



Office of the Chief Investigator
Transport Safety

**Rail Safety Investigation
Report No 2017/07**

Collision
Trams 6042 and Tram 6019
Nicholson Street, Melbourne
15 October 2017

THE CHIEF INVESTIGATOR

The Chief Investigator, Transport Safety is a statutory position under Part 7 of the *Transport Integration Act 2010*. The objective of the position is to seek to improve transport safety by providing for the independent no-blame investigation of transport safety matters consistent with the vision statement and the transport system objectives.

The primary focus of an investigation is to determine what factors caused the incident, rather than apportion blame for the incident, and to identify issues that may require review, monitoring or further consideration.

The Chief Investigator is required to report the results of an investigation to the Minister for Public Transport or the Minister for Ports. However, before submitting the results of an investigation to the Minister, the Chief Investigator must consult in accordance with section 85A of the *Transport (Compliance and Miscellaneous) Act 1983*.

The Chief Investigator is not subject to the direction or control of the Minister in performing or exercising his or her functions or powers, but the Minister may direct the Chief Investigator to investigate a transport safety matter.

SAFETY SUMMARY

What happened

On 15 October 2017, Tram 6042 operated by Yarra Trams was on a scheduled commuter service from Bundoora to Docklands. At about 2050, the tram turned into Nicholson Street and travelled south. At 2053 and after crossing Victoria Parade, the tram collided with Tram 6019 that was stopped at the Albert Street intersection of Nicholson Street. As a result of the collision, several passengers fell and sustained minor injuries.

What the Chief Investigator found

It was found that the driver of Tram 6042 probably experienced hyperglycaemic induced drowsiness, culminating in a micro-sleep as the tram approached the Albert Street intersection. The driver had not taken his medication for diabetes for two days.

Yarra Trams introduced new medical standards for its tram drivers in 2017 and commenced examining existing employees against this standard in July 2017. However, the driver involved in this incident had not yet been assessed under the new medical regime.

It was found that the tram vigilance system was unable to detect and respond to this short period of inattention. At the speed the tram was travelling, the task-linked vigilance system would not intervene for at least 30 seconds.

What has been done as a result

Following this and other similar incidents, Yarra Trams accelerated its roll-out of Category 1 medical assessment of its drivers and completed all drivers by December 2018; and have updated their procedures for the reporting and monitoring of health condition of drivers.

Yarra Trams is reviewing the vigilance system activation on the E Class tram and the availability of new technology to assist with driver alertness/drowsiness detection. The operator is also investigating systems that automatically identify possible hazards in front of the vehicle and warn drivers.

Safety message

It is important that rail safety workers are familiar with effects of missing doses of prescribed medication particularly where that may affect their ability to perform rail safety work.

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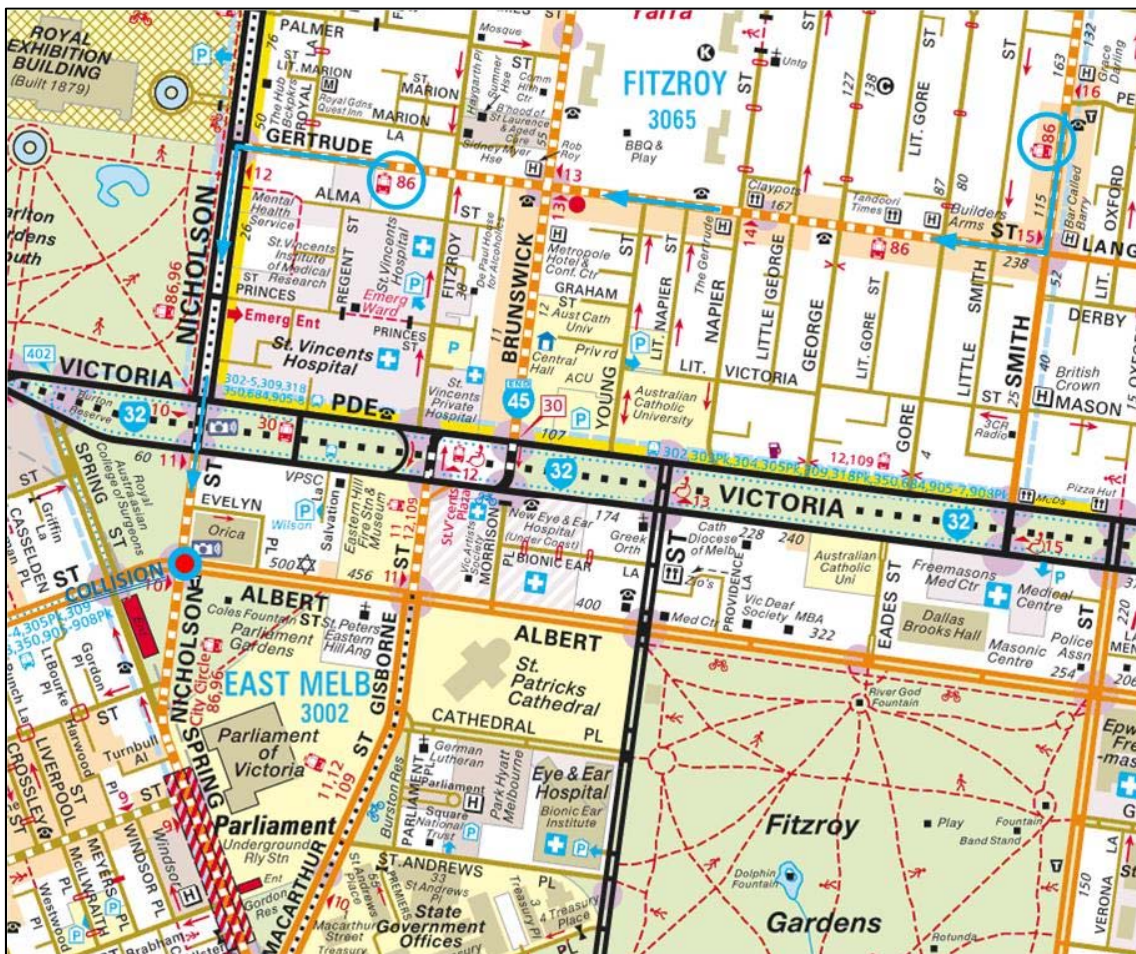
1. THE OCCURRENCE

On the evening of 15 October 2017, Tram 6042 was scheduled to provide a route 86 service from Bundoora to Docklands. The driver for the service had worked the afternoon roster and after a dinner break at the New Preston Depot, joined the outbound Tram 6042 at Preston (Stop 42) and drove the remainder of that service to Bundoora. The driver then changed driving ends and prepared for the inbound service to the Docklands precinct.

The tram departed the Bundoora terminus (Stop 71) at about 1945. The tram reached Stop 15 at the intersection of Smith and Gertrude Streets at about 2040, about 20 minutes later than scheduled. The driver reported that at about this time he started to feel drowsy.

Tram 6042 turned from Smith Street into Gertrude Street, travelling west towards Nicholson Street. The tram stopped at the intersection of Gertrude and Nicholson Streets, at which time Tram 6019 crossed ahead of it, travelling south on Nicholson Street towards the city. At about 2052 Tram 6042 turned into Nicholson Street and stopped briefly Stop 12 (opposite the museum). At this time Tram 6019 was stopped at St Vincent's Hospital (Stop 11), at the intersection of Nicholson Street and Victoria Parade (Figure 1).

Figure 1: Route of Tram 6042 through to Nicholson and Spring Streets



Source: eWay Melway 2017 with annotations by Chief Investigator Transport Safety

Both trams resumed driving at about the same time. There were no passengers wanting to board or alight Tram 6042 at Stop 11 and the traffic lights had a 'proceed' aspect, so the driver continued driving across the intersection with Victoria Parade. At that time Tram 6019 was stopped at the traffic signals at the Albert Street intersection with Nicholson Street, about 130 m ahead.

Driving across Victoria Parade, the driver of Tram 6042 applied traction for about 1.5 second, increasing tram speed to about 21 km/h, then made three slight brake applications to maintain that speed. The master controller was returned to the coast position when the tram was about 60 m (and 10 seconds) from the stationary Tram 6019.

At about 2054, Tram 6042 collided with the rear of the stopped Tram 6019. At the point of collision, Tram 6042 was travelling at a speed of about 21 km/h and the brakes were not being applied. The impact pushed Tram 6019 forward about five metres. Five tram passengers suffered minor injuries and were treated by paramedics at the site.

This collision followed a similar tram-to-tram collision on the corner of Bourke and Spencer Streets on 2 August 2017. That collision was also investigated.¹

¹ Chief Investigator Report No 2017/003 Collision Trams 6008 and 6005 Bourke Street, Melbourne 02 August 2017.

2. CONTEXT

2.1 Yarra Trams

Yarra Trams operates the tram network in Melbourne across 24 different tram routes. At the time of the incident, it managed nine tram depots with a fleet of about 490 trams including 70 E Class trams and employs more than 1,200 tram drivers.

2.2 The trams

2.2.1 Tram construction

Tram 6042 and Tram 6019 are E Class trams. The E Class tram is a three-section, four-bogie articulated tram that was first introduced to the Melbourne tram network in 2013. The trams are supplied by Bombardier Transportation.

Figure 2: E Class Melbourne tram



Source: Yarra Trams, Melbourne

The E Class tram has a maximum design speed of 80 km/h. It can carry 64 seated and 146 standing passengers and has a fully loaded weight of about 62 t.

2.2.2 Driving cabin

A driver's cabin is located at each end of the tram and is fully enclosed by laminated glass windscreen and cab-side windows. The driving seat is situated on the centre line of the tram. When seated, the driver has a near 180° field of vision, with minor obstruction in the line of the corner frames. Rear view mirrors are installed outside the cabin to provide the driver sight along the sides of the tram and to the rear.

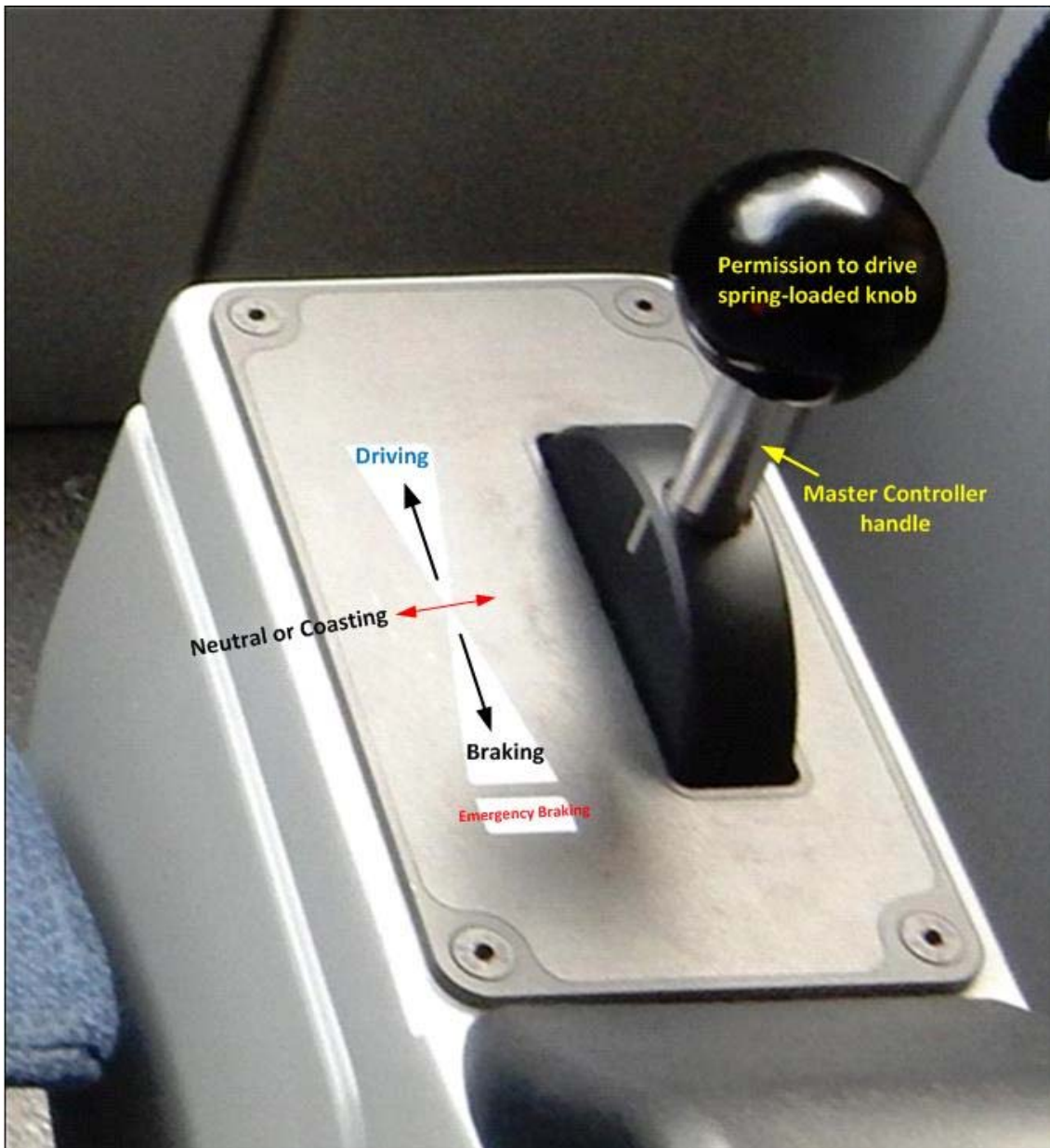
The front windscreen of the cab is fitted with a retractable sun shade. There is no shading on the side windows. The side window to the right of the driver is fitted a 300 mm x 300 mm sliding window that can be opened. At the time of the incident, the cabin temperature was being maintained at 20 °C.

2.2.3 Driving controls

All driving controls are installed on the driver's seat armrests. The master controller is installed on the right armrest (Figure 3).

The controller must be depressed to activate the driving/braking function. The handle can then be moved forward to drive the tram and backward to brake. Post-incident testing of the incident tram indicated that a downward force of about 15N was needed to activate the driving/braking function.

Figure 3: Master Controller



Source: Chief Investigator Transport Safety

2.2.4 Deadman function

The deadman function is integrated within the master controller. Depressing the controller handle and maintaining the controller in its driving/braking mode will prevent a deadman system response. The force required to maintain the handle in the driving/braking mode was specified as 6N \pm 3N. This force can typically be achieved with the resting weight of the hand and forearm. Post-incident testing of the incident tram driving end found that the force required to maintain the master controller in its active position was within the specified range.

If the master controller is released, there is a rapid system response. The response includes acoustic and visual warnings, followed two seconds later by a forced braking application.

2.2.5 Vigilance function

The E Class tram is fitted with task-linked vigilance system. Whilst the tram is moving the vigilance timer will be reset by normal driving tasks. Driver tasks that reset the vigilance timer include a change in the position of the master controller; activation of the gong, horn, sanding, door select, track brake and hazard lights; pushing down on the master controller; and pressing the vigilance button on the side of the driver's left armrest (Figure 3) or on the driver's control panel.

If a driver action is not detected in a prescribed time, there is firstly a visual warning. If there is no driver response to that warning, there is an audible warning, followed by a forced brake application.

The response time of the vigilance system varies depending on the speed of the tram. If the speed of the tram is less than 25 km/h, the visual warning will commence after 30 seconds. If not acknowledged within 5 seconds, the audible warning will commence, and 5 seconds later forced braking is activated. If the speed of the tram is 25 km/h or greater, the system response is based on distance travelled rather than time. The visual warning commences after the tram has travelled about 210 m, the audible warning after a further 35 m, and forced braking after a further 35 m.

2.2.6 Collision absorption systems

The trams were constructed to comply with European Standard EN 15227² for crash worthiness. The E Class tram is fitted with a Crash Energy Management System (CEMS) with energy absorption capacity at tram ends and couplers.

The main absorption systems are located at the tram ends and consist of two stages. A reversible stage has an 80 mm stroke and uses a gas-hydraulic element intended to absorb energy from very low speed impact and then return the element to its original position. This system can therefore accommodate repeated small impacts. A second, irreversible stage for higher speed impacts uses deformation tubes that do not return to their original condition. The deformation tubes in this irreversible stage have a maximum stroke of 270 mm.

The speed of impact in this collision exceeded the capacity of the reversible stage and engaged the deformation tubes.

² Railway Applications – Crashworthiness Requirements for Railway Vehicle Bodies

2.3 Tram driver

2.3.1 Qualifications and experience

The driver of Tram 6042 had been a tram driver for about 30 years. He was qualified to drive A, B and E Class trams on Routes 11 and 86 and had been driving E Class trams on these routes since May 2016. His last driver observation trip was on 29 March 2017 with a reported 100 per cent compliance. His last driver refresher training was in September 2017. At the time of the incident his qualifications were current.

2.3.2 Medical

In accordance with Yarra Trams' policy at that time, the driver underwent a Category 2 medical examination in April 2017.³ He was declared fit to continue driving trams.

The driver of Tram 6042 reported that he had been diagnosed with diabetes about 10 years previously and had been treated by his personal GP since then. He was prescribed medication to be taken twice daily and six-monthly checks to monitor his blood-sugar levels. The treating GP informed him that failure to take his medication would result in his blood-sugar levels rising and cause him to feel sleepy.

The day before the incident the driver had a rostered day off. He reported that he did not take his medication that day. The next day, the day of the incident, the driver arrived at work but forgot to bring his medication with him. As a result, he did not have his medication on this day. Following the incident, the driver was required to undergo a Category 1 medical examination, that also includes tests for diabetes, and was subsequently passed fit to resume driving.

2.4 Health Standards

Tram drivers are subject to the *National Standard for Health Assessment of Rail Safety Workers* (the Standard) developed by the National Transport Commission (NTC). The Standard provides that a rail safety worker should receive the level of health assessment commensurate with their rail safety work risk category and that rail safety workers⁴ with health conditions have the monitoring and support they need to keep themselves and the rail system safe.

Prior to 2017, Yarra Trams had assessed its tram drivers as Category 2 Safety Critical Workers⁵ – those whose work requires high levels of attentiveness, but for whom fail-safe mechanisms or the nature of their duties ensure sudden incapacity or collapse does not affect safety of the rail network. The Category 2 clinical examination assesses the key body systems to identify conditions including cardiovascular, neurological, psychological, musculoskeletal and visual systems.

³ In accordance with the National Standard for Health Assessment of Rail Safety Workers, August 2017, a Category 2 health assessment requires the person to complete self-administered questionnaires on sleep disorders, alcohol dependency and psychological problems; and undergo medical examination to assess the key body systems to identify conditions that might affect rail safety task performance including cardiovascular, psychological, musculoskeletal and visual systems.

⁴ Tram drivers are rail safety workers within the scope of the Standard.

⁵ Safety Critical Workers are those workers whose action or inaction may lead directly to a serious incident affecting the public or the rail network.

In review and prior to this event, Yarra Trams reassessed risks associated with its operations and re-categorised tram drivers as Category 1 Safety Critical Workers. A Category 1 medical examination includes, in addition to the above, a cardiac risk level assessment as well as tests for diabetes and serum cholesterol. According to the Standard, a person with non-insulin dependent diabetes is subject to an annual review by an endocrinologist or diabetes specialist to determine their fitness for safety critical work.

2.5 Diabetes (hyperglycaemia)

Diabetes mellitus, commonly referred to as “diabetes” is a medical condition caused by an excess of sugar (glucose) in the blood (hyperglycaemia). Under normal circumstances, the blood sugar level is tightly controlled to prevent the adverse effects of either too little or too much blood sugar. After eating, the process of digestion liberates glucose which then enters the blood for delivery to the body’s organ systems for use as a fuel source. Insulin is a key regulating hormone for the control of blood glucose.⁶ When blood glucose levels rise, insulin is released from the pancreas to reduce the excess level of glucose in the blood, to the normal range.

The liver is important in glucose control, as both a storage depot and a producer of glucose. It takes up glucose when there is an abundant supply in the blood, storing it in the form of glycogen, and reducing its own production of glucose. When the blood glucose level is low, as in the fasting state, it releases glucose back into the circulation. This glucose is derived from the breakdown of internal glycogen stores and an increased production of glucose.⁷

In the fed state, therefore, the effects of insulin predominate, whereas in the fasting state, other hormones that promote glucose release into the blood stream predominate, and insulin levels are significantly decreased. The net effect of this regulatory process is that blood glucose levels tend to be controlled within a fairly tight range, under normal circumstances. The disease known as diabetes mellitus is essentially a failure of this metabolic control process either because the pancreas is unable to produce enough insulin (type 1 diabetes) or because the body is resistant to the effects of insulin or does not produce enough insulin to maintain a normal glucose level (type 2 diabetes). As a result, glucose tends to build up in the bloodstream and may reach dangerously high levels if not treated properly.

Physical symptoms of hyperglycaemia are fatigue, loss of weight, blurry vision, headache, increased thirst and urination and persistent infections.^{8 9} Regular tiredness, particularly tiredness following meals due to the intake of carbohydrate (which causes a spike in blood-sugar levels) combined with insufficient medication dosage, is a common symptom of diabetes.¹⁰

Insulin or other drugs are used to lower blood sugar levels. Type 1 diabetes is treated with injecting or pumping insulin into the blood stream. Type 2 diabetes, previously known as non-insulin-dependent diabetes, may be treated with a variety of drugs. The driver was being treated for Type 2 diabetes with a non-insulin drug.

⁶ Alberti KGMM, Hockaday TDR. Diabetes Mellitus. In: Weatherall DJ, Ledingham JGG, Warrell DA. Oxford Textbook of Medicine. Oxford, Oxford University Press, 1987:9.51-9.101.

⁷ Dinneen S, Gerich J, Rizza R. Carbohydrate metabolism in non-insulin-dependent diabetes mellitus. N Engl J Med 1992; 327: 707-13.

⁸ American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care 2004; 27:S5-S10.

⁹ Mayo Foundation for Medical Education and Research (MFMER)

¹⁰ www.diabetes.co.uk/tiredness-and-diabetes

2.6 Fatigue management

Yarra Trams' 2013 Fatigue Management Policy outlined the organisation's approach to managing fatigue in the workplace. This was followed in 2015 with its Fatigue Management Program that had a stated purpose to assist managers and employees to understand and manage the risks associated with fatigue in the workplace.

Transport Safety Victoria (TSV) audited Yarra Trams' fatigue management in March 2016 and found deficiencies with some elements in its Fatigue Management Program. These included monitoring of driving hours, fatigue awareness training and implementing a risk register for fatigue management.

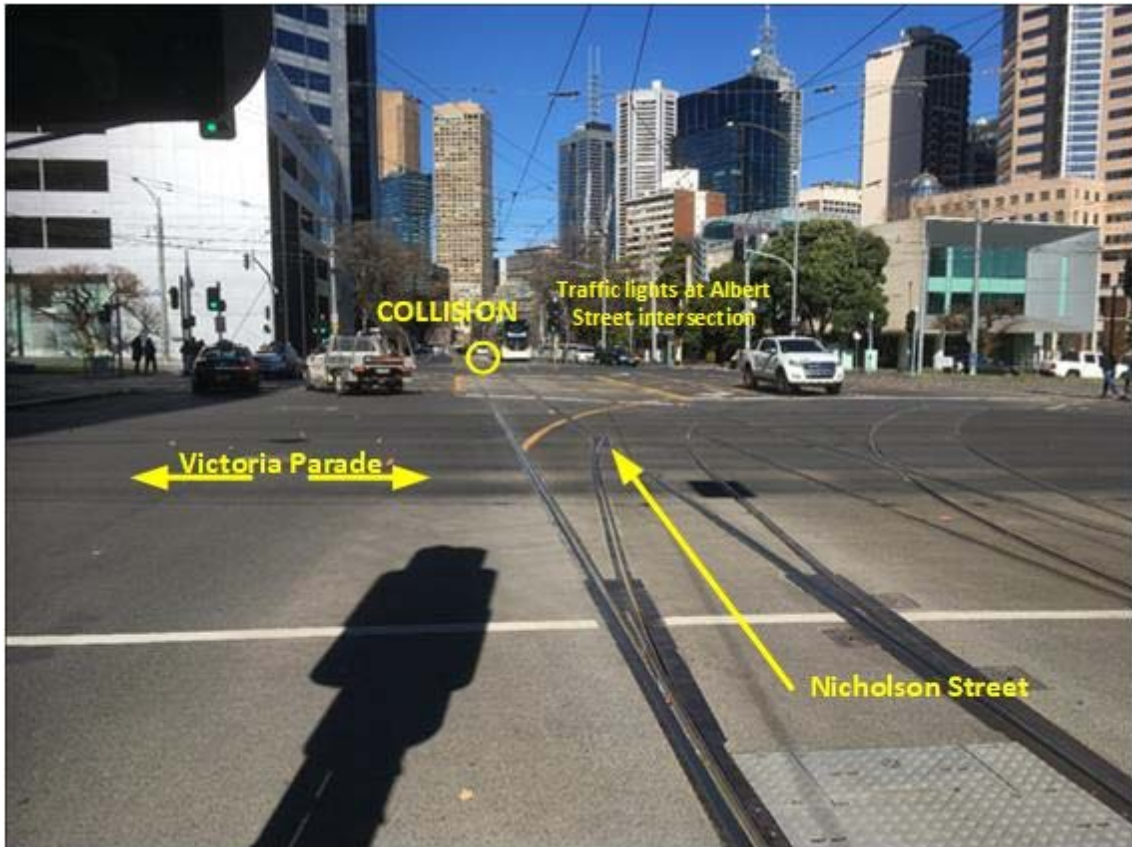
Pursuant to the audit, Yarra Trams implemented a system for monitoring driver actual working hours and introduced fatigue awareness training for driver initial induction and thereafter at least once a year during refresher training. The training consisted of a 1 hour module that covered the causes, symptoms and signs of fatigue, managing off-duty behaviour and on-duty rosters to prevent fatigue and common medical and health conditions affecting driver alertness. The training module did not provide drivers with information related to reporting fatigue or managing the risks associated with fatigue. In September 2016, Yarra Trams issued an additional fatigue management policy document. Among other things, the policy provided for 'developing appropriate fatigue management plans to identify, assess and manage the risks' and 'educating Workers to use their training to identify, report and manage any risks likely to be associated with fatigue'.

At the time of the incident, Yarra Trams had not yet implemented a Risk Register or updated their Risk Management Procedures. These items that were outstanding from the audit, were completed in December 2017. An updated Fatigue Management Procedure was published, 'to provide a process for Yarra Trams to identify and manage, so far as reasonably practicable, all fatigue related risks for its operations'.

2.7 Infrastructure

Nicholson Street is a major thoroughfare providing access to the Melbourne CBD from the north. The street runs in an approximate north-south direction, merging with Spring Street near Parliament House. The distance from Stop No 11 (north of the Victoria Parade intersection) to the rear of Tram 6019, when stopped north of the intersection with Albert Street, was about 130 m. Visibility along the tram corridor is good and the track in the vicinity of the incident dry and clean.

Figure 4: Looking from Stop 11, across Victoria Parade and towards Albert Street intersection



Source: Chief Investigator Transport Safety

3. SAFETY ANALYSIS

3.1 The incident

The driver reported feeling drowsy about nine minutes before the collision, when the tram arrived at the intersection of Smith and Gertrude Streets. Later, after departing Stop 11 at the intersection of Nicolson Street and Victoria Parade (Figure 4), there was no driver action for about 10 seconds before the collision. This equates to a travelled distance of about 60 m. This suggests that the driver lost attention between this point and impact.

It is probable that the driver had a microsleep episode within this 60 m distance to impact. Studies have shown that such microsleep events can occur frequently in individuals engaged in prolonged monitoring and vigilance tasks such as driving.¹¹ While in a microsleep, a person fails to respond to outside information.

3.2 Medical factor associated with driver microsleep

The driver of Tram 6042 had a pre-existing diabetic medical condition and was prescribed non-insulin medication to keep the illness under control. However, he had not taken his medication for two days. The untreated diabetes coupled with recent food intake probably led to a hyperglycaemia condition in the driver, which is known to promote sleepiness and drowsiness. and he probably experienced a microsleep soon after crossing Victoria Parade.

Yarra Trams had introduced Category 1 medical assessment of existing tram drivers from July 2017, and this driver had not yet been assessed against this higher standard, that included assessment and monitoring of diabetic conditions. The new medical regime, that was initiated prior to this incident, will improve the risk management associated with driver medical conditions.

3.3 Tram vigilance systems

3.3.1 Deadman function

By its design, the Deadman function is unlikely to detect loss of alertness or driver microsleep. The tram's task-linked vigilance system is relied upon for this.

3.3.2 Task-linked vigilance system

The E Class tram vigilance system is designed to respond to driver inaction after the tram had travelled 210 m (or 30 seconds). The E Class time settings are consistent with several other trams within the Yarra Trams fleet. However, the 30 seconds setting was not able to detect and respond to the shorter period of inattention as occurred in this instance.

3.3.3 Other technologies for monitoring driver attention

There are a range of technologies in use and in development for monitoring driver attention and responding to driver inattention.¹²

¹¹ Poudel GR, et al. Losing the struggle to stay awake: divergent thalamic and cortical activity during microsleeps. Human brain mapping. 2014 Jan 1; 35(1):257-69.

¹² Chief Investigator Report No 2017/003 Collision Trams 6008 and 6005 Bourke Street, Melbourne 02 August 2017.

4. FINDINGS

4.1 Context

The following findings are made with respect to the Collision between Tram 6042 and Tram 6019 at the intersection of Albert and Nicholson Streets on 10 October 2017. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Findings are expressed as safety factors. A *safety factor* is an event or condition that increases safety risk and if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include occurrence events, individual actions such as errors and violations, local conditions, risk controls and organisational influences.

4.2 Contributing factors

A *contributing factor* is a safety factor that, had it not occurred or existed at the time of an event, then the event would probably not have occurred and/or its adverse consequences would probably not have occurred or would have been less.

- The driver of Tram 6042 probably experienced a micro-sleep episode as the tram approached the Albert Street intersection. This was probably the result of the driver experiencing hyperglycaemic induced drowsiness following two days without diabetic medication.
- **The E Class tram vigilance system was unable to detect and respond to the short period of inattention by the driver and no other system was fitted to detect and respond to driver inattention. [Safety Issue]**

5. SAFETY ISSUES AND ACTIONS

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Chief Investigator, Transport Safety expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the Chief Investigator prefers to encourage relevant organisation(s) to proactively initiate safety action.

All of the directly involved parties are/were provided with a draft report and invited to provide submissions. As part of that process, each organisation is/was asked to communicate what safety actions, if any, they have/had carried out or are/were planning to carry out in relation to each safety issue relevant to their organisation.

5.1 Driver vigilance monitoring

Number:	2018-07-001
Issue owner:	Yarra Trams

Safety issue description

The E Class tram vigilance system was unable to detect and respond to the short period of inattention by the driver and no other system was fitted to detect and respond to driver inattention. [Safety Issue]

Proactive action taken by Yarra Trams

Yarra Trams has established a Tram to Tram Collision Improvement steering group to review:

- the E-Class vigilance system, to determine the most suitable timing of vigilance control actions for the hazards and risks unique to the Melbourne tram network and its operating environment;
- availability of suitable new in-cab technology to assist with driver alertness/drowsiness detection and management;

Yarra Trams have also engaged with the tram manufacturer regards developing a system to automatically identify possible hazards in front of the vehicle and warn drivers via acoustic and visual warning. The first trial of this system is expected to start in the 4th quarter of 2019.

Following a review of driver fatigue issues, Yarra Trams has revised their safety management system and updated several procedures and training modules to ensure greater awareness of the effects of health conditions and the hazard of fatigue on Rail Safety Workers. The operator has also implemented a Lessons Learned Fact Sheet and initiated a 12:45 monthly conference call to share and discuss investigation outcomes with all depots and managers.

In addition to classifying tram drivers as Category 1 Safety Critical Workers (therefore, enhanced medical requirements), Yarra Trams have revised their procedures to ensure that tram drivers inform their supervisor and/or request a triggered health assessment if they are affected by a temporary or ongoing health condition or a change in health status that may affect their ability to perform their work safely; and that supervisors actively monitor the reported health condition of drivers.