Office of the Chief Investigator
Transport Safety

Rail Safety Investigation

Report No 2018/01

Derailment of Tram No.190

At Moonee Ponds, Victoria

27 March 2018

THE CHIEF INVESTIGATOR

The Chief Investigator, Transport Safety (CITS) 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

In the early hours of 27 March 2018, Tram 190 (a Z3 Class tram) was travelling on route 57d from West Maribyrnong to Moonee Ponds Junction. At about 0013, the tram derailed as it was negotiating the left-hand curve from Maribyrnong Road into Ascot Vale Road. It continued to the edge of Ascot Vale Road and collided with road-side infrastructure.

The tram was not carrying passengers at the time, and its driver was not injured. There were also no pedestrians or other vehicles involved. There was extensive damage to the tram and infrastructure.

What was found

It was found that the tram was probably travelling at about three-times the operational speed limit for the curve. The tram was not being actively controlled and entered the intersection in an uncontrolled state.

It was concluded that the driver of the tram probably experienced a microsleep as the tram approached the intersection. The most significant factor contributing to this fatigue-related event was the driver's disrupted sleep prior to this shift.

The tram was not fitted with any systems that might have detected the driver's loss of alertness. The driver-incapacitation safety system fitted to the Z3 Class tram was ineffective as a defence for this type of fatigue-related event.

What has been done as a result

Yarra Trams is undertaking a business case assessment for a contemporary vigilance control system in Z class trams. Subject to a positive business case outcome, installation of the system is expected to commence in July 2019.

Yarra Trams is also evaluating new technologies for the detection of driver drowsiness.

Safety message

It is important that public transport operators review vehicle defences against loss of attention by the driver, as part of their ongoing risk management.

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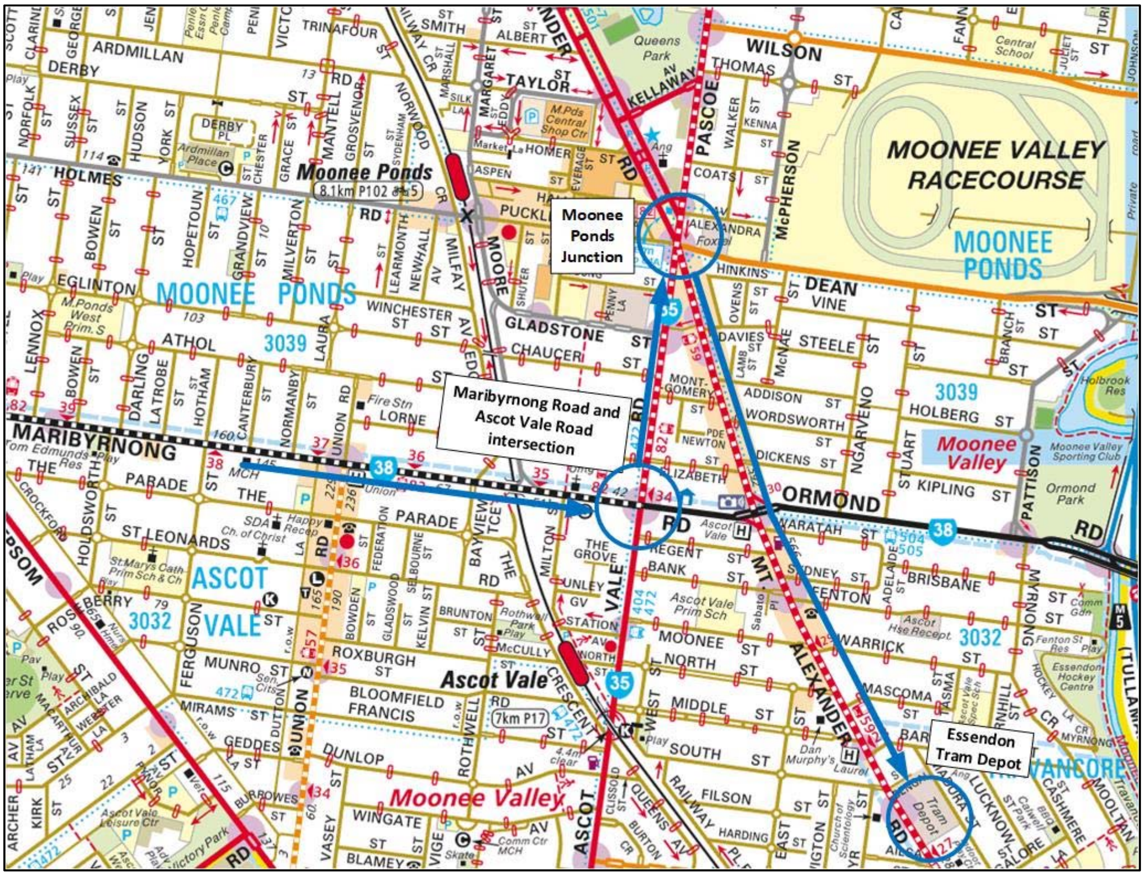
1. THE OCCURRENCE

At about 1530[1] on 26 March 2018, the driver of the incident tram commenced his shift. He first operated trams on route 82 between Moonee Ponds and Footscray until a rostered meal break at the Essendon Depot between 2014 and 2104.

After his meal break, the driver took over Tram 190 to run route 57 between West Maribyrnong and the city (Flinders Street). He joined the tram mid-route at 2129 and completed the remainder of its journey to Flinders Street. He then drove the tram to West Maribyrnong and return, arriving at the Flinders Street stop at about 2325. The driver reported that he disembarked the tram to get some fresh air and commenced the next journey to West Maribyrnong at about 2330. He arrived at West Maribyrnong at about 0006. All these journeys were operated at or near the relevant schedules.

The driver was then to drive the tram on route 57d, a shortened service finishing at Moonee Ponds Junction. He would then take the tram back to the Essendon Depot to complete his shift (Figure 1).

Figure 1: Maribyrnong Road and Ascot Vale Road intersection (route shown in blue)



Source: eWays (Melways) 2017, annotations by Chief Investigator Transport Safety

Tram 190 departed West Maribyrnong on the 57d service at about 0008. No passengers boarded the tram. At about 0012 the tram was travelling along Maribyrnong Road when

[1] All times referred to in this report are local time, Australian Eastern Daylight Time (AEDT).

it approached the Moore Street stop (Stop 35) about 250 m before Ascot Vale Road. The driver slowed the tram but did not stop as there was no-one waiting at the tram stop.

After passing Stop 35, the tram continued towards Ascot Vale Road. The tram was not fitted with a data logger to provide information about its operation or speed. However, sampling of its speed was available through the network's AVM system.[2] This data indicated that Tram 190 was travelling at about 45 km/h when it was about 100 m from the intersection. The driver had no recollection of events approaching the left-hand curve at this intersection (Figure 2).

Figure 2: Intersection of Maribyrnong and Ascot Vale Roads

Source: PASS Assets Public Transport Victoria, annotations by Chief Investigator Transport Safety

Figure 3: Derailment marks

Source: Yarra Trams

There was no evidence that the tram's brakes were applied in the approach to or within the curve. It is therefore probable that the tram was travelling around the polled 45 km/h speed as it entered the intersection. The curve has a design speed of 13 km/h. The tram derailed to the outside of this curve (Figure 3).

The derailed tram collided with road infrastructure and a tram overhead stanchion, causing extensive damage to the tram and infrastructure.

The tram driver was not injured and there were no other persons injured in the event.

[2] The Automatic Vehicle Monitoring System (AVM) is a system to monitor the tram fleet for service delivery.

2. CONTEXT

2.1 Yarra Trams

Yarra Trams is the trading name of the tram network operator in Melbourne[3]. The network consists of 24 routes and nine depots. There is a fleet of about 490 trams including 111 Z3 Class trams. The company employs more than 1,200 tram drivers.

2.2 Infrastructure

Maribyrnong Road intersects Ascot Vale Road at 90 degrees. The intersection was fitted with active traffic controls (Figure 4), although their status at the time of the event is unknown.

Figure 4: On Maribyrnong Road approaching Ascot Vale Road in the same direction as the tram.

Source: Google Maps, Street View September 2016, annotations by Chief Investigator Transport Safety

The track was rail-in-concrete that included a check rail. The curve at the intersection had a radius of 18.3 m and was tight compared to other mainline curves. Yarra Trams advised that the design limit speed through this curve was 13 km/h although operational rules permitted a speed of 15 km/h. There was no signage specifying the speed limit for this curve.

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[3] The current franchise is operated by Keolis Downer.

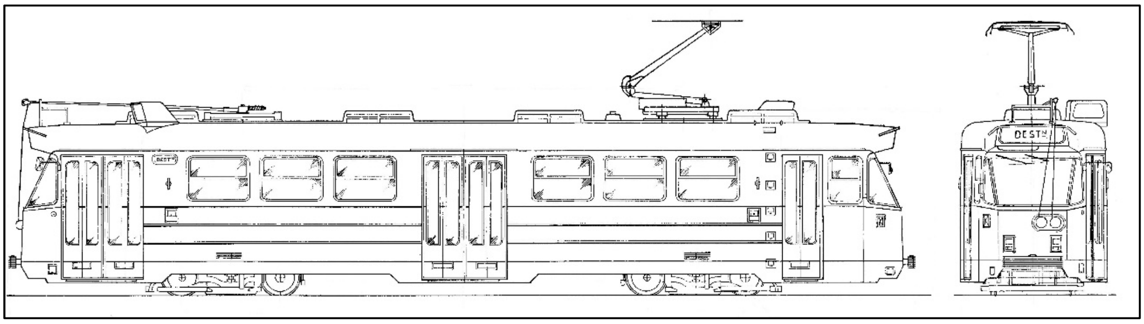
The track was dry and clear of debris, and street lighting operational. Following the derailment, track gauge and rail head measurements were taken, and the track was within allowed tolerances. There is no evidence to indicate the condition of the track contributed to the incident.

2.3 Tram 190

2.3.1 Background

Tram 190 is a Z3 Class tram (Figure 5) built by Commonwealth Engineering (Comeng) in Dandenong and came into service in 1980. It is a pantograph equipped, double-ended non-articulated double bogie (four axle) tram, driven by two 195 kW AEG motors. The vehicle has driver consoles at both ends and has a 42-passenger seating capacity and a 125-passenger total capacity. It has a length of 16.6 m, a tare weight of 21.8 t and a maximum service speed of 70 km/h.

Figure 5: The Z3 Class tram

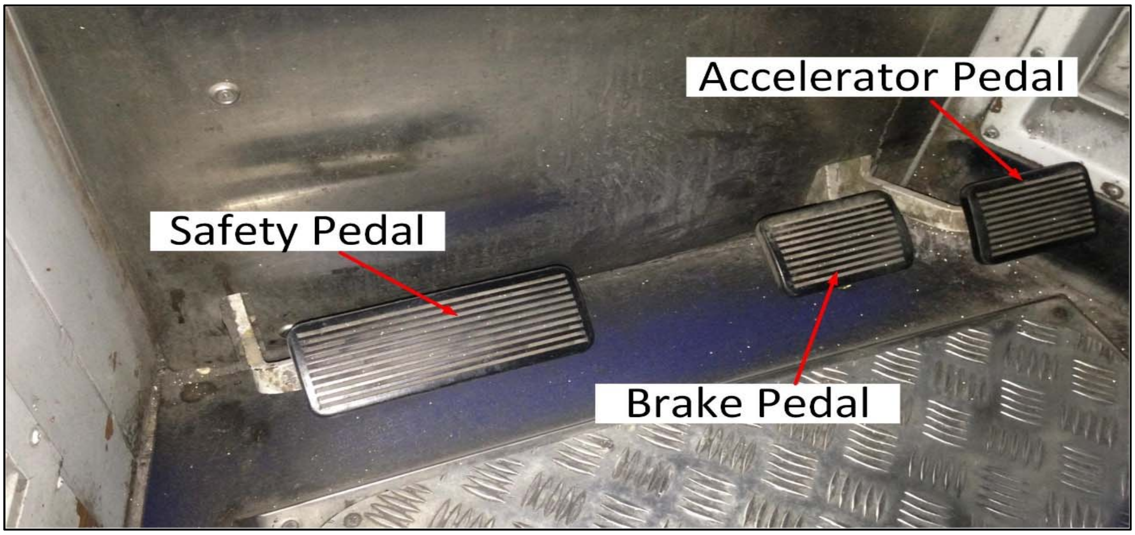


Source: Yarra Trams, annotations by Chief Investigator Transport Safety

2.3.2 Driving controls

Traction and braking controls of the Z3 Class tram are foot-operated from a seated position. Pedals include a safety pedal operated by the left foot, and accelerator and brake pedals operated by the right foot (Figure 6). There is a footrest platform in front of the pedals.

Figure 6: Z3 Class tram driving controls



Source: Chief Investigator Transport Safety

Safety pedal

The safety pedal is the ‘deadman’ system on the Z3 Class tram. It is intended to stop the tram in the case of driver incapacitation. To operate the tram, the safety pedal is depressed to a ‘mid-way’ position that completes a safety circuit. If the pedal is released or fully depressed while the tram is in motion, braking is applied automatically.

This class of tram was not equipped with a task-linked driver vigilance system as typically fitted to late model trams.

Traction

The accelerator pedal controls traction. Traction effort is proportional to pedal travel and the maximum acceleration is 1.4m/s^2.

Braking

The Z3 Class has three independent braking systems:

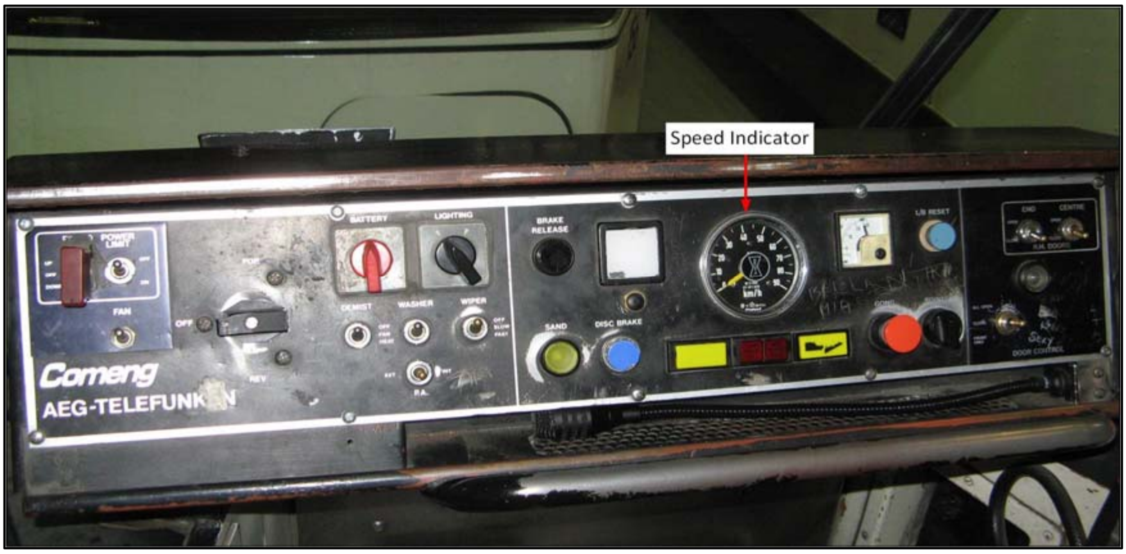
- Dynamic braking[4] is the tram’s main form of braking and is effective down to about 7 km/h.
- Disc braking is introduced at lower speeds as the dynamic braking becomes less effective. It also acts as the holding brake when the vehicle is stopped.
- Track brakes supplement other braking during emergency braking. Track brakes are suspended just above the rails, between wheels. When activated, the track brakes are magnetically attracted to each rail applying a friction surface to the rail.

Application of the foot brake reduces the speed of the tram with deceleration proportional to the pedal travel. Full depression of the pedal results in an emergency braking application, incorporating the highest level of dynamic braking and track brakes.

Console

In front of the driver is a console that includes a range of auxiliary controls and a speed indicator (Figure 7).

Figure 7: Z3 Class tram driver console



Source: Chief Investigator Transport Safety

[4] The traction motors act as generators to retard the tram, and reclaimed power is fed into the traction supply network.

2.3.3 Driver cabin environment

The Z3 Class driver cabin is fitted with heating and air conditioning, and options for natural ventilation. The driver reported the cab temperature was comfortable and the heater was off. The cabin window and a vent were open. At the time of the incident, the outside temperature was about 11 degrees Celsius. There was no recording of internal cab temperature.

2.4 Tram driver

2.4.1 Qualifications and experience

The tram driver was qualified to drive B and Z Class trams and had about 11 years' experience driving. He had attended the driver training refresher course in November 2017. On 21 March 2018 (six days before the incident), he undertook a task observation test, which he completed satisfactorily.

2.4.2 Medical status

The driver was medically assessed on 26 May 2017 and declared fit for duty. The assessment was against Category 2 Safety Critical Worker[5] requirements. Yarra Trams commenced a two-year phase-in of Category 1[6] medical testing in 2017, and this worker had not yet been assessed against that criteria.

The driver stated that he was diagnosed with Sleep Apnoea about five years previous and was being treated by his General Practitioner. He used a Continuous Positive Airway Pressure (CPAP) device and stated that he slept well after he started using the device. The driver advised that he reported the condition to his Team Manager at the time of diagnosis. The condition was not recorded in the relevant Yarra Trams management system and there is no clear procedure for this information to be formally recorded.

Sleep apnoea and treatment

Sleep apnoea is a syndrome in which periods of breathing cessation occur during a sleep period.[7] There are two predominant forms of sleep apnoea: Central Sleep Apnoea (CSA) and Obstructive Sleep Apnoea (OSA). OSA is when ventilatory difficulties arise due to obstruction of the upper airway. OSA is by far the most common form of sleep apnoea[8] and the driver had been diagnosed with this type.

The most common form of treatment for OSA is CPAP.[9] This involves wearing a face mask while sleeping, through which air is delivered under a slight positive pressure via a nearby ventilator. The slight positive pressure effectively helps to prevent upper airway collapse and the OSA sufferer is able to sleep uninterrupted. The CPAP has been shown

[5] Category 2 Safety Critical Worker – 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. Ref: National Standard for Health Assessment of Rail Safety Workers 3rd Edition 2017.

[6] Category 1 Safety Critical Workers - workers who require high levels of attentiveness to their task and for whom sudden incapacity or collapse may result in a serious incident affecting the public or the rail network - Ref: National Standard for Health Assessment of Rail Safety Workers 3rd Edition 2017

[7] Dempsey JA, et al. Pathophysiology of sleep apnoea. Physiological reviews 90.1 (2010): 47-112.

[8] Newman DG, Expert Opinion, Flight Medicine Systems 2018.

[9] Sullivan C, Berthon-Jones M, Issa F, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. The Lancet. 1981 Apr 18;317(8225):862-5.

to significantly reduce subsequent daytime sleepiness, as well as improving cognitive functions and general well-being.[10]

2.4.3 Working hours and rest periods

The driver returned to work on 18 March after two weeks of annual leave. He completed two day shifts on 18 and 19 March, before taking a rostered day off on 20 March. The driver then completed another three, rostered day shifts from 21 March to 23 March. During this period (18-23 March) the average daily sleep was about 7 hours per night.

The driver was rostered off on 24 March. However, he was requested to work on that day due to demand over the Melbourne Grand Prix weekend. This shift was completed at 1712 and the driver reported sleeping about 8 hours 30 minutes that night.

On 25 March, the driver reported waking at about 0600. He had a nap for about 1 hour 30 minutes in the afternoon and commenced the first night shift at about 1730. This shift concluded at about 0110 and the driver reported going to bed at about 0300.

He reported being woken at about 0715 on the morning of 26 March by road works outside his house. He had a nap for about 1 hour 30 minutes in the afternoon prior to his night shift that was rostered to commence at 1534.

Based on the driver's estimations, he probably had no more than 5 hours 45 minutes sleep in the 24 hours preceding the incident and about 7 hours 15 minutes sleep from around 0600 on 25 March.

2.5 Fatigue Management

Yarra Trams drivers were rostered using a roster scheduling software program. The program incorporates a bio mathematical fatigue assessment tool. Rostering rules and practices are articulated in Yarra Trams Fatigue Management Procedures.[11]

The Fatigue Management Procedure also articulated the shared responsibility for fatigue management between Rail Safety Workers (RSW) and Management. The procedure outlined the responsibilities of both parties and included responsibilities for RSW to obtain sufficient sleep and notify their manager if sufficient sleep had not been gained prior to the shift. The latest version of the procedure was released in late 2017 and was being phased-in across the organisation.

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[10] Engleman HM, Martin SE, Douglas NJ, Deary IJ. Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea/hypopnoea syndrome. The Lancet. 1994 Mar 5;343(8897):572-5.

[11] Yarra Trams Document c017pr4655 v2.0 dated 27.12.2017, SMS 7.6.1 Fatigue Management Procedure

3. Safety Analysis

3.1 The Incident

At 0013 on 27 March 2018, Tram 190 entered the left-hand curve at the intersection of Maribyrnong and Ascot Vale Roads at an estimated speed of 45 km/h (12.5 m/s). This speed significantly exceeded the design speed of 13 km/h for this curve, and the tram derailed to the outside of the curve.

The tram driver recalled passing Stop 35 that was about 250 m before the intersection. However, he had no recollection of events from this point until collision with the infrastructure in Ascot Vale Road. It is probable that the driver experienced a microsleep after passing Stop 35. Travelling at 45 km/h, a microsleep of 10 seconds would equate to a distance travelled of 125 m.

3.2 Microsleeps

A microsleep is a transient episode of sleep, lasting for only a short time.[12,13] Expert opinion suggests it can be anywhere up to 30 seconds. A microsleep has also been defined as "episodes of psychomotor unresponsiveness secondary to sleep-related lapses of alertness."[14,15] It is often associated with behavioural markers such as head nodding and slow eyelid-closure, as well as encephalography (EEG) changes.[16,17,18]

A vehicle operator is unable to process sensory information during a microsleep episode. This is dangerous when in a situation that demands constant vigilance, such as driving a vehicle.[19] In one study, operators of vehicles showed significant deterioration in driving performance and vehicle control during microsleep events.[20] The likelihood of a microsleep is increased when performing a vigilance task with little actual physical work.

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[12] Durmer JS, Dinges DF. Neurocognitive consequences of sleep deprivation. In: Seminars in Neurology 2005 Mar (Vol. 25, No. 01, pp. 117-129).

[13] Tirunahari VL, Zaidi SA, Sharma R, Skurnick J, Ashtyani H. Microsleep and sleepiness: a comparison of multiple sleep latency test and scoring of microsleep as a diagnostic test for excessive daytime sleepiness. Sleep medicine. 2003 Jan 1;4(1):63-7.

[14] Risser MR, Ware JC, Freeman FG. Driving simulation with EEG monitoring in normal and obstructive sleep apnea patients. Sleep 2000;3:393–8.

[15] Guilleminault C, Billiard M, Montplasir J, Dement W. Altered states of consciousness in disorders of daytime sleepiness. J Neurol Sci 1975;26:377-93.

[16] Malla AM, Davidson PR, Bones PJ, Green R, Jones RD. Automated video-based measurement of eye closure for detecting behavioral microsleep. In: Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE 2010 Aug 31 (pp. 6741-6744). IEEE.

[17] Shoorangiz R, Weddell SJ, Jones RD. Prediction of microsleeps from EEG: preliminary results. In: Engineering in Medicine and Biology Society (EMBC), 2016 IEEE 38th Annual International Conference of the 2016 Aug 16 (pp.4650-4653). IEEE.

[18] Poudel GR, Innes CR, Bones PJ, Jones RD. The relationship between behavioural microsleeps, visuomotor performance and EEG theta. In: Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE 2010 Aug 31 (pp. 4452-4455). IEEE.

[19] Poudel GR, Innes CR, Bones PJ, Watts R, Jones RD. Losing the struggle to stay awake: divergent thalamic and cortical activity during microsleeps. Human brain mapping. 2014 Jan 1;35(1):257-69.

[20] Boyle LN, Tippin J, Paul A, Rizzo M. Driver performance in the moments surrounding a microsleep. Transportation research part F: traffic psychology and behaviour. 2008 Mar 1;11(2):126-36.

3.3 Fatigue

3.3.1 Rest and working hours

Time spent continuously awake

At the time of the incident, the driver had been awake for approximately 10 hours. This is not an unusually long period and time spent continuously awake is unlikely to have been a factor.

Fatigue accumulated over the previous 7 days (cumulative fatigue)

From 18 to 23 March, the regular sleeping hours of about 7 hours per night suggests that this was the typical routine for this individual during his day shift roster. There was no evidence to support significant cumulative fatigue for this individual through this period.

Fatigue prior to duty (acute fatigue)

The tram driver began work in the afternoon of 26 March having had his sleep disrupted and so achieving less sleep than had been intended. The driver attempted to supplement his shortened sleep by having a nap in the early afternoon, however his total sleep in the preceding 24 hours was less than 6 hours.

Various studies have suggested a dose-response relationship between loss of sleep the night before and subsequent increased daytime sleepiness. In one study, people reporting more than 7 hours 30 minutes sleep had significantly less probability of falling asleep than those reporting sleep durations less than 6 hours 45 minutes per night.[21] Other studies have confirmed that chronic sleep restriction to fewer than 6 hours per night has been shown to impair performance and to increase the tendency to involuntarily fall asleep.[22]

The effects of sleep reduction on cognitive performance, vigilance and daytime alertness have been well documented by several authors. The driver's sleep restricted state is very likely to have contributed to the performance impairment at the time of the incident.

The time of day (Circadian low)

The circadian low is a specific phenomenon, based on the normal human circadian rhythm. It occurs to an extent in everyone, albeit to varying degrees between people. A circadian low that occurs in the early hours of the morning (between 0200 and 0600) results in a significant dip in alertness and can produce a physiological need for sleep.[23] There is clear evidence that individuals working through a low point in the circadian rhythm are at higher relative risk of an accident.[24] At midnight the driver's circadian rhythm would have been progressing towards the window of circadian low.

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[21] Banks S. Behavioral and physiological consequences of sleep restriction. Journal of clinical sleep medicine. 2007 Aug 15;3(05):519-28.

[22] Carskadon MA, Dement WC. Cumulative effects of sleep restriction on daytime sleepiness. Psychophysiology. 1981 Mar;18(2):107-13.

[23] Rosekind. M, 1999, 'Fatigue in Transportation: Physiological. Performance and Safety Issues', National Transportation Safety Board, Evaluation of US Department of Transportation Efforts in the 1990s to Address Operator Fatigue, Safety Report NTSB/SR-99/01, Washington DC, p.71.

[24] Australian Parliament, House of Representatives' Standing Committee on Communication, Transport and the Arts. Beyond the Midnight Oil: an inquiry into managing fatigue in transport. October 2000, Commonwealth Government.

3.3.2 Sleep Apnoea

Various cognitive functional impairments have been described in OSA sufferers due to disordered sleep architecture and reduced sleep quantity. These include impaired decision-making, cognitive flexibility, memory, planning and vigilance.[25,26,27,28,29,30] However, in a comprehensive review, Tregear et al found that CPAP reduces the accident risk in drivers suffering from OSA to a statistically significant extent.[31] However, the effectiveness of CPAP is clearly highly dependent on its ongoing, regular and consistent use.[32]

The tram driver reported that he regularly used the CPAP device and was sleeping well. However, the use of the machine and its effectiveness were not further examined in this investigation.

3.3.3 Rostering

The driver was in his sixth consecutive day of work. The driver initially had a rostered day off (RDO) on 24 March, that he subsequently worked as a result of a management request. At the time of the incident, the driver was 7 hours into the shift.

3.4 Tram systems for detecting driver condition

3.4.1 Deadman system on Melbourne trams

In 2004 a trial was conducted on several Melbourne trams, including the Z Class, to test the efficacy of the type of safety pedal used in these trams.[33] Functional tests were carried out with four drivers of body mass ranging from 62 kg to 120 kg. The report concluded that it was possible to rest the foot on the pedal in a standard driving posture and hold the pedal in a set position without effort, and probably while incapacitated.

It was found that due to the pedal dual spring mechanism, the pedal would function as a foot rest with minimal safety utility for a large proportion of the drivers. Further, it appeared that accommodating occupational health requirements to minimise lower limb

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[25] El-Ad B, Lavie P. Effect of sleep apnoea on cognition and mood. International Review of Psychiatry. 2005 Aug 1;17(4):277-82.

[26] Saunamäki T, Jehkonen M. A review of executive functions in obstructive sleep apnoea syndrome. Acta Neurologica Scandinavica. 2007 Jan;115(1):1-1.

[27] Lis S, Krieger S, Hennig D, RÖder C, Kirsch P, Seeger W, Gallhofer B, Schulz R. Executive functions and cognitive subprocesses in patients with obstructive sleep apnoea. Journal of sleep research. 2008 Sep;17(3):271-80.

[28] Engleman H, Joffe D. Neuropsychological function in obstructive sleep apnoea. Sleep Medicine Reviews. 1999 Mar 1;3(1):59-78.

[29] Saunamäki T, Jehkonen M. A review of executive functions in obstructive sleep apnoea syndrome. Acta Neurologica Scandinavica. 2007 Jan;115(1):1-1.

[30] Engleman HM, Kingshott RN, Martin SE, Douglas NJ. Cognitive function in the sleep apnoea/hypopnea syndrome (SAHS). Sleep. 2000 Jun;23:S102-8.

[31] Tregear S, Reston J, Schoelles K, Phillips B. Obstructive sleep apnoea and risk of motor vehicle crash: systematic review and meta-analysis. Journal of clinical sleep medicine. 2009 Dec 15;5(06):573-81.

[32] Newman DG, Expert Opinion, Flight Medicine Systems 2018.

[33] McIntosh, A, 2004. *Review of Deadman Pedal Forces & Function on Melbourne Trams*. 39 Brady St, Croydon, Sydney 2132, Australia: McIntosh Consultancy and Research.

activation and static muscular work in the design of safety pedals had compromised the safety function of the safety pedal.[34]

This study supports the conclusion that the 'deadman' control system on Tram 190 was ineffective in detecting the driver's loss of attention and probable microsleep.

3.4.2 Task-linked vigilance systems

Z class trams are not equipped with a task-linked vigilance system that is a typical fit on a modern tram. Such systems monitor driver activity and, in the event that a driver does not perform an activity in a specified time, the system will attempt to alert the driver and if there is no response, will activate emergency braking.

3.4.3 Drowsiness and distraction detection technologies

There are several new in-cab technologies currently available for detecting drowsiness or a loss of attention. Some involve the driver wearing specific items such as spectacles for eye blink rate monitoring or special caps for brain activity (EEG[35]) monitoring and subjects these EEGs to an algorithm to detect symptoms of fatigue. Other systems use in-cab cameras to monitor the driver's facial activity to determine alertness and eye gaze movement to detect distraction.[36] Some systems use infrared devices to detect eye movement and eye closure.

Systems have also been developed to observe driver behaviour and record driver profile at the beginning of the trip. Sensors then monitor behaviour during the journey and compare that data with the original driver profile. This form of monitoring detects transition from wakefulness to drowsiness and provides a warning to the driver when symptoms of fatigue are detected.

Currently, there is limited research or in-field studies substantiating the effectiveness of vigilance technologies.[37] However, research has shown that some of these technologies may have the potential to predict decrement in performance of sleep deprived individuals.[38]

As in this instance, 'deadman' devices used on trams and trains have been shown to be limited in their ability to detect driver incapacitation. In this context, it would be appropriate for Yarra Trams to research and trial technologies to monitor alertness.

Similar occurrence and recent installations

Following an incident in the United Kingdom, in which a tram derailed at high speed due to the driver experiencing a micro-sleep,[39] Croydon Tramlink[40] installed 70 alertness

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[34] McIntosh, A, Vecellio, E, Lai, A and Friswell, R 2010. *OED Pedal Project Report*. School of Risk and Safety Sciences, University of New South Wales.

[35] An electroencephalogram is a test that monitors electrical activity of the brain.

[36] http://www.seeingmachines.com/industry-applications/automotive/ retrieved 24 July 2018

[37] Duck, N., Moss, S., Lynch, M. (2018). Literature Review on potential benefits of technology to mitigate sleep-related occurrences by tram drivers.

[38] Rajaratnam, S., & Howard. M. E. (2011). Evaluation of the SmartCap technology to monitor drowsiness in healthy volunteers exposed to sleep restriction – Relationship between the SmartCap fatigue algorithm and frequent misses on the Osler Test, Monash University.

[39] https://www.gov.uk/government/news/report-182017-overturning-of-a-tram-at-sandilands-junction-croydon: retrieved 7 August 2018

[40] Tramlink is a light rail tram system serving Croydon and surrounding areas in South London, England,

monitoring devices on their trams (two per tram). These devices are also being fitted on 400 new buses in Singapore and 74 buses on Transport for London bus routes. They use face and eye tracking to determine whether a driver is fatigued or distracted. Audio alarms and seat vibration are activated to warn the driver to re-focus their attention to the driving task.

4. Findings

4.1 Context

The following findings are made with respect to the derailment of Tram 190 at the intersection of Maribyrnong Road and Ascot Vale Road in Moonee Ponds on 27 March 2018. These findings should not be read as apportioning blame or liability to any 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.

- Tram 190 travelled at a speed that was excessive for the left-hand curve at the intersection of Maribyrnong and Ascot Vale Roads, resulting in its derailment.

- The driver of Tram 190 probably experienced a microsleep approaching the intersection resulting in the tram entering the intersection in an uncontrolled state.

4.3 Other factors that increase risk

Other factors that increased risk are safety factors that existed but did not meet the test for directly contributing to this event. These other factors are considered important to communicate in an investigation report in the interests of improved transport safety.

- **The Z3 Class tram was not fitted with systems that would be effective in detecting a loss of driver attention. [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 directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation communicated what safety actions, if any, they have carried out or are planning to carry out in relation to each safety issue relevant to their organisation.

5.1 Detection of driver inattention

Number:	2018-01-001
Issue owner:	Yarra Trams

Safety issue description

The Z3 Class tram was not fitted with systems that would be effective in detecting a loss of driver attention.

Response to safety issue by Yarra Trams

Yarra Trams has conducted a review of the safety pedal system on Z Class trams that has resulted in a recommendation to install a contemporary vigilance control system in Z class trams. The proposed recommendation is undergoing a business case assessment and installation of the system is expected to commence in July 2019.

Yarra Trams is also evaluating new technologies for the detection of driver drowsiness.

5.2 Additional safety actions

Yarra Trams has updated their procedure to ensure that all rail safety workers inform their supervisor if they are affected by a temporary or ongoing health condition or change in health status that may affect their ability to perform their work safely. Managers are required to record the notification.

Yarra Trams has issued a safety alert to all Rail Safety Workers to inform them of their responsibility to notify the employer of any temporary or ongoing health condition or change in health status that is likely to affect their ability to perform their work safely.