level crossing in a southbound direction a short time before the collision. He said that he had seen a train on his right (southbound) at an estimated 300 to 350 m from the level crossing and that the flashing lights at the crossing were not working at this time. He said that before this there had been a lot of talk on the CB radio about the lights at the 'middle' level crossing south of Cardwell flashing continuously in the absence of any train. At Ingham he heard over the CB radio that there had just been a crash at the level crossing he had traversed a short time before.[16]

On-board staff

After leaving Ingham at 1430 the PSS had proceeded to his workstation in the trailing end of Car A in order to complete some clerical duties. Shortly after leaving Ingham he received a telephone call from one of the catering staff in the club car who told him that the drink refrigerator seemed to have stopped working as it was reading 17 (plus) degrees Celsius.

The PSS said that he had just finished his clerical duties and was halfway out of his seat, intending to walk to the club car to attend to the errant fridge, when he was 'slammed' up against the wall and the desk at the workstation. He said he called out a warning to the PA who was also in Car A to "hold on, we're in the dirt". In the moments after the collision, the PA, who was near a left-hand window, told the PSS that "we've hit a truck". Neither the PSS nor the PA saw or heard anything before the impact. After the impact the PA, despite being thrown to the floor momentarily, saw the lead power car coming to rest on the ground beside where he was seated and pieces of yellow fibreglass flying about.

At the time of the collision all three catering staff were in the galley of the club car, Car E. The catering staff said that, at impact, they heard two loud noises, a

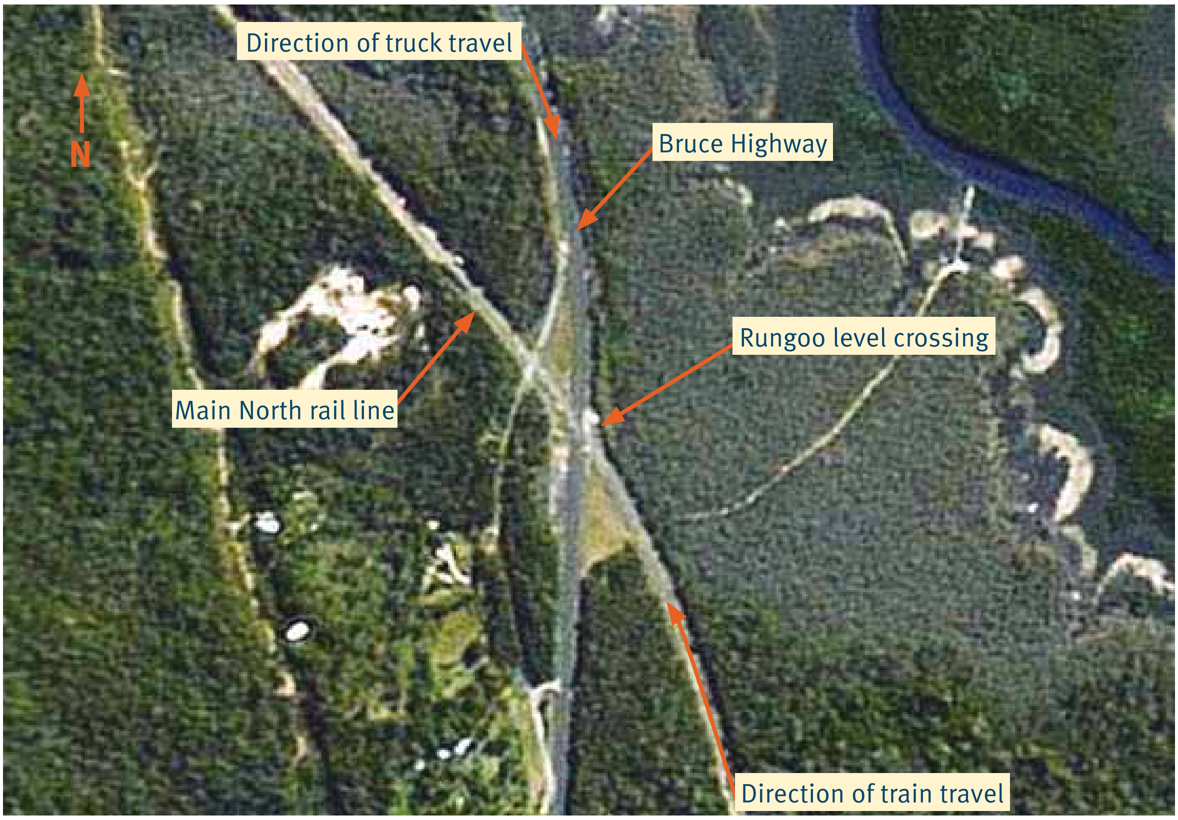
16 The previous southbound train that traversed the Rungoo level crossing was the Sunlander passenger train at about 1407.

short pause, and then another noise, all from the front of the train. They said the sudden deceleration threw them about a bit although all fixtures in the club car remained in place.

1.2.4 The collision

The orientation of the rail line with respect to the Bruce Highway at the Rungoo level crossing meant that train VCQ5 was travelling in a north-westerly direction and the B-double truck was travelling in a southerly direction.

Figure 5: ***Overview of Rungoo level crossing***



Google Earth – 2007 MapData Sciences Pty Ltd Copyright

The leading end of the lead power car of train VCQ5 impacted the A trailer of the B-double truck at a point about eight metres from the front bull-bar of the prime-mover. Figure 6 shows a schematic diagram of the point of impact. The photo in figure 6 shows where the front of the train 'slid' along the trailer before 'catching' on the bogie between the A and B trailers. The initial point of impact is just out of range to the left of the photo.

Figure 6: *Point of impact B-double truck*

The impact force caused the power car to derail to the left-hand side of the level crossing and, as the train moved forward, the A and B trailers of the truck 'wrapped' around the power car before splitting in two. The prime-mover and 'A' trailer then yawed in an anti-clockwise direction away from the point of impact while the B trailer yawed in a clockwise direction away from the point of impact. Having now broken through the B-double truck, the lead power car was pushed forward by the train's momentum at an angle to the left of the rail line before rotating about 135 degrees in an anti-clockwise direction.

During this sequence the right-hand side of the power car impacted the concrete block supporting the wayside level crossing control equipment cabinet. The power car was still upright at this stage. The power car then overturned onto its right-hand side a few metres from coming to rest, sliding backwards in the process. When it came to rest, the power car was facing in a south-south-easterly direction.

The luggage car was upright but derailed all wheels, the front bogie was derailed to the left side of the track and the rear bogie to the right side of the track, consistent with the forces exerted in a southerly direction when the power car impacted the southbound B-double truck. The remaining six carriages and rear power car did not derail.

Figure 7: ***Final position of power car showing impact with concrete block***

The prime-mover of the B-double truck rotated anti-clockwise about 70 degrees and came to a rest almost parallel with the rail line. The leading wheels of the prime-mover came to rest on the edge of the bitumen in the north-bound lane of the Bruce Highway.

The A trailer, which was still coupled to the prime-mover, had ruptured and the load of empty pallets were scattered over the immediate area.

Figure 8: ***Prime-mover and ruptured A trailer***

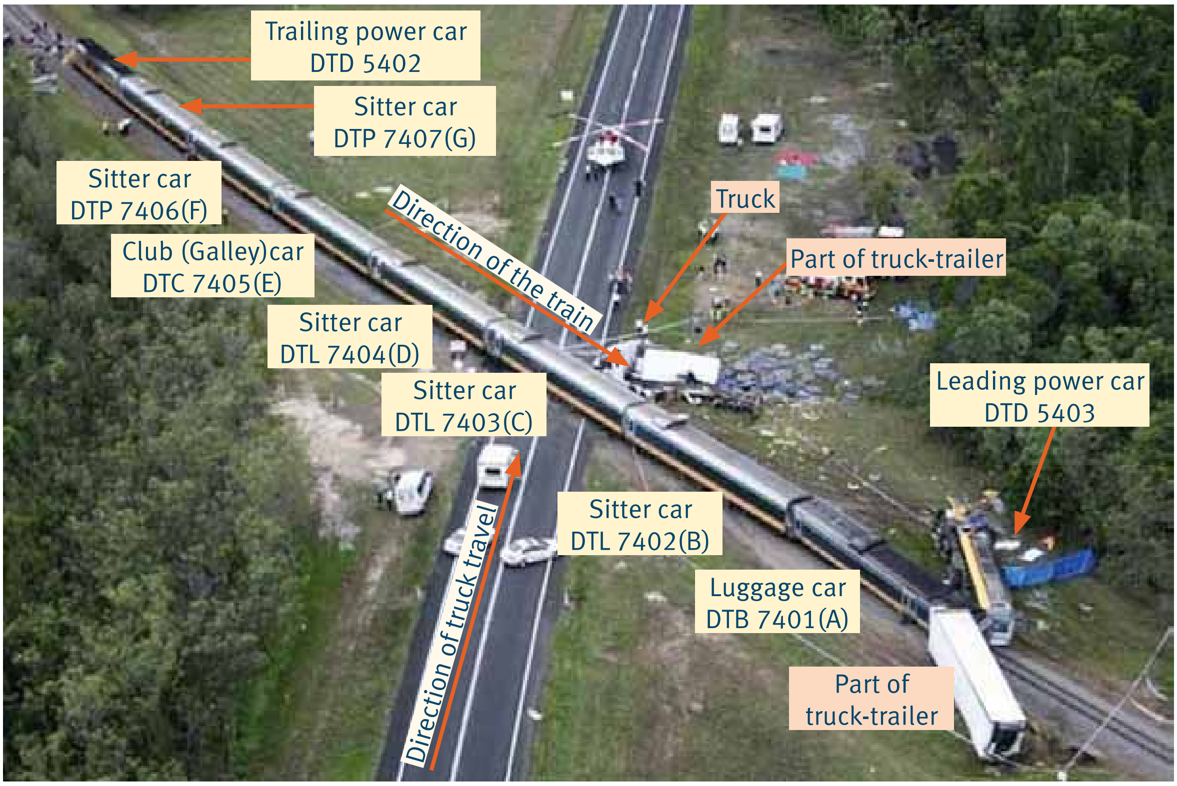
The rear end of the B trailer had become wedged in the leading end of the luggage carriage and was pushed forward about 55 m by the momentum of the train. The B trailer came to a rest facing in the same direction as the train ('north-westerly').

Figure 9: ***B trailer wedged in the front of the baggage car***

Of note is that 46.9 m of skid marks, close to the centre of the southbound lane, were found on the northern side of the level crossing. These marks extended to within several metres of the level crossing. Although faint, about halfway along these marks there appeared to be overlapping dual tyre markings, indicating that the actual braking distance was about 21 m, 46.9 m minus the length of the B-double truck (26 m).

Figure 10: ***Skid marks 46.9 m long***

Figure 11: *Aerial view of crash site*



Photograph – Cairns Post Pty Ltd.

1.3 Post occurrence

1.3.1 Emergency response

On-board staff

Immediately after the collision, the PSS tried to contact the train drivers by radio and telephone but there was no response. Train control was then contacted and advised of the collision. After obtaining some equipment such as a safety vest, radio and mobile telephone, the PSS went back through the train to check on passengers and staff and requested all passengers remain in their seats. The PSS said that a female passenger in Car C introduced herself as being medically qualified and asked if she could detrain and attend to the train drivers. The PSS told her that it was policy that passengers were not to go to a crash site but that she could accompany him and assist in assessing the condition of passengers and staff on board.

The PSS and the medically qualified passenger then moved through the train to render any assistance required. When this task was completed the PSS detrained on the left-hand (southern) side of the train through a door positioned near or on the road surface (Car C or D). He then requested a staff member to lock the door behind him.

The PSS said that the first person he encountered was the truck driver and that, apart from shock, he appeared to be alright. In response to a question from the PSS the truck driver said that the two train drivers were still in the 'locomotive' and that one appeared to be deceased and the other seriously injured. The PSS then went over to the power car and asked a motorist who was rendering assistance to the train drivers if they were able to continue with this task. This person replied in the affirmative. The PSS noted that there were two other persons on the under-side of the power car who were attempting to stop a flow of diesel leaking from the fuel tank.

The PSS said he then called triple-O from his mobile telephone but was told by the operator that they had been notified of the crash some time ago. He said that shortly after finishing this telephone call (within minutes) the first of the emergency services, a unit from the Queensland Fire and Rescue Service (QFRS), had arrived. The QFRS officers from this unit went straight over to the lead power car. The police and ambulances arrived shortly after whereupon the PSS consulted with these officers in regard to the examination of passengers by ambulance personnel and the evacuation of the train.[17] The ambulance personnel indicated a strong preference to attend to the passengers while they were still on board the train and the police wanted to record the names and addresses of all passengers before or during the evacuation process. By this time the PSS had been in contact with QR management in Brisbane in regard to alternative transport arrangements for the passengers.

The PA remained on the train and, as instructed by the PSS, was positioned by the left-hand door of Car B which was left open as the air-conditioning system had shut down.[18] As the emergency services personnel progressively arrived the PA was able to direct them to the location of the PSS and provide a general overview of the situation from this location.

The catering staff said that, in an attempt to allow fresh air into the train and to lower the temperature as much as possible, most of the doors on the right-hand side of the train (the opposite side to the bulk of the wreckage) were opened but barricaded with tape. They later moved through the train providing cool (non-alcoholic) drinks and refreshments to the passengers during their confinement on the train. They said there was concern from some of the passengers in regard to the decision to keep them confined to the train, particularly in the early stages when there was a strong smell of diesel fuel through the train. However, at interview, the on-board staff said that they (and later) the emergency services personnel felt that it was hotter outside the train than in the train, even without air-conditioning.

17 See 1.3.3 for evacuation times.

18 In the initial stages one of the two rear power car engines and alternators were still running. This provided air-conditioning to the last carriage; Car G. This engine was subsequently shut down by the PSS at the request of emergency services personnel at 1535 to negate the possibility of electrical current reaching the lead power car.

Because the wreckage could be clearly seen through the windows of Cars B and C, the catering staff tried to move passengers from these carriages to lessen trauma impact, however, some were reluctant to move. The on-board staff said that there were no readily apparent injuries to the passengers but they could see that a number of them appeared to be in shock.

Train control

The Townsville Network Control Centre was initially advised of a collision at the Conn level crossing by the QPS at 1455 and that the emergency services were in the process of responding. Shortly after, the collision site was corrected to that of the Rungoo level crossing.

Since the emergency services were already mobilising, the role of the Townsville Network Control Centre focused primarily on QR incident management issues. This included advising corporate media, arranging the attendance of infrastructure staff and a 'breakdown gang', advising Queensland Transport (QT), arranging for alternate transport of passengers and a number of other rail corridor management issues.

External agencies

Records from the QPS show that the Innisfail District Police Communications Centre was advised of the collision at 1449. The person who called was the driver of a vehicle that witnessed the collision (the delivery van driver, see 1.2.3). Between 1449 and 1506 five police units were ordered to respond. At 1510 the first police unit (from Cardwell) arrived at the site. At this time further advice regarding the collision, including that of one person deceased and one critically injured (both trapped), no major injuries to passengers or the truck driver, was relayed to the Innisfail communications centre. At 1545 this advice was upgraded to that of a double fatality.

Records of the QFRS show that initial notification was received by a triple-0 call at 1450:46. At 1453:47 the first of two fire and rescue vehicles departed Ingham with four QFRS personnel on board. Arrival at the Rungoo level crossing was recorded as 1507:52. At 1517:04 and 1517:16 a second and third unit from Halifax[19] and Ingham (respectively) arrived at the Rungoo level crossing. There were seven QFRS personnel aboard these vehicles. A further five fire and rescue vehicles subsequently arrived (from the north) from Cardwell, Innisfail, Tully and Cairns between 1523:08 and 1759:30. In total, eight QFRS fire and rescue vehicles with 30 personnel attended the scene. In addition, four QFRS officers from Ingham, Tully, Innisfail and Cairns attended the crash site.

Records of the Queensland Ambulance Service (QAS) show that a triple-0 call was received at the Far Northern Communications Centre (Cairns) at 1449. Two ambulances with three paramedics on board were dispatched from Ingham at 1454 and 1456, arriving at the site at 1508 and 1510 respectively. From this time

19 Halifax is a settlement about 19 km to the north-east of Ingham and about 21 km from the Rungoo level crossing.

resources in the form of ambulances, two Queensland Rescue Helicopters and one emergency response vehicle were dispatched from Townsville, Ingham, Halifax, Northern Beaches, Cardwell, Mission Beach and Cairns bases.

1.3.2 Injuries

Apart from the two train drivers who were fatally injured, nine passengers sustained injuries that QAS officers deemed to be in need of further treatment. In general terms, these injuries consisted of chest pain, shortness of breath, soft tissue injury, back pain and anxiety. The truck driver experienced chest wall pain, cervical pain and graze/abrasions to his hands.

1.3.3 Evacuation

Evacuation of passengers from train

A decision was made by the emergency services personnel, in conjunction with the PSS, to evacuate the nine passengers who had been assessed as requiring medical treatment before the remaining passengers. Because the rear left-hand door of Car C was positioned on the bitumen surface of the Bruce Highway and was only a short distance from the waiting ambulances, it was decided to evacuate these nine people from the train at this door.[20] One of the train's two emergency ladders was then obtained and positioned at the door, however, problems were experienced in securing it properly. Therefore, the PSS and a QPS officer had to hold the ladder in place while these passengers were evacuated from the train. This evacuation commenced at about 1650.

During this time, further discussion had taken place between the emergency services personnel and the PSS in regard to the evacuation of the remaining 72 passengers. Due to the problems with the emergency ladder[21] it was decided not to evacuate such a large number of people from Car C. The right-hand (northern) door of Car F (the second last carriage) was then chosen as it was remote from the main wreckage and the ground was relatively level. The emergency ladder used at Car C was then carried to Car F and the evacuation process commenced at about 1715.

Transportation from crash scene

At 1730 the truck driver was air-lifted from the scene and flown to the Cairns Base Hospital, arriving at 1815. At 1735, 1800 and 1905 the nine injured passengers were transported in three ambulances to the Ingham Hospital, arriving at 1750, 1820 and 1920 respectively. At 2030 one passenger was transferred from the Ingham hospital to the Townsville hospital as a precautionary measure, arriving at 2140. The QAS also transported six uninjured passengers who did not wish to travel north to Cairns, back to the QAS station at Ingham.

20 Due the close proximity of the evacuation point to the crash scene, tarps were erected to lessen any passenger trauma.

21 The emergency ladders are intended for use at ground levels that are normally lower than road surfaces.

Two buses from Townsville arrived at the crash site at about 1805 and proceeded via a temporary deviation to the northern side of the level crossing. Here the 66 remaining passengers[22] who wanted to travel through to Cairns boarded the two buses. Departure for Cairns was at about 1835. Two ambulances escorted the buses to Cairns in addition to QAS paramedics and the PSS who accompanied the passengers on board the buses. A stop for dinner was made at the Calwell road-house, and the journey to Cairns re-commenced at about 2025.

At about 2350 both buses arrived in Cairns where they were met by a local manager from QR Passenger who provided assistance with accommodation and transport requirements for the passengers where this was required.

1.3.4 Damage

Cairns Tilt Train

The lead power car (DTD 5403) incurred severe structural damage. This damage was particularly severe in the vicinity of the driver's vestibule and cabin. A detailed description of the damage and analysis of the crashworthiness of lead power car (DTD 5403) is provided at sections 2.4 and 2.5.

Figure 12: ***Driver's cab and vestibule***

The luggage car (DTB 7401) incurred damage to both bogies, leading end interconnecting door, electrical cables, air hoses and the coupler assembly. The interconnecting canopies at both ends were also damaged. The rest of the train was relatively undamaged and, as detailed at 1.3.5, was able to be hauled to Brisbane by a locomotive about 43 hours after the collision.

22 72 passengers, less six, who elected to be transported south to Ingham.

Infrastructure

Damage to infrastructure was, given the magnitude of the collision, relatively minor. A length of rail on the immediate southern side of the level crossing was buckled and there were a number of gouges in the bitumen road surface. Track on the northern side of the level crossing was extensively damaged. The level crossing electrical control cabinet on the southern side of the crossing was destroyed as was the flashing light assembly on this side of the track. Track circuit cabling in the vicinity of the level crossing was also severed.

B-double truck

Structurally, the B-double's prime-mover was relatively undamaged apart from some minor body deformation at the rear of the driver's sleeper compartment. The A-trailer incurred major damage to the chassis (badly deformed at and beyond the point of impact) and the tri-axle bogie. Also, the trailer body had 'ruptured' and had been torn off.

The body of the B trailer was slightly deformed towards the rear of the trailer and a hole had been punched through the left-hand side of the upper body towards the leading end of the trailer. The refrigeration unit at the leading end was also damaged.

1.3.5 Site recovery

The CTT remained across the Bruce Highway at the Rungoo level crossing from the time of the collision until about 2250 on Friday 28 November 2008 (just under 32 hours). For the much of this time road traffic was diverted around the level crossing on a temporary road deviation immediately to the west of the Bruce Highway. This deviation was on the alignment of the 'old' Bruce Highway and necessitated the construction of a temporary level crossing (consisting of compacted road base) over the rail line about 50 m in front of the leading portion of the CTT. Road traffic continued to use this deviation until mid-afternoon on Saturday 29 November 2008.

At 2250 on Friday 28 November 2008 the train was split between the luggage car (car A) and the sitting car (car B).[23] The rear six carriages and rear power car were then hauled about two carriage lengths clear of the level crossing by two locomotives that had been attached to the trailing (southern) end of the CTT. At 1025 on Saturday 29 November 2008 the rear portion of the CTT departed the crash site bound for the Mayne servicing depot, Brisbane.

The baggage car (car A) departed the crash site on a low loader at 1125 on Saturday 29 November 2008 and the lead power car (DTD 5403) departed on a low loader at 1240 on Sunday 30 November 2008. Due to the damage sustained in the collision, the driver's cab had to be removed (cut off) from the power car and sent south separately.

23 Cutting equipment was needed to perform this task.

In summary, the Bruce Highway was re-opened for road traffic over the Rungoo level crossing mid-afternoon on Saturday 29 November 2008, about 48 hours after the collision and the rail line re-opened to rail traffic at 1300 on Sunday 30 November 2008, about 70 hours after the collision.

1.4 Train operations

1.4.1 Safeworking system

The passage of trains between Purono[24] and Cairns is managed by network controllers at the Townsville North Coast Train Control Board. Network controllers authorise the passage of trains in accordance with the applicable safeworking system in use on a given section of track.

The safeworking system in use between Purono and Woree[25] is Direct Traffic Control (DTC). This is a system in which the movement and separation of trains and on-track vehicles is governed by the transfer of ownership of section blocks[26] between the network controller and the train or on-track vehicle. The transfer of these blocks is facilitated by the exchange of numeric codes that are generated by 'linked' computers located in the train control centre and the driving cabin on the train or on-track vehicle.

At 1427 on Thursday 27 November 2008, three minutes before the train departed from Ingham, the network controller on the Townsville North Coast Train Control Board gave an authority for train VCQ5 (the CTT) to proceed from Ingham to the block limit board at Bilyana, a crossing loop about 75 km north of Ingham. As the Rungoo level crossing is within the boundaries of this authority, the CTT was authorised to traverse the Rungoo level crossing.

1.4.2 Crash history at Rungoo level crossing

QT records indicate that there have been no previous collisions between road vehicles and trains at the Rungoo level crossing for in excess of 25 years. QR Network reports indicate that a near miss between a train and a semi-trailer occurred in July 2005. This incident was reported to the Townsville Network Train Control Centre by the traincrew involved.

24 Purono is about 27 km north of Townsville. The section of track between Townsville and Purono is managed by train controllers stationed at the Townsville Suburban train control board.

25 Woree is about 5 km south of Cairns station.

26 Section blocks are that portion of track between two adjoining block limit boards.

2 Analysis

On Thursday 27 November 2008 QT and the ATSB dispatched a team of investigators to the collision site at the Rungoo level crossing in northern Queensland. Arrival at the site was shortly before midnight on the day of the collision.

Evidence was sourced from the truck driver who was involved in the collision, the transport company that employed the truck driver, motorists who were witnesses to the collision, local residents who heard the collision, on-board train staff, QR, the emergency services agencies, Main Roads (MR) and QT.

An examination of this evidence has determined that the CTT and the B-double truck had no defects that would have contributed to the collision, the B-double truck driver and the train drivers were appropriately licensed/qualified and the CTT had the correct authority to traverse the section of track where the Rungoo level crossing is located.

However, some witnesses, including the truck driver, reported that the flashing lights at the level crossing did not activate before the CTT entered the level crossing or that they were not activated at or immediately after the collision. Therefore, an analysis of the electronic level crossing data obtained at the site was undertaken in order to determine whether or not the level crossing flashing lights activated as designed before the CTT entered the Rungoo level crossing.

In addition, the following analysis focuses on other potential factors which may have contributed to the accident such as:

- whether the level crossing was compliant with the relevant standards;
- conspicuity of the level crossing warning signs and lights;
- the actions of the truck driver; and
- the actions of the train drivers.

Also, the emergency response measures enacted, the crashworthiness of the driver's cab of the CTT, differing safety systems in the road industry and testing for alcohol and illicit substances following a crash are examined.

2.1 Sequence of events analysis

2.1.1 Level crossing data recorder analysis

Level crossing control equipment

Active level crossing traffic control systems are complex pieces of safety equipment that require regular inspection and maintenance to ensure reliability of operation and to guard against any unwanted operation. The traffic control system at the Rungoo level crossing uses relay control circuits to detect approaching trains and activate the warning system (flashing lights) to alert road vehicle operators. The system is powered by batteries which are charged using solar cells.

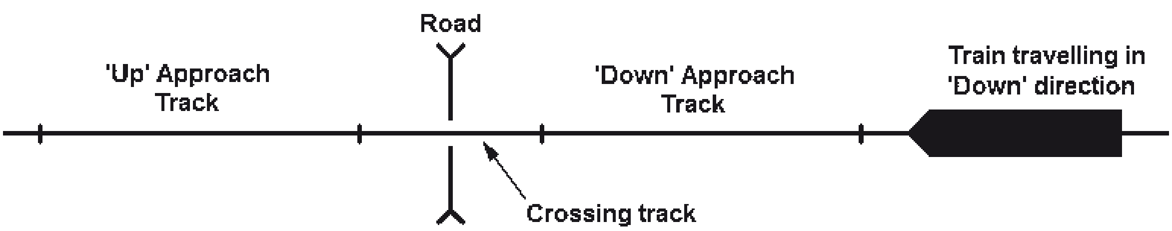
The Rungoo level crossing consists of a single track, upon which trains could approach from either direction (referred to as the 'Up' direction or 'Down' direction). Consequently, the train detection system consisted of two track circuits for the 'Up' and 'Down[27]' approaches and a crossing track circuit (figure 13).[28]

The following sequence describes the mode of operation for a train travelling in the 'Down' direction (the direction that train VCQ5 was travelling):

- A train is detected on the 'Down' approach track circuit, the 'Down' directional relay energises and the control circuits start the lights flashing;
- The lights continue to flash as the train approaches the crossing;
- The train is detected on the crossing track circuit followed by detection on the 'Up' approach track circuit, the lights continue to flash and the 'Down' directional relay remains energised;
- The lights continue to flash until the rear of the train clears both the 'Down' approach track circuit and the crossing track circuit at which point the control circuits stop the lights flashing;
- The 'Down' directional relay remains energised to prevent the lights flashing while the train occupies the 'Up' approach track circuit. That is, the lights do not flash while the 'Up' approach is occupied by a train that is moving away from the crossing in the 'Down' direction; and
- As the rear of the train clears the 'Up' approach track circuit, the directional relay de-energises and the crossing is ready to operate for a train approaching from either direction.

The operation is similar for trains travelling in the 'Up' direction except that the track occupancy sequence is reversed and the 'Up' directional relay energises.

Figure 13: *Level crossing track circuit layout*



Level crossing - Remote Monitoring System

A Remote Monitoring System (RMS) was installed at the Rungoo level crossing to provide offsite testing and monitoring of the level crossing traffic control equipment. The RMS has the capacity to capture and record data events. The data can be uploaded by radio transmission upon request from a central data storage system.

27 On the north coast line the Down direction is from Brisbane to Cairns, the Up direction is Cairns to Brisbane.

28 The crossing track is the section of track that crosses the road. The crossing track extends for about 14 m beyond both sides of the bitumen edge of the road.

The RMS at Rungoo recorded:

- **Level crossing lights on/off.** The input for this data is derived from the flashing light control relay. Contacts from this relay also control the flashing light circuits;
- **Directional relay energised/normal.** The input for this data is derived from the operation of either the 'Up' or 'Down' directional relays. A 'normal' indication is provided when all tracks are clear and both directional relays are de-energised;
- **Crossing track occupied/clear.** The input for this data is derived from the crossing track relay;
- **12V Supply OK/low.** The input for this data is derived directly from the 12V battery supply; and
- **Lamp alarm.** The input for this data is indirectly derived from the current flowing in the flashing light circuits and will provide an alarm if any lamp units have failed.

Rungoo level crossing operation – 27 November 2008

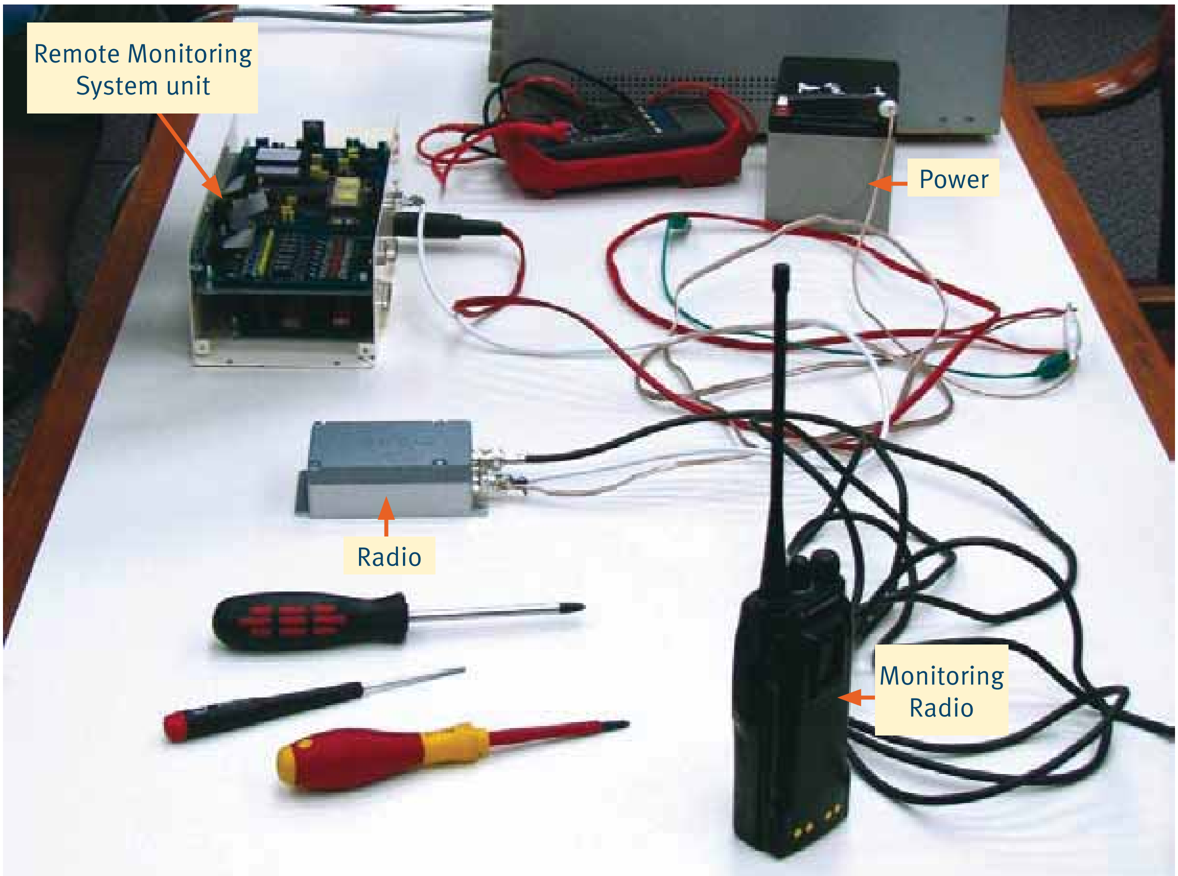
It would be normal practice to fully validate the operation of level crossing traffic control system circuits and associated warning devices following any reported level crossing incident. However, the collision on 27 November 2008 resulted in the destruction of the level crossing control equipment box which prevented on-site testing of level crossing equipment. Consequently, analysis to determine if the Rungoo level crossing traffic control system was operating at the time of the collision focused on what data was recorded and how that data was derived from the control circuits.

Damage to the Rungoo level crossing control equipment box prevented the uploading of data to the central data storage system. Consequently, the RMS unit was removed from the damaged equipment box and taken to the QR maintenance facilities in Townsville for analysis and data recovery.[29]

The approach taken for data recovery was to build a test RMS station (figure 14) which was configured to allow communication of data to the central data storage system. The data memory chip was then removed from the damaged unit and inserted into the test unit. The central data storage system was then configured to request data from the test system and the data stored on the memory chip was successfully uploaded for data analysis.

29 The QPS retained possession of the RMS during transportation and were present during all stages of data recovery.

Figure 14: ***Test Remote Monitoring System***



Examination of the data indicated five level crossing traffic control system operations on the day of the collision:

- The first operation was recorded at about 0134. The data indicated that the crossing operated normally with the lights flashing for 25 seconds before the crossing track showed occupied;
- The second operation was recorded at about 0754. The data indicated that the crossing operated normally with the lights flashing for 26 seconds before the crossing track showed occupied;
- The third operation occurred at about 0829. The data showed no indication of track occupancy, but indicated that the lights were flashing for about 5 seconds. This is consistent with the crossing being tested by operating the level crossing test switch;[30]
- The fourth operation occurred at about 1405. The data indicated that the crossing operated normally with the lights flashing for 29 seconds before the crossing track showed occupied; and
- The fifth operation was the final operation before the loss of recorded data. The events logged during this operation are detailed in table 3.

30 The level crossing was tested by QR technicians between 0800 and 0900 on 27 November 2008.

Table 3: ***Remote Monitoring System Data***

Recorded Time	Recorded Description	Comment
1446:36	Level crossing lights on	Train occupies the approach track and lights begin to flash.
1446:36	Directional relay energised	
1447:01	Crossing track occupied	Train occupies the crossing track.
1447:05	Crossing track clear	Crossing track indicates clear and lights stop flashing.
1447:05	Level crossing lights off	
1447:06	Directional relay normal	The directional relay input changes state and the supply voltage indicates 0 volts.
1447:06	Directional relay energised	
1447:06	Directional relay normal	
1447:06	12V Supply low = 0 Volts	

The first three events are consistent with the normal operation of the level crossing traffic control system. That is, the train was detected as occupying the approach track and the warning lights began to flash. Twenty five seconds later, the train was detected as occupying the crossing track.

The remaining six events are not consistent with the normal operation of the level crossing traffic control system. Following the collision, the train had physically continued to occupy the crossing track after coming to a complete stop. However, the data indicated that the crossing track cleared and the lights stopped flashing four seconds after the train had first occupied the crossing track.

When considering the train speed at the point where it would have passed onto the crossing track (57 km/h recorded by the CTT Train Management System), the train would travel about 63 m in four seconds. The level crossing equipment control box was located about 60 m past the point where the equipment would detect the train occupying the crossing track. Considering also the loss of supply voltage and the absence of any further recorded data, it is likely that the last six events recorded by the RMS were a result of the train colliding with the equipment box.

Verification of level crossing traffic control system operation

In most cases, the RMS system records the status of various relays within the level crossing traffic control system control circuits. It is important to understand what controls these relays, and what these relays control, to clearly understand the meaning of the data recorded. The first three recorded events were examined more closely to determine if the level crossing traffic control system operated correctly for the approach of the CTT on 27 November 2008.

The data recorded as 'Directional relay energised' is determined by the status of the 'Up' and 'Down' directional relays. These relays are controlled by the sequencing of the two approach track circuits and the crossing track circuit. An indication of 'Directional relay energised' implies that a train has been detected on one of the approach tracks. While a train remains detected on any track circuit, the RMS will continue to indicate 'Directional relay energised'. In this case, the RMS recorded 'Directional relay energised' at 1446:36 and did not change state until the equipment box was damaged by the derailed train. This implies that the train was detected on the approach track and remained detected for the entire distance while approaching the level crossing.

The data recorded as 'Crossing track occupied' is determined by the status of the crossing track relay. An indication of 'Crossing track occupied' implies that a train has been detected on the crossing track. At the Rungoo level crossing, a train would be about 14 m from the road crossing when first occupying the crossing track. In this case, the RMS recorded 'Crossing track occupied' at 1447:01, 25 seconds after the train was first detected on the approach track.

The data recorded as 'Level crossing lights on' is determined by the status of the flashing light control relay. This relay controls the flashing light circuits. It is important to note that an indication of 'Level crossing lights on' does not verify that the lights were flashing, but does verify that the relay controlling the lights has operated. However, in conjunction with the status of the 'Lamp alarm' indication, operation of the flashing lights can be implied. The 'Lamp alarm' indications are indirectly derived from the current flowing in the flashing light circuits. The absence of an alarm implies that the correct current was flowing in the flashing light circuits. In this case, the RMS recorded 'Level crossing lights on' at 1446:36 and the status did not change until the equipment box was damaged by the derailed train. At no time was a 'Lamp alarm' recorded.

In summary, the data indicated that the flashing light circuits were active, the correct current was flowing through the circuits and, as a result, the lights were flashing for the entire time that the train was approaching the level crossing.

2.1.2 Recorded data, train VCQ5

Train Management System

Train VCQ5 had an EKE-Electronics Ltd Train Management System (TMS) installed. The TMS is a train control and diagnostics system which performs the following functions:

- Integrates all intelligent subsystems along the train;
- Provides a common, menu-based, interface for the user that monitors the train functions. In addition, it diagnoses and informs the user of any problem;
- Provides appropriate instructions for the user to eliminate the problem based on pre-determined messages;

- Diagnoses the train functions and stores diagnostic information in coach databases for maintenance use;
- Provides a centralised user interface for subsystem control and monitors systems such as lighting controls, door locking/release and air conditioning settings;
- Provides automatic (or semi-automatic) functions for door control, air system, communications and smoke detectors; and
- Contains two data loggers[31] that record identical data in both Power Cars.

The TMS train data logger functionality is contained on a data card part contained within the TMS coach computer in both power cars. The TMS also records a fault log on the central processing unit card that is contained within the TMS coach computer in both power cars.

Automatic Train Protection system

Train VCQ5 had an Automatic Train Protection (ATP) system installed. The ATP system is a computer controlled system designed to make sure the train does not:

- exceed the current speed limit;
- exceed the limit of authority generated by the interlocking;[32] and
- make unreasonable train movements during shunting, when stationary, or at start-up.

ATP is a protection system and not a control system. It is designed to protect the train when the train driver cannot, or does not do so. Under normal operating conditions, the ATP system should never have to protect the train by applying the brakes. The ATP system includes a data event recorder[33] function that records data relevant to the operation of the ATP system.

Hierarchy of power car recorded data

The TMS records most data at either one or two second intervals. The ATP only records data when an event occurs, therefore the TMS data will be recorded at a higher rate than the ATP system data. When available the TMS recorded data will take precedence over the ATP system recorded data.

On train VCQ5 the traincrew were operating the train from the leading power car (DTD 5403). The relative timing of data from the leading power car (headlight, horn, etc) will be more accurate than the trailing power car (DTD 5402) because there are no propagation delays associated with transmitting the data from the leading power car to the trailing power car. When available, the TMS data recorded by the leading power car on train VCQ5 will take precedence over the TMS data recorded by the trailing power car.

31 Data Logger – A recorder that records data at set time intervals.

32 Interlocking is a railway term used to describe rail infrastructure such as points and signals that are interconnected with each other in regard to operation.

33 Data Event Recorder – A recorder that records data whenever an event occurs.

In summary, when the data is available the recorded data precedence will be:

1. Power Car DTD 5403 TMS data.
2. Power Car DTD 5402 TMS data.
3. Power Car DTD 5403 ATP system data.

Key parameters recorded by the TMS and ATP data systems on the CTT are:

- Time;
- Speed;
- Headlight operation (TMS only);
- Horn operation, both town and country settings;
- Power/Brake controller position (TMS only);
- Brake-pipe pressure; and
- System fault log (TMS only).

For further details in regard to the continuity of evidence of the recorded data and a description of what and how parameters are recorded see Appendix B: Technical Analysis Report.

2.1.3 Combined train and level crossing analysis

Recorded data was available from train VCQ5 (TMS and ATP) and the level crossing control equipment (RMS). For sequence of events analysis, the data needed to be compared against a common reference point. The selected reference was the point at which the train was detected as occupying the crossing track. This reference point was about 14 m from the bitumen road edge and the approximate point of collision.

The TMS data recorded the leading power car of the train near this reference point (about 16 metres from the point of collision) at 1447:12. The RMS data recorded the train near this reference point (crossing track occupied) at 1447:01. The RMS is an event recorder similar to ATP and is therefore recorded at a lower rate than the TMS. As such TMS data takes precedence over RMS data.

The following sequence of events adopts the TMS time as the 'local time' and adjusts the RMS event times accordingly.

Table 4: ***Sequence of events***

Local time	Recorded parameters, CTT	Level crossing control equipment	Comment
1446:30	Distance collision = -755 m Speed = 78 km/h decreasing Power/Brake Controller = 0 % Brake Brake Pipe Pressure = 498 kPa Brake Cylinder Pressure = 61 kPa decreasing Main Reservoir Pressure = 893 kPa decreasing Headlight = On Country Horn = Off Town Horn = Off Driver Emergency Brake = False Passenger Emergency Brake = False Emergency Stop = False		Train speed decreasing in preparation for temporary 60 km/h track speed limit
1446:38	Distance collision = -588 m Speed = 74 km/h decreasing Power/Brake Controller = 29 % Brake increasing Brake Pipe Pressure = 496 kPa Brake Cylinder Pressure = 3 kPa Main Reservoir Pressure = 889 kPa decreasing		
1446:46	Distance collision = -434 m Speed = 65 km/h decreasing Power/Brake Controller = 34 % Brake Brake Pipe Pressure = 496 kPa Brake Cylinder Pressure = 147 kPa		

Local time	Recorded parameters, CTT	Level crossing control equipment	Comment
1446:47	Distance collision = -416 m Speed = 64 km/h decreasing Power/Brake Controller = 34 % Brake Brake Pipe Pressure = 496 kPa Brake Cylinder Pressure = 147 kPa Main Reservoir Pressure = 883 kPa decreasing	(RMS time 1446:36) Level crossing lights ON Directional relay energised	Train occupies the approach track and lights begin to flash.
1446:50	Distance collision = -366 m Speed = 60 km/h decreasing		By now train had passed the 60 km/h temporary speed board and was now at speed limit.
1446:53	Distance collision = -316 m Speed = 60 km/h decreasing Power/Brake Controller = OFF/REL Brake Pipe Pressure = 495 kPa Brake Cylinder Pressure = 76 kPa decreasing Main Reservoir Pressure = 879 kPa decreasing		Train brakes releasing
1446:58	Distance collision = -235 m Speed = 58 km/h decreasing Brake Pipe Pressure = 495 kPa Brake Cylinder Pressure = 3 kPa Main Reservoir Pressure = 877 kPa decreasing		Train near 'Whistle board'. Train brakes nearly fully released.
1447:05	Distance collision = -125 m Speed = 56 km/h Country Horn = On		Horn sounded for about one second
1447:06	Distance collision = -109 m Speed = 56 km/h Country Horn = Off then On		
1447:07	Distance collision = -94 m Speed = 56 km/h Country Horn = Off		

Local time	Recorded parameters, CTT	Level crossing control equipment	Comment
1447:09	Distance collision = -63 m Speed = 56 km/h Country Horn = On		Horn sounded a second time for about two seconds
1447:12	Distance collision = -16 m Speed = 56 km/h Power/Brake Controller = 99 % Brake Driver Emergency Brake = True Country Horn = Off	(RMS time 1447:01) Crossing track occupied	Power/Brake Controller to 'Emergency Brake' Train occupies the crossing track.
1447:13	Distance collision = 0 m Speed = 57 km/h Brake Pipe Pressure = 492 kPa decreasing Brake Cylinder Pressure = 25 kPa increasing Country Horn = On then Off		Collision between train and truck. DTD 5403 TMS recorded 'ID Block' data
1447:14	Distance from collision = 15 m Speed = 54 km/h		
1447:15			DTD 5403 TMS did not record 'Analog 1 Block' data
1447:16		(RMS time 1447:05) Crossing track clear Level Crossing lights OFF	DTD 5403 TMS recorded 'ID Block' data twice DTD 5403 TMS did not record 'Analog 1 Block' data Crossing track indicates clear and lights stop flashing. These events most likely caused by train colliding with the equipment box.

Local time	Recorded parameters, CTT	Level crossing control equipment	Comment
1447:17			DTD 5403 TMS did not record 'Analog 1 Block' and 'Analog 2 Block' data
		(RMS time 1447:05) Directional relay normal Directional relay energised Directional relay normal 12V Supply low = 0 Volts	The directional relay input changes state and the supply voltage indicates 0 volts. These events most likely caused by train colliding with the equipment box.
1447:25			DTD 5403 TMS did not record 'Analog 1 Block' data and 'Analog 2 Block' data
1447:26	Tacho Speed = 0 km/h (Recorded on trailing power car)		Power car DTD 5402 stopped
1447:45	Door Open Indication = True (Recorded on trailing power car)		Power car DTD 5402 recorded Door open indication

The following six figures are screen captures taken from an animation developed by the ATSB and are intended to illustrate key points from when the train neared the whistle board on the approach to the level crossing to when all movement of the train ceased.

Figure 15: *VCQ5 near 'whistle' board 235 m from impact.*

Figure 16: *VCQ5 63 m from impact, horn sounding*

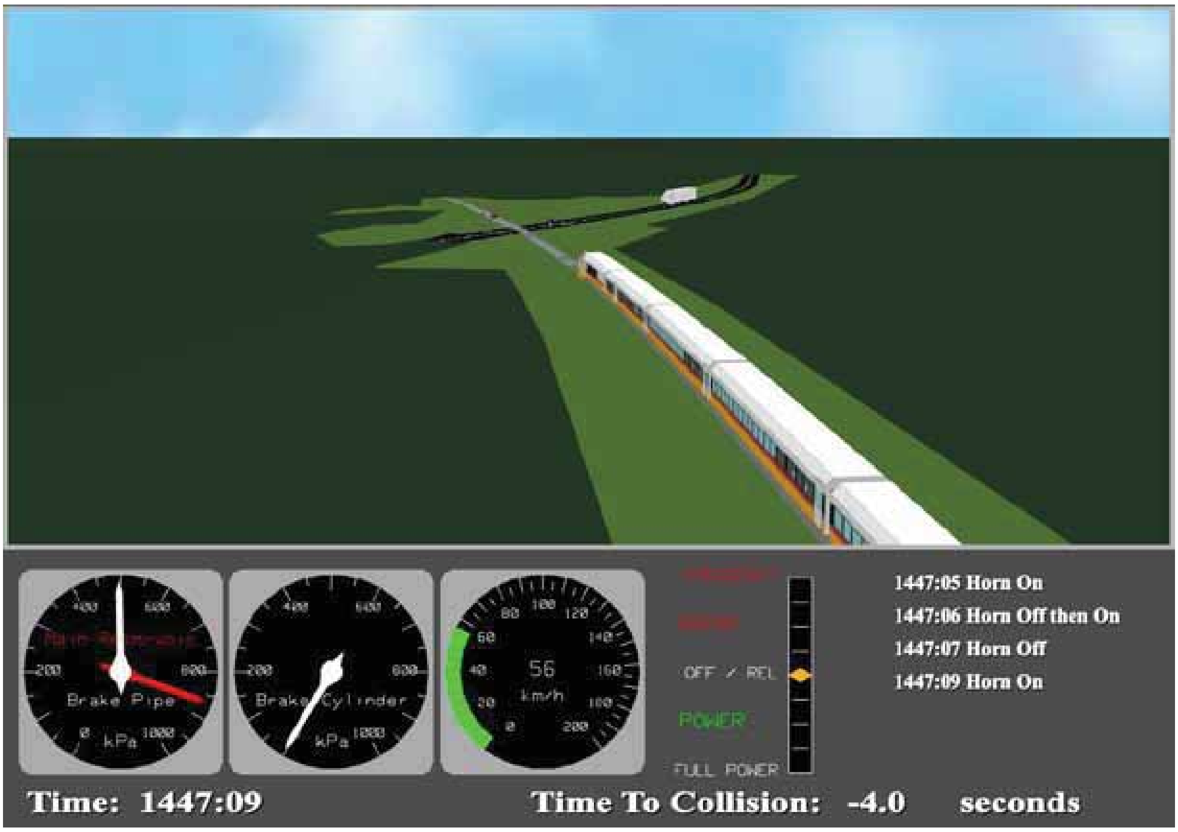


Figure 17: *VCQ5 16 m from impact, brake to emergency*

Figure 18: *Impact*

Figure 19: *Level crossing signals cease to flash*

Figure 20: *Rear power car comes to a stop*

Figure 21: *Collision sequence based on TMS data*

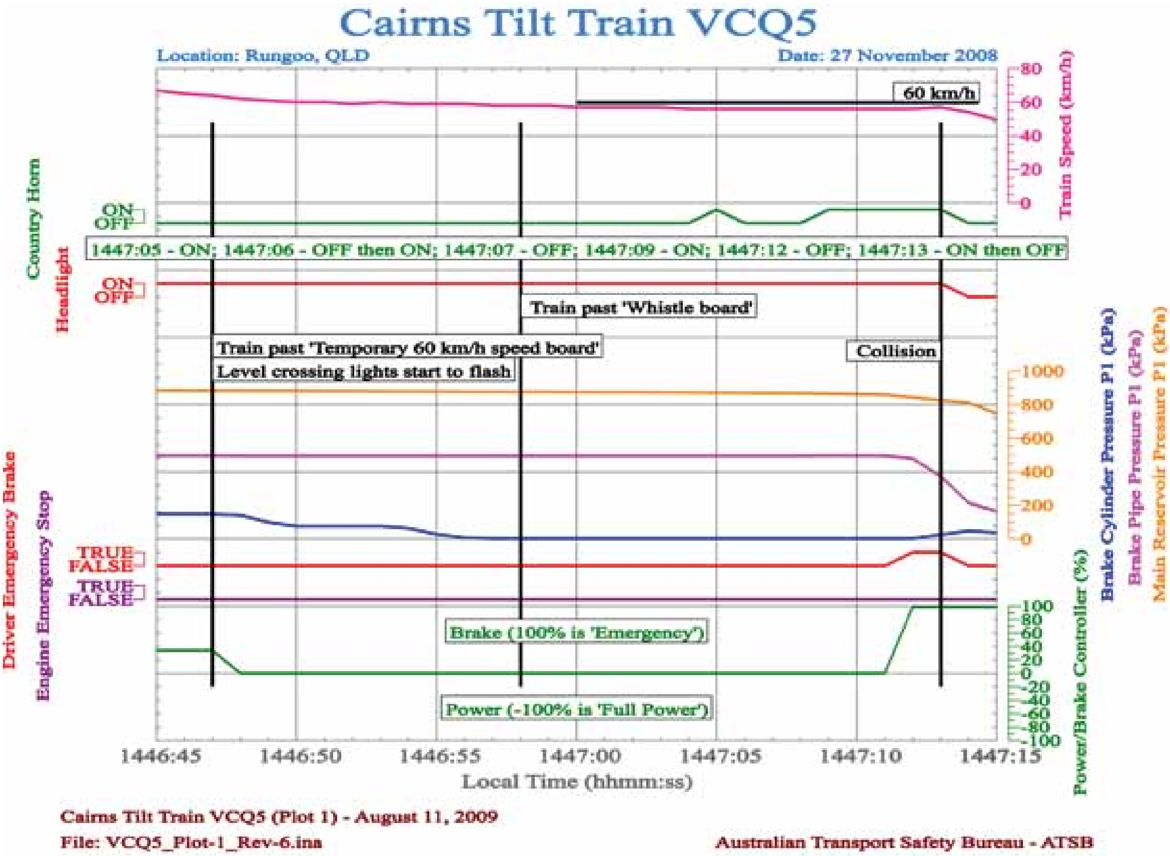
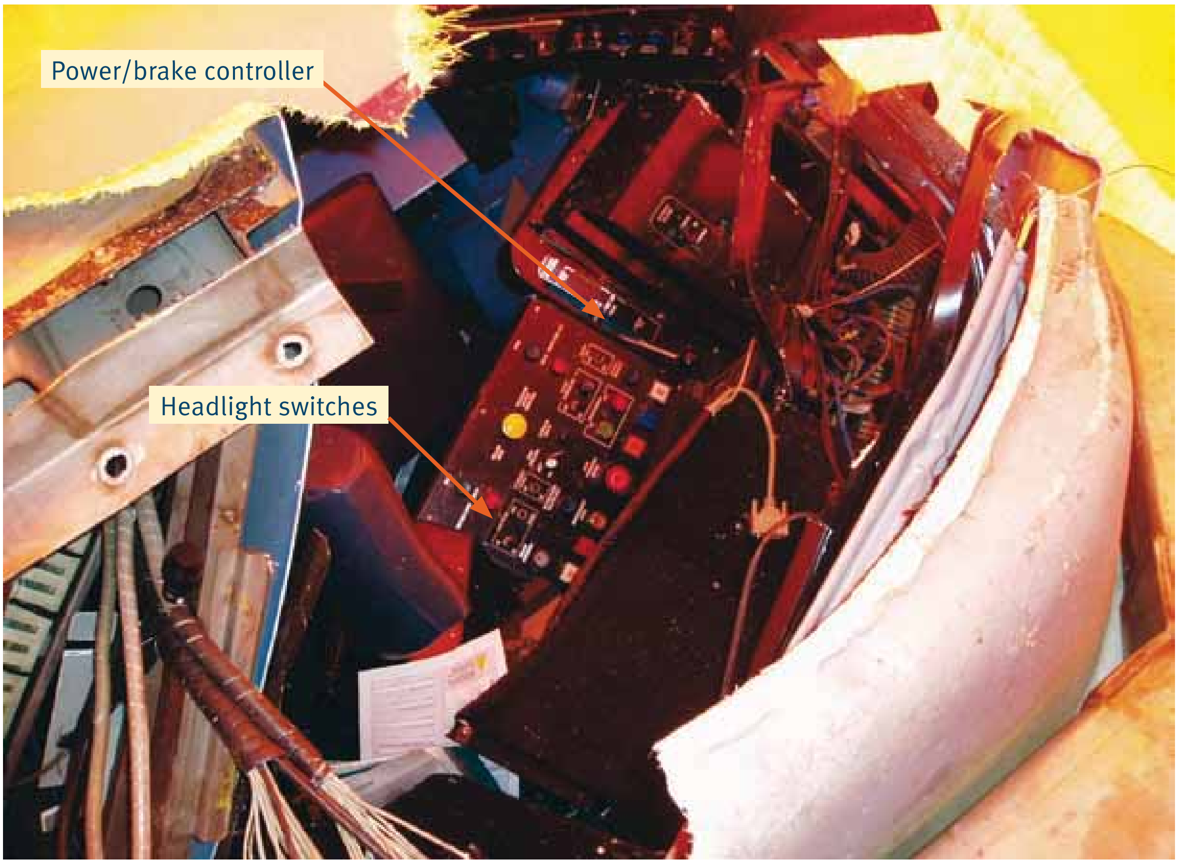


Figure 21 displays the timings of the train controls based on the TMS data and figure 22 shows the train driver's console as found on site. The forward position of the brake handle indicates it is in the emergency position; the far right-hand toggle switch indicates that the headlight switch is in the 'on' position (up is on) and the toggle switch to the immediate left indicates that the headlight switch is in the 'dim' position.

Figure 22: *Train driver's console as found*



2.1.4 Point of perception

The term 'point of perception' is used in this report to refer to that place where a person has first realised that a hazard confronts them which requires some action on their part. The recorded data obtained from train VCQ5 indicated that the (second) sounding of the train horn occurred four seconds before the collision and an emergency brake application was initiated one second before the collision (table 5). This information is important when endeavouring to determine the relative location of the B-double truck at the point of perception of the truck by the train drivers. An explanation of how the data is recorded and its limitations follows.

Table 5: *Recorded data for horn*

1447:09	Country Horn = On
1447:12	Country Horn = Off Power/Brake Controller = 99 % Brake (Emergency Brake)
1447:13	Country Horn = On then Off

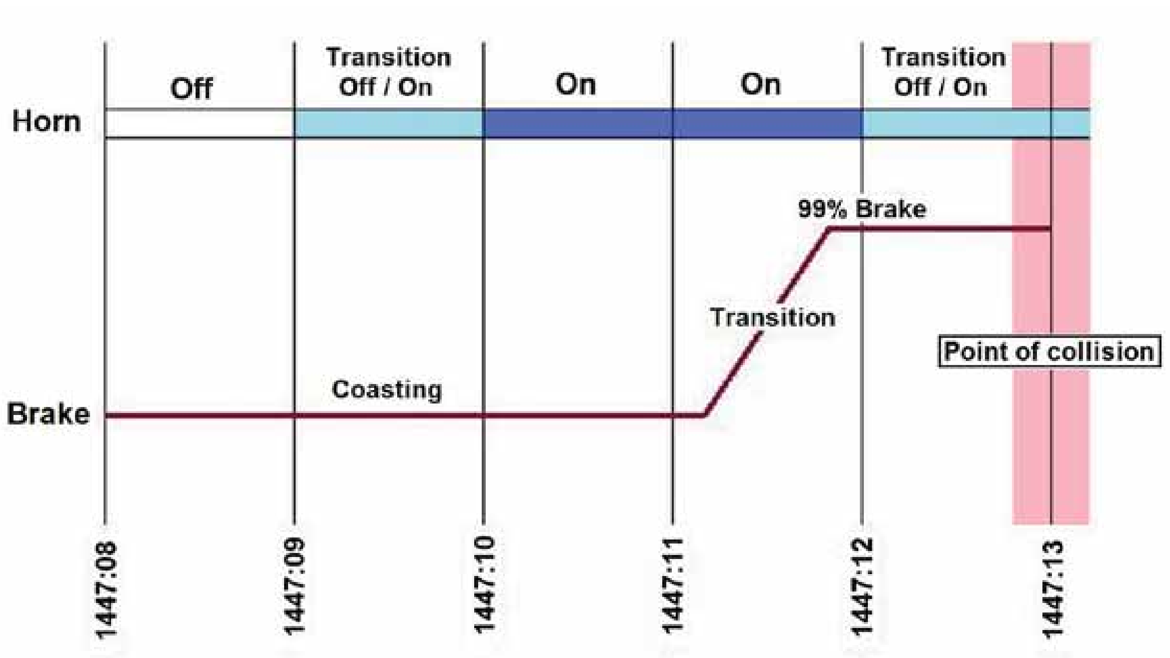
Horn data is a digital input that records events when a change of state is detected. This means that when a horn data event is recorded and logged against a specific time, this event could occur within a one second period. In this case, 'Country Horn = On' was recorded at 1447:09 meaning that the horn was sounded sometime between 1447:09.000 and 1447:09.999. Similarly, the record at 1447:12 of 'Country Horn = Off' means that the horn stopped sounding sometime between 1447:12.000 and 1447:12.999.

Power/Brake controller data is an analogue input that records the percentage of power or brake application that is present at a given point in time. In this case, 99 percent brake application was recorded at 1447:12. The data also showed that at 1447:11 and before, the percentage brake application was zero and the train had been coasting for some time. This implies that at some time between 1447:11 and 1447:12, an emergency brake application was initiated by the train driver.

Examination of the data concluded that the collision occurred at 1447:13. However, it should be noted that considering the way the data was recorded, it is possible that the point of collision could have been a fraction of a second either side of this time.

This means that the train driver would have started sounding the horn between three and four seconds before the collision, and also, that it is possible that the horn was sounded continuously until impact.[34] It is also evident that an emergency brake application has occurred while the horn was being sounded and that the emergency brake application occurred between one and two seconds before impact.[35] Figure 23 provides a graphical illustration of the data log events for train horn and brake application.

Figure 23: *Recorded data for horn and brake controller*



34 As stated by the witness in the vehicle immediately behind the B-double truck, see 1.2.3

35 The power/brake controller is designed for operation by the left hand. The horn is designed for operation by the right hand.

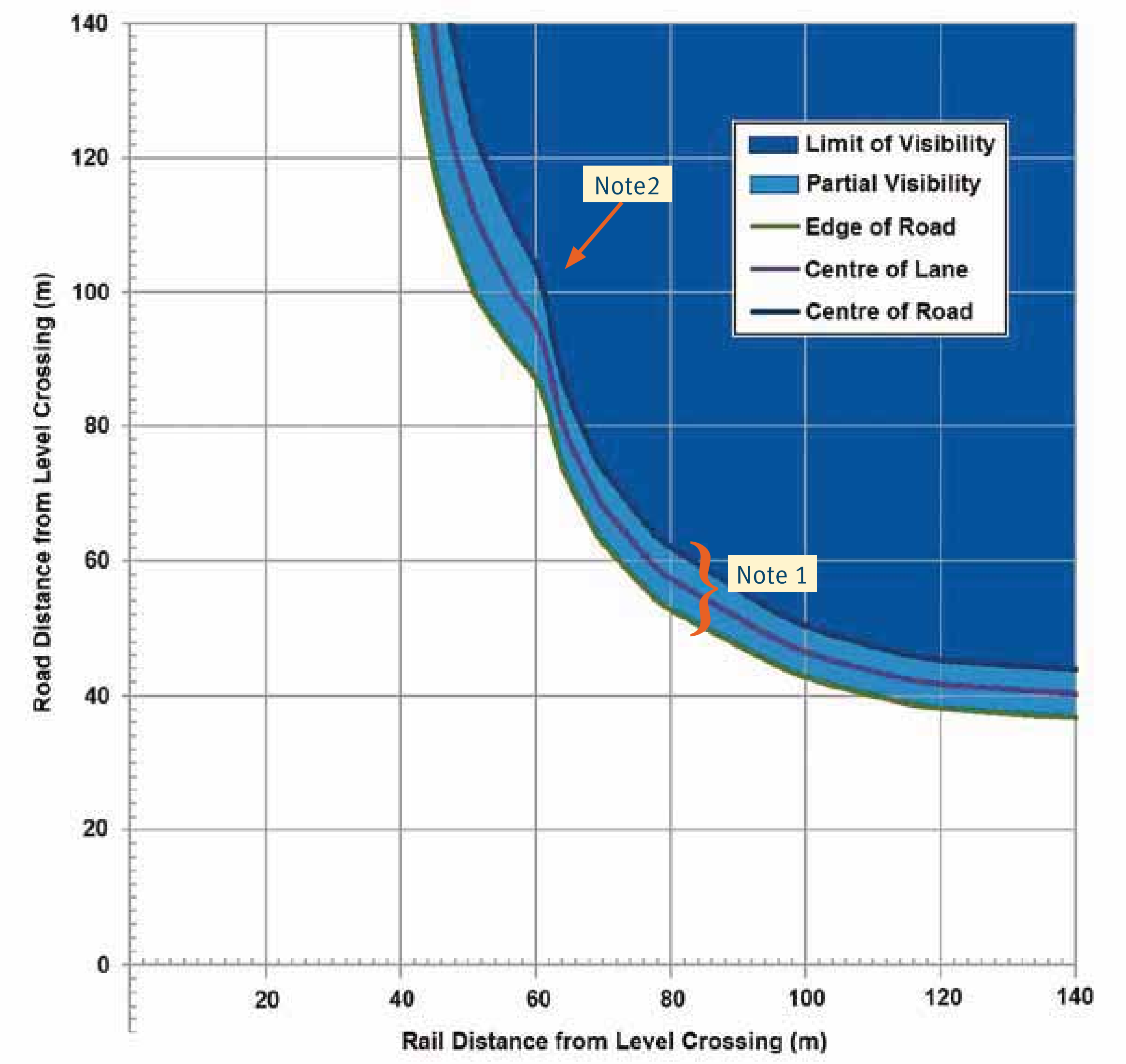
Sighting approaching traffic

Due to trees and foliage near the boundaries of the Bruce Highway and the rail corridor a train driver is afforded limited vision of road traffic approaching the Rungoo level crossing from the north. Similarly, a southbound road user is afforded limited vision of a train approaching from the south-east. A sighting profile, based on the site survey, photographic evidence and GPS positioning, was developed for the Rungoo level crossing.

Figure 24 illustrates the sighting profile as a graph with road distance on the vertical axis and rail distance on the horizontal axis. The graph indicates the sight limit available to a train driver travelling north-west to see an object that is located to the north at three locations on the road, centre line of road (blue trace), centre of southbound lane (purple trace) and left edge of road (green trace).[36] A road vehicle usually approaches in the left lane between the edge and centre of the road. Consequently, only part of the vehicle will initially be visible to a train driver, indicated by the light-blue shaded area. The dark-blue shaded area indicates where clear vision is unavailable. It should also be noted that an intermittent view through the vegetation could improve sighting slightly under some conditions. Similarly, figure 24 also illustrates the sight line for a southbound road user to see an object that is on the rail line to the south-east.

36 The difference in road distance from the level crossing is due to the train driver's line of sight crossing the road at an angle.

Figure 24: *Sighting profile – Rungoo level crossing*



Note 1: Example - for a train located 80 m from the crossing, road vehicles will:

- Not be visible when greater than about 62 m from the crossing
- Be partially visible if between about 52 m and 62 m from the crossing
- Be fully visible when less than about 52 m from the crossing.

Note 2: The deformed profile is due to the shape of the tree line in the north-eastern corner of the Rungoo level crossing.

Point of perception, train drivers

The locomotive data log indicated that the horn was sounded between three and four seconds before the collision. Assuming that the sounding of the train horn was an indicator of the train driver's point of perception of the truck and allowing for response time[37], the train driver's point of perception would be between 6.5 seconds (4 seconds plus 2.5 second response time) and 4 seconds (3 seconds plus 1 second response time) before the collision.

37 Response time – Research has shown that average response time in an unexpected situation exhibited by a person unaffected by drugs, alcohol, fatigue, illness etc usually ranges from one to 1.5 seconds. However, many drivers will take longer to respond. Therefore, for design purposes such as highway design manuals and sighting distance calculations for level crossings, a figure of 2.5 seconds is typically applied to ensure that sufficient response time is allowed for the majority of persons.

If the train driver's point of perception of the truck was 6.5 seconds before impact, the distance of the train from impact would have been about 103 m (calculated at a train speed of 57 km/h). Considering the sighting profile illustrated in figure 24, the train driver would be able to see approaching road traffic if it were within about 50 m of the crossing. Figure 25 illustrates the view of the road from a point on the track about 100 m from the centre of the crossing.

Figure 25: ***View from track, about 100 m from crossing***

If the B-double truck was sighted by the train drivers at this point then the truck would have to be travelling at about 28 km/h which is clearly at odds with the other evidence.

If the train driver's point of perception of the truck was 4 seconds before impact, the distance of the train from impact would have been about 63 m. Again considering the sighting profile illustrated in figure 24, the train driver, at this distance, would be able to see approaching road traffic if it were within about 90 m of the crossing. Figure 26 illustrates the view of the road from a point on the track about 50 m from the centre of the crossing. While 13 m closer than 63 m, it illustrates both the improved sighting and intermittent vision available through the trees and vegetation. The orange sign visible through the trees is a barrier that was fencing off a temporary road diversion; this barrier was about 180 m from the level crossing.

Figure 26: *View from track, about 50 m from crossing*

Given the sighting restrictions of road traffic approaching from the north, it is almost certain that the sounding of the train horn at 63 m (four seconds) from the level crossing is indicative of the train driver's point of perception of the truck rather than when the train was 103 m (6.5 seconds) from the level crossing.

In summary, it is likely that the train driver's response time to the presence of the truck was in the order of one second.

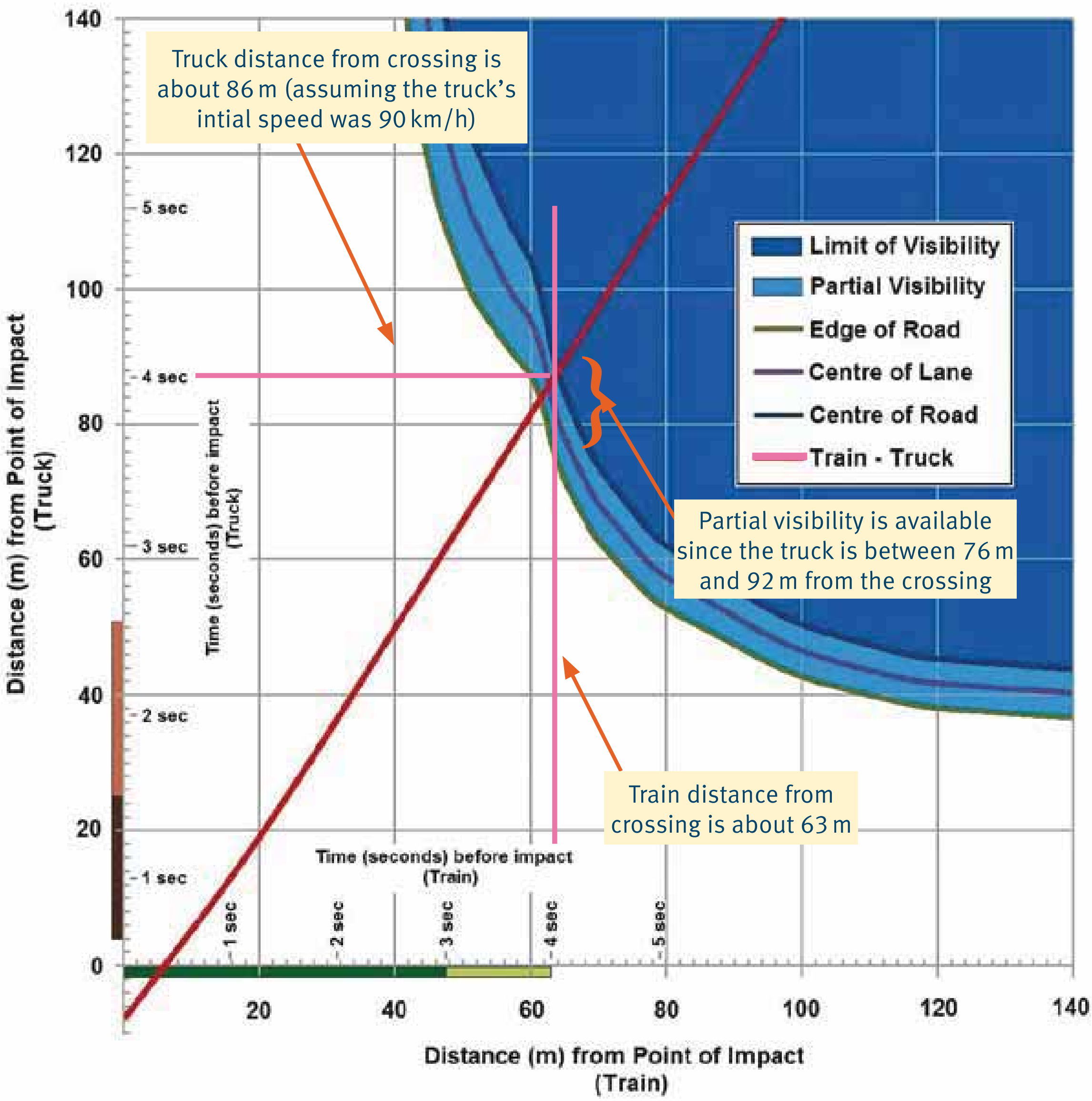
Point of perception, truck driver

Based on the skid marks and the point of impact on the truck, it is estimated that the truck may have attempted to accelerate for about 12 m before the collision occurred. As the collision point on the truck was about eight metres from the front of the prime-mover, this would imply that acceleration was attempted when the front of the truck was about four metres from the level crossing. Assuming the furthermost point of the skid marks were those of the rear bogie of the B-trailer, then the front of the prime-mover would have been 26 m in advance of this point. This places the cabin of the prime-mover about 25 m from the level crossing when the truck driver applied the brakes (47 m skid minus 26 m truck length plus four metres equals 25 m from the level crossing).

Figure 27 shows the sighting profile graph and illustrates the location of the train and truck about four seconds before impact. The distance relationship between the train and truck is illustrated (Red trace) based on a train speed of 57 km/h and a truck speed of 90 km/h reducing to 75 km/h due to braking. The three second sounding of the train horn is shown on the horizontal axis (dark green) along with the train driver's one second reaction time (light green). The truck braking area is shown on the vertical axis (brown). The time intervals for each vehicle are also indicated along their respective axis.

It is evident that the two vehicles were just becoming visible to each other about four seconds from impact. At this point in time, the train was about 63 m from the crossing and the truck about 86 m from the crossing.[38] Consequently, the truck has travelled about 61 m from the point where the driver could first see the train (86 m from crossing) and the point at which the truck started to skid (25 m from crossing). This equates to about 2.4 seconds of travel time, assuming a truck speed of 90 km/h (25 m/sec). If the truck brake lag time[39] was 0.5 of a second, it is evident that the time taken between the truck driver seeing the train and acting by putting his foot on the brake pedal (response time) was about 1.9 seconds.

Figure 27: ***Sighting profile – about four seconds from impact***



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38 Note that if the truck was about 88 m from the crossing, the train would be about 64 m from the crossing. At this point, the red trace intersects the blue trace and the vehicles are unlikely to be visible to each other.

39 Truck brake lag time is the time required for the truck brakes to apply after the driver has put his foot on the brake pedal.

2.1.5 Effect of truck braking

The truck driver estimated that he was travelling at about 90 km/h as he approached the level crossing. After realising the train was moving he said he applied the brakes hard momentarily and then applied power. The road surface was coarse and, at the time of the crash, the surface was damp. Calculations (Appendix C) found that the truck was likely to have skidded for slightly less than one second and slowed from 90 km/h to about 75 km/h. The rate of subsequent acceleration of the 56 t B-double truck in the moments before the collision (as the driver applied power) was considered to have negligible effect on final speed.

2.1.6 Sequence of events summary

Level crossing control equipment

Analysis of the level crossing control equipment found:

- The train was detected on the approach track and remained detected for the entire distance while approaching the road crossing;
- The train was detected on the approach track for 25 seconds before the train was detected on the crossing track; and
- The flashing light circuits were active and the correct current was flowing through the circuits for the entire time that the train was approaching the road crossing.

Based on the evidence available it is almost certain that the level crossing traffic control equipment operated correctly and the lights flashed continuously for at least 26 seconds as the CTT approached the Rungoo level crossing.

CTT data and event recorders

The CTT data and event recorders fitted to train VCQ5 have provided a valuable insight into the actions of the train drivers in the moments before the collision on Thursday 27 November 2008. Key points to note are that:

- The train was travelling within the speed limit;
- The horn (country setting) was sounded about 125 m and about 48 m before impact;
- The headlight was on; and
- An emergency brake application was made within two seconds before impact.

This shows that the drivers of train VCQ5 were performing their duty in accordance with the applicable rules and procedures.

Individual actions

Assuming the approach speed of the B-double truck was 90 km/h, it is likely that at four seconds before the collision the truck and the train were just becoming visible to each other.

The train driver's reaction by sounding the train horn in response to the approaching truck appears to be very timely; in the order of about one second.

The calculations relating to the point of perception of the B-double truck and the reaction time of the train drivers show that there was no further action that the train drivers could have taken to avoid the collision.

The truck driver's reaction by applying the brakes in response to the approaching train also appears to be timely at about 1.9 seconds. The evidence is that the B-double truck was travelling at about 90 km/h on the approach to the crossing. Momentary braking is calculated to have reduced the speed to about 75 km/h at the point of collision.

2.2 Road traffic control system effectiveness

Applicable standards

Signage and active warning requirements for level crossings in Queensland are prescribed in the MR *Manual of Uniform Traffic Control Devices (MUTCD) Part 7 Railway Crossings* Issue one, dated August 2003. The MUTCD Part 7 was formulated using a previous version of Australian Standard (AS) 1742.7-2007 *Manual of Uniform Traffic Control Devices, Part 7: Railway Crossings*.

At the Rungoo level crossing MR is responsible for the installation and maintenance of road pavement markings and approach warning signage. QR Network Pty Ltd is responsible for the maintenance of the railway crossing itself and the level crossing flashing signal assembly. MR uses the MUTCD as the standard for the road pavement markings and approach warning signage and QR Network Pty Ltd uses AS 1742.7-2007 as the standard for the flashing signal assembly. It was noted though that these standards are, for the purpose of assessing the Rungoo level crossing, essentially identical.

2.2.1 Level crossing compliance, Rungoo

The level crossing at Rungoo was fitted with a combination of road-side signs, road pavement markings and active control measures aimed at providing a road user with advance warning of the level crossing's presence and an indication that a train is approaching. The active control measure consisted of a level crossing signal assembly that comprised rail cross-arms and a 'stop on red signal' sign mounted on the same pole as four sets of twin red circle 300 mm light emitting diode (LED) signals arranged horizontally and designed to flash alternately.

The order in which the signage, pavement markings and level crossing signal assembly should be encountered by an approaching road user is stipulated in the MUTCD as:

- Railway crossing flashing lights active advance warning signal assembly sign W7-4;
- 'RAIL' pavement marking;
- 'X' pavement marking;
- Level crossing flashing signal assembly; and
- Stop line (on sealed road) indicating a safe place for the road user to stop.

The southbound Rungoo level crossing signage, pavement markings and level crossing signal assembly were examined by the investigation team. The results of the examination were:

- There were two W7-4 750mm x 750mm advance warning signs positioned opposite each other on both sides of the road at 300 m. There was a further W7-4 advance warning sign of the same size on the left side of the road 224 m from the level crossing. These signs were in good condition. The provision of three advance warning signs in this manner exceeds the minimum requirements of the MUTCD;
- The 'RAIL X' pavement markings were in good condition and, apart from a very minor non-conformance in regard to size, were in accordance with the MUTCD;
- The RX 5 level crossing signal assembly was in good condition although there was a slight non-conformance with the subordinate RX 6-9 'Stop on Red Signal' sign in terms of size. The level crossing signals consisted of 300 mm LED's on a 500 mm matt black background;
- The stop line was 18 m from the rail line as measured in the centre of the southbound lane, it was noted that the visibility along the rail line from this position was good;[40] and
- The order of and positioning of signage and pavement markings was as per the requirements of the MUTCD.

Figure 28: ***RX 5 level crossing signal assembly Rungoo crossing (northern)***

40 AS 1742.7-2007 *Manual of Uniform Traffic Control Devices, Part 7: Railway Crossings* stipulates that the stop line at an active level crossing must be a minimum of 3 m back from the flashing signal pedestal. The flashing signal pedestal must be a minimum of 3.5 m back from the nearest rail line. Maximum distances are not specified.

2.2.2 Control measure effectiveness

Sighting warning devices

Equally important as the conformance to standards that stipulate the order and design of the road-side signs, pavement markings and level crossing signal assemblies, is the road user's ability to see these devices. That is, the road user's view must be as unimpeded as possible. Factors such as road-side obstructions (e.g. vegetation), road geometry, approaching road traffic, environmental conditions and even the condition of the vehicle windscreen can all affect the road user's ability to see the warning signs and devices.

Of particular importance is whether the level crossing signal assembly at the level crossing itself remains in the road user's field of vision from initial sighting and whether the 'transitioning' of the front lights to back lights (e.g. in the face of oncoming traffic) is as seamless as possible. That is, does the road user always have at least one set of lights in their field of vision?

Figure 29: *Rungoo level crossing signal assembly showing front (north) and back (south) warning lights*

At the Rungoo level crossing the southbound approach along the Bruce Highway was examined. It was found that the RX 5 level crossing signal assemblies (flashing lights) were clearly visible to a southbound vehicle from a measured 385 m from the level crossing (figure 30). Also, there were no impediments to the sighting of the advance warning signs or road markings. In addition, the windscreen of the prime-mover was found to be clean and relatively clear of cracks and chips.

In combination with the cloudy conditions at the time and the lack of southbound road traffic in advance, the truck driver's sighting of the level crossing and associated traffic control measures should have been unimpeded.

Figure 30: ***First sighting of level crossing signal assembly (Southbound)***

Conspicuity of flashing light signals

The Rungoo level crossing flashing light signals were converted from incandescent lights to LED light signals on 15 September 2004. In regard to the 'spread' or focus of light, an LED light signal emits a more 'evenly spread' beam of light than an incandescent lamp which, in essence, has a 'hotspot' that has to be focused at specific points along the roadway. The nominal range rating by the manufacturer applicable to the type of LED light signal at the Rungoo level crossing is 1000 m. This is the maximum distance at which the light, in favourable environmental conditions, should be discernable to a road user. In practice though, an LED light signal is generally aligned to the vicinity of the RAIL X pavement markings (120m from light signal) with the spread of light encompassing a much wider area.

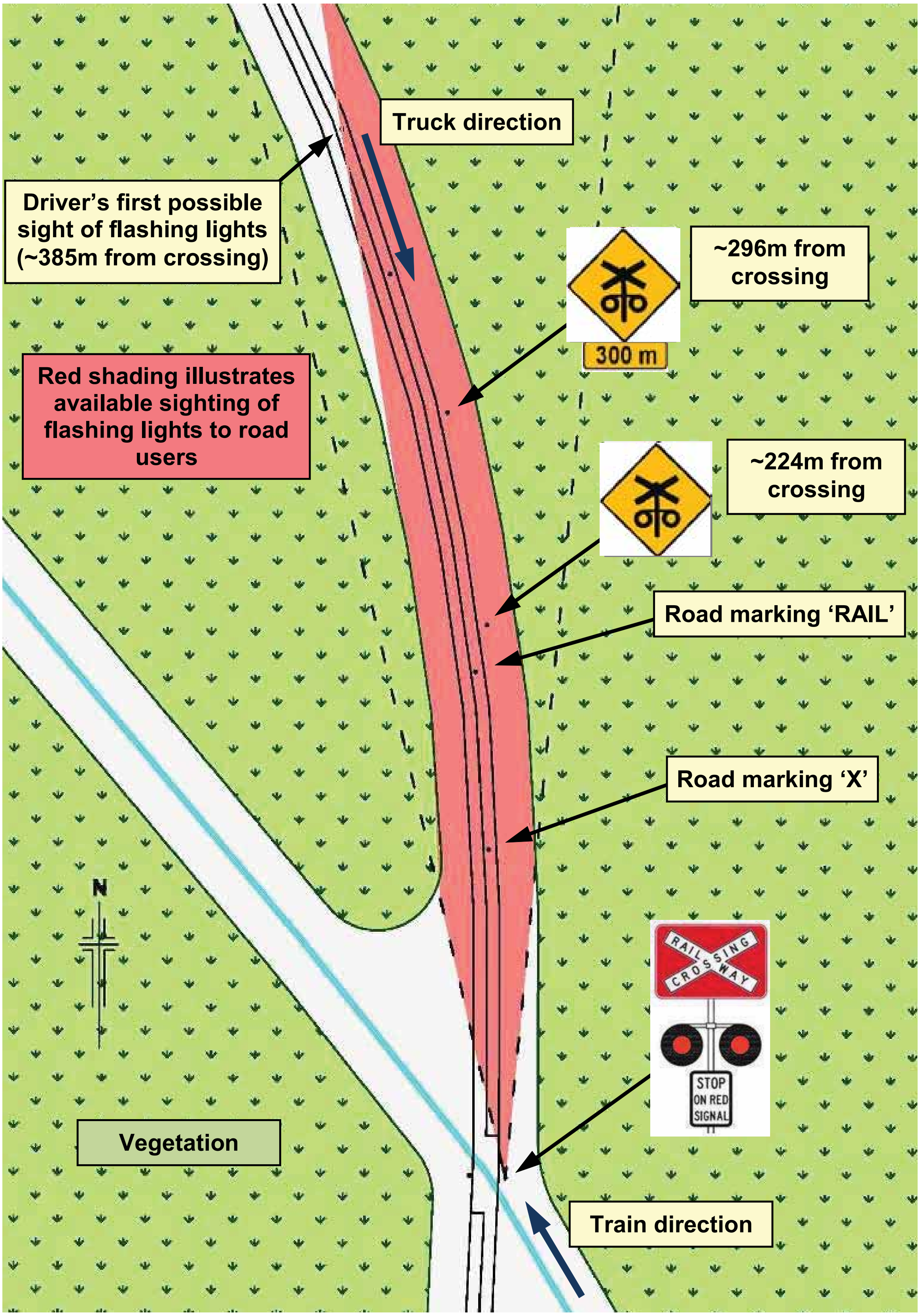
There are a number of significant advantages of LED's when compared to incandescent lights. For example, an incandescent flashing light signal generally has one lamp within each sealed light unit whereas the LED light signal fitted at the Rungoo level crossing had 196 individual LED's (in an interconnected matrix) in each sealed light unit (figure 31). Therefore, the risk of complete light source failure is significantly reduced when compared to an incandescent light signal.[41] LED light signals are not voltage dependent and light output is basically constant once the required threshold voltage is reached. Conversely, the light output from incandescent lamps is critically linked to applied voltage.

Figure 31: ***Close up of Rungoo LED light signals, individual LED's visible***

Figure 32 is a schematic representation of the spread of light from the LED light signal at the Rungoo level crossing at the time of the collision. This representation is based on the QR Network Flashing Lights Locality Plan for the Rungoo level crossing. The alignments of flashing light signals at level crossings are checked annually. This inspection was carried out at the Rungoo level crossing on 6 June 2008 and all components of the inspection were satisfactory.

41 Individual LED's are rated by manufacturers as being over 1000 times more reliable than an incandescent lamp.

Figure 32: *Sighting of north facing flashing lights, Rungoo level crossing*



2.2.3 Traffic control system effectiveness summary

The approach warning signage and road pavement markings were compliant with the MUTCD. There were no apparent impediments to a southbound road user in regard to the sighting of the level crossing traffic control measures or the level crossing itself at the time of the collision. In addition, the alignment of the flashing light signals and the provision of LED sealed units was such that the lights would have been visible to southbound road users from 385 m north of the level crossing, right up to the crossing.

2.3 Truck Driver Performance

2.3.1 Level crossing defences

The driver of the truck involved in the collision at the Rungoo level crossing did not stop before entering the level crossing, thereby leading to a conflict with the approaching CTT. There are a number of potential ways in which the presence of an approaching train at the Rungoo level crossing could be indicated to a road user. These potential indicators were:

- Visually detect the train;
- Audibly detect the train horn;
- Visually detect the level crossing warning lights;
- Other vehicles stopped at the Rungoo level crossing; and
- CB radio reports of a train approaching the Rungoo level crossing.

The latter two indicators are not formal defences or risk controls, and neither appeared to be available to the truck driver at the time of the collision. The truck driver reported that there were no other vehicles stopped at the Rungoo level crossing immediately in front of the truck. The QPS reported that an inspection of the truck cab found the CB radio to be turned on, however, the truck driver stated at interview that he did not have the CB radio on and, as such, heard no talk regarding flashing lights or anything else for that matter.

This leaves the three possible formal defences at the Rungoo level crossing which are discussed in the following sections.

2.3.2 Sequence of events

The evidence is that the flashing light signals activated 26 seconds before the collision. If the B-double truck was travelling at 90 km/h then the flashing lights activated when the truck would have been approximately 650 m from the level crossing (26 seconds × 25 m/s). The first point at which the truck driver should have been able to see the flashing lights was 385 m from the level crossing, 10.6 seconds after their activation. He then had another 15.4 seconds in which to observe the operation of the flashing light signals before entering the level crossing.

Using the formula contained in AS 1742.7-2007, a B-double truck travelling at 90 km/h (25 m/s) would require approximately 203 m to stop. This distance is inclusive of 2.5 seconds response time[42] and a one second brake delay time.

42 A response time of 2.5 seconds is commonly used for purposes such as highway design manuals, and level crossing sight distance calculations. 2.5 seconds is the assumed performance for the surprised 85th percentile driver, meaning 15 percent of drivers may have a slower response time. Normal response times may be less than this.

The difference between the calculated distance required to stop and the point at which the truck driver could first possibly see the lights is 182 m (385 m – 203 m). Therefore, at 90 km/h the driver had a leeway of about seven seconds to perceive the lights and stop before entering the level crossing (182 m ÷ 25 m/s = 7.28 seconds). However, the truck driver stated that the level crossing lights were not flashing and therefore he did not attempt to stop prior to sighting the CTT.

Based on the information available to the investigation a sequence of events, table 6, was developed which includes the truck, CTT and the formal defences or risk controls present for the Rungoo level crossing at the time of the collision.

It is important to note that any braking after the point at which the truck driver needed to start braking to stop before the collision had the possibility to change the nature of the collision but would not have changed the fact that there would have been a collision.

Table 6: ***Sequence of events, truck and train***

Time	Truck	CTT	Comment
1440[43]	8.36 km from Rungoo level crossing[44]		Truck arrives at Conn level crossing with flashing lights and other traffic stopped ahead[45]
1441[43]	8.36 km from Rungoo level crossing		Truck proceeds across activated Conn level crossing following other vehicles after no train is forthcoming
1446:47	650 m from Rungoo level crossing	416 m from collision	Train occupies the approach track and lights begin to flash Flashing lights not visible from the truck
1446:58	385 m from Rungoo level crossing	235 m from collision	Flashing lights first visible from the truck
1447:05	203 m from Rungoo level crossing	125 m from collision Horn sounded	Final point at which application of brake would stop the truck before the collision
1447:09	86 m from Rungoo level crossing	63 m from collision Horn sounded	Truck and train first visible to each other
1447:11	25 m from Rungoo level crossing Brake application	32 m from collision	
1447:12		16 m from collision Emergency brake application	
1447:13			Collision between truck and CTT

43 Times are approximate given the distances and assumed timings involved.

44 Note that the impact point of the truck was about eight metres behind the 'bull-bar'.

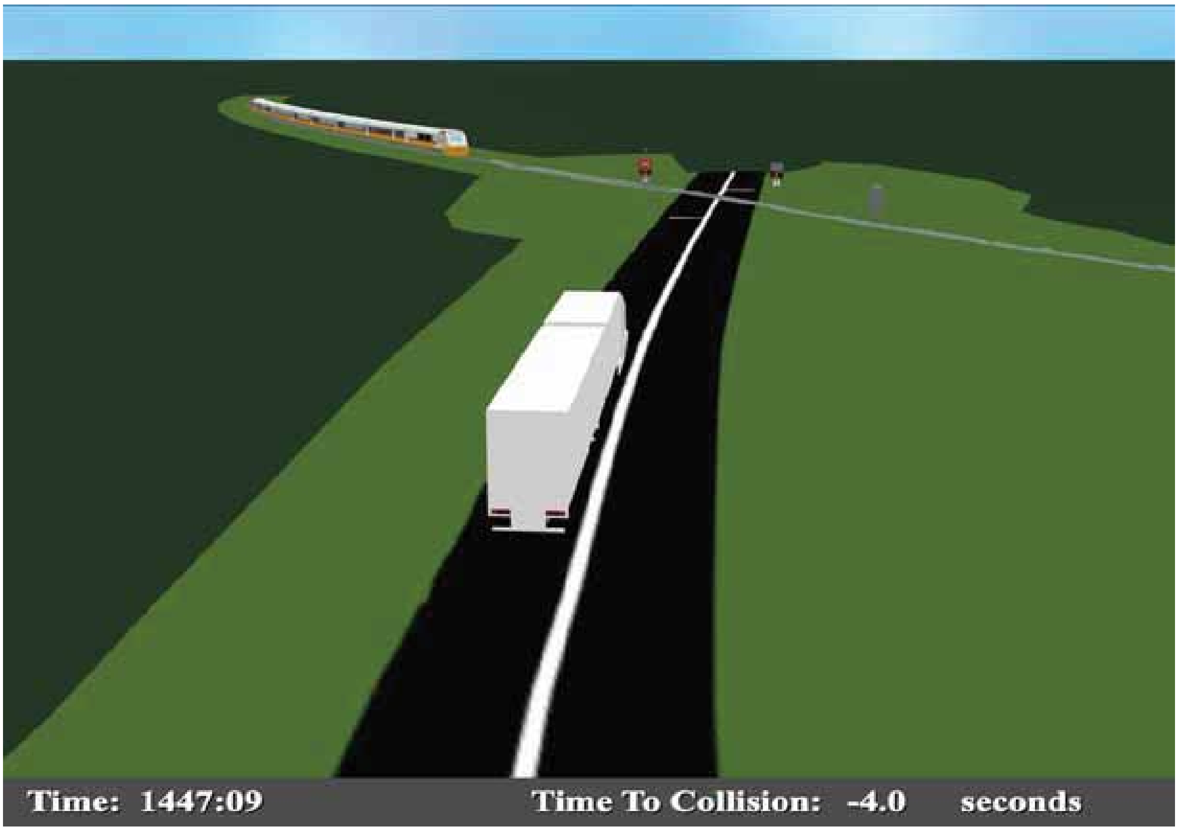
45 The flashing lights at the Conn level crossing were operating continuously because of a fault in the level crossing circuitry. Level crossings are designed to 'fail safe' in the event of a fault occurring that affects, or has the potential to affect, the correct operation of the flashing lights. Thus the lights will provide a continuous warning to the road user.

2.3.3 Visual detection of the CTT

As discussed at 2.1.4, the earliest point at which the train and truck could see each other was about four seconds before impact when the train was about 63 m and the B-double truck about 86 m from the collision. Given that the distance for the B-double truck from the level crossing was less than the calculated stopping distance, a collision was unavoidable.

Figure 33 is a 'screen capture' of an animation produced by the ATSB of the collision. The dark green area between the truck and the train represents the dense foliage that restricted vision.

Figure 33: *Train – Truck position four seconds before impact*



It can therefore be concluded that, given the nature of the crossing and the speed of the two vehicles, the truck driver could not have visually detected the presence of the CTT and stopped before entering the Rungoo level crossing.

2.3.4 Audible detection of the CTT

The National Transportation Safety Board (NTSB, 1998), in cooperation with several Oklahoma based companies, conducted research on the audibility of train horns in different types of road vehicles. They measured the amount of insertion loss[46] that occurred for each vehicle and also the audibility level of the train horn under different vehicle conditions (including windows up with engine at idle and air-conditioning fan on high).

46 Insertion loss refers to the difference between the measured sound values from an exterior sound source taken outside the highway vehicle and inside the vehicle (NTSB, 1998)

The train horn sound level used in the research was 96 dB(A)[47] at 30 m from the vehicle. In seven of the 13 vehicles tested the train horn was not audible over the fan and engine at idle noise. This study did not include other potential noise sources such as radio/music, engine noise above idle or road noise generated by a moving vehicle. The NTSB also concluded that these results underestimated the level of interior noise that would be present within the vehicle cabin under normal operating conditions.

The horn on the CTT was required to comply with QR's Safety Standard 3: STD/0049/TEC – *Rollingstock Visibility and Audibility*, section 5.1.3. This standard required the minimum sound level of a warning horn to be 96 dB(A) at 30 m in front of the train and 1.5 m above the track centreline. The design requirement for the CTT as set out in Project MRE.9809: Volume 2, Section 7 – *External Environment* stipulated that with the train stationary, the warning horns shall provide a sound level of 95 – 105 dB(A) at 100 m continuously for 30 seconds.

In the Rungoo collision sequence the first use of the train horn was recorded seven seconds before the collision when the train was 109 m from the level crossing. If the B-double truck was travelling at 90 km/h then it was about 175 m from the level crossing at this time. This would result in the distance between the train and truck (in a straight line) being approximately 248 m. The train horn was again sounded when the train was 63 m from the level crossing, at this time the B-double truck would have been in the vicinity of 85 m from the level crossing or approximately 130 m (in a straight line) from the train.

The truck driver reported that he did not hear a train horn. It is likely that the train horn was not able to be detected by the truck driver for the following reasons:

- The distance of the train from the truck;
- The dense foliage that lay between the truck and the train;
- The engine and road noise;
- The background noise associated with the cabin air-conditioning on a high (3 out of 4) fan-speed setting; and
- The truck cabin windows closed (wound up).

In summary, it can be concluded that it was unlikely that the truck driver would have been able to audibly detect the CTT and stop before entering the Rungoo level crossing.

2.3.5 Visual detection of the level crossing warning lights

It has been established by the investigation that it is almost certain that the flashing lights at the Rungoo level crossing were working as required (see section

47 The decibel (dB) is a logarithmic unit used to measure sound. The human ear does not respond equally to all frequencies. It is much more sensitive to sounds in the range of 1,000 to 4,000 Hz, than to very high or very low frequencies. The A scale is a filter that responds to frequency in a similar way to the human ear (http://www.phys.unsw.edu.au/jw/dB.html).

2.1.1), were aligned correctly and that a southbound road user should have been able to sight the level crossing traffic control measures or the level crossing itself (see section 2.2).

Given that the lights were almost certainly working there are two possible scenarios for why the truck driver did not stop before entering the Rungoo level crossing:

- Scenario A: The truck driver detected the flashing lights but had limited confidence that the lights indicated the presence of an approaching train.
- Scenario B: The truck driver did not detect the flashing lights.

These two possible scenarios are discussed in the following sections.

2.3.6 Scenario A: Low confidence in lights

Level crossing, legal obligations

There is a legal obligation on road users at level crossings to stop when required and penalties apply in the case of breaches.[48] The failure of a road user to stop or proceed without stopping before a level crossing with flashing lights can sometimes be explained by the road user's low level of expectation of being detected by relevant authorities and the social stigma which they attach to breaking traffic laws. If the road user does not expect to be detected or breaking the law is not stigmatised then they may be less likely to comply with the relevant rules.

The road user's perception that they are unlikely to be caught is reinforced every time they do not comply with the law and do not get penalised either through the law or socially. The road user's response to a possible hazard is influenced by both the perceived probability of the adverse event occurring (being caught by the relevant authorities) and of that individual's understanding of the severity of the consequence of the event (the size of the fine). A person's perception of the probability of a given event is strongly influenced by past experience, and the frequency with which they encounter enforcement will influence the likelihood of the road user obeying the law. If the level of enforcement is relatively low this expectation is continually reaffirmed.

Road user behaviour at level crossings

Between 2001 and 2007 there were 551 reported collisions with road vehicles at Australian level crossings (ATSB, 2008). Although fatalities and injuries resulting from accidents at railway level crossings are only a small proportion of the total fatalities and injuries that occur on Australian roads each year, railway level crossing crashes, particularly when they involve heavy road vehicles, have the potential to be catastrophic.

Research has shown that a road user's behaviour can reflect risky decision-making rather than adherence to the law (McKelvie, 1986). For instance, the UK Health

48 Queensland's *Transport Operations (Road Use Management—Road Rules) Regulation 1999* section 123 stipulates a maximum penalty of 20 penalty units for entering a level crossing if warning lights are operating.

and Safety Executive (HSE) commissioned a report into vehicle driver behaviour at level crossings in the UK (Pickett and Grayson, 1996). Based on statements from 419 witnesses of violations at active control level crossings, it was determined that 55 percent of violators were unwilling to stop, 13 percent were unable to stop and 27 percent were unaware of the crossing.[49]

A factor to consider at level crossings is the type of vehicle that is being driven by the road user and the layout of the road. Stopping and then restarting a car does not require much 'effort'. In a loaded B-double truck, coming to a complete stop and then restarting can be time consuming and require much more 'effort' on the part of the driver. About 850 m south of the Rungoo level crossing the Bruce Highway begins a relatively steep climb over the Cardwell Range. However, the truck driver reported that the truck had plenty of power and that he was not thinking of the hill ahead.

As detailed at 1.1.4 the truck driver had a number of driving offences recorded, however none of these offences were related to level crossings or other controlled intersections.

Expectation of encountering a train

A factor which also influences the behaviour of road users at level crossings is their expectation of encountering a train (NTSB, 1998). If the road user does not expect to encounter a train they may simply not look for one and behave accordingly or they may look but not see a train because they were not expecting to see one. It is possible that that this applies equally to level crossings with which they are familiar or new ones where they may transfer their experience from familiar crossings.

A person's perception of the probability of a given event is strongly influenced by past experience (Schoppert and Hoyt, 1968 cited in NTSB, 1998). The frequency with which they encounter a train at a level crossing will influence the likelihood of the motorist stopping (NTSB, 1998).

The road user's perception that a train is unlikely to be at a crossing is reinforced every time the road user traverses a crossing without seeing a train or encounters a crossing that has failed safe and where the signals are continuously flashing when no train is present. In addition, an individual's response to a possible hazard is influenced by both the perceived probability of the adverse event occurring and that individual's understanding of the severity of the consequence of the event (Leibowitz, 1985). That is, individuals may not believe that traversing a level crossing with the lights flashing will result in them being hit by a train or that the collision could result in multiple fatalities.

49 Unwilling to stop: drivers openly admitted that they had deliberately ignored the warning systems.
Unable to stop: drivers were already on the crossing when warning systems operated or were followed by other cars too closely to safely stop.
Unaware of crossing: drivers did not remember the incident, did not recall the warning system in operation, or did not recall the crossing.

Approximately 41 trains traverse the Rungoo level crossing weekly (i.e. about six trains per day). Of note is that on a given Thursday, between the hours of 0600 and 1800 (hours of daylight) four trains are scheduled to traverse this level crossing. Therefore the probability of seeing a train at the Rungoo level crossing is relatively low.

The truck driver said that, despite having travelled this route for several years (including three return trips in the three weeks preceding the collision), he had never seen a train passing over the Rungoo level crossing and had rarely seen trains at the other level crossings that he regularly used. It follows that he may have had a low expectation of seeing a train at this level crossing.

It is also possible that the truck driver's expectation of encountering a train was influenced by his most recent experience at the Conn level crossing. At the Conn level crossing the truck driver encountered continuously flashing lights with no train apparently approaching. The truck driver reported stopping behind another truck and some other cars that all proceeded over the Conn level crossing when no train was forthcoming. By the time he reached the Rungoo level crossing though, he was at the lead of several southbound vehicles and there were no vehicles stopped at the flashing lights immediately in front of him. This situation could have been interpreted by him as suggesting that these other drivers had already traversed the Rungoo level crossing while the lights were flashing because no train was approaching.

However, the truck driver said that the 'false' operation of the Conn level crossing flashing lights did not influence his actions at the Rungoo level crossing, but rather he did not detect the flashing lights at the Rungoo level crossing. The truck driver stated that, prior to the day of the crash, he had once previously observed a set of lights at a level crossing at Ayr which were continuously flashing with no train approaching.

In summary, with the truck driver's experience at the Conn level crossing, it is possible that the truck driver saw the flashing lights at the Rungoo level crossing but had limited confidence that they indicated the presence of an approaching train.

Misjudgement

Road users are often unable to judge the speed and distance of an approaching train, which can lead to a road user attempting to cross the tracks before a train arrives at the crossing. However, given the short distance that a southbound road user can see along the rail track (figure 34) it is unlikely that misjudgement of train speed and distance was a factor because the truck driver would not have been able to see far enough along the rail line to attempt to beat a train to the level crossing.

Figure 34: *Restricted view of rail line, approach to Rungoo level crossing*

Truck driver response time

As discussed in section 2.1.4, the point of perception for the truck driver is important to his response time. Based on the calculation in section 2.1.4 the truck driver's response time was 1.9 seconds. If he was driving in such a way as to suggest that he had detected flashing lights but had limited confidence that the lights indicated the presence of an approaching train his response time would be expected to be reduced. A response time of 1.9 seconds for a surprised driver is within the expected boundaries.

Scenario A summary

In summary, it is possible that the truck driver detected the flashing lights at the Rungoo level crossing but had a low expectancy that the lights provided a reliable indication of the presence of an approaching train. The truck driver may, therefore, have elected to continue at a normal speed towards the crossing, actively looking for any sign of an approaching train. However, this scenario is inconsistent with the truck driver's statement to the investigation that he did not detect the flashing lights.

2.3.7 Scenario B: Not detecting the lights

The truck driver reported that the lights at the Rungoo level crossing were not operating. However, it has been established by the investigation that it is almost certain that the flashing lights at the Rungoo level crossing were working as required.

As discussed in section 2.3.2, the truck driver had 15.4 seconds in which to observe the operation of the flashing light signals before entering the level crossing.

A range of factors could increase the likelihood that a road user may not detect a particular signal. Before discussing these factors, it is useful to review in general terms how humans process information.

Human information processing

Both active and passive control level crossings rely on the appropriate behaviour of the road user. Figure 35 shows a version of 'Wickens' model of human information processing (Wickens, 1984). This model provides a high-level framework for understanding how humans process information when performing operational tasks.

In both actively and passively controlled level crossings the requirement for the road user is the same. Firstly, a stimulus, for example flashing lights or the presence of a 'Stop' sign, must be present.

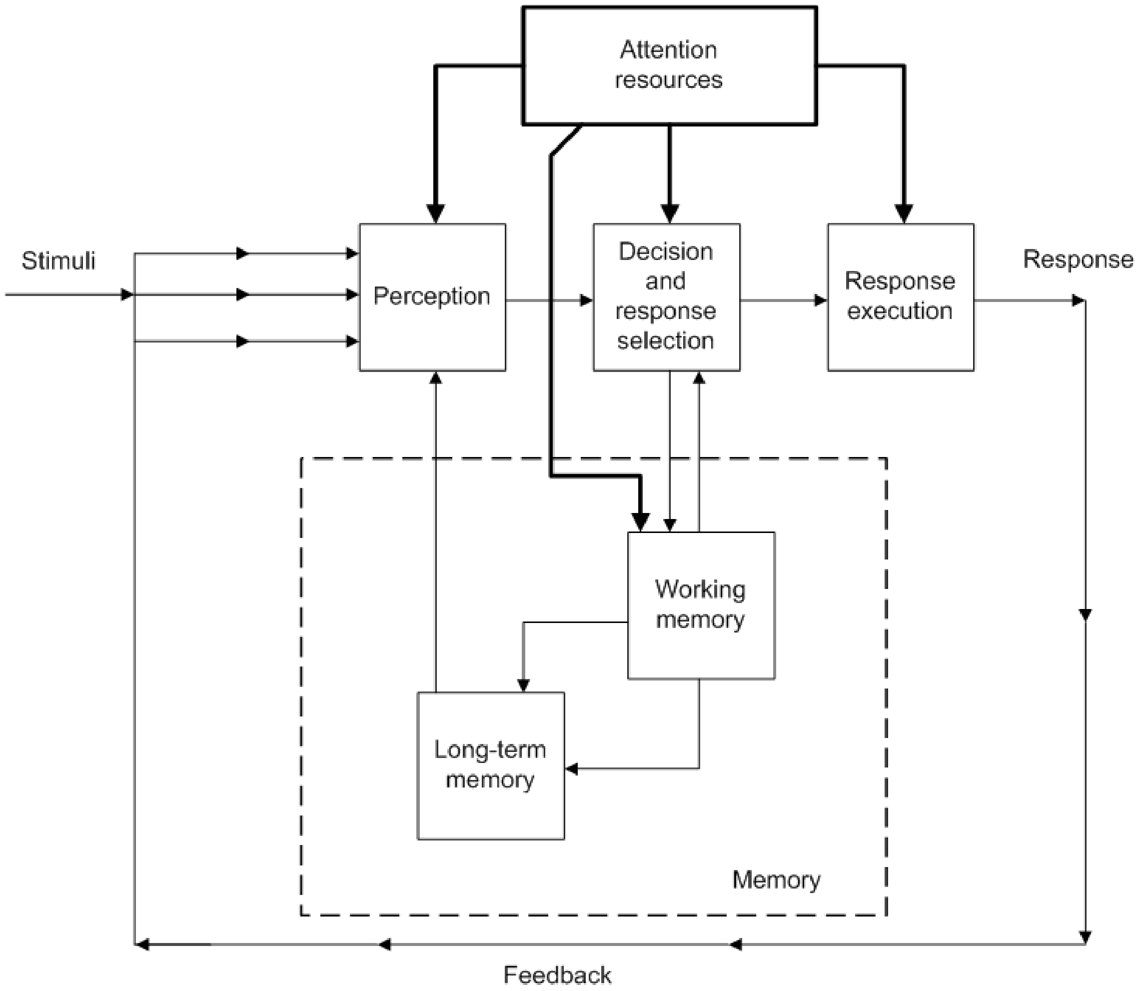
The road user must then perceive the stimulus which requires attentional resources and long-term memory to understand the meaning of the stimulus. Next the road user uses attentional resources and both their long-term and working (or short-term) memory to make a decision on their response. Once the decision has been made and a response selected, the road user can execute the response and monitor the outcome through the feedback loop to ensure that it was appropriate.

In the case of a road user approaching an actively controlled level crossing with flashing light signals, the stimulus of the flashing lights is present. The road user must firstly detect the flashing lights. Based on their perception of the lights and their understanding of what the lights mean, the road user will make a decision about whether to stop before entering the level crossing. The road user will then apply the brakes on the vehicle and, based on the response of the vehicle, will monitor that the vehicle stops before the level crossing.

Driving is primarily a 'skill-based behaviour' for experienced drivers. Rasmussen (1986) defined skill-based behaviour as "sensorimotor performance during acts or activities that, take place without conscious control as smooth, automated, and highly integrated patterns of behaviour". In simple terms, at the level of skill-based behaviour, the individual is very familiar with the task and will often require minimal attentional resources to do the task effectively, although frequent attentional checks on progress will be required.

Unfortunately, due to a wide range of factors, human information processing is not infallible and errors can occur. One of the issues with human information processing is that humans have a limited amount of attentional resource, which limits the amount of information that can be perceived, the number of decisions that can be made and the number of responses that can be executed.

Figure 35: ***Model of human information processing***



Looked but did not see errors

Research by Green and Senders (2004) has shown that in road crashes critical or important information may have been detectible but the motorist did not attend to or notice it because their mental resources were elsewhere. These types of incidents are often termed 'looked but did not see' and cover phenomena such as 'change blindness' and 'inattentional blindness'. These two phenomena are related and closely fit with the model of human information processing in figure 35.

As observers of a scene, people believe that they see the entire picture in great detail and can immediately notice any changes. However, this is not the case and change or inattentional blindness can occur and has been shown to be not uncommon (Wickens and McCarley, 2008).

Change blindness occurs when a person does not notice something that is different about the visual environment relative to before the change. Research has shown that in some cases quite dramatic changes are not detected (Simons and Levin, 1998), particularly if changes occur when the observer is not looking at the relevant part of the visual environment at the time.

As the level crossing lights were almost certainly flashing before the truck driver was first able to view them, the phenomena of change blindness is not applicable to this incident and is not discussed.

Inattentional blindness occurs when a person does not notice an object which is fully-visible, but unexpected, because their attention is engaged on another task. It is a failure to perceive what would appear to others as an obvious visual stimulus. However, this does not necessarily mean an individual was 'not paying attention', merely that their attentional resources were occupied elsewhere. As all individuals have limited attentional resources, it is possible for an individual to simply miss vital visual stimuli if their attention is allocated on another task.

Research on human information processing suggests that inattentional blindness can occur when attention is filtered away from information and can be affected by mental workload, expectation, conspicuity and capacity. As attentional resources are limited, if the viewer is attending to something else, it is possible that the driver may not notice the stimulus. Research by Mack and Rock (1998) has shown how a person may fail to detect an object even though they were looking directly at it.

Research has shown that people overestimate their ability to detect changes or objects in their visual environment (Levin et al, 2000). When asked whether they can detect a particular type of change or object, many people say they can. However, actual detection rates are much lower than these expectations. Therefore, although the presence of flashing lights at a level crossing may seem obvious to someone who knows they are flashing, it is not necessarily salient to someone who does not know they are flashing.

2.3.8 Potential reasons for not detecting the lights

Medical and physiological factors

At the request of the investigation team the truck driver undertook an eye examination in March 2009. This examination revealed that he had normal visual fields (side vision) and his visual processing and divided attention were at a high level. He was categorised by the examination as being "Very Low Risk" for crashes using the Useful Field Of View (UFOV) test.[50] Of note also was that he had normal colour vision.

The truck driver was also tested by the police for the presence of alcohol after the accident, with a negative result. By law, QPS officers must suspect that a person is under the influence of another substance before they can request testing for illicit substances. In this instance, QPS officers advised that there was no such suspicion and as such, a test for illicit substances was not performed.

50 The UFOV test is a computer base test where targets are identified in the centre of the screen at the same time as identifying the position of a target at the edge of the screen. The test measures visual speed of processing and divided attention and has been shown to be strongly predictive of crash risk in older adults.

The truck driver said he was in good health and had no medical impediments to driving the truck at the time of the collision. In addition, his heavy vehicle licence had no restrictions relating to medical issues placed upon it.

In summary, a review of the evidence available did not provide any information on medical or physiological factors that were relevant to understanding why the truck driver may not have detected the flashing lights on the approach to the Rungoo level crossing.

Visual obstructions in the cab

An inspection of the truck cab as found at the crash site determined that the windscreen was relatively clean and free from any defects which may have affected the truck driver's vision prior to the collision.

The truck cab also provided good forward vision and it is unlikely that any part of the truck cab, including the pillars and posts, would have continually obscured the truck driver's view of the flashing lights on the approach to the Rungoo level crossing, to stop him from detecting the flashing lights.

Distractions and workload

The controls of the Freightliner prime-mover as found at the crash site are depicted in figure 36. The air-conditioning fan speed can be seen at setting three and the air flow directed at the face of the truck driver. Also, it can be seen that the differential locks are off, the air suspension is in auto and the trailer brakes are off. These latter settings are consistent with the routine operation of this vehicle. In addition, the AM/FM radio was found to be turned off.

Figure 36: *Truck console at crash site. Note air-conditioning setting*

The QPS reported that the CB radio was turned on, however, the truck driver reported that the CB radio was off before the collision. He also reported that he was not using his mobile telephone at the time of the collision. A review of the truck driver's phone records confirmed that he did not have any incoming or outgoing calls before the collision.

The truck driver reported that his small dog was travelling in the truck cab with him at the time of the collision but that the dog had not distracted him on the approach to the Rungoo level crossing. There were no other occupants of the truck and no evidence to suggest that the truck driver was engaged in other tasks as he approached the Rungoo level crossing.

Driving a vehicle for an experienced operator is a skill-based task which does not constitute a high level of workload for the operator under normal conditions. However the truck driver would be engaged in tasks such as scanning of the road, mirrors, instruments and other relevant information. Outside the cab, it is believed that there were no discernable distractions such as road works or traffic that may have distracted the truck driver. In addition, witnesses following the truck did not report significant speed variations or any struggle to maintain lane control that would indicate that the truck driver was experiencing high levels of distraction.

In summary, the evidence available suggests that neither distraction nor high workload were factors in the truck driver's apparent failure to detect the flashing lights on the approach to the Rungoo level crossing.

Time pressure

Time pressure has many effects on human performance. Research has shown time pressure leads to a reduction in the number of information sources accessed, and the frequency or amount of time these sources are checked (Staal, 2004).

The truck driver reported in his first interview that the truck company was good to work for and that he was not time pressured at work. At a later interview the truck driver reported that he was running out of time in relation to his driving hours which may suggest a time pressure to reach a certain location. However, the only specific requirement was to return to Brisbane by 29 November 2008.

In summary, it is possible that the truck driver's failure to detect the lights on the approach to the Rungoo level crossing was influenced by perceived time pressure to reach a particular location by a certain time. However, there is insufficient evidence to make a conclusion in this area.

Environmental conditions

The term 'glare' is used in situations where light affects a person adversely and is used to define the property of the light, rather than the effect the light has. To describe the effect of glare on people, two terms are used: 'discomfort glare' and 'disability glare'.

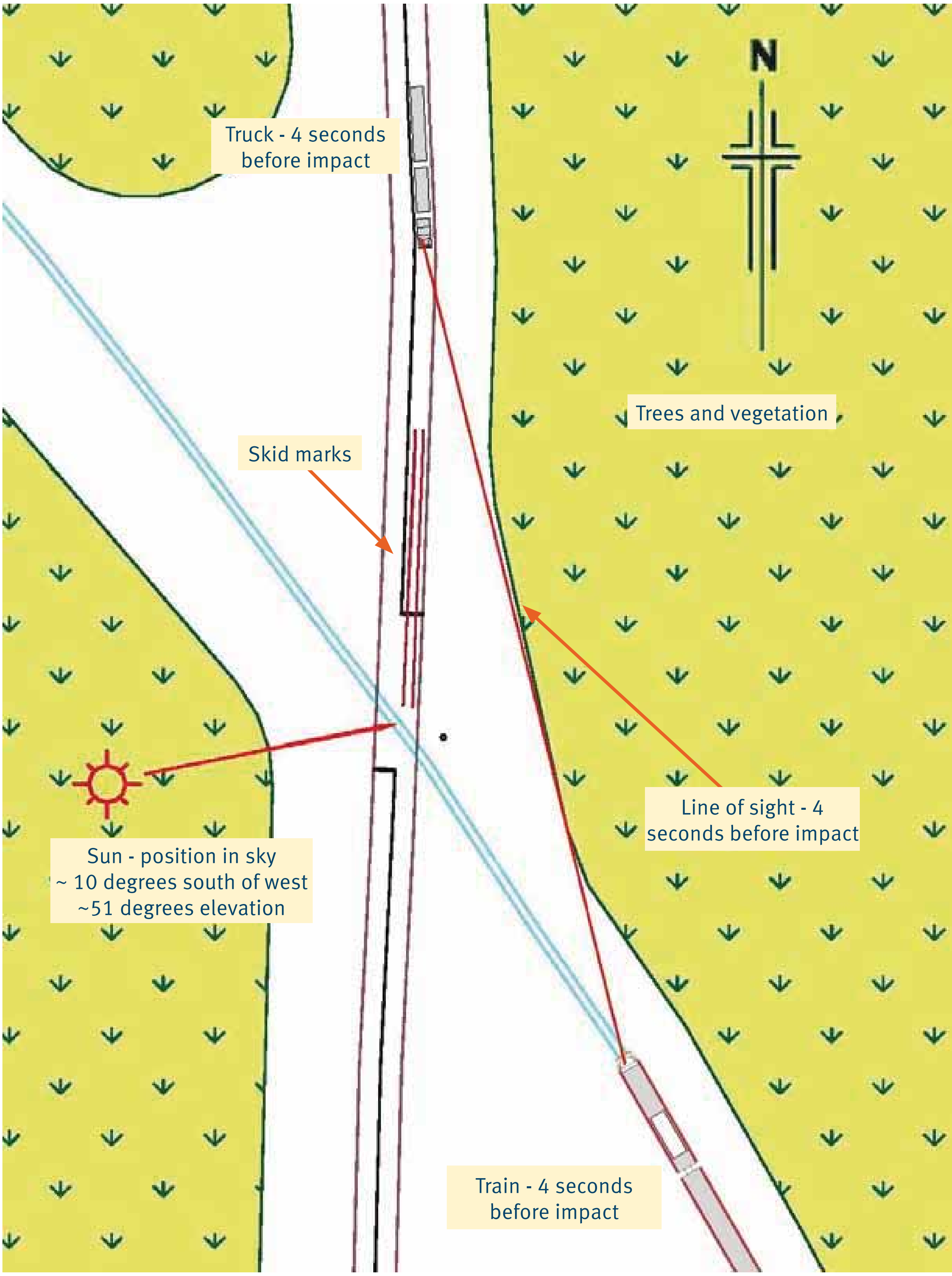
At low levels of glare, discomfort glare can occur which may be reported as an annoyance rather than discomfort. Discomfort glare is subjective and although overall performance can be affected, visual performance will generally be unaffected. Disability glare occurs when the contrast between an object and its background is reduced or when the retinal image contrast is reduced within the eye. Disability glare is associated with a reduction of visual performance.

Research by Gray and Regan (2007) has shown that significant deteriorations in road user visual performance have been found with the position of the sun at an angle of 45 degrees to the side of a road user's line of sight and at 20 degrees above the road level.

According to Geoscience Australia[51], at the Rungoo level crossing on the day and time of the collision, the sun had an azimuth of about 259 degrees and altitude of about 51 degrees above the horizon. As the truck driver's heading was approximately 180 degrees, the sun was positioned about 80 degrees to the left of the driver as shown in figure 37.

51 Geoscience Australia is a prescribed agency within the Resources, Energy and Tourism portfolio. It provides geoscientific information and knowledge including the computation of the sun's azimuth and elevation for a given point (http://www.ga.gov.au/geodesy/astro/smpos.jsp).

Figure 37: *Train – Truck Sighting and position of sun*



As discussed in section 1.1.5, information from witnesses indicated that at the time of the crash at the Rungoo level crossing there was predominantly fine weather with showers about the tops of the hills in the vicinity and an overcast sky. In addition, the road was described as being wet. As such, it is unlikely there were any significant reflections on the road or other surfaces outside or inside the truck cab which would have produced significant glare.

In summary, the position of the sun in relation to the truck and the level crossing and the overcast conditions at the time meant it was unlikely that direct glare from the sun caused any decrease in the truck driver's visual performance.

Effectiveness of signal

The salience (or conspicuity) of a visual stimulus, such as lights, can be influenced by several factors, such as size, contrast (relative to the background) and movement. The more salient the stimulus then, in general, the more likely it is to be detected.

In section 2.2 of this report, the LED flashing signals, warning signs and markings at and on the approach to the Rungoo level crossing and the overall advantages of LED signals were discussed. Compliance to the relevant standard was noted.

Contrast refers to the difference in brightness (or luminance) between an object and its background. Contrast plays an important part in many visual tasks, including being able to see a flashing light in a complex visual environment. The level of contrast can influence how easily an object is identified and if the contrast is strong enough it can draw an individual's attention.

The flashing lights at the Rungoo level crossing were mounted on matt black backgrounds and had covers to reduce glare. The background behind the lights when viewed from along the road was a dark background which provided a good level of contrast for the flashing lights. As discussed in the previous section on 'environmental conditions', it is also unlikely that the weather or glare from the sun had an influence on the effectiveness of the flashing lights.

In general, moving stimuli are much easier to detect than stationary stimuli. For this reason, active control level crossings are fitted with flashing lights to draw the road user's attention away from what they may otherwise be focusing on and warn them of an approaching train.

In summary, the effectiveness of the flashing lights was not considered a factor that may have affected the truck driver's ability to detect the flashing lights on the approach to the Rungoo level crossing.

Crossing awareness

The truck driver's familiarity with the route meant he would have been aware of Rungoo and the other level crossings along the Bruce Highway. It is considered highly unlikely that the truck driver's actions in not detecting the lights were due to a lack of awareness of the presence of the level crossing or the existence of the flashing lights.

Expectancy

As discussed in section 2.3.6, a factor which influences the behaviour of road users at level crossings is their expectation of encountering a train. In addition to this, expectancy can influence the visual system, including how and where people look for information. The six factors which affect the visual system are (Wickens and McCarley, 2008):

- Habit;
- Salience;
- Event rate (individuals look at something as a lot is happening there);
- Contextual relevance (individuals look at something as they believe there is relevant information there);
- Information value (individuals look at something as it has intrinsic value to them); and
- Effort conservation.

Habit, event rate and contextual relevance can all potentially be affected by an individual's expectancy. As a result, an individual's visual scanning can potentially be influenced by the individual's expectancy. For example, if the truck driver had a low expectancy of seeing a train at the Rungoo level crossing, this may have resulted in visual scanning that did not include looking for trains or warning devices.

The truck driver said that he had never seen a train passing over the Rungoo level crossing and had rarely seen trains at the other level crossings that he regularly used. It follows that he may have had a low expectancy of seeing a train at a level crossing. This may have led to an increased potential of the truck driver not looking for trains or warning devices or looking but simply not seeing trains or warning devices.

Fatigue

The term fatigue has many different meanings and to an extent has not been defined in any concrete fashion (Maher and McPhee, 1994). In the context of human performance, fatigue is a physical and psychological condition that is primarily caused by prolonged wakefulness and/or insufficient or disturbed sleep.

Fatigue can result from a number of different sources, including time on task, time since awake, acute and chronic sleep debt and circadian disruption (i.e. factors which affect the normal 24-hour cycle of body functioning). A review of fatigue research was conducted by the Batelle Memorial Institute (1998), which noted that fatigue can have a range of influences, such as:

- Increased anxiety;
- Decreased short-term memory;
- Slowed reaction time;
- Decreased work efficiency;
- Reduced motivational drive;

- Increased variability in work performance; and
- Increased errors of omission.

When a driver is fatigued, although the driver is not asleep, the driver's performance can be impaired and the essential information necessary for safe driving may not be perceived.

However, while many of these symptoms generally only appear after substantial levels of sleep deprivation, even the loss of sleep for one night generally has negative influences on several aspects of human performance. The review also made the following observations:

- A common symptom of fatigue is a change in the level of acceptable risk that a person tolerates, or a tendency to accept lower levels of performance and not correct errors;
- Error rates increase during the period 0000 to 0600;
- Most people need eight hours sleep each day to achieve maximum levels of alertness and performance;
- Decrements in alertness and performance intensify if the time awake is 16 to 18 hours. These performance decrements tended to result in ineffective decision-making;
- Fatigue is cumulative; and
- There is a discrepancy between self-reports of fatigue and actual fatigue levels, with people generally underestimating their level of fatigue.

In addition to these findings, the Australian House of Representatives (2000) enquiry into managing fatigue in transport also stated that an individual who is fatigued is unable to function at a normal level of alertness and efficiency, possibly leading to slowed reaction times, reduced vigilance, memory lapses, inattention to tasks, complacency, lack of awareness, lack of communication, mood changes, lack of judgement, decline in motivation, and falling asleep.

This enquiry also highlighted the performance decrements for cognitive psychomotor tasks which reduce for each hour of wakefulness between 10 and 16 hours to an equivalent performance decrement observed with a 0.004 percent rise in Blood Alcohol Concentration (BAC) per hour. After 17 hours of sustained wakefulness, performance decreased to a level equivalent to the performance impairment observed at a BAC of 0.05 percent. After 24 hours of sustained wakefulness, performance decreased to a level equivalent to the performance deficit observed at a BAC of roughly 0.10 percent.[52]

Research has also shown that partial sleep loss from going to sleep later or waking earlier can also influence behaviour. For instance, waking 2 hours earlier than normal has been shown to lead to a decline in performance on more difficult short-term memory tasks.[53]

52 Dawson, D., & Reid, K. (1997). Fatigue, Alcohol and Performance Impairment. *Nature, 388* (July-August), 235.

53 Campbell, S. S. (1992). Effects of sleep and circadian rhythms on performance. In A.P. Smith & D. M. Jones (Ed.s) *Handbook of Human Performance*, vol 3, 196-216.

When an individual is fatigued it is also possible that the physiological drive to sleep can result in a 'microsleep' lasting from a few seconds to a few minutes. The terminology is the result of electroencephalogram recordings showing that during these lapses in information processing, subjects momentarily slip into a light sleep. Microsleeps can occur with the eyes open and usually without the knowledge of the individual. Microsleeps result in intermittent lapses in consciousness that can impair performance by leading to errors or omissions due to missed information.

Microsleeps are associated with events such as blank stare, head snapping, and prolonged eye closure which may occur when a person is fatigued but trying to stay awake to perform a monotonous task like driving a car or watching a computer screen. While in a microsleep, a person fails to respond to outside information, as a result a road user may not see a red signal light or notice that the road has curved. Microsleeps are most likely to occur at certain times of the day, such as pre-dawn hours and mid-afternoon hours due to circadian rhythms, and increase with cumulative sleep debt.

In a fatigued state the driver is also not aware of microsleeps. A study by the Austin Hospital (Howard, 2002) indicated that sober, drug-free truck drivers, when fatigued, do not recognize the signs of microsleeps until they are experiencing approximately 50 seconds per hour of microsleeps. This project examined the driving of 15 professional drivers in a laboratory driving simulator over a 24 hour period and measured objective psychomotor vigilance performance; subjective vigilance performance; subjective ability to drive and physiological measures of sleep related fatigue and microsleeps. Drivers stated that they would continue driving to complete a short journey, during 75% of sessions when 50 to 100 seconds per hour of microsleeps were present.

To minimise the likelihood of fatigue influencing heavy vehicle driver behaviour, the Queensland Government implemented the National Driving Hours Policy on 29 September 2008. The policy was introduced through the *Transport Operations (Road Use Management – Fatigue Management) Regulation 2008* and makes use of work diaries, prescriptive driving, and work and rest limits. Significant penalties apply in the case of breaches.

MFT Transport Pty Ltd was accredited to operate under the standard work hours option. In essence, this allows 12 hours work time in any 24 hour period provided that rest breaks of prescribed periods are taken. The rest period requirements are allotted at prescribed intervals over 24 hour, seven day and 14 day periods. For example, over a 24 hour period a minimum 'block' of seven hours stationary rest time must be taken away from the truck or in an approved sleeper berth of a stationary truck.[54]

The schedule for the truck driver showed that his current trip started from Brisbane on 25 November 2008. Prior to this the schedule shows two days off,

54 Full details of standard hours can be found at http://www.ntc.gov.au

which were confirmed by the truck driver at interview, in which he said he was well rested. The schedule shows that the truck driver was meant to travel from Brisbane to Tully on 25 and 26 November before continuing on to Cairns then back through Ayr to Bowen and to Brisbane on 27 and 28 November 2008.

The logbook of the truck driver involved in the collision at the Rungoo level crossing was incomplete. However, the log book shows the driver left Brisbane at approximately 1345 on 25 November before arriving in Marlborough at 2315 and spending the night there. On 26 November the logbook shows the truck driver departing Marlborough at 0615 before arriving in Gumlu (45 km north of Bowen) at 1115, before returning south to Sarina arriving at 1630. The logbook shows that in this period preceding the collision that the truck driver exceeded the requirement of the standard hours work option of 12 hours in any 24 hour period.

The logbook then shows the truck driver leaving Sarina at 1800 and arriving at Proserpine at 2015 and spending the night there. The final entries in the logbook show the truck driver departing Proserpine at 0430 on 27 November 2008 before arriving at Townsville at 0700. There are no further entries in the logbook.

At the first interview with the truck driver he stated that he started his journey on 25 November 2008 from Brisbane, he did not stipulate where he spent that night. The night of 26 November 2008 was said to be spent in Tully where he slept in his cab. On the morning of the crash the truck driver stated that he awoke at 0500 before unloading the truck in Tully and driving to Cairns for a collection. The truck driver reported leaving Cairns at around 1100 before stopping south of Innisfail at around 1230 for lunch.

At the second interview conducted with the truck driver, he was asked to clarify some points regarding the trip. He stated that the trip started on 25 November 2008 at approximately 1400, before spending the night at Marlborough. On 26 November 2008 the truck driver stated that he travelled from Marlborough to Tully, where he spent the night, arriving at approximately 1900.

As described, there were a number of discrepancies between the logbook and the truck driver's account of locations and times. However, the truck driver strongly contended that he spent the night in the sleeping cabin of his prime-mover at Tully. There is no evidence to dispute this and calculations regarding the point to point journey times reveal this to be reasonably possible (although probably not in compliance with the National Driving Hours Policy). Even if this was so, he said at interview that the sleep he obtained at Tully was "as good as you're going to get in a truck cabin". He also said that it was hot and stuffy and that he had to start the truck engine a couple of times to run the air-conditioner. This indicates, at best, a broken sleep.

The truck driver reported that he did not see the flashing lights at the Rungoo level crossing. He also reported that he did not feel fatigued. However, the studies referred to have found that there is a discrepancy between self-report of fatigue and actual fatigue levels and that people generally underestimate their level of fatigue. A review of the truck driver's traffic record also detailed three offences relating to logbooks and fatigue over the previous four years.

It is possible that the driver of the truck was experiencing some fatigue and/or may have suffered a microsleep, which resulted in him being less likely to be able to detect the flashing lights at the level crossing. Given the incomplete record of the truck driver's work and sleep patterns in the days prior to the crash, there was insufficient evidence to draw any definite conclusions with respect to fatigue affecting specific events or the behaviour of the truck driver before the collision. However, fatigue remains a possible factor in the collision.

Scenario B summary

In summary, it is possible that the truck driver did not detect the flashing lights at the Rungoo level crossing due to a number of factors. The truck driver may, therefore, have elected to continue at a normal speed towards the crossing, as he had not detected the flashing lights. This scenario is consistent with the truck driver's statement to the investigation that he did not detect the flashing lights.

2.3.9 Truck driver performance summary

Given that the flashing lights were almost certainly working at the level crossing the investigation identified two possible scenarios for why the truck driver did not stop before entering the Rungoo level crossing:

- Scenario A: The truck driver detected the flashing lights but had limited confidence that the lights indicated the presence of an approaching train.
- Scenario B: The truck driver did not detect the flashing lights.

Based on the information available, a definitive reason as to why the B-double truck driver did not stop at the Rungoo level crossing could not be determined. Both scenarios are possible but, with the information available it is not possible to say one scenario is more likely than the other. However, it is important to note that, in this instance, the defences present at the Rungoo level crossing were not sufficient and a single point of failure has resulted in the collision.

2.4 Power car crashworthiness[55]

2.4.1 Overview, QR/ Evans Deakin Industry (EDI) CTT construction and design alliance

The CTT is, in essence, a diesel powered 'evolution' of the electrically powered Rockhampton Tilt Train (RTT) that was constructed in the late 1980's. The RTT was the first narrow gauge tilt train ever built, worldwide. Because of the uniqueness of the construction task QR entered into an alliance with EDI to build the RTT and later, the CTT.

55 Crashworthiness means the vehicle's ability to provide passive safety for the occupants (passengers and crew) through dissipation of the vehicle kinetic energy during a collision. Crashworthiness is achieved through a balanced design with some elements which promote the development of the plastic zones for efficient energy transfer, and with other structural elements which help to preserve the occupant's residual survival space.

Unlike any normal design and construct tender the focus of an alliance is not on price but how to develop a team that the client would have the greatest confidence to successfully deliver the project. Alliances are typically used throughout the construction industry to design and build unique or evolutionary constructions in the shortest possible time and at the lowest cost.

In simple terms, when the alliance forms all parties, including the client, are expected to remove their corporate banner and wear a single alliance banner. The focus of the alliance is on the best project outcomes, and not individual or corporate outcomes. Consequently, contracts are structured so that the alliance partners have no right to engage in the pursuit of legal remedies against each other and project risks are managed by project specific insurance. Any variations are agreed by the alliance leadership team, which includes senior management from each alliance partner. This concept ensures that all parties share the risks together and is designed to focus the team on the best project outcomes.

In this instance, the QR/EDI alliance enabled the CTT design to be developed with shorter lead times with the caveat that the final design would then be separately and independently verified by other QR staff working on behalf of QR Ltd as the operator.

2.4.2 Previous incident CTT November 2004[56]

On 15 November 2004, the CTT was involved in a derailment on the Berajondo to Baffle section of track between Bundaberg and Gladstone. The ATSB/QT investigation found that the derailment was due to the train entering a 60 km/h curve at excessive speed (112 km/h) which resulted in the power car rolling to the right and then skidding along on its right-hand side before coming to a stop 108 m from the point of derailment. The power car collided with the earth embankment and electrical support masts on the right-hand side of the track during the derailment sequence and suffered extensive damage as a consequence.[57] The lead power car involved in this derailment, DTD 5403, was the same lead power car that was involved in the level crossing collision at Rungoo on 27 November 2008.

Figure 38 shows the damaged driver's cab at Maryborough before repair. The right-hand side of the driver's cab can be seen to be badly damaged and the right-hand side cab window is missing. Part of the right-hand side corner pillar and the longitudinal beam connected to it can be seen to be exposed, both are intact, but there was some minor deformation of the longitudinal beam. The right-hand side door was in place but damaged, however, the lateral collision beam (above the windscreen) was intact and undeformed.

56 The complete report is "Rail Safety Investigation QT1472 – Derailment of Cairns Tilt Train VCQ5 North of Berajondo, Queensland 15 November 2004", ISBN 1 921092 13 0 published by Australian Transport Safety Bureau and also available on the Queensland Department of Transport and Main Roads website.

57 The rest of the train, despite also rolling and skidding on the right-hand side, suffered relatively minor structural damage and remained intact.

In summary, the front of the driver's cab was relatively undamaged in this derailment and this is especially evident when the condition of the lateral collision beam is noted.

Figure 38: *Power car DTD 5403 after the Berajondo derailment 2004*

Certification of the CTT return to service after the 2004 accident

As part of this investigation, QR confirmed that no post-build structural modifications were undertaken on the CTT that would have any material impact on the structural or crashworthiness integrity. The repairs to CTT power car DTD 5403 following the November 2004 roll-over were based on "like for like" replacement of all identified damaged cab side structural elements, and certified by QR Certificate of Engineering Compliance no. E2007- 0163 as "fit for purpose" following those repairs. Power car DTD 5403 was returned to service on 15 June 2007.

2.4.3 Rungoo level crossing collision

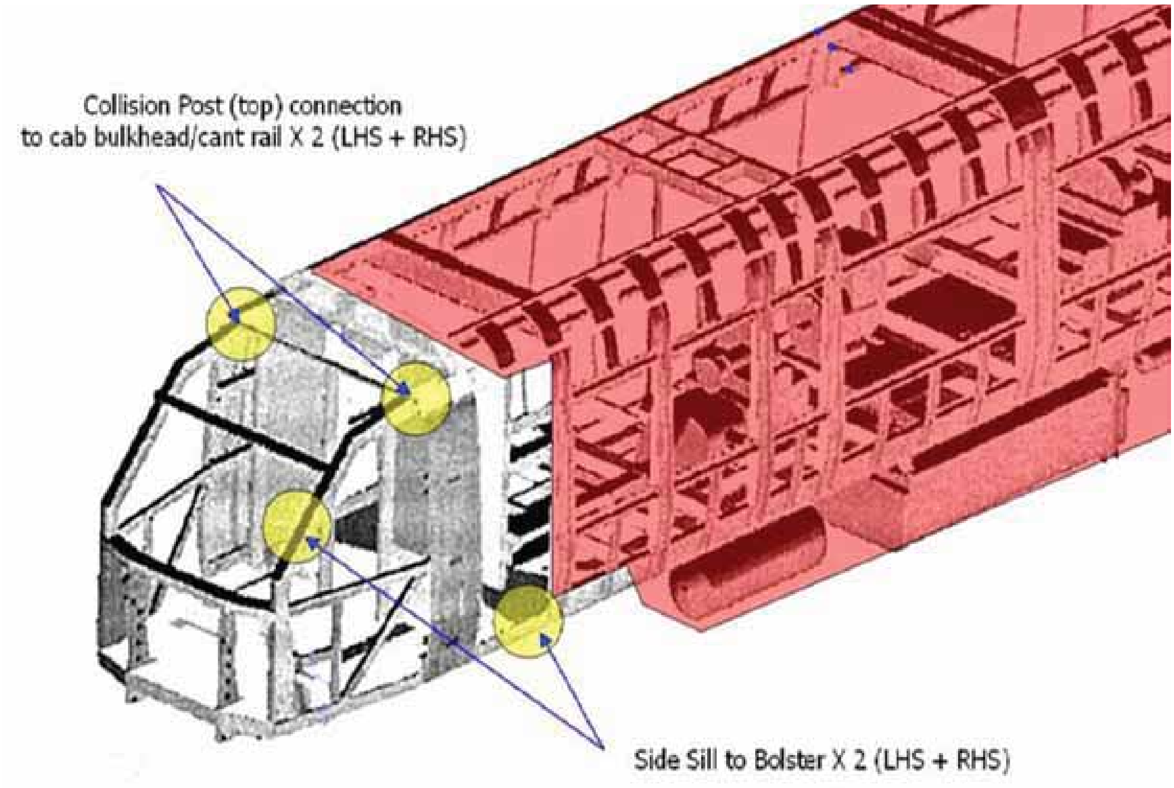
The cab of power car DTD 5403 lozenged[58] as a result of the collision at the Rungoo level crossing on 27 November 2008. The investigation sought to establish why this occurred and the circumstances that may have contributed to this failure. A firm of independent international rail technology consultants was engaged to review the specification, design and construction of the CTT. The engineering consultants were to review and report on the following:

58 Lozenge- four sided planar figure with a diamond shape; a rhombus that is not a square.

- Carry out a visual inspection of the mechanical and maintenance condition of the CTT power car and running gear in order to assess its fitness to run prior to the collision;
- Carry out an inspection of the CTT power car cab and surrounding structure to examine the extent of the damage in the collision;
- Determine whether the CTT power cars, and in particular the power car involved in the collision on 27 November 2008, was in compliance with the:
  - Crashworthiness requirements of the design technical specification;
  - QR crashworthiness design standards applicable at the time of design and build; and
  - International crashworthiness standards of the day applicable at the time of design and build.
- Compare the CTT design crashworthiness with current QR and international crashworthiness standards; and
- Make appropriate recommendations to improve the crashworthiness for future builds.

In addition to the engineering work conducted by the independent international rail technology consultants, weld samples from left and right side collision posts (top) connections and side sill to bolster connections (figure 39) were sent to Canberra for assessment by the ATSB against Australian Standard 1554 *Structural steel welding*.

Figure 39: ***Location of cab structure samples***



Mechanical and maintenance condition

A visual inspection of the mechanical and maintenance condition of power car DTD 5403 and running gear was conducted in order to assess its fitness to run prior to the collision.

Based on the inspection, the investigation has concluded that there was no evidence to suggest that the CTT power car was not maintained in a mechanical and operating condition suitable to operate to its design capacity. There is no evidence to suggest that the damage incurred in the collision at Rungoo was caused or exacerbated by the prior mechanical condition of power car DTD 5403.

Extent of the damage from the collision

A visual inspection of the extent of the damage to power car DTD 5403 as a result of the collision found:

Cab condition:

The condition of headlights, windscreen, windscreen wipers, horn and cab controls in the leading cab showed the cab had incurred extensive damage during the collision. The cab frame was extensively lozenged (figure 40) and had broken away on the left side from the bulkhead and cant-rail[59] leading to the engine compartments.

Figure 40: ***Lozenging of driver's cabin***

59 Cant-rail means the longitudinal structural part of the bodywork above the side windows including the curved transition to the roof structures.

Wheels:

All wheel tread profiles were good. The derailed wheel-sets showed minor surface damage consistent with the derailment.

Brakes and suspension:

Significant damage was evident to the running gear and brake equipment of the lead power car and luggage car. The damage to the running gear and brake equipment was consistent with the damage to the bodies of both vehicles and consistent with the expected and observed movement of vehicles, bogies and other components in the circumstances of the derailment. One hydraulic damper was observed to be defective on a derailed bogie and secondary suspension rubber springs were scuffed. Again, damage to these components was consistent with derailment damage. It was noted that all brake blocks were within acceptable wear limits; some park brake pads were chipped but this had no effect on serviceability.

Drawgear:

The lead portion of the drawgear on the baggage car (figure 41) was disengaged from a position behind the coupling head. The coupling head, inter-car cabling and rubber position stop had been pulled sideways from the baggage car as the momentum of the train moved the baggage car past the power car. Looking in the direction of travel, the coupling at the rear of the power car was bent towards the right hand side. No loose or damaged parts were observed, beyond that already damaged in the collision.

Figure 41: ***Drawgear damage between power car and luggage car***

Body side damage:

The left-hand side of the body of the power car was buckled about two metres behind the leading bolster. The right-hand side was bent along the solebar[60] and the leading bolster was displaced by about 100 to 150 mm. The remaining damage was to the right-hand side of the power car, consistent with contact being made with the trailing road trailer. There was no significant scoring damage to the power car body side or any other evidence that the vehicle had run for any distance on its side (or roof).

Design and construction standards when the CTT was built

The structural design and crashworthiness of the power car was reviewed by the independent consultants to verify the specification, design and construction of the CTT.

STD/0057/TEC Version 1.0 *Rollingstock Structural Requirements* (STD 57) contained the minimum crashworthiness design for all rollingstock operating on the QR network. STD 57 was reviewed and found to be generally compatible with the international standards of the time (circa 1999) including:

- GM/RT2100 *Structural Requirements for Railway Vehicles (Issue two, April 1997)*. This standard is part of the suite of Railway Group Standards (RGS) mandated by Network Rail for all vehicles running on the UK infrastructure; and
- 49CFR238 *Passenger Equipment Safety Standards (issued 1999)* is a Code of Federal Regulations (CFR) created by the USA Department of Transport. As a code, it is mandatory that all railway vehicles in the USA comply with the requirements of this standard.

Of note is that the 1999 version of STD 57 requirements for locomotives concentrated on heavy haul locomotives. The CTT, including the power cars, is a passenger train and so the question of what different requirements a dedicated power car may have compared to a heavy haul locomotive had not arisen with QR before. Derogation R.644[61] was issued to the alliance to modify the requirements of STD 57 to better match the requirements for the design of a power car hauling much lower train loads at higher speeds. These changes were then incorporated into later revisions of STD 57.

MRE 9809 *Tilt Train Contract Technical Requirements* was the technical specification for the CTT and had been developed by QR based on STD 57 (Version 1.0). Section 11 of specification MRE 9809 *Body Structure and Body Mounted Components* set out a description of the technical requirements for the designer with respect to structural strength, durability (fatigue), dynamic response, testing,

60 Solebar - Principal side structural member of car body shell or bogie. On a rollingstock body, the solebar usually forms the side of the underfloor framing.

61 STD 57 (version 1) set out the QR standards for locomotives. It was recognised that the CTT power cars did not require the full longitudinal strength of heavy haul locomotives and R.644 recognised this and pre-empted changes to STD 57 to recognise that power cars had separate construction requirements.

certification and collision response. Section 11 was the only section of MRE 9809 reviewed by the investigation.

MRE 9809 included some aspirational (not mandatory) qualitative requirements in excess of the minimal quantitative requirements for certification to operate on the QR Network that were contained in STD 57. These aspirational requirements were not verified as a component of the final certification to operate on the QR Network. A full description of the certification against STD 57 is at Appendix D.

Of note is that circa 1999 neither the QR standards nor the international standards required or considered:

- Collision scenarios other than frontal events where loads to the power car body structure are longitudinal (i.e. a collision with another train or stationary obstacle on the same track); or
- Definition of a safety cell for the drivers.

Construction and testing of the CTT when built

Subcontractors to the QR/EDI alliance were used for the specialist Finite Element Analysis (FEA)[62] work when the CTT was designed. The size of the individual elements in the grid used in FEA work is a direct function of the power of the computers available when the work is performed. As computers have become more powerful the grid used in an analysis has become finer, the individual elements smaller, and thus the results of the analysis more accurate. When compared to the technology available in 2009, the 1999 FEA performed for the CTT was relatively inaccurate.

The FEA work for the CTT was validated by strain gauge[63] testing of the prototype cab to the load cases required by STD 57. The FEA had indicated high stress levels at some locations in the original design and this was proven by the plastic deformation of the structure when loaded with the STD 57 and MRE 9809 load requirements. The structure was then rebuilt and strengthened in those places.

The redesigned structure was then run through and passed the FEA process. The investigation noted though that the power cars were then built to this modified design but strain gauge re-validation of the modified structure was not conducted.

62 A FEA means non-linear, explicit, computational mechanics study used to assess crashworthiness of the vehicle and to predict its dynamic, structural response during accidents. The FEA method originated from the need to solve complex elasticity and structural analysis problems in civil and aeronautical engineering. FEA allows detailed visualisation of where structures bend or twist, and indicates the distribution of stresses and displacements. FEA software provides a wide range of simulation options for controlling the complexity of both modelling and analysis of a system. FEA allows entire designs to be constructed, refined, and optimised before the design is manufactured.

63 A strain gauge is a device used to measure the strain of an object. The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive. As the object is deformed, the foil is deformed, causing its electrical resistance to change. From the change in electrical resistance the amount of applied stress may be inferred.

Current design and construction standards for power cars

The CTT crashworthiness specification was compared with the current QR crashworthiness standard and current international crashworthiness standards from the UK, Europe and the USA. At the time of preparing this report the available international standards that may apply if a CTT or similar train was built in 2009 are listed in table 7.

Table 7: *Contemporary standards power cars*

Country/continent	Crashworthiness requirements	Issued
UK	GM/RT2100 Issue3	October 2000
Europe	EN 12663:2000 (& EN 15227:2008)	June 2000 & (Sep 2008)
USA	49CFR238 USA APTA SS-C&S-034-99 Rev.2	2009 June 2006

While it is noted that the CTT crashworthiness specification was based on the predecessor to the current QR STD 57, it is also noted that the requirements in the current QR standard in terms of crashworthiness are essentially the same. The current version of STD 57, like its predecessors, covers general crashworthiness requirements.

Contemporary UK and European standards regard EN 15227 *Railway applications - Crashworthiness requirements for railway vehicle bodies* as being the key standard defining the crashworthiness requirements in Europe. Aspects of safe design were developed on the basis of the most common types of collision that cause injuries and fatalities and these were assessed as:

- A head-on collision between two identical train formations;
- A head-on collision between the train and a different type of rail-mounted vehicle;
- A collision between the train and a large road vehicle (15 t) on a level crossing; and
- A collision between the train and a smaller obstacle, such as a car on a level crossing, an animal or debris.

In considering these collision scenarios, EN 15227 goes beyond STD 57 and defines specific requirements that vehicle manufacturers have to meet. However, there are no specific requirements in EN 15227 for oblique or lateral collisions (as was the case at Rungoo).

The US CFR standard applies to all railroad passenger equipment excluding those operating on lines where there is no freight traffic, no level crossings and speeds are lower than 126 km/h. This standard is supported by the American Public Transport Association (APTA) document in particular for Tier I vehicles[64]

64 Maximum operating speed not exceeding 200 km/h.

where the CFR standard does not explicitly define any specific crashworthiness requirement.

For Tier II vehicles[65], the CFR standard defines the following requirements:

- 13 MJ shall be absorbed at each end of the train through controlled crushing of unoccupied areas;
- At least 5 MJ of the 13 MJ shall be absorbed ahead of the operator's cab in each power car;
- At least 3 MJ of the 13 MJ shall be absorbed between the operator's cab and the first trailer car; and
- At least 5 MJ of the 13 MJ shall be absorbed at the end of the first trailer car.

The CFR standard also defines deceleration requirements of 8g[66] anywhere in a trailer car for a 30 mph (50 km/h) collision with an identical train.

The CFR standard also covers rollover and roof/side structure strengths. The roll-over strength is covered by ensuring that the body-shell can rest on its side or on its roof without significant permanent deformation. The side structure strength is covered by ensuring that the body-side can withstand an inward transverse load applied at various heights between solebar and cant-rail levels.

The APTA document referred to defines the recommended practice for Crash Energy Management Systems (CEMS) applicable to most vehicle types. The CEMS defines the collision scenarios that shall be considered as being at least the following:

- Face to face collision;
- Impact with a freight vehicle; and
- Impact with a highway vehicle at a level crossing.

The CEMS document does not specify the velocity for each of these collision scenarios. It leaves it to the operator to decide what is appropriate based on a risk assessment of their operation. The APTA document also describes the requirement to use acceptance criteria for demonstration of compliance with the CEMS. Overall, these requirements are similar to the European/UK requirements (same scenarios, similar criteria).

The QR STD 57 buff load condition at the collision posts load at 1650 mm above rail level and shearing load for the collision posts are similar to the equivalent US requirements and higher than the equivalent UK and European standards. The current version of STD 57 is lacking in terms of buff load structural strength requirements at and above window sill level when compared to current international standards. STD 57 does however, include a roll-over case which loads the cab end structure laterally at solebar and cant-rail levels. This inclusion represents a higher requirement than the equivalent USA and European standards.

65 Maximum operating speed over 200 km/h and not exceeding 240 km/h.

66 The acceleration due to gravity of 9.81 m/s^2.

Of particular note is that the crashworthiness standards of the UK, Europe and the USA consider head-on or rear-on collisions, all of which include and require compressive front end load scenarios. None consider an oblique or lateral load case.

2.5 Assessment of collision performance CTT power car

2.5.1 Collision dynamics

Following the collision, the CTT power car rotated about 135 degrees and rolled onto its side before coming to rest. The crash site examination and an examination of the body-side damage revealed that the power car rolled onto its side just before coming to rest. Therefore, almost all of the damage occurred in the collision with the B-double truck.

Prima-facie, a collision with a B-double truck can be considered to be similar to a collision with another rail vehicle as both the power car and truck had somewhat similar masses; 67 t and 56 t respectively. The significant difference though is that in the case of the collision at Rungoo the truck was moving in a direction at about 97 degrees with respect to the direction of the train. The net effect of the collision was a momentum transfer between the 56 t truck travelling at an estimated 75 km/h and the train travelling at 57 km/h that caused the power car body structure to experience compressive and transverse loading, the latter force directed in a way which was trying to bend the power car to the left. This lateral bending force caused the cab to shear to the left. This is evidenced by the buckle to the solebar about two metres behind the leading bolster (figure 42).

Figure 42: *Solebar buckle*

The lateral bending and compressive loading caused the left side of the power car body to buckle and the right side to bend. This combination of compressive and left side movement was responsible for the solebar failure on the left side and not on the right.

The large transverse component of the B-double truck's momentum at the time of impact, the overall power car body bending distortion and the high compressive force needed to buckle the body-side in conjunction with a broken engine mounting beam, all suggest that the lateral loading on the power car was more significant than the compressive loading at impact in determining the structural behaviour of the power car.

The destruction of the upper superstructure of the driver's cabin probably occurred because it could not accommodate the substantial movement of the lozenged underframe and it simply detached from the roof and waist rail. Additional damage was probably incurred as the two trailers of the B-double truck wrapped themselves around the front of the driver's cabin of the CTT. Of note is that the ATSB metallurgical examination of the fractured welds in the collision post and side sill to bolster and cant-rail structures found that they were of an appropriate size and strength. There were no gross defects observed that may have significantly contributed to the fractures.

2.5.2 Collision performance

There was relatively little compressive crushing of the cabin structure of DTD 5403 that is normally associated with head-on collisions. The lozenging of the cab area occupied by the train drivers and the destruction of the superstructure resulted in the seats becoming trapped between the driver's desk and a steel bulkhead forming the rear of the cabin. There was no buckling of the underframe structure over this section of the driver's cab and the reduction in survivable space was primarily as a result of the lozenging of the driver's cab to the left. It should be noted that, in addition to the permanent 'plastic' deformation, there would have been considerable recoverable 'elastic' deformation during the impact. As the cab was in contact with the B-double truck under the action of a compressive and transverse force, the extent of the lozenging and the loss of cabin survivable space would have been greater than when the force was removed with subsequent spring-back.[67]

STD 57 for locomotives and subsequent derogation R.644 required only that the vehicle be able to withstand specific static loads and there was no requirement for structural crashworthiness or for the vehicle to sustain a lateral load case. The collision behaviour of power car DTD 5403 was therefore fully consistent with that of a vehicle designed to this mandatory standard.

67 Evidence from the QFRS emergency services personnel in attendance was that in order to free one of the train drivers they had to use spreader bars to push the driver's desk and seat further apart.

A question to be posed at this stage is, if the aspirational specifications contained in MRE 9809 had been incorporated in the design, would the outcome have been any different?

No evidence was provided that an analysis of the collapse behaviour of the CTT driver's cabin using non-linear analysis was undertaken. If a non-linear analysis had been undertaken and showed that the front end of the power car collapsed as expected with (compressive) load at solebar level, the high lateral load is still likely to have caused the lateral shearing action observed in the collision. It is opined that, even if the power car had been fully compliant with MRE 9809, the retention of survivable space for the train drivers would not have been significantly improved.

Modern crashworthiness standards and procurement specifications are generally fairly prescriptive. Most standards aim to prescribe discrete levels of energy absorbing structure, usually in the vehicle underframe because it has a high longitudinal strength for operational requirements and the collapse force and therefore energy absorption can be maximised. Additionally, collapse is designed to occur under controlled conditions at prescribed locations, away from occupied areas. Analysis is usually undertaken to ensure the design behaves as intended and that it offers adequate protection to cab occupants in head-on impacts up to between 36 and 60 km/h. None of the modern specifications, however, have a lateral load case requirement.

It is likely therefore that even if a cab was built to a current crashworthiness standard it would not offer a significantly greater amount of survivable space than that afforded by the CTT power car cabin.

Possible enhancements

During the investigation the question was raised as to whether practicable improvements could be made to enable leading vehicles of trains to better protect occupants in the event of a collision of the type experienced at Rungoo. In theory, the power car structure could have been made strong enough to resist the lozenging deformation but this would almost certainly lead to a significant increase in weight. Additionally, there is a limit to the lateral load a vehicle sustains before it derails. It is unlikely therefore that it would be practicable to specify a lateral structural strength of sufficient magnitude that would prevent the front end from lozenging when struck by a 56 t vehicle travelling upwards of 75 km/h at 97 degrees to the direction of train travel.

Simple practical measures could be employed to incrementally improve the structural integrity of the CTT cab structure. Typically, steel and aluminium structures fail under large plastic displacements and this is what occurred in the collision. This can be improved by such items as the addition of patch plates and redundancy at critical joints or a fully plated roof structure attached to the cant-rails and collision beam to provide improved resistance to lozenging.

2.6 Emergency response analysis

2.6.1 QR emergency management procedures

In the event of an emergency, QR emergency management procedures and associated training place particular emphasis on traincrew or on-board staff notifying train control as the first point of contact. They do so by following emergency communication protocols and provided no immediate danger is apparent (smoke, fire, risk of second collision etc), retain the passengers on the train in the first instance.[68]

Pending the arrival of emergency services, the on-site coordinator, in this instance the PSS, is also required to:

- Assess the situation and remember 'safety first';
- Within the limits of safety and training, check on the condition of other persons on the train and help anyone who is injured;
- Maintain regular contact with train control;
- Locate and record details of witnesses; and
- Keep passengers apprised of the situation.

After the arrival of emergency services the on-site coordinator is required to:

- Liaise with emergency services personnel;
- Hand over command to the next on-site coordinator;
- Consult with the on-site coordinator and applicable QR staff regarding a plan to evacuate the train;
- Ensure, as far as possible, that the evacuation occurs at doors that have steps or ladders;
- Ensure, as far as possible, that the evacuation occurs at a point clear of the affected area;
- Determine what the needs of disabled passengers may be and which passengers should be evacuated first;
- Determine the evacuation assembly point once detrained;
- Keep unauthorised persons well clear of the emergency site;
- Account for passengers on the train manifest and advise the on-site commander; and
- Maintain contact with train control.

2.6.2 Response measures enacted

Evidence from QPS, QFRS, QAS, CTT on-board staff, passengers (see 2.6.3) and QR logs is as follows:

68 QR emergency management procedures cover a wide gamut of situations that potentially require an emergency response and, in some situations, an evacuation. Key points of these procedures discussed in this report are those that are pertinent to the Rungoo level crossing collision.

- The PSS, after attempting to contact the train drivers, contacted the Townsville Network Train Control Centre at 1454:01.[69] Passengers and staff were then checked for injury and notified of their temporary confinement to the train;
- Other members of the on-board staff were delegated various tasks such as train security and passenger comfort issues;
- The PSS liaised with the emergency services personnel upon their arrival and handed over the role of on-site coordinator to the QPS;
- Passengers were examined by QAS officers within the confines of the train;
- The PSS, in consultation with the emergency services personnel, prioritised the evacuation of the nine passengers deemed in need of medical treatment;
- The PSS and on-board staff, in consultation with the emergency services personnel, agreed a plan and location for the evacuation of the remaining passengers;
- The evacuation of the remaining 72 passengers took place via an open door with steps at a location remote from the emergency site;
- QPS officers recorded the details of all passengers as they detrained; and
- The PSS accompanied the 66 passengers who elected to continue their travel to Cairns by road.

The evidence indicates that the CTT on-board staff complied with the QR emergency management procedures to a high degree. However, there are a couple of factors that warrant further consideration.

Firstly, evidence obtained in the form of interviews and communication logs indicate that after the initial and timely notification of the collision to the Townsville Network Train Control Centre, subsequent communication from the collision site was largely with QR Passenger operations management based in Brisbane. The prioritisation of communication to train control from a crash site is an issue that has arisen in a number of other (interstate) investigations. In general terms this tendency seems to be a result of people who are in a stressful situation 'defaulting' to communicating with their line manager, particularly when dealing with operational contingencies such as alternate travel arrangements for passengers. In this instance, the communication to QR Passenger operations management was undertaken with the best of intent and resulted in the formulation of plans for the transfer of passengers from the scene and other relevant issues. However, the responsibility for the operational management of a rail corridor is vested in the relevant train control centre. As such, the train control centre needs to be regularly informed of events in the field, particularly those concerning emergency management.

Secondly, before the arrival of the emergency services personnel, the PSS accepted an offer of assistance from a female passenger who introduced herself as being medically qualified. This person rendered valuable assistance to the PSS and other on-board staff by conducting a preliminary assessment of the condition of those on board the CTT. However, an offer to attend to the train drivers in the leading

69 Time recorded at the Townsville Network Train Control Centre.

power car was refused on the grounds of the QR policy to keep unauthorised persons well clear of an emergency site. The policy of not allowing unauthorised access to the emergency site is understandable from a number of perspectives. Trauma and exposure to risks are very real deterrents to accepting an offer of assistance from someone who is not a QR employee. However, a decision to reject an offer of assistance needs to be balanced with the realities of what is present at a crash site.

This investigation acknowledges the difficult situation that a rail operator is confronted with in an emergency situation should such an offer of assistance be made. It may be that the person in charge at the time (in this instance the PSS) should be delegated the authority to accept or reject such an offer based on the situation they are confronted with.

2.6.3 Passenger survey

A survey (questionnaire) was sent to passengers who were on the CTT at the time of the collision. The survey was designed to canvas a number of matters relevant to the collision and the subsequent emergency response. In seeking feedback in this manner the investigation was endeavouring to gauge the circumstances of the collision, the effectiveness of the emergency response measures and the effectiveness of the safety briefings and related material on the CTT from the perspective of the passengers.

Of the 81 passengers on board surveys were posted out to 71 passengers (88 percent) whose identity and address was known.[70] Responses were received from 33 passengers (41percent) with two being returned as undeliverable. Although not all of the returned surveys were fully completed, it was determined that both quantitative data analysis and comments would be reviewed.

The passenger survey indicated that the majority of respondents had some awareness of safety information pertaining to the CTT, whether this awareness was gained by listening to on-board announcements, reading of safety cards or watching the safety video. The majority of respondents also reported hearing instructions from on-board staff following the collision, although some indicated that the standard of this communication could have been better.

Adverse comments were received in regard to the decision to confine passengers to the CTT, particularly with the smell of diesel fuel and the lack of air-conditioning of the carriages when the power was lost. Similar to the issue of communications with train control, the confinement of passengers on trains following a collision has been a contentious issue in several other (interstate) rail investigations. Providing there is no risk of secondary collision, smoke, fire or intolerable environmental conditions such as heat or lack of fresh air, it has been previously concluded that confinement to the train is generally the option that presents the least risk to passengers. In this instance there was no risk of

70 This is notwithstanding that the QPS collected names and addresses as passengers detrained. Some of the names and addresses supplied were invalid when compared with data bases that the QPS has access to.

secondary collision and there was no fire. Although the carriages were hot, the evidence from the emergency services personnel and on-board train staff was that it was hotter outside the CTT than inside the carriages (see 1.3.1).

Finally, the passenger survey revealed that the train manifest was not accurate with respect to every passenger's identity and/or address. There are many reasons why the passenger manifest of any passenger transport operation, be it road, rail or air, needs to be accurate. In particular, in the event of an incident or service delay, there can be the need to contact either the passenger or a nominated contact as a priority.

2.6.4 Response from external agencies

The collision at the Rungoo level crossing occurred just after 1447 on 27 November 2008. A call from a motorist who witnessed the collision to the emergency call service (triple-zero) was passed onto the Cardwell Police Station at 1449. Within four minutes of the collision advice had been passed to QPS (1449) QAS (1449) and QFRS (1450). At 1507 a QFRS fire appliance arrived at the Rungoo level crossing followed at 1508 by a QAS ambulance. Both of these units came from Ingham. At 1510 a police unit from Cardwell also arrived at the Rungoo level crossing. Upon arrival QPS officers assumed the role of 'on-site command'.

Subsequent arrival of emergency services vehicles and personnel from Townsville, Ingham, Halifax, Northern Beaches, Innisfail, Tully, Mission Beach and Cairns continued until a total of five QPS vehicles, eight QFRS fire and rescue vehicles, and 12 QAS units were in attendance. Also, Emergency Management Queensland (EMQ) helicopters were dispatched from Townsville and Cairns. These arrived on site at 1615 and 1620 respectively.

In total, 81 people were assessed and, where necessary, triaged by the QAS. In addition, the QAS provided a paramedic escort on both buses that were used to transport passengers from the crash site to Cairns. The QAS also transported those passengers not wanting to continue their travel north, back to Ingham.

2.6.5 Summary

The PSS and other members of the CTT on-board staff were confronted with a very stressful situation. This is particularly so as they knew the condition of their colleagues (the two train drivers) shortly after the collision. The evidence is that, despite this distress, they performed their duties in accordance with the intent of the QR emergency management procedures and common sense. In addition, the PSS, in electing to accompany the passengers through to their destination of Cairns, arguably went beyond what would normally be expected in such circumstances. The evidence also indicates that the QR emergency management procedures (and, by implication, staff training in these procedures) were adequate for the purposes of managing the emergency response to this accident. The need for train control to be regularly informed of events at a crash site, firstaid treatment by medically qualified persons and the need for an accurate train manifest are considered matters for further consideration by QR.

The first emergency services units from the QFRS, QAS and QPS were at the crash site within 23 minutes of the collision. These units came from Ingham and Cardwell, a distance of about 34 km and 19 km respectively. During the course of proceedings in excess of 37 emergency services personnel and 20 'units' attended the collision site. The timeliness of attendance and the number of resources provided by the QFRS, the QAS, EMQ and QPS is considered to be excellent. In addition, the evidence from a number of sources is that there was close liaison between the QPS on-site command officer, other emergency services personnel and the PSS of the CTT.

2.7 Level Crossings

2.7.1 Overview

There are about 9400 level crossings in Australia, of which 3315 are in Queensland.[71] In essence, level crossings are the physical interface between the road and rail transport systems, both of which operate as entirely separate entities. That is, they have different rules, procedures and characteristics in terms of operational constraints[72] and neither generally has advance knowledge of when the other will be encountered at the road/rail interface. Even at actively controlled crossings, the warning that a train is approaching is mostly given at, and not in advance of, the level crossing to the road user.

Traffic control measures at level crossings comprise two major categories, passive control and active control.

Passive control level crossings control the movement of vehicular or pedestrian traffic using signs and devices (including 'Give Way' or 'Stop' signs), none of which are activated during the approach or passage of a train, to warn road users of an approaching train.

Active control level crossings, control the movement of vehicular or pedestrian traffic using devices such as flashing lights, bells, gates or barriers, or a combination of these in addition to advance warning signage. The devices at the crossing are activated by an approaching train and provide a visual and/or physical warning that a train is approaching.

2.7.2 Acknowledgement of risks

Acknowledgement of the risks posed at level crossings has been heightened by a number of serious collisions across Australia in recent years. A number of these have involved heavy road vehicles and passenger trains, which has increased awareness of the potential that these collisions have for major loss of life. To date,

71 As at June 2009, of the 3315 level crossings in Queensland, there are 1657 private level crossings. The majority of these private level crossings have 'Stop' sign control however some have gates with no signs.

72 Given their relative size and weight, trains cannot brake at anywhere near the rate of even the largest road vehicle.

the starkest example in Australia has been the collision between a passenger train and a loaded semi-trailer at Kerang (in rural Victoria) on 5 June 2007. Eleven passengers were killed and 14 were injured as a result of this collision. In terms of the potential to cause collateral damage, the collision that occurred at Lismore, Victoria, on 25 May 2006 is also noteworthy. In this instance the truck driver died and the damage bill was finally estimated to be in excess of $30 million. This amount is insignificant though in a scenario whereby a passenger train is substituted for the freight train involved in this collision.

Figure 43: ***Aerial photograph of the Lismore crash site.***

Photograph – Warrnambool Standard Pty Ltd, Warrnambool, Victoria 3280. Copyright © 2006.

The collision at the Rungoo level crossing on 27 November 2008, as well as several other recent collisions involving trains and large road vehicles, has highlighted the severity of the unfortunate consequences that can be expected to result to occupants of trains and road vehicles in such instances. Some of these collisions have occurred in situations where a single error by one road user (not detecting the signal at the crossing) was sufficient to result in the collision. Although such collisions are still very rare relative to the total movements of trains and large road vehicles, the potential for significant crashes involving trains (particularly those carrying passengers) in such situations is an issue of obvious concern.

At present there are many endeavours in place to review and improve the current situation regarding the safety of level crossings in Queensland and Australia in general. The following is a broad overview of a few examples.

Funding

In March 2009 the Federal Government announced a $150 million rail crossing improvement program for the upgrading of over 200 level crossings nationally. Of this amount, $42.7 million was allocated for the upgrade of level crossings in Queensland. The Queensland State Government had already allocated $31 million for level crossing upgrades[73], meaning that a total of $73 million will now be spent on the upgrade of level crossings in Queensland.

Of note is that the Bruce Highway (as part of the national Auslink road network and funded by the Federal Government) has been allocated $90 million for an upgrade at the Cardwell Range. This project involves the easing of road curvature and grade of the Bruce Highway for a distance of 4.2 km on the northern side of the Cardwell Range. Included in a broader design of this project was the elimination of the Rungoo level crossing by a road over rail overpass. Confirmation that the project would include a rail overpass at the site of the Rungoo level crossing was received from the then Queensland Government Minister for Main Roads and Local Government shortly after the collision between the CTT and the B-double truck on 27 November 2008.

Education

An educational campaign titled “Some things are worth waiting for” was launched in February 2009. This campaign is a joint QT and QR initiative that focuses on road user behaviour at level crossings and takes the form of television, radio, magazine and newspaper advertisements throughout Queensland. In addition, there are a number of other educational programs being conducted across Australia, some of which are aimed at specific target groups such as school children.

73 About one million dollars of the $31 million was allotted for educational programs.

Level crossing standards

It is apparent that there are many reasons why a road user may not see warning devices such as level crossing advance warning signage or notice the level crossing flashing lights operating.

There are a number of alternate warning measures, be they active or passive, which could be installed on the approach to and/or at level crossings. A number of these measures have been examined and a number have been trialled, some to the extent that they have been included as options in relevant standards. For example, AS 1742.7-2007 was amended to make provision for active advance warning assemblies to be installed to supplement the active protection at level crossings. The active advance warning assembly lights are designed to activate a predetermined number of seconds before the lights activate at the level crossing itself. AS 1742.7- 2007 notes that:

> These assemblies are particularly effective in improving safety on high speed road approaches used by heavy vehicles, such as road trains, and where the required visibility to the flashing lights at the crossing cannot be maintained by normal measures.

Surveillance and enforcement

QR and other operators across Australia regularly receive reports from employees, particularly traincrew, of road users (including pedestrians) failing to adhere to level crossing traffic control requirements.

A successful trial of safety surveillance cameras was conducted in Brisbane in 2008. The reliability and quality of the recordings was such that QR is intending to continue with a pilot implementation program during 2009. These cameras will be placed at selected level crossings where multiple infringements and near misses have been reported with the aim of enforcing road rules applicable to level crossing road traffic and pedestrian control measures.

Similar measures are being considered in a number of other jurisdictions. For example, in Victoria safety surveillance cameras are in place at a number of level crossings and it is intended that, by the end of 2009, road users who ignore level crossing traffic control requirements will be photographed and fined.

House of Representatives Standing Committee

On 22 June 2009 the House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government tabled a report titled *Level Crossing Safety* in the Federal Parliament. This report had evolved from the original 2004 *Train Illumination Inquiry* by the same standing committee. The *Level Crossing Safety* report offers recommendations to improve level crossing safety around Australia and will now be considered by the Federal Parliament.

The recommendations are for the Federal Parliament to consider:

- Consistent penalties across jurisdictions;
- 80 km/h speed limits at level crossings located on roads which currently have higher speed limits;
- Visibility of locomotives;
- Research regarding auxiliary lighting on trains;
- Further trials of passive rumble strips at selected level crossings across the country;
- Trialling of active rumble strips;
- Research into Intelligent Transport Systems;
- Research into the feasibility of a cut-in warning system which would warn motor vehicle drivers of on-coming trains as they approach a level crossing;
- A national database which aggregates data from level crossing crashes and fatalities in all Australian States and Territories; and
- A revised National Railway Safety Strategy as part of the new National Transport Policy.

2.7.3 Systemic level crossing safety issue

It can be seen that significant endeavours to improve level crossing safety are currently underway or proposed across Australia by a variety of committees assigned by various Governments and organisations. These endeavours are looking at risk controls however, (arguably) the approach seems to be finding a solution for the problem when, in many cases, the causes of the problem(s) have not been defined. For example, in three recent major level crossing collisions involving passenger trains at Kerang, Ban Ban Springs and Rungoo, train visibility has not been a factor. Indeed, in the case of actively controlled level crossings, train visibility should never be a factor as the emphasis is not on sighting the approaching train but rather, the level crossing signal light assembly and, if fitted, the boom barriers.

Level crossing crashes are nearly always a result of road user behaviour and while some research has been done in this area, little has been done to link the effectiveness of risk controls and human behaviour. Given the number of level crossings in Australia and the consequent exposure to risk for rail operators and road users, further research on road user behaviour in the context of the effectiveness of current and potential road traffic control measures at level crossings would be of great benefit.

2.8 Additional defences

Factors that had the potential to influence the behaviour of the B-double truck driver have been considered earlier in this report. Additional defences against these risks from a road user or operator's perspective will now be examined.

2.8.1 A 'best practice' transport company

A best practice road transport company is generally regarded as a company that has systems in place that ensure:

- Random and event based drug and alcohol testing;
- Medical examinations;
- Driver rosters;
- Trip schedules;
- Motel type accommodation for longer rest periods; and
- GPS vehicle tracking.

By having measures such as these in place, risks such as driver incapacitation, driver impairment, fatigue and excessive speed can be substantially mitigated.

Best practice road transport companies are also accredited under the National Heavy Vehicle Accredited Scheme (NHVAS) and accredited in accordance with either the Basic Fatigue Management (BFM) or Advanced Fatigue Management (AFM) schemes. Solo drivers working for companies that are BFM accredited are allowed to operate under a flexible work hours option that includes 14 hours work time in any 24 hour period. Solo drivers working for companies that are AFM accredited are also allowed to operate under a flexible work hours option that includes being able to split continuous rest periods and, except in NSW and Victoria, to work to an outer limit of 16 hours in any 24 hour period.

In order to achieve BFM or AFM accreditation, companies have to implement systems that address trip schedules, driver rosters, driver fitness for duty, responsibilities, internal review and records and documentation. In essence, these companies have to demonstrate greater accountability for managing the risks associated with fatigue, driver impairment and the risks that could lead to sudden driver incapacity.

2.8.2 MFT Transport company

MFT Transport is typical of many road transport companies in that it was not accredited under the BFM or AFM fatigue management options. As such MFT were not required to implement the additional measures associated with these accreditations. This means that truck drivers employed by MFT were required to work under the standard hours option that, in essence, allows a maximum of 12 hours work time in any 24 hours.

Unlike rail operations, which have a number of systems and/or recording devices in place that can plan and track the movement of a given train and 'best practice' road operators that have monitoring devices such as GPS vehicle tracking, some road transport operators have little in the way of such oversight. In this instance, the passage of the B-double truck from Acacia Ridge to Cairns and back was planned by the allocation of four and a half days to complete the run. No start or finish times were nominated and the truck driver was to plan the trip in accordance with the statutory requirements in regard to road rules and driving hours and rest was to be taken in the truck cabin sleeping berth.

The log book of the truck driver involved in the collision at Rungoo contained many irregularities. For example, the work time recorded during the previous 24 hour period (1400 Tuesday 25 November until 1400 Wednesday 26 November 2008) was recorded as 15 hours and 15 minutes and some journey segments and rest locations did not correlate. It also needs to be noted that the truck driver had previously had his licence suspended over issues relating to log book irregularities, yet this behaviour was continuing.

MFT Transport ceased operating in early 2009, therefore no recommendations have been directed at this company.

2.8.3 Heavy vehicle monitoring and fatigue

The ability to monitor the passage of heavy vehicles is fundamental to ensuring driving hours and speed limits or average speeds are not exceeded. Given that there are many transport companies that do not have the systems in place that the 'best practice' transport companies have, existing and alternate methods warrant consideration.

Safe-T-Cam's

In NSW and SA Safe-T-Cam's have been in place on designated heavy vehicle routes for over ten years.[74] A Safe-T-Cam is an automated monitoring system that uses digital camera technology to record the front number plate of heavy vehicles. Safe-T-Cam's are intended to identify heavy vehicles that have:

- Travelled at an excessive average speed;
- Travelled beyond the prescribed hours;
- Attempted to avoid detection by Safe-T-Cam devices; and
- Been operated while unregistered.

Since the introduction of Safe-T-Cam's they have achieved success in regard to reducing the instances of irregularities in the above mentioned points.

Intelligent Access Program

The Intelligent Access Program (IAP) is a system that uses the global navigational satellite system to monitor heavy vehicles' road use. The IAP was originally trialled in Tasmania in 1999. This trial demonstrated the feasibility of monitoring the movements of freight vehicles, in particular log trucks in that State. The IAP (at that stage a project rather than a program) commenced when the Tasmanian

74 There are 24 Safe-T-Cams in NSW and 11 in SA.

Department of Infrastructure, Energy and Resources approached other jurisdictions to initiate a national project. A number of jurisdictions joined Tasmania in this project, contributing in-kind and direct funds.

The project then explored the technical, regulatory, functional, privacy and implementation requirements as well as the policy and administrative framework to enable the IAP to work. Transport Certification Australia Limited (TCA) is a public company that was established during this process in order to develop and administer the IAP system.

Within IAP the participating heavy vehicle is monitored using telematics services with an in-vehicle-unit that is supplied by an IAP provider certified by TCA. The in-vehicle unit can be used to monitor the vehicle's identification, position, time, speed and self declaration of information. The IAP has a reporting process that generates a report to the road authority when the vehicle does not adhere to its operating conditions.

The National Transport Commission's *(Model Legislation - Intelligent Access Program) Regulations 2006* provide the legal and privacy framework for the IAP. Jurisdictions will use the model Bill set out in the schedule of these Regulations to develop their own legislation implementing the IAP.

The IAP is a voluntary program. The initial intent of the program was to improve heavy vehicle access to the road network by monitoring route compliance. Improved access to the road network is one of the reasons why a large number of road transport companies have regarded IAP as beneficial. At the release of this investigation report it was reported that nationally, over 100 companies that operate heavy vehicles were doing so under the IAP.

In November 2008 the Australian Transport Council of State, Territory and Commonwealth Ministers responsible for transport (ATC) announced that State Transport Ministers had agreed to develop an Australian performance-based specification for electronic devices to extend the scope of IAP to monitoring issues relating to heavy vehicle speed and driver fatigue. This was to give a practical effect to the enabling provisions contained in the Heavy Vehicle Driver Fatigue Management Reforms which came into effect in a number of States on 29 November 2008. The intention is for TCA to work with the National Transport Commission (NTC) to deliver specifications to the ATC in late 2009.

In Queensland IAP participation became a requirement for Higher Mass Limit (HML) access from 1 July 2009. A HML application allows for a higher tonnage to be carried over a nominated route and can be granted when MR is satisfied with road friendly suspension and road design/engineering considerations.

The investigation into the collision at the Rungoo level crossing has highlighted the importance of accurate vehicle monitoring. The lack of road vehicle monitoring is in stark contrast to the situation of the CTT where monitoring of the train was overseen and recorded by train control and where data and event loggers were used to determine the position of the train to within a second. The reliance on log books that are manually compiled by the truck driver has, in this investigation, been shown to produce unreliable records. In short, the lack of accurate road vehicle monitoring or recording in this instance has raised questions regarding the work hours of the truck driver which in turn has raised questions in regard to fatigue.

Sleeping accommodation

The only instances in Australia where traincrew are required to sleep on the train is when they are participating in relay working. Relay working is where the resting crew are accommodated in an air conditioned, fully equipped relay van that provides accommodation standards equal to paying passengers in terms of sleeping facilities, sound proofing etc. In addition, cooking facilities are provided. This type of working constitutes a small component of total workings across the Australian rail network and is not used at all in Queensland. In all other instances, traincrew rest is taken at motels or company barracks. Air conditioning, noise and light reduction measures are standard and proper eating facilities are provided at or in close proximity to the accommodation.

This situation is in contrast to many road transport companies where rest is undertaken in a sleeping berth in a truck cabin. While some truck sleeping berths have air-conditioning that is powered separately to the main truck engine, many have not. In the case of the truck driver involved in the collision at Rungoo, he was attempting to gain a satisfactory night's sleep in warm to hot and humid conditions. That he was having difficulty in achieving this is evidenced by his statement of having to run the truck engine a couple of times during the night to cool the truck cabin down.

2.8.4 Summary

In terms of safety systems it is apparent that there is a considerable difference between rail operators and road transport companies that are at 'best practice' levels and road transport companies that have yet to reach this level. In regard to the collision at Rungoo on 27 November 2008 the transport operator involved had little in the way of systems that mitigated the risk of inappropriate driver performance, drivers working excess hours and fatigue in general. Of particular note is that as they were accredited for standard hours only (rather than BFM or AFM), there was no requirement to have in place a number of the measures often used by 'best practice' transport companies. In this instance, there was little chance of accurately assessing the truck driver's work hours or whereabouts in the days and hours before the collision.

There are a number of monitoring devices available to road authorities that can assist with compliance monitoring of heavy vehicle road traffic. For some years Safe-T-Cam's have been in place in NSW and SA. It is evident that they have been successful in reducing the instance of non-compliance in terms of heavy vehicle work hours, registration and average speeds but equally, it is apparent that they are being superseded by superior technology. The Intelligent Access Program has considerable potential to further manage factors associated with heavy vehicle speed, route compliance and driver fatigue issues. The Australian Transport Council has recognised this with their decision to consider a draft specification for performance-based electronic devices to monitor all heavy vehicles.

2.9 Post incident testing for illicit substances

2.9.1 Legislative requirements for taking a blood specimen

The (Queensland) *Transport Operations (Road User Management) Act 1995* (TORUM) at section 79(1) creates the offence of driving a motor vehicle, tram, train or vessel while under the influence of alcohol or of a drug. Section 79 also creates offences for driving a motor vehicle, tram, train of vessel with a breath alcohol concentration which exceeds zero (specified vehicles such as trains, and heavy vehicles) and offences for drivers above the general alcohol limit of .05% BAC. Section 70 of the TORUM creates a saliva based drug testing offence on the presence of specific drugs; MDMA (ecstasy), Methamphetamine (ice, speed) and Cannabis (marijuana).

Section 80 of the TORUM Act provides the legislative basis for the procedural operation relating to the taking of blood, breath and saliva specimens to determine whether an offence has been committed. Specifically, subsections 8C and 8D relate to the taking of a specimen of blood from a person who is taken to hospital for treatment following a crash. Those sections state:

(8C) Police officer may require specimen if person at hospital

If a person whom a police officer may require under subsection (2), (2AA) or (2A) to provide a specimen of breath for a breath test, or a specimen of saliva for a saliva test, by the person (an authorising requirement) is at the hospital for treatment, that person may be required by any police officer to provide at the hospital:

(a) if the specimen that may be required under the authorising requirement is a specimen of breath—a specimen of the person's breath for analysis by a breath analysing instrument or a specimen of the person's blood for a laboratory test; or

(b) if the specimen that may be required under the authorising requirement is a specimen of saliva—a specimen of the person's saliva for saliva analysis or a specimen of the person's blood for a laboratory test.

(8D) Limitation applying to requisition under subsection (8C)

A requirement for a person to provide a specimen under subsection (8C) must not be made under the subsection unless:

(a) a doctor who is familiar with the person's injuries and apparent state of health at the time of the requirement approves of the person providing the specimen; and

(b) the requirement is made as soon as practicable and:

(i) if the specimen that may be required under the authorising requirement is a specimen of breath—within 2 hours of the event that authorises the police officer to make the authorising requirement; or

(ii) if the specimen that may be required under the authorising requirement is a specimen of saliva—within 3 hours of the event that authorises the police officer to make the authorising requirement.

Meaning of sections 80(8C) and 80(8D)

80(8C) The section sets up the ability for a member of the QPS to make a requirement (an authorising requirement) that the person provides a specimen of blood in the circumstances where that person is at a hospital for treatment and the police would in normal circumstances be able to require the taking of a specimen of breath or saliva at the roadside.

80(8D) This section creates limitations on the police to make a requirement for the taking of a specimen of blood from a person who is at a hospital for treatment as a result of an incident. The limitations provided are twofold. Firstly, a doctor who is familiar with the person's injuries and state of health must approve the taking of the specimen. Secondly, the requirement made before the taking of the specimen (for the purposes of alcohol testing) must be made within 2 hours of the incident that provided the authorisation for the police officer to make the requirement.

2.9.2 Rungoo collision

The B-double truck driver was tested for the presence of alcohol on site with a negative result. He was not tested for the presence of illicit substances because there were no indicators of driver impairment readily apparent to QPS officers and the QPS officers were not trained in the use of, and were therefore not in possession of, a drug test kit.

In this instance, the truck driver was air-lifted from the crash site at about 1730 and arrived at the Cairns Base Hospital at 1815. This is about 3.5 hours after the collision which would have rendered the blood tests inadmissible in a prosecution. However, the crash site was not remote and, as evidenced by the 1730 departure of the helicopter from the site, the injuries to the truck driver were not such that transportation to a hospital was an immediate requirement. It is therefore reasonable to assume that had a test for illicit drugs been carried out and had a positive result been returned, then transportation to Ingham (twenty minutes at the most) would have been arranged as a priority for the taking of a blood sample.

2.9.3 Testing for illicit drugs, road and/or rail crashes

Setting aside the medical issues that can preclude blood samples being taken, there are three impediments to testing for illicit drugs after road and/or rail crashes in Queensland:

(a) Testing of a motor vehicle driver or a traincrew member for illicit drugs is not mandatory even when following a major crash such as that which occurred at Rungoo. If the QPS officers do not have reasonable suspicion then they are unable to conduct such testing as the taking of the specimen may well have constituted an offence of unlawful assault by the police officer (and indeed the doctor, if involved) in making the requirement and performing the test.

(b) The remote locations of some crash sites can make the existing time limitations of two hours for alcohol and three hours for drug testing as prescribed by section 80(8D)(b)(i and ii) difficult to achieve. This can be particularly so in circumstances where the person from whom the blood specimen is to be taken has to be transported long distances and/or the period of time required to extract the person from a vehicle if an entrapment has occurred may mean that the person does not reach hospital within the time-frames. It is noted that the Victorian *Road Safety Act 1986* allows three hours between when the person last drove a motor vehicle and the assessment for alcohol and/or illicit drugs.

(c) Not all QPS officers are trained in the use of the drug test kit. The particular officers who attended this crash had not been trained and were not qualified to administer the test.

It is noted that the provisions for alcohol and drug testing, either random or event based, vary considerably across the States and Territories of Australia. For example, in SA from 1 July 2008 all motor vehicle drivers and riders who present at hospital, either for attendance or admittance as a result of a road crash are required to have a blood sample taken for an alcohol and illicit drug test. If a positive result is returned, they will be penalised accordingly. In Victoria though, reasonable suspicion of impairment due to drugs is required. It is also recommended that the person so suspected be filmed before the blood test is undertaken for additional proof of suspicion.

3 Conclusions

3.1 Context

At about 1447 on Thursday 27 November 2008 a loaded B-double truck drove into the path of the northbound Cairns Tilt Train (train VCQ5) at the Rungoo level crossing near Ingham in North Queensland. As a result of the ensuing collision the two train drivers were fatally injured.

Based on the available evidence, the following findings are made with respect to the collision but should not be read as apportioning blame or liability to any particular individual or organisation.

3.2 Findings

1. Train VCQ5 had no faults or defects that contributed to the collision.
2. The B-double truck had no faults or defects that contributed to the collision.
3. Train VCQ5 was in possession of a safeworking authority that authorised the passage of the train over the Rungoo level crossing.
4. The train drivers were appropriately qualified and held current competencies applicable to the operation of the train VCQ5 and the section of track between Townsville and Cairns.
5. Both train drivers were classed as medically fit for duty in accordance with the *National Standard for Health Assessment of Rail Safety Workers*.
6. The complete rostered and actual working hours of the two train drivers of train VCQ5 was within the limits of QR's safety management system.
7. Both train drivers had a good work history.
8. All five on-board staff of train VCQ5 held appropriate qualifications pertaining to their respective duties.
9. The B-double truck driver held a current MC(0) class heavy vehicle licence.
10. The B-double truck driver had no visual impairments that could have contributed to the collision.
11. The B-double truck driver, by the entries in his log book, had worked 15 hours and 15 minutes in the 24 hour period until 1400 on Wednesday 26 November 2008. The amount of work performed in the subsequent (approximate) 24 hour period up until the collision could not be confirmed.
12. At the time of the collision it is possible that the truck driver may have been experiencing a degree of fatigue which could have affected his performance.

13. The B-double truck driver had a poor driving history in terms of licence suspension due to an accumulation of demerit points for speeding and log book irregularities.

14. The Rungoo level crossing was essentially compliant with the relevant standards with respect to advance warning signs, road pavement markings and position of the flashing light level crossing signal assemblies.

15. The level crossing signal assembly and the signal lamps were aimed in accordance with the applicable specifications.

16. The first sighting of the level crossing signal assembly was measured at 385 m from the level crossing. There were no road-side impairments that hindered or obstructed the sighting of the level crossing advance warning devices or the level crossing signal assembly.

17. The spread of light emitted by the flashing light signals encompassed the entire northern approach to the Rungoo level crossing from the first sighting of the level crossing signal assembly.

18. Environmental conditions at the time of the collision were such that they did not impede the sighting of the advance warning signs or the level crossing signal assembly.

19. The level crossing flashing light signals operated as designed (for 26 seconds) before the collision.

20. Witnesses in the vehicle immediately behind the B-double truck said they saw the flashing light signals operating and that they were clearly visible before the collision.

21. Foliage to the north-east of the level crossing impedes the sighting of road movements from the north for a train approaching from the south-east. Similarly, this foliage impedes the sighting of a train approaching from the south-east for a road user approaching from the north.

22. On the approach to the Rungoo level crossing train VCQ5 was being operated in accordance with the applicable rules and procedures with respect to train speed, operation of the headlight and the sounding of the train horn.

23. The B-double truck was approaching the level crossing within the maximum speed limit of 100 km/h at an estimated 90 km/h. The truck driver said he did not see the advance warning signs and road markings. The truck driver did say he saw the level crossing flashing light signal assemblies but the flashing lights were not working.

24. The B-double truck driver braked heavily for about 21 m before the level crossing and then applied power. Calculations are that, if the road speed before braking was 90 km/h that this should have been reduced to about 75 km/h at impact.

25. The train driver initiated an emergency brake application within two seconds before impact. The train driver could do nothing else to avoid or minimise the effects of the collision.

26. The driver's cabin of the Cairns Tilt Train lozenged during the collision sequence thereby reducing the amount of survivable space within the driver's cabin.

27. Australian and international rollingstock standards do not take into account high levels of lateral loading in their crashworthiness requirements.

28. The Cairns Tilt Train was constructed in accordance with the QR crashworthiness requirements of the applicable standard of 1999, (STD 57).

29. The QR crashworthiness standards used in the construction of the Cairns Tilt Train were consistent with European and American Standards for crashworthiness of the time.

30. Not all of the aspirational specifications contained in MRE 9809 (Section 11: *Body Structure and Body Mounted Components*) were fully confirmed as being incorporated in the design of the Cairns Tilt Train driver's cabin.

31. The Finite Element Analysis (FEA) work for the Cairns Tilt Train driver's cabin was validated by strain gauge testing of the prototype cab to the load cases required by STD 57. High stress levels indicated by the FEA were proven when the structure was loaded to the STD 57 requirements. The structure was redesigned, rebuilt and strengthened. The redesigned structure did have an FEA re-analysis but no reloading of the structure was then conducted.

32. It is likely that even if the Cairns Tilt Train driver's cabin had been fully compliant with all the aspirational requirements of MRE 9809, that the survivable space would not have been significantly greater.

33. It was unlikely that a train driver's cabin built to a modern crashworthy standard, if subjected to the forces involved in the collision at Rungoo, would have resulted in significantly greater survivable space.

34. The independent consultant engaged by the investigation has determined that practical measures could be employed to incrementally improve the structural integrity of the Cairns Tilt Train cab structure.

35. The emergency response measures enacted by the on-board staff of train VCQ5 for ensuring the welfare of the passengers were in accordance with QR policy and of a very high calibre.

36. The emergency response measures enacted by the emergency services personnel were effective with respect to timely attendance and the resources provided.

37. The initial notification of the collision to the Townsville Network Train Control Centre was timely. Subsequent updates from the accident scene to the Townsville Network Train Control Centre were intermittent.

38. An offer of assistance to the train drivers in the minutes following the collision by a medically qualified passenger was declined due to the application of QR policy.

39. The passenger manifest of train VCQ5 did not contain all the contact telephone numbers or addresses of the passengers.

40. There is considerable difference in terms of vehicle monitoring and driver fatigue management between best practice road and rail operations and those used by many road transport companies. From the data recorders on the CTT the investigation team was able to reconstruct the seconds leading up to the collision. The B-double truck had no such equipment fitted.

41. Systems to monitor heavy vehicle compliance (for example, the Intelligent Access Program) over a range of safety and efficiency related parameters including vehicle speed and driver fatigue should be investigated.

42. The truck driver's failure to stop at the level crossing could be attributed to:

    - a failure to detect the flashing lights due to a number of reasons including inattentional blindness, expectancy and fatigue; or

    - a low expectancy that the flashing lights provided a reliable indication of the presence of an approaching train given his previous experience of never having seen a train at the Rungoo level crossing and the continuous operation of the flashing lights at the Conn level crossing.

43. More research into the effectiveness of level crossing road traffic control and protection measures with respect to their effectiveness in influencing driver behaviour is needed.

44. Setting aside the medical issues that can preclude blood samples being taken, testing for alcohol or illicit drugs after road and/or rail crashes is not mandatory in Queensland. Differences in regard to the manner and extent of testing for illicit drugs apply between different State and Territory jurisdictions.

3.3 Contributing factor

1. The driver of the B-double truck failed to stop at the level crossing before the arrival of train VCQ5.

4 Safety actions

The safety issues identified during this investigation are listed in the Findings and Contributing factors sections of this report. Queensland Department of Transport and Main Roads (DTMR) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s).

All of the responsible organisations for the safety issues identified during this investigation were given the opportunity to review the draft report and invited to provide comment. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or proposed in relation to each safety issue, relevant to their organisation.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the rail industry, DTMR may issue safety recommendations or safety advisory notices as part of the final report.

4.1 Australian Transport Council

Safety issue

Systems to monitor heavy vehicle compliance (for example, the Intelligent Access Program) over a range of safety and efficiency related parameters including vehicle speed and driver fatigue should be investigated.

Finding 41

Recommendation already underway

That the Australian Transport Council continue to investigate options aimed at expanding the Intelligent Access Program (or alternate programs) that will enable issues relating to heavy vehicle speed and driver fatigue to be better monitored and enforced.

Safety issue

More research into the effectiveness of level crossing road traffic control and protection measures with respect to their effectiveness in influencing driver behaviour is needed.

Finding 43

Recommendation already underway

That the Australian Transport Council continue to monitor/oversee research underway by the Rail Cooperative Research Centre pertaining to understanding and improving road user behaviour at level crossings.

4.2 Queensland Department of Transport and Main Roads

Safety issue

There is considerable difference in terms of vehicle monitoring and driver fatigue management between best practice road and rail operations and those used by many road transport companies. From the data recorders on the CTT the investigation team was able to reconstruct the seconds leading up to the collision. The B-double truck had no such equipment fitted.

Finding 40

Recommended safety action

That DTMR consider the differences in terms of the safety and monitoring systems required for road transport companies compared to rail operators.

Safety issue

Setting aside the medical issues that can preclude blood samples being taken, testing for alcohol and illicit drugs after road and/or rail crashes is not mandatory in Queensland. Differences in regard to the manner and extent of testing for illicit drugs apply between different State and Territory jurisdictions.

Finding 44

Recommended safety action

To determine if drugs or alcohol consumed by a driver contribute to a crash at a level crossing or alternatively, all serious injury and fatal crashes, it is recommended that DTMR give consideration to:

- Reviewing the period of time available for a police officer to make a requirement for the taking of a specimen of blood for an alcohol and/or drug analysis from a person at a hospital for treatment.
- Mandating the provision of a blood specimen when a person is attending or admitted to a hospital for treatment as a result of a road and/or rail crash.
- Mandate that a blood specimen to be taken from the drivers of all vehicles involved in fatal or serious crashes, whether that driver is injured or not.

4.3 Rail Industry Safety and Standards Board

Safety issue

Australian locomotive crashworthiness standards do not take into account high levels of lateral loading.

Finding 27

Recommended safety action

The Rail Industry Safety and Standards Board progress the issue of locomotive crashworthiness standards that take account of high levels of lateral loading.

4.4 QR Passenger Pty Ltd

Safety issue

The independent consultant engaged by the investigation has determined that practical measures could be employed to incrementally improve the structural integrity of the Cairns Tilt Train cab structure.

Finding 34

Recommendation already underway

QR Passenger Pty Ltd has engaged consulting engineers to examine ways in which the structure of the driver's cabin of the Cairns Tilt Train can be practically improved.

Safety issue

The initial notification of the collision to the Townsville Network Train Control Centre was timely. Subsequent updates from the crash scene to the Townsville Network Train Control Centre were intermittent.

Finding 37

Recommended safety action

That QR Passenger Pty Ltd reinforce the need for their personnel at a crash site to keep the relevant train control centre regularly informed of events at the site.

Safety issue

An offer of assistance to the train drivers in the minutes following the collision by a medically qualified passenger was declined due to the application of QR policy.

Finding 38

Recommended safety action

That QR Passenger Pty Ltd considers the circumstances in which an offer of assistance from a medically qualified member of the public may be appropriate.

Safety issue

The passenger manifest of train VCQ5 did not contain all the contact telephone numbers nor addresses of the passengers.

Finding 39

Recommended safety action

That QR Passenger takes action to ensure, as far as possible, passenger train manifests are accurate in terms of names, addresses and contact telephone numbers.

Appendix A: Sources and submissions

Sources of information

- Australian Transport Council.
- Bureau of Meteorology.
- Driver of the B-double truck.
- EDI/Walkers Pty Ltd.
- MFT Transport Pty Ltd.
- National Transport Commission.
- On-board staff of the Cairns Tilt Train.
- Passengers on the Cairns Tilt Train.
- Rail Cooperative Research Centre.
- QR Limited.
- Queensland Ambulance Service.
- Queensland Fire & Rescue Service.
- Queensland Police Service.
- Queensland Transport.
- Transport Certification Australia Limited.
- Witnesses to the collision.

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- 49CFR238 *Passenger Equipment Safety Standards*.

Appendix B: Technical analysis report

Train Management System

Both power cars in train VCQ5 had an EKE-Electronics Ltd train management system (TMS) installed. One function of the TMS is to record train data. The train data is recorded on the Data Card part number GSR1249A contained within the TMS Coach Computer. A fault log is recorded on CPU Card part number CPU1306A contained within the TMS Coach Computer.

Power Car DTD5402

Power car DTD5402 contained Data Card part number GSR1249A serial number 039997.

Data from 1430 to 1450 on 27 November 2008 was downloaded using Portable System Tester (PST) software version 2.28.

The data being downloaded from the TMS is shown in figure 44 below.

Figure 44: *TMS data downloading on power car DTD5402*

File '5402_2009_11_28_1740.TDR' was created during the download process from GSR1249A card serial number 039997.

Power car DTD5402 contained CPU Card part number CPU1306A serial 039756. The fault log was viewed and stored as image file '5402-27112008.bmp'.

Power Car DTD5403

Power car DTD5403 was damaged to an extent that it could not be used to download the data from the TMS. Data Card part number GSR1249A serial number 037831 and CPU Card part number CPU1306A serial number 042469 were removed from power car DTD5403.

The Data Card and the CPU Card from power car DTD5403 were installed into the TMS in power car DTD5402 to enable downloading.

Data from 1430 to 1450 on 27 November 2008 was downloaded using PST software version 2.28.

File '5403_2009_11_28_1726.TDR' was created during the download process from GSR1249A card serial number 037831.

The fault log was viewed and stored as image files '5403-27112008-1.bmp' and '5403-27112008-2.bmp'.

Automatic Train Protection System

QR provided the following files downloaded from the Automatic Train Protection (ATP) system:

- 5403 VCQ5 Accident Download - 09-01-09c$$.RAW.
- 5403 VCQ5 Accident Download - 09-01-09f$$.RAW.
- 5403 VCQ5 Accident Download - 09-01-09o$$.RAW.

QR also provided the following ATP data file in Microsoft Excel format:

- 5403 VCQ5 Accident Download - 09-01-09-EZI.xls.

Locomotive recorded data analysis

Analysis software

Train management system

Train Inspection Program (TIP) software version 1.20 was used to export the data into a comma separated variable (csv) file.

Microsoft Excel was used to convert the csv file exported from the TIP software to a file that was compatible with Insight Analysis software.

The Insight Analysis software compatible file was imported into Insight Analysis software.

Insight Analysis software was used for analysis of the data.

Automatic Train Protection System

Microsoft Excel was used to convert the ATP file '5403 VCQ5 Accident Download - 09-01-09-EZI.xls' to a file that was compatible with Insight Analysis software.

The Insight Analysis software compatible file was imported into Insight Analysis software.

Insight Analysis software was used for analysis of the data.

Time Correlation

Power car DTD5403 TMS time will be used as the standard time reference in this report. Train speed was used to correlate DTD5402 TMS time and DTD5403 ATP time to DTD5403 TMS time.

Power Car DTD5402 TMS Time

Six seconds must be subtracted from power car DTD5402 TMS time to correlate with power car DTD5403 TMS time.

Power Car DTD5403 ATP Time

Ninety seconds must be added to power car DTD5403 ATP time to correlate with power car DTD5403 TMS time.

Time Of Collision

Power car DTD5403 TMS

A TMS 'ID Block' data is recorded at start up, when the Wired Train Bus (WTB) topology is changed, when the train number is set, when the active cab is changed, at 00:00 and 12:00. Power car DTD5403 recorded 'ID Block' data at 1447:13 and twice at 1447:16.

A TMS 'Analog 1 Block' data is recorded once per second when the TMS is operating correctly. Power car DTD5403 TMS did not record 'Analog 1 Block' data at 1447:15, 1447:16 and 1447:17.

At 1447:14 power car DTD5403 TMS recorded the speed as 54 km/h, a reduction of 3 km/h from the previous second.

Power car DTD5403 ATP

At 1447:14 the ATP recorded a logging message and 3 fault messages.

Time of collision conclusion

The TMS 'ID Block' data recorded on power car DTD5403 at 1447:13 is the first indication recorded in the data of a collision. The time of collision was likely 1447:13. In this report 1447:13 will be used as the time of collision.

Speed

TMS Speed Recording

Three separate speed sources in the train are used to display and record the train speed. These 3 sources are:

- Car A tacho generator A.
- Car A tacho generator B.
- Brake Control Unit (BCU) reference speed.

Speed from Car A tacho generator A and B are calculated separately. The higher tacho speed is stored in parameter 'TachoSpeed'.

The BCU reference speed is recorded in parameter 'WspRefSpeed'.

Car A tacho speed is displayed and recorded as the train speed when Car A tacho speed is considered valid.

Car A tacho speed is considered valid when its value is greater than 90 percent of the local BCU reference speed.

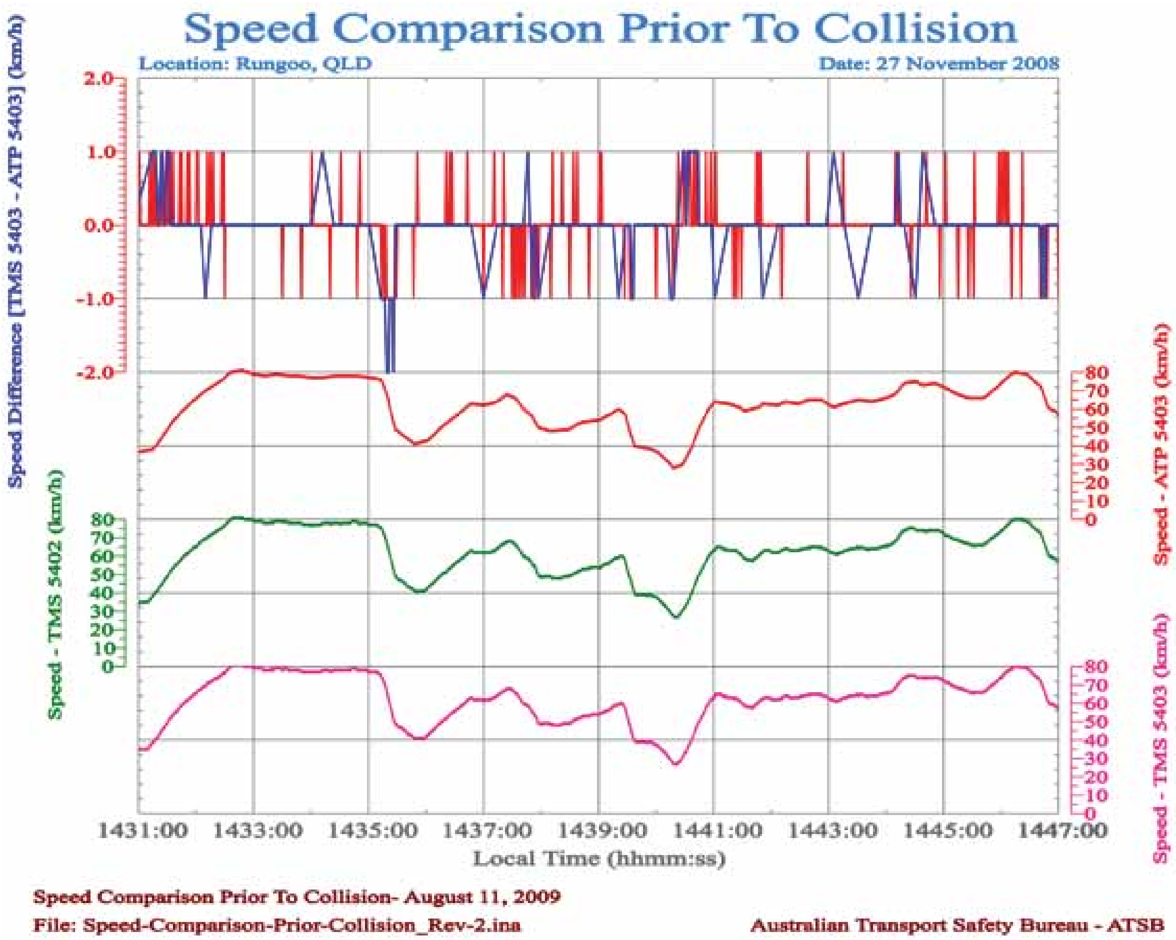
When Car A tacho speed is not valid the BCU reference speed is displayed and recorded as the train speed.

Train Speed Correlation Prior To Collision

The train speed recorded by power car DTD5402 TMS and power car DTD5403 ATP was compared to power car DTD5403 TMS.

In the 16 minute period 1431:00 to 1447:00 the maximum train speed difference was 2 km/h as shown in figure 45.

Figure 45: *Train speed correlation prior to collision*

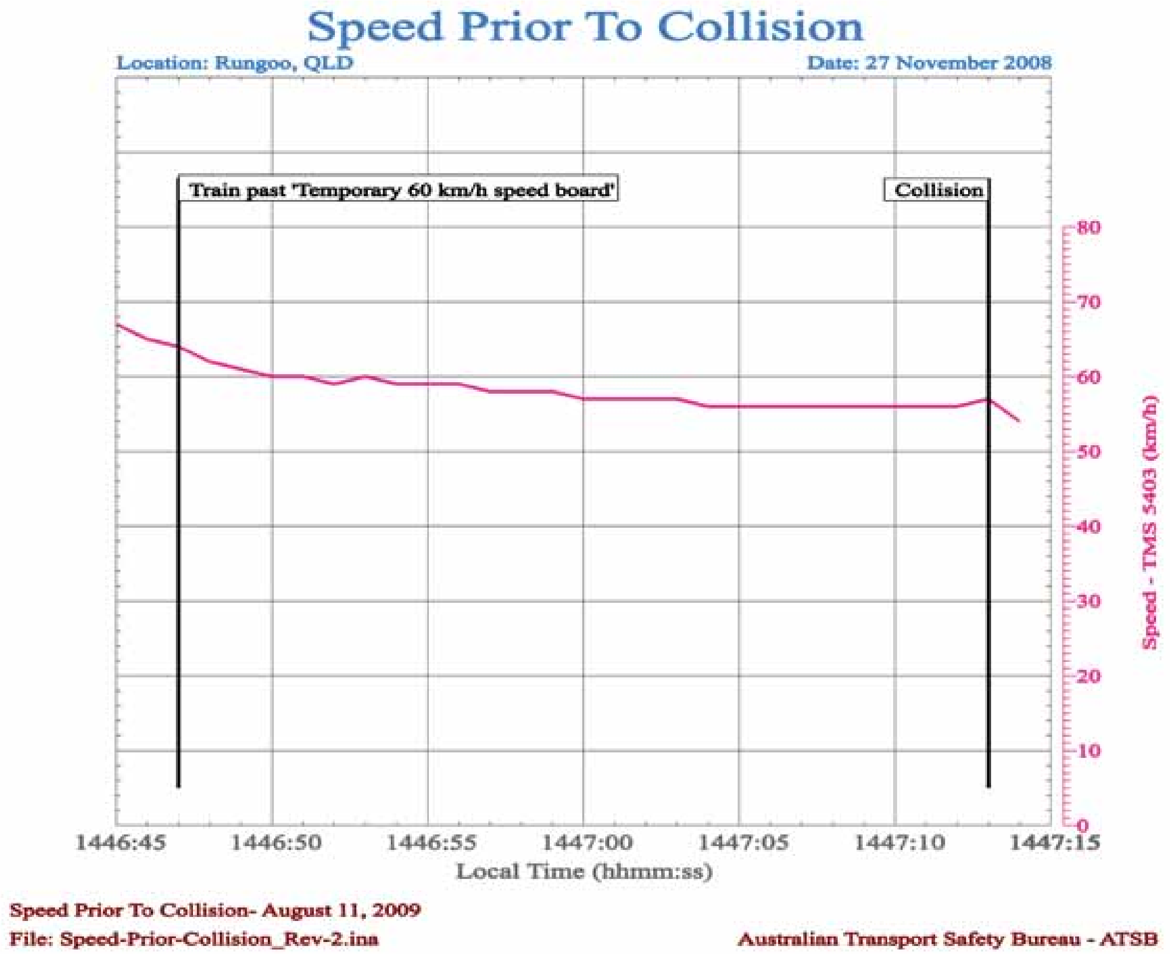


The train speed recorded by power car DTD5403 TMS, power car DTD5402 TMS and power car DTD5403 ATP closely correlate prior to the collision. This close correlation indicates the speed recorded by power DTD5403 TMS was recorded correctly prior to the collision.

Speed Prior To Collision

The last train speed recorded by power car DTD5403 TMS was at 1447:14 which was one second after the time of the collision. The train speed prior to the collision is shown in figure 46.

Figure 46: *Speed prior to collision*



Speed After Collision

The last speed recorded by power car DTD5403 ATP was at 1447:13 which was the time of the collision. Power car DTD5403 ATP did not record any speed data after the collision.

After the collision the measured tacho speed would be closer to the true speed than the BCU reference speed. The tacho speed recorded by both power cars are shown in the following figure. The individual data points are marked with a diamond on the trace in figure 47.

Figure 47: *Speed after collision*

Speed conclusion

Prior to the collision the train speed recorded by power car DTD5403 TMS will be used as the speed of the train.

After the collision power car DTD5403 recorded a tacho speed of 54 km/h at 1447:14. The next tacho speed recorded by power car DTD5403 was four seconds later at 1447:18 was 0 km/h. It is likely that power car DTD5403 was still moving at 1447:18.

After the collision the tacho speed recorded by power car DTD5402 TMS will be used as the speed of the train.

After the collision the true speed of power car DTD5403 may be different to the tacho speed recorded by power car DTD5402 TMS.

At 1446:47 the train passed the temporary 60 km/h speed board while braking at 64 km/h. Three seconds later the train speed was 60 km/h. At 1447:13 the train speed was 57 km/h when the train collided with the truck. At 1447:26, thirteen seconds after the collision, the trailing power car came to a stop.

Headlight

Power car DTD5403 TMS

Power car DTD5403 TMS recorded the headlight as ON from 1429:30 to 1447:13 when the headlight was recorded as ON then OFF.

Power car DTD5402 TMS

Power car DTD5402 TMS recorded the headlight as ON from 1429:30 to 1447:14 when the headlight was recorded as OFF.

Power car DTD5403 ATP

The ATP system does not record headlight.

Headlight conclusion

Power car DTD5403 headlight was ON from 1429:30 until the time of the collision at 1447:13.

Horn

Power car DTD5403 TMS

On approach to the level crossing power car DTD5403 TMS recorded the country horn as follows.

- 1447:05 On.
- 1447:06 Off then On.
- 1447:07 Off.
- 1447:09 On.
- 1447:12 Off.
- 1447:13 On then Off.

Power car DTD5402 TMS

On approach to the level crossing power car DTD5402 TMS recorded the country horn as follows.

- 1447:05 On.
- 1447:06 Off.
- 1447:07 On.
- 1447:08 Off.
- 1447:09 On.
- 1447:13 Off.

Power car DTD5403 ATP

The ATP system records both the town and country horn as a single parameter horn. QR stated that the horn must be On or Off for more than 1 second for the event to be recorded.

On approach to the level crossing power car DTD5403 ATP recorded the horn as follows.

- 1447:07 On.

Horn conclusion

The country horn signal recorded by power cars DTD5402 and DTD5403 TMS both have the ON/OFF sequence. The country horn signal recorded by power car DTD5402 TMS has a maximum propagation delay of 650mS compared to power car DTD5403 TMS. The timing of the country horn signal recorded by power car DTD5403 TMS is more accurate than the country horn signal recorded by power car DTD5402 TMS.

The country horn signal recorded by power cars DTD5402 and DTD5403 TMS varies from power car DTD5403 ATP horn signal. The ATP system did not record the short duration (less than 1 second) changes in the horn signal.

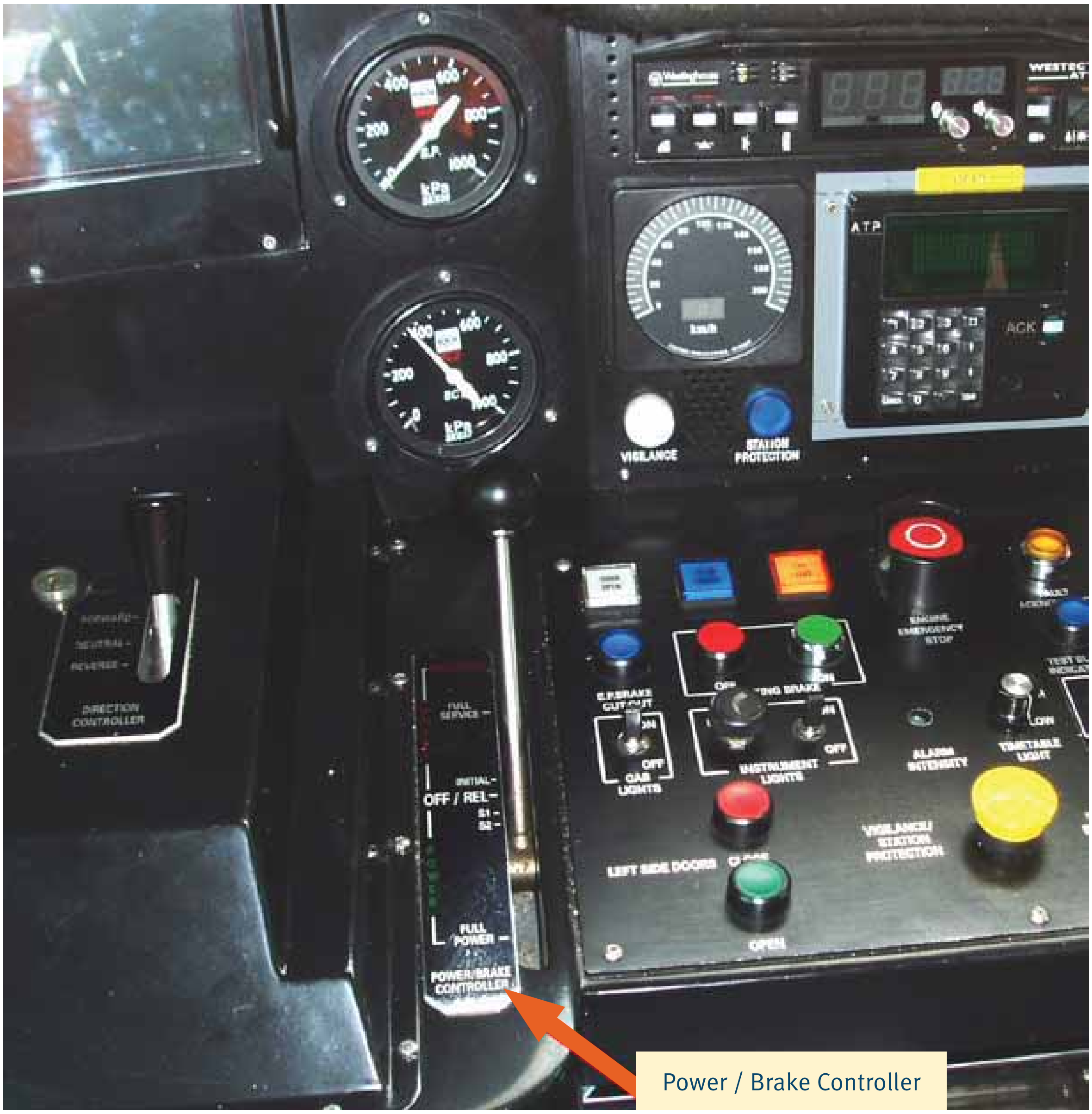
The country horn signal recorded by power car DTD5403 TMS will be used as the country horn signal of the train in this report.

Power/Brake Controller

Power/Brake Controller Operation

The Power/Brake Controller is the train driver's main control for regulating the speed of the train. The Power/Brake Controller handle is moved towards the driver to increase locomotive power. The Power/Brake Controller handle is moved away from the driver to increase brake. The Power/Brake Controller is shown in figure 48.

Figure 48: *Power/Brake Controller*



Power/Brake Controller handle position recording

The TMS records the following parameters related to Power/Brake Controller:

- HBrakeDemand (0-100 percent).
- PowerMotoring (True or False).
- PowerBraking (True or False).

The PowerMotoring and PowerBraking discretes are used to determine if the Power/Brake Controller handle is in the 'Off/Rel' centre position, power or braking. The coding of the PowerMotoring and PowerBraking discretes are shown in table 8.

Table 8: *Power/Brake Controller Position Coding*

Power/Brake Controller Position	PowerMotoring	PowerBraking
Brake	False	False
Power	True	True
Off/Rel	True	False
Off/Rel	False	True

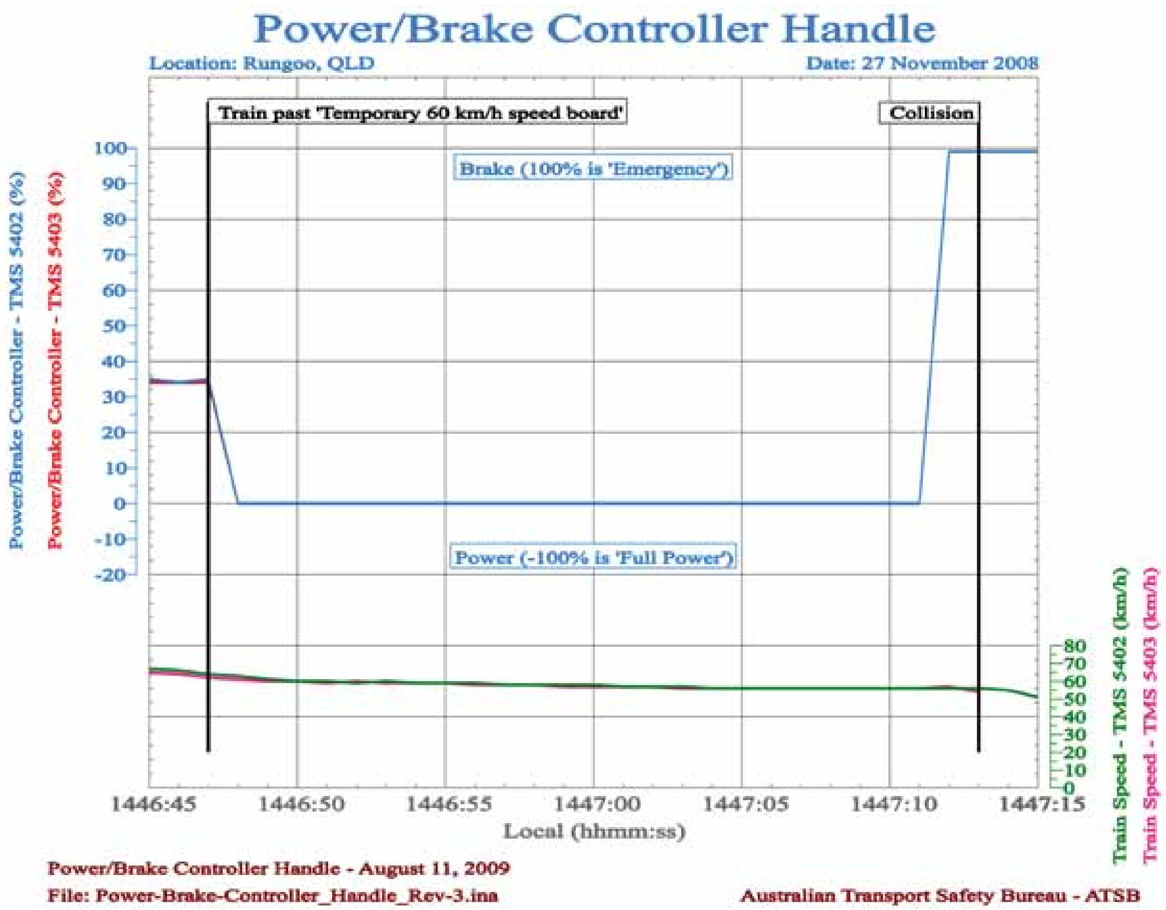
Parameter HBrakeDemand records the amount of demanded power or braking, 0-100 percent. HBrakeDemand value of 0 percent is no power or braking demanded. HBrakeDemand value of 100 percent is full power or emergency braking demanded.

Parameters PowerMotoring, PowerBraking and HBrakeDemand can be combined into a single parameter Power/Brake Controller handle position.

Power/Brake Controller handle position prior to collision

The Power/Brake Controller handle position prior to the collision is shown in figure 49 below.

Figure 49: *Power/Brake Controller handle position prior to collision*



The Power/Brake Controller handle position recorded by power car DTD 5403 TMS and power car DTD5402 TMS closely correlate prior to the collision.

Power/Brake Controller handle position conclusion

The Power/Brake Controller handle position recorded by power car DTD 5403 TMS will be used as the Power/Brake Controller handle position in this report.

At 1446:41 the Power/Brake Controller handle position was reduced to 34 percent braking. Six seconds later at 1446:47 the train passed the temporary 60 km/h speed board with the Power/Brake Controller handle position still at 34 percent braking. One second later at 1446:48 the Power/Brake Controller handle position was reduced to the 'Off/Rel' position (centre position). At 1447:12 one second before the collision the Power/Brake Controller handle position was increased to 99 percent braking (Emergency braking position).

Train Braking

ATP Braking Information

The following braking information was entered into the ATP system on 27/11/2008 at 1158:39.

- SB Brake Delay = 3.5 seconds.
- EB Brake Delay = 4.3 seconds.
- SB Deceleration Rate = 1.11 m/s2.
- EB Deceleration Rate = 1.32 m/s2.

Train braking recording

The TMS records the following parameters related to train braking every second:

- Brake Pipe Pressure P1.
- Brake Pipe Pressure P2.
- Brake Cylinder Pressure P1.
- Brake Cylinder Pressure P2.
- Brake Cylinder Pressure A.
- Brake Cylinder Pressure G.

The TMS records the following parameters related to train braking every three seconds:

- Master Reservoir Pressure P1.
- Master Reservoir Pressure P2.
- Brake Cylinder Pressure from all cars.

Train braking prior to collision

The train braking prior to the collision is shown in figure 50.

Figure 50: *Train braking prior to collision*

Train braking conclusion

The brake pressures recorded by power car DTD5403 TMS will be used as the brake pressures in this report.

After 1446:48 the brake pressures respond to the Power/Brake Controller handle position being reduced to the 'Off/Rel' position (centre position). At the time of the collision 1447:13 the brake pressures had just started to respond to the Power/Brake Controller handle position being increased to 99 percent braking (Emergency braking position) at 1447:12.

Train management system fault log analysis

Power car DTD5403 TMS Fault Log

The TMS fault log recorded on power car DTD5403 from 1430 to 1450 is shown in figure 51.

Figure 51: ***Power car DTD5403 Fault Log from 1430 to 1450***

Ready to download.

○ Download All unread events

◉ Download all events by date and time

Starts: Date 27/11/2008 Time 14:30:00

Ends: Date 27/11/2008 Time 14:50:00

Download | Erase log and clear OC counters | Abort

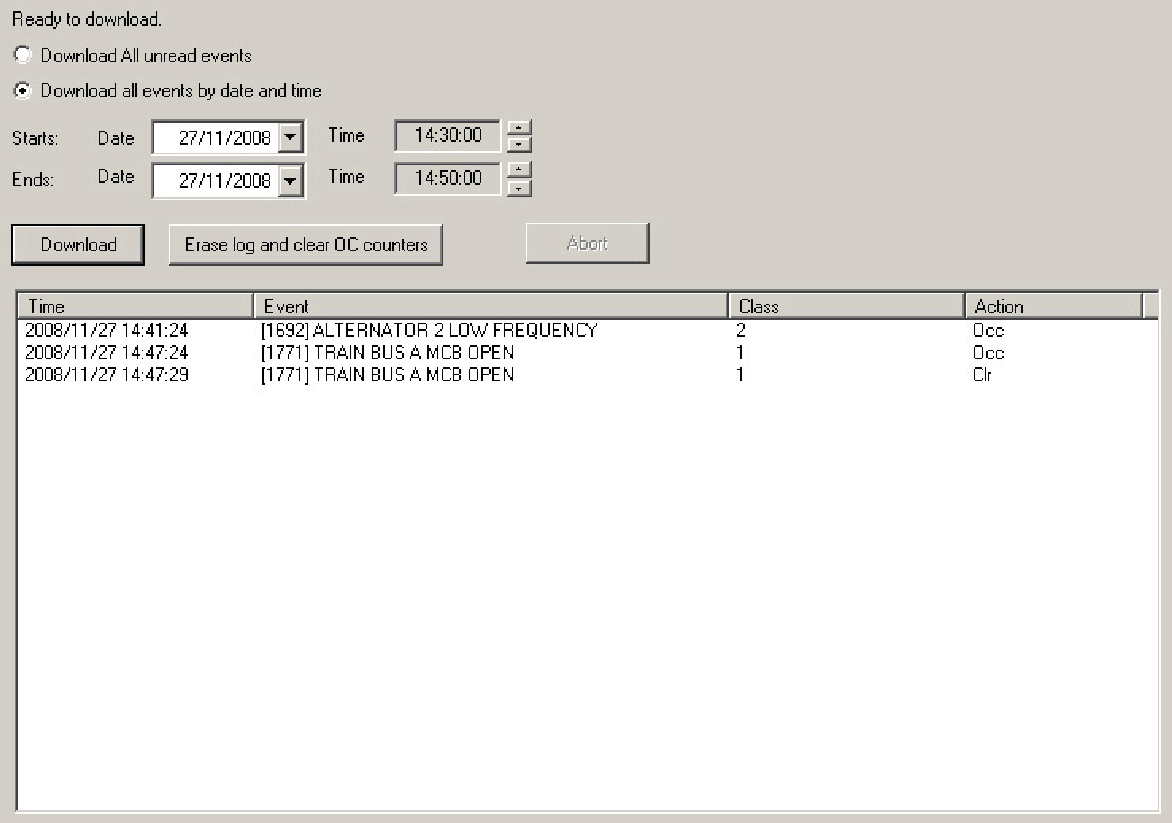
Time	Event	Class	Action
2008/11/27 14:47:16	[1911] LEFT TAIL LIGHT FAULT	1	Occ
2008/11/27 14:47:16	[1860] AC LOCKER CB TRIP	3	Occ
2008/11/27 14:47:16	[1912] RIGHT TAIL LIGHT FAULT	1	Occ
2008/11/27 14:47:16	[2710] A/C SUPPLY FAN TRIP	1	Occ
2008/11/27 14:47:16	[2730] A/C HEATER CB TRIP	1	Occ
2008/11/27 14:47:16	[2700] A/C COMPRESSOR TRIP	1	Occ
2008/11/27 14:47:17	[2091] DOOR A FORCED OPEN	2	Occ
2008/11/27 14:47:17	[1380] VIGILANCE/STN PROTECTION SYSTEM ISOLATED	3	Occ
2008/11/27 14:47:17	[1890] BATTERY BOX CB TRIP	1	Occ
2008/11/27 14:47:17	[1810] HIENZMAN CONTROL CB TRIP	1	Occ
2008/11/27 14:47:19	[2821] FIRE WARNING - ENGINE ROOM 1	2	Occ
2008/11/27 14:47:21	[4008] DIO MODULE 8 FAULT	1	Occ
2008/11/27 14:47:23	[1321] AXLE 1 SPEED SENSOR	1	Occ
2008/11/27 14:47:23	[351] ENGINE 1 LO P-LUBE OIL	3	Occ
2008/11/27 14:47:23	[411] ENGINE 1 SS SECURITY SHUTDOWN	3	Occ
2008/11/27 14:47:23	[861] ENGINE 1 SECURITY CHANNEL	3	Occ
2008/11/27 14:47:23	[931] ENGINE 1 SS P-LUBE OIL	1	Occ
2008/11/27 14:47:23	[1323] AXLE 3 SPEED SENSOR	1	Occ
2008/11/27 14:47:27	[4005] DIO MODULE 5 FAULT	1	Occ
2008/11/27 14:47:27	[4006] DIO MODULE 6 FAULT	1	Occ
2008/11/27 14:47:27	[4007] DIO MODULE 7 FAULT	1	Occ
2008/11/27 14:47:29	[861] ENGINE 1 SECURITY CHANNEL	3	Clr
2008/11/27 14:47:34	[921] ENGINE 1 SS COOLANT LEVEL	1	Occ
2008/11/27 14:48:18	[4052] DOOR B ISOLATED OR DCU COMMS FAULT	1	Occ
2008/11/27 14:48:18	[4054] DOOR D ISOLATED OR DCU COMMS FAULT	1	Occ
2008/11/27 14:48:26	[4040] SMOKE UNIT LINK FAIL	1	Occ
2008/11/27 14:47:16	[1840] CAB LOCKER CB TRIP	3	Occ
2008/11/27 14:47:16	[1395] ATP PENALTY BRAKE APPLIED	2	Occ
2008/11/27 14:47:17	[1451] H.DRIVE 1 OIL LEVEL FAULT	2	Occ
2008/11/27 14:48:18	[4051] DOOR A ISOLATED OR DCU COMMS FAULT	1	Occ
2008/11/27 14:47:17	[1410] MULTIPLE NEUTRAL/EARTH CONNECTION	1	Occ
2008/11/27 14:47:21	[1410] MULTIPLE NEUTRAL/EARTH CONNECTION	1	Clr
2008/11/27 14:47:16	[3750] IVAN UNIT POWER OFF	3	Occ
2008/11/27 14:41:16	[1772] TRAIN BUS B MCB OPEN	1	Occ
2008/11/27 14:41:21	[1772] TRAIN BUS B MCB OPEN	1	Clr
2008/11/27 14:47:16	[2740] A/C HEATER OVERTEMP	1	Occ
2008/11/27 14:47:34	[591] ENGINE 1 LO COOLANT LEVEL	2	Occ
2008/11/27 14:48:18	[4053] DOOR C ISOLATED OR DCU COMMS FAULT	1	Occ
2008/11/27 14:49:59	[4041] ALTERNATOR 1 LINK FAIL	1	Occ

Power car DTD5403 TMS Fault Log did not contain any faults from 1430 until after the time of the collision.

Power car DTD5402 TMS Fault Log

The TMS fault log recorded on power car DTD5402 from 1430 to 1450 is shown in the figure 52.

Figure 52: ***Power car DTD5402 Fault Log from 1430 to 1450***



Power car DTD5402 TMS Fault Log did not contain any faults from 1430 until after the time of the collision.

TMS Fault Log Conclusion

The TMS fault log recorded on power cars DTD5402 and DTD5403 did not record any faults from 1430 until after the time of the collision.

Appendix C: Truck braking and acceleration

Truck braking

When a vehicle brakes heavily and skids to a stop, the friction force generated between the skidding tyres and the roadway must do enough work on the vehicle to reduce its kinetic energy to zero. Assuming a level grade, the vehicle skid-to-stop velocity formula is defined as:

Where:

$$s = \frac{v^2 - u^2}{2 g \mu}$$

s = distance travelled (m)

v = initial velocity (m/sec)

u = final velocity (m/sec)

g = acceleration due to gravity (9.81 m/sec^2)

μ = coefficient of (longitudinal) friction

The coefficient of friction is a dimensionless value which describes the relationship between the force holding two objects together and the force required to slide the objects in relation to each other. A low coefficient of friction implies the objects will slide easier than if the coefficient of friction was high. For road/ vehicle interaction, the coefficient of friction is dependent on road surface texture and tyre composition. Ideally, the coefficient of friction is determined by skid testing at the site of interest. However, an estimate can be made based on road surface observations and typical values determined in similar conditions.

In the case at Rungoo, the following values were known or assumed:

s = 21 m (length of skid mark)

v = 25 m/sec (initial velocity 90 km/h)

g = 9.81 m/sec^2

μ = between 0.45 and 0.50

Therefore, the formula to determine the final velocity is defined as:

$$u = \sqrt{v2 - 2 s g \mu}$$

Having established the final velocity of the vehicle at the end of the skid marks the time (seconds) taken to skid that distance is calculated from:

$$t = \frac{v - u}{\mu g}$$

Table 9 documents the calculation results at either extreme of the coefficient of friction range.

Table 9: *Calculation results*

	$\mu = 0.45$	$\mu = 0.50$
Final velocity (m/sec)	21 m/sec	20.5 m/sec
Final truck speed (km/h)	75.6 km/h	73.8 km/h
Duration of skid (sec)	0.91 sec	0.92 sec

Truck acceleration

The formula for showing the relationship between distance, acceleration and velocity is defined as:

$$u^2 = v^2 + 2\,a\,s$$

Where:

s = distance travelled (m)

v = initial velocity (m/sec)

u = final velocity (m/sec)

a = rate of acceleration (m/sec^2)

In this case, the following values were used to calculate the effect that acceleration may have had on the final speed of the truck:

- Distance travelled while accelerating – Based on the skid marks and the point of impact on the truck, it is estimated that the truck may have attempted to accelerate for about 12 m before the collision occurred.
- Initial velocity – The final velocity after skidding for about 21 m (calculated above) is used as the initial velocity before acceleration.
- Rate of acceleration – Australian Standard AS1742.7-2007 *Manual of uniform traffic control devices – Part 7: Railway crossings* includes a table of typical design acceleration figures for different vehicle types. In this case, the vehicle was a B-double truck which has a design acceleration defined as 0.36 m/sec^2.

Based on these figures, the B-double truck was calculated to have increased speed by about 0.7 km/h due to accelerating after heavy braking. Note that these calculations due not take into account the delay between braking and accelerating. Consequently, it is likely that the change in speed was negligible.

Truck velocity at impact

Table 9 shows that the differences between the coefficients of friction makes little difference in the truck speed after skidding and before the final attempt to clear the crossing. The acceleration over the final few metres made little difference so for the purpose of this report 75 km/h is assumed to be the final velocity of the B-double truck at impact.

Appendix D: Standard 57 compliance

Table 10: *Compliance to STD/0057/TEC Version 1.0 Rollingstock Structural Requirements*

STD 57 Clause or derivative	Description	Compliance Reference	Notes
5.1	The structure and attachments on all rolling stock shall withstand normal train forces without yielding, fracture, or buckling, withstand cyclic loading without fatigue failure during the design life, and minimise risk of injury during collision and derailment.	Not certified separately	
5.2.1	The requirements for locomotives shall be as set out in Railways of Australia Manual of Engineering Standards and Practices, Section 13.7.1.	See ROA MESP in detail below	1
ROA MESP 13.7.1.1.1	The critical design stress shall be taken as either the yield stress or the critical buckling stress for the structural members involved, whichever is applicable.	CT- 91.PS.018 12351.R1.0	
ROA MESP 13.7.1.1.2(a)	The safeworking stress for underframe and superstructure members shall be taken as follows: The maximum combined stress shall be taken as one half of the yield strength or critical buckling stress or one third of the ultimate strength, whichever is the greater, but shall not exceed two thirds of the yield strength of the material.	CT-91.PS.018 12351.R1.0	1
ROA MESP 13.7.1.1.2(b)	The maximum direct stress shall be taken as one half of the yield strength or one third of the ultimate strength of the material, whichever is the lesser.	-	2
ROA MESP 13.7.1.1.2(c)	Safeworking stress: For columns whose ratio of length to least radius of gyration is less than 40 the combined and direct stresses as above shall apply, but when the ratio exceeds 40 the section shall be determined by a suitable column formula.	-	1
ROA MESP 13.7.1.3.2	R.644 Buff Load	12351.R1.0	
ROA MESP 13.7.1.3.7(a)	Anti collision beams shall be provided and vertical members shall generally be in accordance with the requirements of AAR S580 (circa 1999)	See AAR S580 in detail below	
ROA MESP 13.7.1.3.7(b)	These beams shall extend to the window height of the cab.	Drawing A0-C11319	
ROA MESP 13.7.1.3.7(c)	The cab sheeting shall be designed to minimise the risk and extent of structural damage and injury to the train crew to impacts from protruding loading on passing trains, equipment fouling the track, or collisions.	-	3

STD 57 Clause or derivative	Description	Compliance Reference	Notes
AAR S580 1.0	The standards, stated in the form of design criteria, may be exceeded depending on the needs of the individual users.	-	3
AAR S580 3.2	R.644 Collision post (bending)	12351.R1.0	
AAR S580 3.2	R.644 Collision post (shear)	12351.R1.0	
5.2.2	The structural integrity of the drivers cab shall be maintained in the event of a rollover. Refer to section 5.2.3.	See 5.2.3 below	
5.2.3	The design of the cab shall complement the collision post design detailed in ROA MESP Section 13.7.1 to produce maximum protection to train crew in the event of the locomotive rolling over onto either its side or roof.	MRE.9809 CT-91.PS.018 12351.R1.0	
5.3	Passenger Vehicles - Considered by QR and EDI to be immaterial to power car (locomotive) assessment	-	
5.5 (a)	Rollingstock designs shall be verified by the following methods: Hand calculations for minor modifications or variations to existing compliant structures.	CTT-DOR-081	
5.5 (b)	Finite element analysis for major modifications and new designs, and shall include linear (static loading) and nonlinear analysis (collision loading) where applicable.	12351.R1.0 CTT-DOR-087	4,6
5.5 (c)	Strain gauge testing for new rolling stock.	CTT-DOR-111	7
5.5 (d)	Collapse mode evaluation for crew and passenger occupiable structures.	-	5,6

Notes:

1. Consideration of critical buckling stress as an assessment criteria of safe working stress during the design process was assessed by the Alliance (EDI) assertion that the members making up the collision posts did not exceed the "ratio of length to least radius of gyration is less than 40" condition. Arguably buckling failure of a structure is a function of geometric stability as well as stress magnitude, specifically as a structure may buckle at stresses well below the safeworking stress.

2. Recognised by EDI.

3. Qualitative Material to Crashworthiness but not directly assessed in the certification process.

4. No evidence for non-linear analysis of collision loading was provided to the investigation. This was an aspirational goal set in STD/0057/TEC clauses 5.1 and 5.2.2 as well as those from ROA clause 13.7.1.4 and AAR S580 clause 1.0.

5. No evidence for collapse mode evaluation for crew occupiable structures was provided to the investigation. This was an aspirational goal set in STD/0057/TEC clauses 5.1 and 5.2.2 as well as those from ROA clause 13.7.1.4 and AAR S580 clause 1.0.

6. However, compliance to STD/0057/TEC clauses 5.2.1 was endorsed and design certification was issued.

7. Strain gauge testing was conducted on the power car structure to verify the FEA model. During the testing the structure deformed and was subsequently strengthened and hand calculations used to verify the increased strength without any re-testing.

Appendix E: International standards

References from railway standards concerning crashworthiness of relevance from around the world.

United Kingdom

GM/RT2100 Issue 3 is part of the suite of Railway Group Standards (RGS) mandated by Network Rail for all vehicles running on the UK infrastructure. This standard covers the structural requirements for railway vehicles and includes both strength and crashworthiness requirements.

Sections 8 and 9 of GM/RT2100 issue 3 define the general and specific crashworthiness requirements and describe three options for the face to face train impact collision scenario.

Option 1 defines the level of energy that needs to be absorbed as 1MJ per vehicle end.

Option 2 states that the required energy distribution shall be derived from a collision simulation at 60 km/h.

Option 3 requires that 2 MJ of energy is absorbed per vehicle, the distribution being in accordance with a theoretical simulation.

Section 9 also describes an overriding scenario for the situation in which one vehicle overrides the other one. In this case, the energy absorption requirement is 0.5 MJ.

Issue 4 of the standard is currently in preparation and introduces major changes to the structural requirements. All the previous strength and crashworthiness requirements are now replaced with a reference to the European standards EN 12663 and EN 15227. These changes are introduced to bring in line UK requirements with the emerging European requirements.

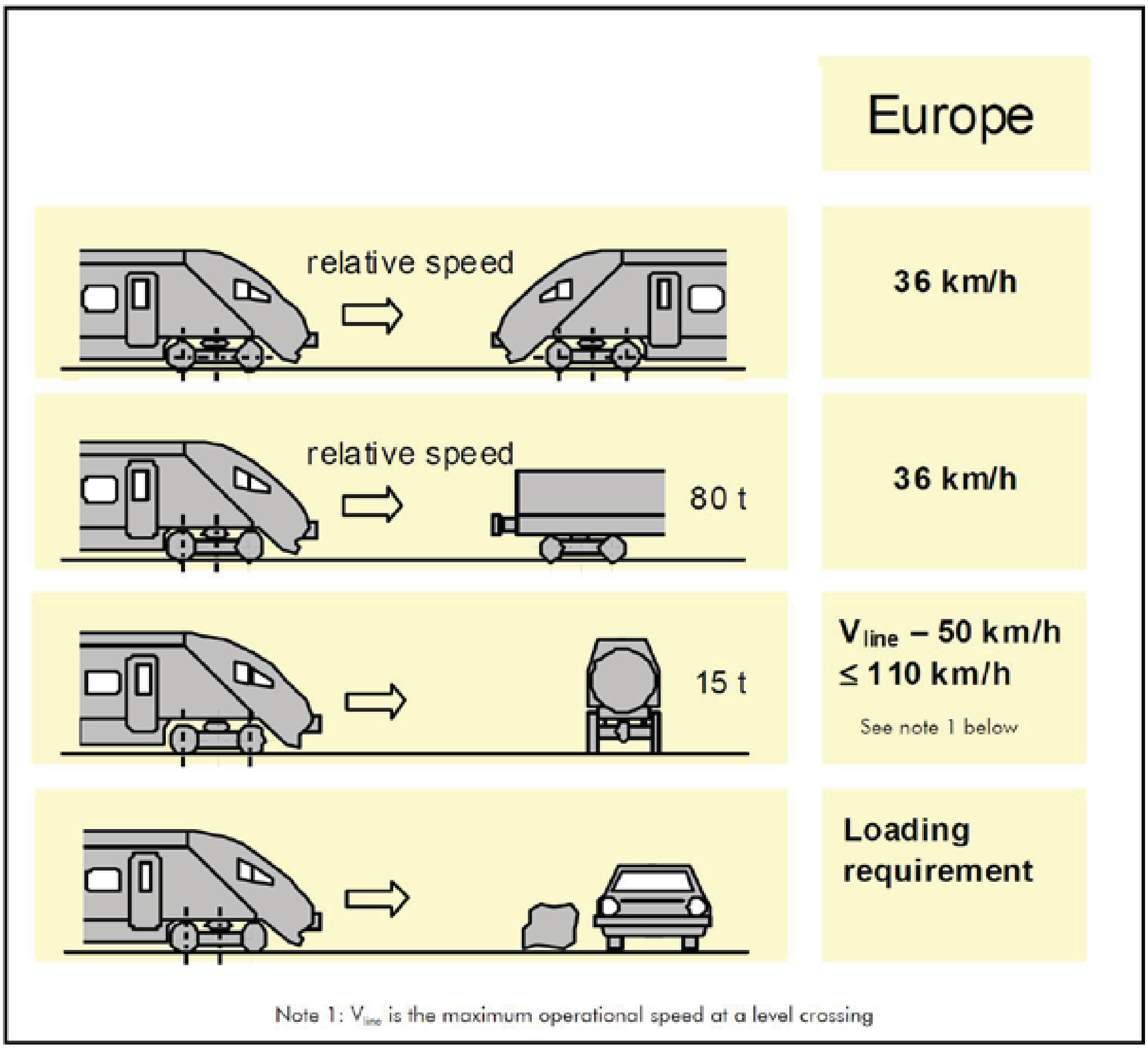
Europe

EN 12663:2000 presents the structural requirements for railway vehicles in Europe and covers only static strength requirements. It is currently being revised but the latest draft of EN 12663-1:2007 does not introduce significant changes.

EN 12663 is to be read in conjunction with EN 15227:2008 which defines the crashworthiness requirements for railway vehicles in Europe.[75] This document is the key to understanding the latest crashworthiness requirements in Europe. It defines four collisions scenarios that need to be met to meet the crashworthiness requirements. One of the scenarios considers a 110 km/h impact with a simulated stationary heavy (15 tonne) road vehicle on a level crossing.

75 EN 15227:2008 has a four year phase in period.

Figure 53: *Collision scenario*



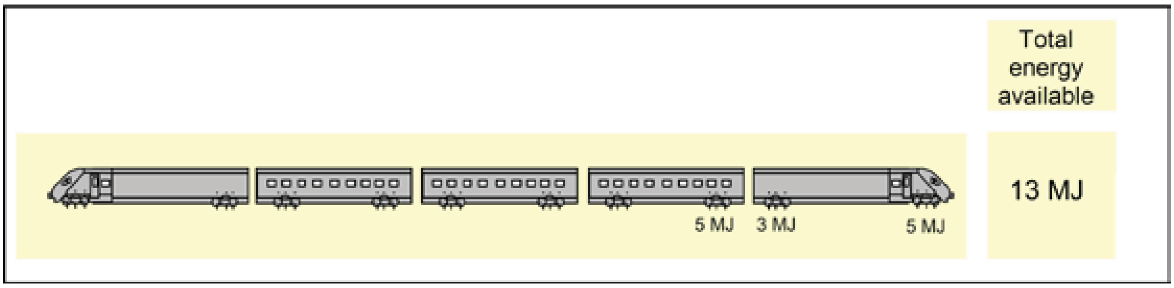
United States of America

Document No 49CFR238 is a Code of Federal Regulations (CFR) created by the USA Department of Transport. As such, it is mandatory in the USA to comply with the requirements of this standard for all railway vehicles. This document defines two categories of vehicles: Tier I and Tier II:

- Tier I is applicable to vehicles whose maximum operating speed does not exceed 125 mph (200 kph).
- Tier II is applicable to vehicles whose maximum operating speed falls between 125 mph (200 kph) and 150 mph (240 kph). Subpart C of 49CFR238 applies to Tier I vehicles.

This section of the standard defines the static strength requirements for vehicle bodies, but does not explicitly cover crashworthiness requirements. Subpart E of 49CFR238 defines the crashworthiness requirements for Tier II vehicles. In particular, it requires that the complete train shall be able to absorb 13 MJ of energy with 5 MJ of energy absorption capability at the front end and 3 MJ at the first inter-vehicle location.

Figure 54: ***Energy absorption***



Document No APTA SS-C&S-034-99 Rev. 2 is a standard created by the American Public Transport Association for the design and construction of passenger rolling stock. The requirements from this standard are not mandatory however they are recommended best practice from across the railway industry in the US. This document is usually referred to in specifications for vehicles for the US market, and is therefore is relevant to this review. This document defines a Crash Energy Management System that includes various scenarios, but does not specify actual impact velocities that the rollingstock is to be designed for.

Notes