Office of the Chief Investigator
Transport Safety

Rail Safety Investigation
Report No 2019/01

Collision

Tram No 3535 and Tram No 3532

St Kilda Junction, Melbourne

13 February 2019

Cover photo source: VicSig.net – photo by Ian Green – used with permission.

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 13 February 2019, Tram 3535 was travelling outbound from the city on Route 5. It stopped at St. Kilda Junction (Stop 30) where the tram was to turn left (and east) away from St Kilda Road and onto Queens Way. Leaving the stop, the tram moved ahead into the facing points. Instead of turning left as required, the tram continued straight and collided with an inbound tram that was turning right from Queens Way onto St Kilda Road. Both vehicles sustained front right-hand panel and mirror damage. There were no reported injuries.

What was found

It is probable that the driver of the outbound tram either did not select a left-turn command or selected the command when the tram was not over the detection loop for the automatic points. These were assessed as the most probable scenarios that lead to the points being set for the straight direction, rather than the left-hand turn as required for this Route 5 tram.

It was also found that the design configuration of signals meant that the traffic signal at the intersection presented a green left-turn arrow to the driver, even though the points were set for the straight. This was probably a factor in the driver proceeding and not correctly perceiving that the points were set for the straight. This junction was a designated ‘off route hot spot’, and there had been 14 off-route incidents at this location in the previous two years.

In the four months following this incident, there were three similar incidents at other locations where trams took an unexpected route that resulted in collision with another tram or a road vehicle. A common factor was that traffic signal indications were in contradiction with the points setting.

What has been done as a result

Yarra Trams instructed two independent Human Factors assessment for signalling standards and driver rules, this resulted in a proposal to simplify lantern design which is currently undergoing a review.

Yarra Trams has also implemented an off-route mitigation program that focuses on the antecedents to human error and infrastructure arrangements at known locations for driver off-route events and updated its driver training for passing through signals and points.

Safety message

At locations like tram junctions, where drivers must perform a series of safety critical steps, it is vital that driver performance is supported by robust safety controls to mitigate the likelihood and effect of a driver error at any one of those steps.

TABLE OF CONTENTS

1. THE OCCURRENCE

On 13 February 2019, Yarra Trams[1] D1 class Tram 3535 was travelling away from the city along St Kilda Road, on Route 5.[2] The route follows St Kilda Road to St Kilda Junction, the intersection of St Kilda Road and Queens Way.[3] At St Kilda Junction, Route 5 trams, and also Route 64 trams, turn left, onto Queens Way (Figure 1).

Figure 1: Junction of St Kilda Road and Queens Way

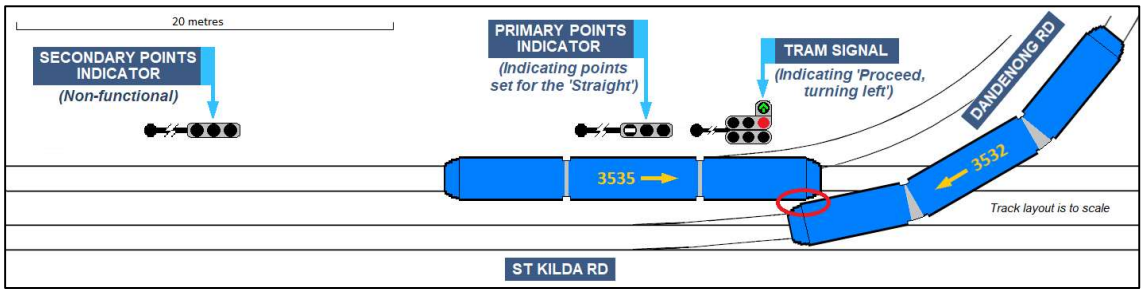
Source: MELWAYS 2017 with annotations by Chief Investigator Transport Safety

[1] Yarra Trams is the trading name of the current franchisee, Keolis Downer.
[2] Runs between Melbourne University and Malvern.
[3] Travelling east, Queens Way becomes Dandenong Road.

At about 1646, Tram 3535 arrived at St Kilda Junction, stopping prior to the stop as it was occupied by Tram 2012, a Route 64 tram. Tram 2012 departed the stop turning left to travel along Queens Way (to Dandenong Road). The driver of Tram 3535 then proceeded toward the platform and recalled selecting a left turn using the console points switch before stopping at the head of the platform for passengers to alight and board. At this point, Tram 3535 was about 14 minutes behind schedule. At the same time, inbound Tram 3532 had arrived from Queens Way and was stopped at the traffic lights prior to the junction, awaiting a green signal, to turn right onto St Kilda Road.

Facing a green left-turn arrow, Tram 3535 then departed the stop, the driver expecting the tram to turn left at the facing points. However, instead of turning left as required, Tram 3535 continued straight and collided with the inbound Tram 3532, that had commenced its right-hand turn from Queens Way into St Kilda Road (Figure 2).

Figure 2: Diagram depicting the points and signal displays at the time of the tram collision



Source: Chief Investigator Transport Safety

The collision occurred at low speed, with only the outbound tram in motion at the instant of impact as the opposing tram had stopped when its driver became aware of the imminent collision. Both vehicles were conveying around 20 passengers and there were no reported injuries. Both trams sustained minor leading-end right-hand panel and mirror damage.

The time of collision was reported as 1648. The weather was fine, with the sun to the west and rear of Tram 3535, and unlikely to have impacted its driver's visibility of signals.

At the time of the collision, Tram 3535 was being followed by Z3 class Tram 188. Consistent with operating rules, this tram did not enter the points selection zone for the St Kilda Junction stop, and therefore did not influence the operation of the automatic points system.

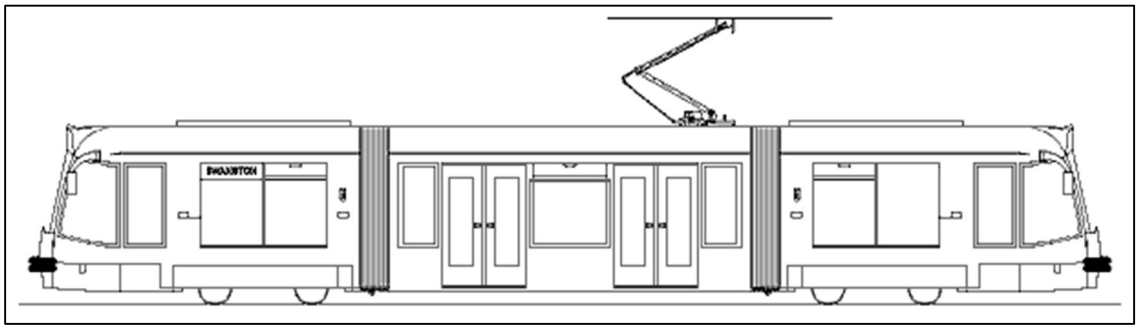
2. CONTEXT

2.1 Tram 3535

Tram 3535 is a D1 class tram manufactured by Siemens Transportation Systems (now Siemens Alstom) in 2004. It is a 3-section, low floor, vehicle designed for bi-directional operation (Figure 3). The tram is designed to carry 32 seated passengers, and 56 passengers overall.

The D1 class tram is 20.04 m long, 2.65 m wide and weighs 25.8 t. Traction is provided by 4 x 100 kW electric motors. Tram 3535 was assigned to the Malvern tram depot.

Figure 3: Yarra Trams D1-class tram



Source: Yara Trams, modified by Chief Investigator Transport Safety

Data downloaded from the Tram 3535 event recorder indicated that the tram stopped at the St Kilda Junction tram stop and on resumption accelerated to about 10 km/h before emergency braking was applied.

Post-incident inspection of the tram indicated that braking performance was within specification and tram points transponders were found to be working. However, the electrical resistances of all wheels which are important for the correct operation of track circuits were outside the allowable range (see section 3.7).

2.2 Driver of Tram 3535

The tram driver had joined Yarra Trams in July 2018 and was assigned to the Malvern depot. The driver had qualified in August 2018 to drive Z class trams and in September 2018 to drive D class trams and had been driving Route 5 since that time. At the time of the incident the driver's qualifications were current.

The driver had been rostered for the day shift commencing late-morning and ending late-evening. This was the tenth consecutive day working this shift. On 11 and 12 February, the driver commenced duty at 0948 and finished at 1932.

On 13 February, the driver commenced at 0948, driving a Route 72[4] tram before returning to the Malvern depot at 1243 for a break. The driver resumed at 1513, driving Tram 3535 on Route 5, arriving at Melbourne University terminus at 1604. The driver changed ends, and the tram departed the University destined for Malvern at 1613. It arrived at St Kilda Junction at about 1646.

There was no evidence to support that the driver was fatigued as a result of the roster. The driver was drug and alcohol tested after the incident and returned a negative result.

2.3 Infrastructure

2.3.1 Network management

The track and electric overhead infrastructure of the Melbourne tram network was owned by VicTrack[5] and leased to Yarra Trams by Public Transport Victoria (PTV)[6] on behalf of the Government of Victoria. Under the terms of the lease agreement, Yarra Trams are the Accredited Operator and are responsible for the operation and maintenance of the network and the same ownership and leasing structure also applies to the trams.

2.3.2 St Kilda Junction

St Kilda Junction is about 4.5 km SSE of Melbourne CBD, located on the bridge over Queens Way (Figure 1). The junction is a 'tram-only' thoroughfare to provide access to Queens Way below. Outbound Route 5 and 64 trams turn off St Kilda Road, to travel along Queens Way, whereas Route 3, 16 and 67 trams travel through the intersection on the straight.

The points system at the St Kilda Road and Queens Way intersection comprised a set of automatic points and associated tangent and curved trackage providing a double-tracked junction.

Post-incident inspection of the track and infrastructure by Yarra Trams found the track to be dry and free of dirt or debris. The inspection also found the points, the primary points lantern and the traffic lights were functioning as designed. However, the secondary points lantern was not operational. On their arrival after the incident, Yarra Trams observed the points to be locked for the straight position and the primary points lantern was displaying the straight direction.

2.3.3 The tram stop

Tram stop 30 at St Kilda Junction is located on the city side of the ramp to Queens Way and services passenger drop-off and pick-up for both outbound and inbound trams. The platform at St Kilda Junction tram stop for outbound trams accommodates one tram at a time. Trams arrive and depart the tram stop about every two to three minutes (Figure 4).

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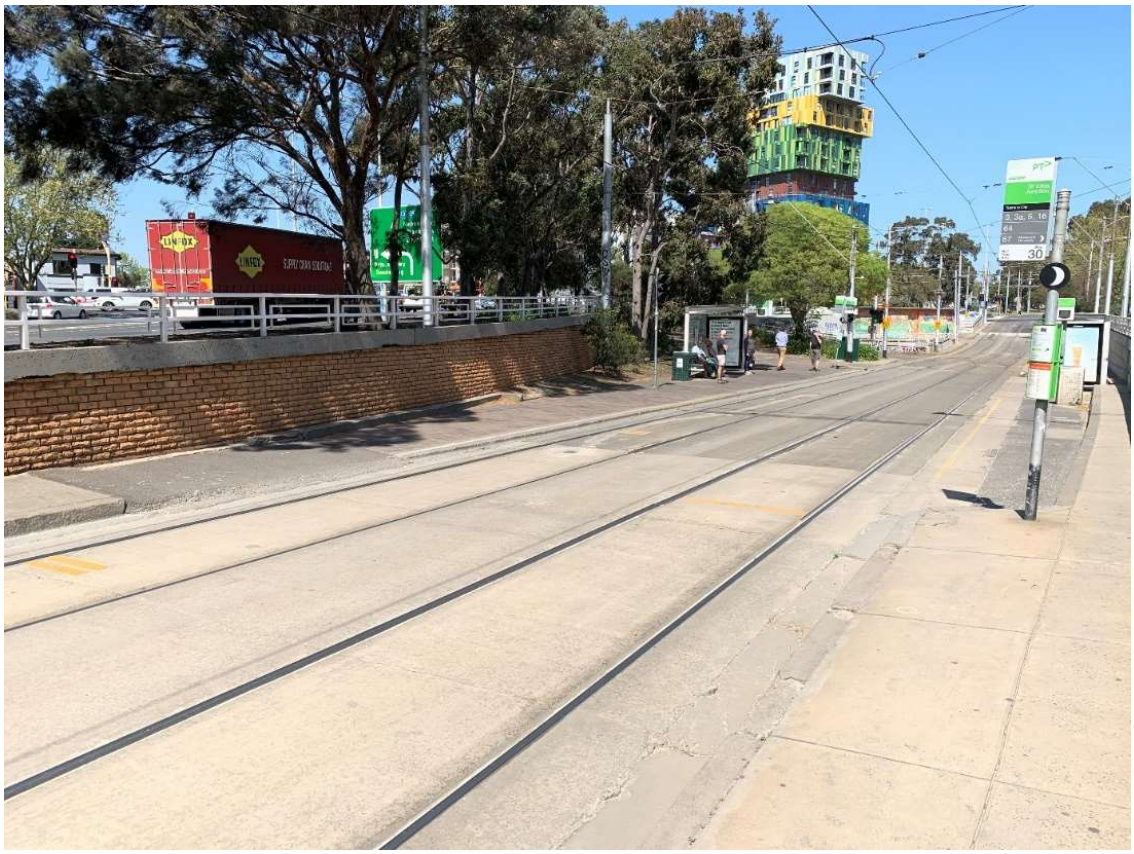
[4] From Malvern to Melbourne University.

[5] VicTrack was the trading name of Victorian Rail Track Corporation, a state-owned enterprise which owns all railway and tram lines, associated land, and other related rail-related infrastructure in Victoria (excluding the tourist & heritage operation Puffing Billy Railway).

[6] PTV was the trading name of the Public Transport Development Authority (PTDA), a statutory authority in Victoria responsible for providing, coordinating and promoting public transport. On 1 July 2019, VicRoads and Public Transport Victoria integrated with and formed part of the Department of Transport.

Figure 4: The tram stop at St Kilda Junction



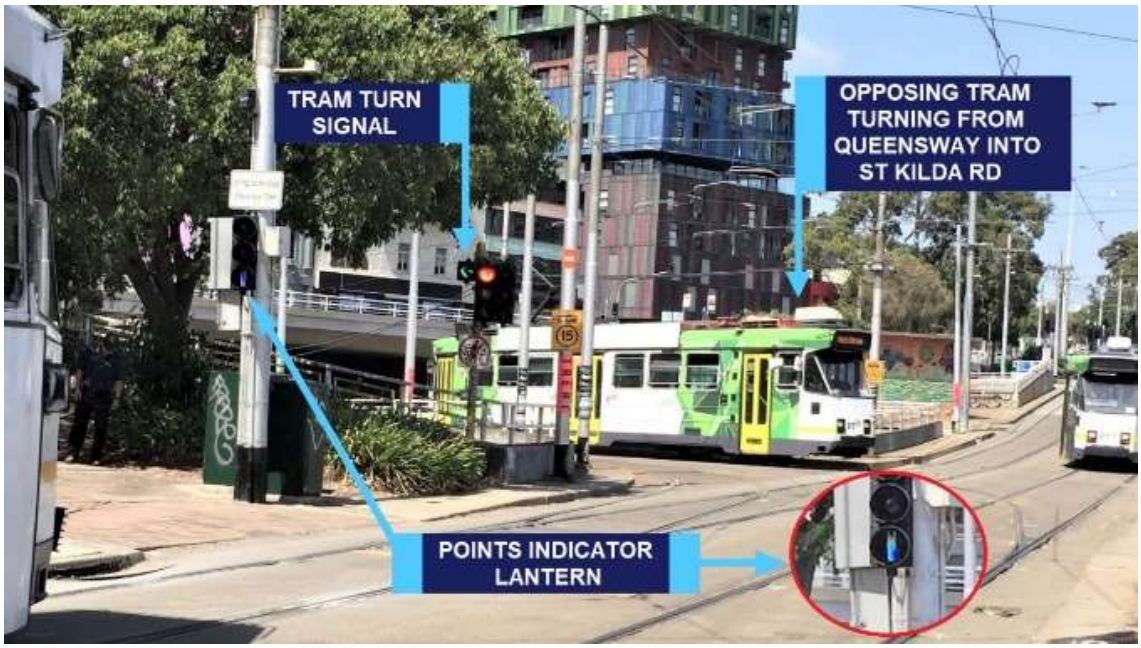
Source: Chief Investigator Transport Safety

2.3.4 Tram traffic signals

When stopped at the platform, the driver of an outbound tram was presented with traffic signals that were configured in a similar fashion to road traffic lights. They included a red-amber-green vertical array for the control of straight tram traffic, and a left-turn (green) arrow for turning trams. Inbound tram traffic arriving at the junction along St Kilda Road, or arriving from Queens Way to turn right onto St Kilda Road, were presented with similar road-style traffic lights that worked in concert with the outbound tram traffic signals. At this intersection, there were no white-illuminated arrows that are the common dedicated tram signals at locations on the network that have mixed tram and road traffic.

For outbound traffic travelling through this junction, the tram signal for the straight was predominately set for green, and the left-turn arrow extinguished. This signal condition permitted all outbound traffic to proceed, whether that be proceeding straight or turning left onto Queens Way. The trigger for a change to the traffic lights controlling outbound movements was when a city (inbound) Queens Way tram approached the junction. When the inbound Route 5 or 64 was detected, the outbound straight movement (for Routes 3, 15 and 67) was halted with a red traffic signal, and the green left-hand arrow was illuminated, providing continued permission for Route 5 and 64 trams to turn left onto Queens Way (Figure 5). In this signal configuration, outbound and inbound trams were permitted to pass while taking the curve.

Figure 5: St Kilda Junction intersection with signals as they were for the incident



Source: Chief Investigator Transport Safety

There was no clear asset manager for these traffic signals. Yarra Trams advised that it was not responsible for the asset. It advised that the traffic signal was not captured in their technical maintenance plan, although it changed the light globes in the signals when they failed. The Department of Transport, formerly VicRoads, also advised that they were not responsible for the maintenance of these traffic signals.

2.4 Automatic points

2.4.1 Automatic points description and operation

St Kilda Junction was fitted with an automatic points system that was comprised of track and trackside infrastructure (Figure 6). From the single-stud marker to the compulsory stop line is about 37 m.

The points selection system was located between the rails and, apart from the stud markers, were mounted subsurface. The track infrastructure consisted of:

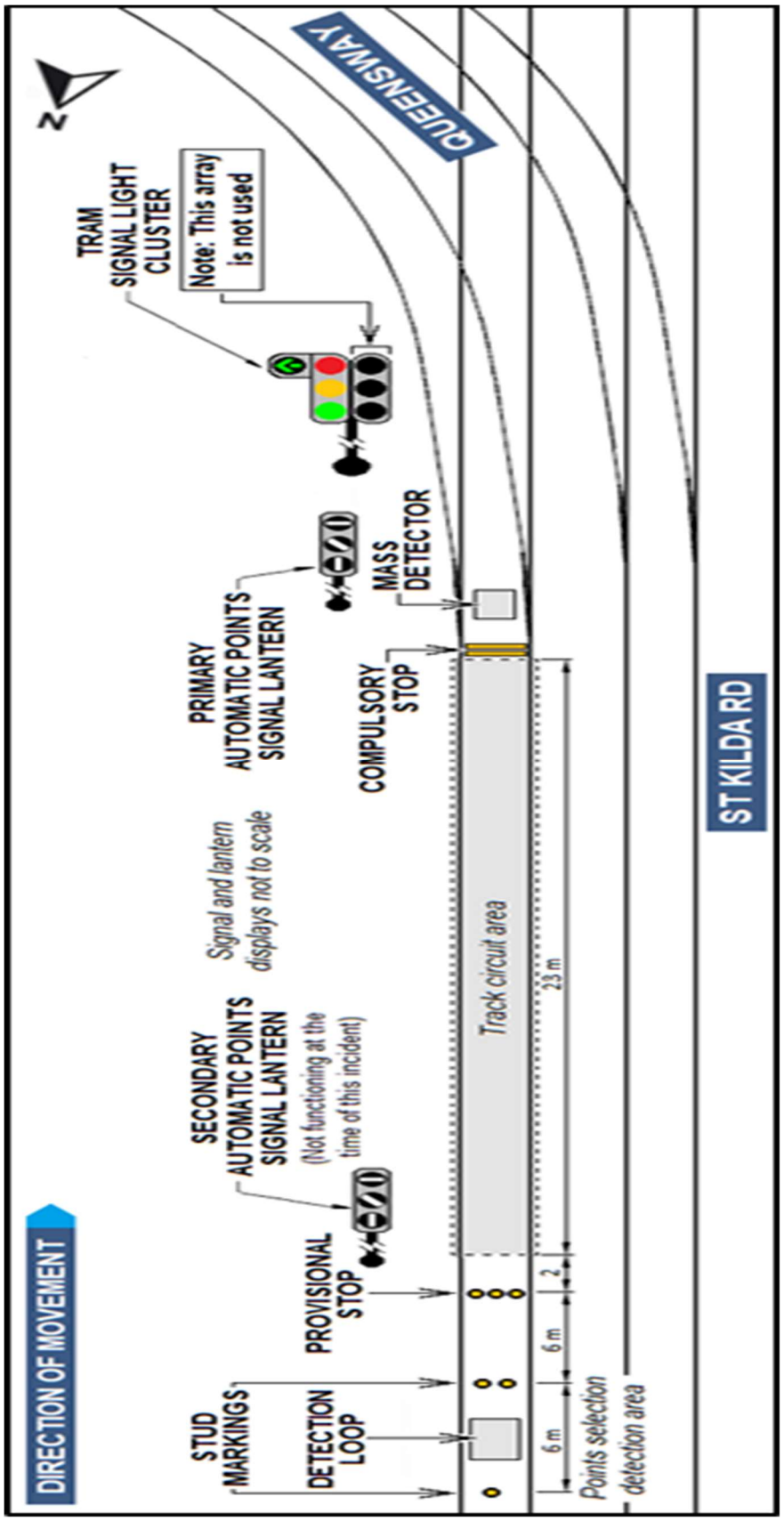
- Coloured *stud markers*:

  These were visual cues for tram drivers. The single and double stud markers defined the extent of the points selection zone. At St Kilda Junction, the distance between the single and double stud markers was about 6 m.

- The points-setting *detection loop*:

  This in-ground loop received the turn call from tram transponders and was in turn connected to the points controller located in a cabinet. At St Kilda Junction, the centre of the detection loop was around 34 m before the points.

Figure 6: Track infrastructure and signal arrangement at St Kilda Junction



Source: Chief Investigator Transport Safety

- An elongated *track circuit area*:

  A track circuit that detected the presence of a tram was used to electrically lock the points in the current position to avoid following trams changing the points direction prior to a tram completing its transit of the points zone. This track circuit detected the presence of tram wheel sets that would electrically bridge or short circuit the two rails that form the track circuit section. At St Kilda Junction, the track circuit was about 23m in length.

- A *mass detector*.

  This subsurface detection loop was situated between the point blades. It detected the presence of a tram and worked in conjunction with the track circuit to ensure that no other tram operated the points locking function until the tram was clear of the points.

The only active device on the tram for the points-setting operation was the points transponder. This device transmitted the points-setting direction (straight or curve) depending on the position of the driver's points-selector switch (Figure 7) located on the driver's console.

Figure 7: Points selector switch

When the tram entered the 'detection loop' section (between the one and two stud markers) the driver if turning, was required to turn and hold the points selector switch to the desired direction of turn. In the case of Tram 3535 at St Kilda Junction, the switch was required to be turned to the left position.

The default position of the switch was straight, and should the driver not make a turn selection, straight ahead was selected and the points, if set for the Queens Way turn, would move to straight-ahead.

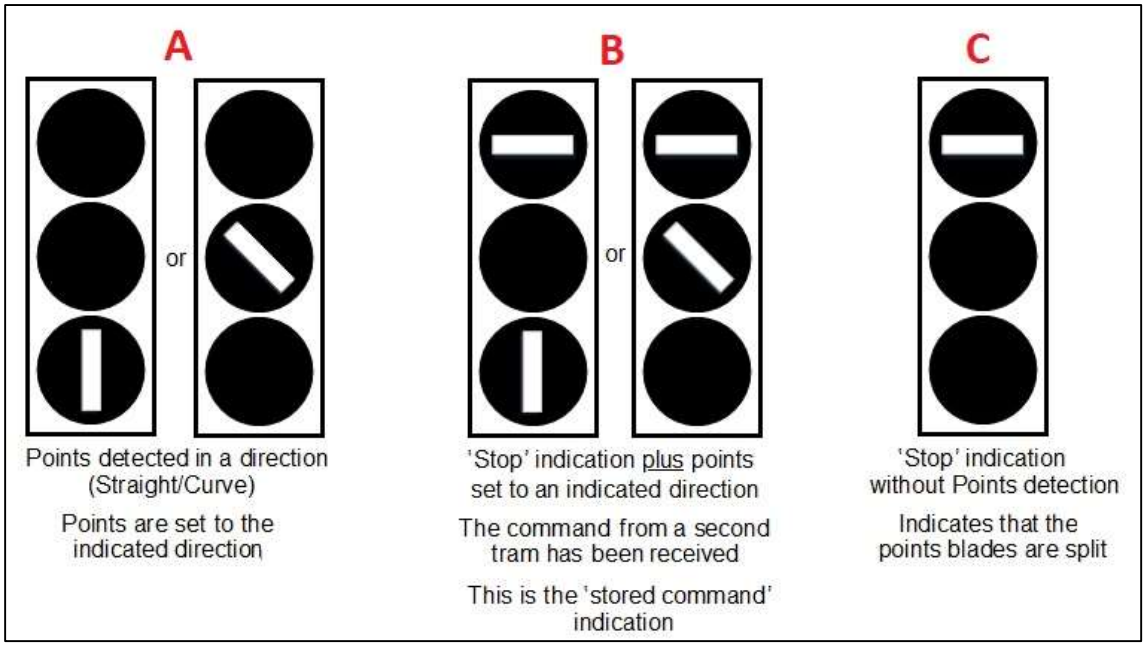
2.4.2 Points selection and points lanterns

At St Kilda Junction, in the outbound direction, the primary points lantern assembly was located close to the compulsory stop. It could be viewed by the driver when stopped at the head of the stop, before the tram reached the points. Another (identical) lantern assembly, the secondary points lantern, replicated the primary indication and was located earlier in the approach direction, adjacent to the provisional stop (Figure 6). The secondary points lantern was so positioned that it was visible to the driver at the provisional stop located at the beginning of the track circuit. The secondary points lantern was not operational at the time of the incident.

The normal state of automatic points was to lie for the direction set by the previous tram through the location. If there was no tram ahead at the stop, the points lantern would display the setting of the points via an illuminated bar: vertical for straight-ahead; or 45 degrees for a turn (in the direction of turn) (Figure 8, Image 'A').

Should there be a tram ahead, stopped or not clear of the mass detection section, and the approaching tram wished to travel in a different direction to the tram ahead, the points lantern would mimic Image 'B' in Figure 8. That is, a horizontal bar meaning stop; and identifying the command from the following tram has been stored. In this instance, the tram must be stopped at the provisional stop until it was clear to proceed to the compulsory stop at the toe of the points.

Figure 8: Indication of the points settings on the points lantern



Source: Yarra Trams, with annotations by Chief Investigator Transport Safety

If the points were not correctly set, a single white horizontal bar (Image 'C') would be illuminated, indicating a possible fault.

Proceeding beyond the provisional stop, a tram entered the track circuit region. When the track circuit detected a tram, the points would be locked in that position until such time that the tram had travelled past the track circuit and the mass detector. Once the tram was clear of the mass detector, the points would be released, and the points controller would respond to the next command.

2.4.3 Driver observation of points setting

Before departing the tram stop, tram drivers are required to identify the lay of points by visual observation and observe the primary points indicator.

2.4.4 Maintenance of automatic points systems

The automatic points systems were required to be checked and maintained in accordance with the Yarra Trams Safety Management System. Its maintenance plan required the automatic points controller and lanterns to be inspected every 12 months. The most recent inspection was four days before the collision on 7 February 2019.

The following systems were not operational at the time of the incident:

- The points data logger
- The secondary points lantern, that had been out of service for some time.

2.4.5 Interface between tram signals and points indicators

The tram traffic signals control system was independent of the tram automatic points system. This meant that the traffic signal could indicate a green left-turn arrow while the points were set for the straight direction (Figure 9). This system independence was common on the Melbourne network.

Figure 9: The points set for the straight, with the traffic signal indicating a left turn green arrow

Source: Chief Investigator Transport Safety

2.4.6 Points control on other tram networks

Eight light rail operations within Australia and overseas were surveyed for details on operation of the points control system. The systems were found to be of two types:

- driver selection at each junction (similar to Melbourne), or
- pre-programmed selection (or auto-routing) for a route.

Within the survey sample, four of each type were reported. Pre-programmed systems reduce the likelihood of a driver selection error that might result in an off-route movement.

2.5 Related risk controls

2.5.1 Risk Triggered Commentary

Yarra Trams had mandated a driver procedure to assist drivers to remain situationally aware when negotiating areas of the network subject to increased risk of error. The procedure incorporated features of Risk Triggered Commentary (RTC) and point and-call techniques, with emphasis on the physical movement. These techniques involve gesturing (finger pointing) to heighten the worker's cognitive focus at critical times and locations. When successfully implemented, RTC may assist drivers to maintain their attentional focus on identifying and managing operational risks and ensuring that the right actions are taken.

While its popularity amongst rail operators in Australia and overseas appears to be increasing, to date the established research to support RTC remains limited. When successfully implemented, RTC may assist drivers to maintain their attentional focus on identifying and managing operational risks and ensuring that the right actions are taken. While RTC has been found to be an effective technique for some drivers, not all drivers have found it useful, and some research has indicated that for some individuals, it may add to cognitive workload and possibly hinder the operation of non-verbal cognitive processes (verbal overshadowing) or interfere with time perception.[7] [8] [9] There is also evidence to suggest that the repetition of phrases leads to increased boredom (and thus loss of conscious attention) and possible loss of meaning (semantic satiation) of the repeated phrase.[10]

2.6 Other collisions and near misses

2.6.1 Incident records

Fourteen off-route[11] and near miss incidents at the St Kilda junction involving the facing points for the left turn from St Kilda Road into Queens Way were reported between March 2017 and the collision in February 2019. This intersection had been identified as a 'hot-spot'[12] for trams going off-route. A warning board advising drivers was posted on the points lantern post (Figure 9). The 'Table' referred to in the sign, is a document detailing the tram routes that the driver will be driving that shift.

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[7] Earl, L, Mavin, T & Soo, K. (2015). Demands on cognitive processing. Implications for verbalisation in complex work environments. Cognition, Technology and Work, 19, 31-46.
[8] Gilhooly, K. J., Fioratou, E. and Henretty, N. (2010). Verbalization and problem solving: Insight and spatial factors. British Journal of Psychology, 101, 81–93.
[9] Hertzum, M. & Holmegaard,K.D. (2015). Thinking Aloud Influences Perceived Time. Human Factors 57(1), 101-109.
[10] Sato, A. & Bowler (2015). Investigating the effect of using risk triggered commentary driving and point and call checks. Fifth International Rail Human Factors Conference 14-17 September 2015 Book of Proceedings (466-476)
[11] Yarra Trams defines an off-route incident as one that results in a non-rostered movement at facing points.
[12] Terminology used by Yarra Trams to identify a location of higher risk

Network-wide, Yarra Trams drivers reported 441 near miss incidents[13] at facing points between 1 January 2015 and 31 January 2019.

2.6.2 Previous investigation

The Chief Investigator Transport Safety (CITS) investigated and reported on a 2010 tram-to-tram collision on Flemington Road.[14] A tram was proceeding along Flemington Road toward the city, when the driver mistakenly altered the setting of the points at the Abbotsford Street intersection. When the traffic lights permitted the tram to proceed straight ahead, the tram was routed for the turn and was struck by an oncoming tram crossing the intersection from the opposite direction. A recommendation from the investigation was that Yarra Trams consider the provision of an appropriate system of interlocking of points and signals that would prevent conflicting movements at junction locations.

2.6.3 Similar occurrences following the St Kilda Junction collision

Three collisions at intersections occurred on the Yarra Trams network in the four months after the collision at St Kilda Junction that exhibited characteristics similar to those of the incident at St Kilda Junction.

Flinders Street and Exhibition Street, Melbourne on 13 April 2019

Two trams travelling in opposite directions on Route 75 along Flinders Street collided when the outbound tram unexpectedly took the right-turn route towards Exhibition Street. The driver of the outbound tram had expected the tram to take the straight route and had proceeded when the traffic signals permissioned the movement of straight traffic.

Glenferrie Road and High Street, Malvern on 24 June 2019

A Route 16 tram travelling north along Glenferrie Road collided with a motor vehicle proceeding south when the tram turned unexpectedly to the right at the High Street intersection. In this case, the transponder signal from the tram (selecting the straight) was not received and the points remained set for the right-hand turn. The driver proceeded on receiving signal permission to proceed straight-ahead.

St Georges Road and Miller Street, Thornbury on 2 August 2019

A Route 11 tram travelling northbound on St Georges Road stopped at the intersection with Miller Street where there was to be a driver change. The outgoing driver had forgotten to set the points at this junction for the Route 11 diverge to the left, and the incoming driver forgot to check. When the tram moved off with signals permissioning the left diverge, it unexpectedly continued straight and collided with an inbound tram.

[13] Yarra Trams define a near miss facing points incidents as one that results in:
- assistance from an officer in charge to avert the tram from travelling in the non-rostered direction
- proceeds through points on the incorrect traffic signal
- proceeds at points in a direction not taken by home depot lines
- report points changed contrary to selection.

[14] CITs Rail Safety Investigation Report No 2010/08, Tram-to -tram collision at the intersection of Flemington Road and Abbotsford Street, North Melbourne on 3 September 2010

3. SAFETY ANALYSIS

3.1 The Incident

At the time of the incident, the points for outbound traffic at St Kilda Junction were set for the straight. Therefore, when Tram 3535 proceeded from Stop 30, rather than turning left onto Queens Way as was required for Route 5, it continued straight and collided with the inbound Tram 3532. It is likely that the driver proceeded on seeing the green turn arrow.

3.2 Route selection

3.2.1 Driver selection of route

Automatic points in Melbourne require tram drivers, on approaching a junction, to make an active turn selection if they are diverging from the straight (turning) or to take no action if they are continuing straight. The selection must be made in advance of the platform stop, within a zone designated by road (stud) markers on either end of the points detection loop (Figure 6). In this instance, the driver was required to make a left-turn selection.

Available evidence does not support scenarios involving a failure in the automatic points system or of the tram transponder that activates the automatic points. The more probable scenario is that the driver either did not make a left-turn selection or made that selection when the tram's transponder was not over the detection loop. Both these scenarios would result in the automatic points system returning the points to the straight, having been set for the left turn by the preceding tram.

The secondary points lantern was also out of service, removing an opportunity for the driver of Tram 3535 to detect an error in points selection prior to passing the provisional stop position.

The tram was also being followed by Tram 188. The scenario of this tram entering the points selection area and moving the points back to the straight with Tram 3535 at the Stop was considered. However, evidence indicates that Tram 188 had not yet entered the points selection area and would therefore not have influenced the automatic points system.

3.2.2 Automatic tram routing

Systems that provide automatic selection of points' setting for each route are common but not universal on other tram networks. Auto-routing systems removes the potential of driver points direction selection errors.

3.3 Observations by driver when stopped at compulsory stop

3.3.1 Observations of the primary points lantern

The points lantern provided an indication against which the driver could confirm their earlier selection of the correct route. Thus, the lantern provided a checkpoint for the driver to ensure that they had correctly set the points, and an opportunity to 'catch' an error before it led to an adverse outcome.

In this case, post-incident review demonstrated that the points lantern nearest to the points was operating as designed, suggesting that the most likely indication presented to the driver was that the points were set for a straight-ahead movement. There was no evidence to indicate that the points lantern was unavailable to the driver. To that end it appears most likely that the driver either did not observe the points lantern or misunderstood its indication.

3.3.2 Observation of the points position

Physical observation of the lay of the points presented a further opportunity for the driver to identify an error in the points selection process. There was no evidence to indicate that the points were not set for the straight when the tram arrived at the compulsory stop, and it appears most likely that the driver either did not observe or misinterpreted the lay of the points.

3.4 Factors influencing the driver's observations

3.4.1 Signal and points visibility

At the compulsory stop, both the points lantern and the traffic signals could be observed from the tram cab. There were no factors, including sun glare, that were likely to impair their observation.

The event occurred in daylight and there was no obstruction to the points being able to be observed by the driver.

3.4.2 Expectancy

During interview, the driver recalled observing the points set for a left turn. This disparity between the driver's recall and the actual lay of the points is potentially the result of expectancy effect, whereby the driver's expectation of having set the points to turn to the left has influenced their observations and recall of the points position. This effect has been most notably established by road user research, particularly with motor vehicle driver failure to observe other road users such as motorcycles or bicycles, simply because they are not expecting to see them, even when looking directly at them.[15] The driver's expectation that the points would be set for a left turn (in accordance with their mental model) possibly overrode the effectiveness of their checking observation.

[15] See for example: Chabris, C. & Simons, D. (2009). The Invisible Gorilla, and Other Ways Our Intuition Deceives Us. Broadway Paperbacks: New York.

3.4.3 Tram driver workload

Human information processing is limited in that each person has finite mental or attentional resources available to attend to information or perform tasks at any particular time. In general, if a person is focussing on one particular task, then their performance on other tasks will be degraded.[16] Further, human capacity for attention normally varies throughout a period of time, such as a working shift. For this reason, it is unrealistic to expect that human performance will be error free.

The tram driver's primary task on approach to and while traversing the junction was to control the movement of the tram and safely negotiate the junction. In doing so, the driver was required to observe the detection loop and select the direction for the points; bring the tram to a stop at the tram stop and supervise passengers alighting and boarding; make announcements; and proceed to the compulsory stopping point[17]; stop the tram; perform the required risk triggered commentary (RTC) tasks; observe and interpret the points indication; confirm the lay of the points by physical observation; and observe and obey the traffic signals before proceeding through the junction. If the attention of the driver was elsewhere, then this may have reduced their capacity to correctly perform the actions and to perceive a setting of the points conflicting with their expectations.

Considering the number of safety critical steps[18] involved in this task, it is vital that driver performance is supported by robust safety controls which will mitigate the likelihood and effect of a driver error at any one of those steps.

3.4.4 Route knowledge

Route knowledge assists drivers with situation awareness[19] and the ability to plan operations by allowing them to think ahead and anticipate future requirements[20], as well as enabling driver detection of abnormal track conditions. To that end, drivers are required to demonstrate sound route knowledge through an assessment of competency for each route they drive.

The driver was qualified and had been operating on this route for about five months. There was no evidence to indicate that a deficiency in route knowledge had negatively impacted on the driver's performance.

3.4.5 Fatigue and other factors

At the time of the collision the driver was about 1.5 hours into a 4.3 hour shift following a 2.5 hour break. There was no evidence to suggest that the driver's performance was adversely affected by fatigue caused by the roster, or other performance shaping factors.

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[16] Kahneman, D. (2011). Thinking Fast and Slow. Farrar, Straus & Giroux: New York

[17] On this occasion, the driver made use of the tram stop as the compulsory stop point owing to the close proximity between the two locations. Yarra Trams procedures permit this discretion, due to full view of the points and signals being available from the tram stop.

[18] That is, steps where if error or non-compliance occurs, this can lead to a significantly adverse safety outcome.

[19] Endsley, M.R. (1995). Towards a theory of situation awareness in dynamic systems. Human Factors, 37(1). 32-64.

[20] McLeod, R.W., Walker, G.H., Moray, N. & Mills, A. (2005). Analysing and Modelling Train Driver Performance. In J.R. Wilson, B. Norris, T. Clarke & A. Mills (Eds.), Rail Human Factors. Supporting the Integrated Railway (pp 70-80). Ashgate: Aldershot.

3.4.6 Reliance on administrative controls

From a human performance perspective, driver negotiation of this junction is subject to numerous error provoking features. Opportunities for error are for the most part resolved with controls which are themselves subject to human performance limitations. Controls such as RTC, warning signs, and driver checks can be effective as control supports only. They are insufficient on their own. Further, combining additional behavioural controls may add to driver workload, thus further increasing risk of error or non-compliance, rather than resolving it.

3.5 Independent traffic signal operation

3.5.1 St Kilda Junction configuration

The tram left-turn proceed signal is operated by the traffic light controller independent of the automatic points system, and therefore independent of the points direction. The driver of Tram 3535 was therefore faced with a turn proceed signal providing permission to proceed even though the points were set for the straight.

3.5.2 Other locations on the network

Incident data indicates that occurrences of trams taking an unintended route at other locations on the network are not uncommon. There were over 400 reports of near-miss incidents at facing points in the four years before the St Kilda Junction collision, and three similar collisions at traffic-signalled junctions in the four months after. It is probable that driver error was a factor in many of these instances, and that driver expectancy and the operation of signals independent of the points setting contributed to many of these errors.

Traffic signals that provide a proceed indication independent of the points setting increase the likelihood of a tram movement in an unintended direction, potentially placing the tram in conflict with other trams or other road users.

3.6 Points equipment condition

The secondary points lantern at the St Kilda Junction outbound platform was not operational. If working correctly, it would have provided an early indication to tram drivers of their setting of the points at this location. Additionally, the data logger for the automatic points system at this location was not functioning.

3.7 Wheel resistance

Automatic points systems on the Melbourne tram network use a track circuit located after the points selection area to detect the presence of a tram. This detection triggers locking of the points setting mechanism to prevent a following tram from changing the points until the preceding tram has cleared.

Tram wheel resistances are regularly tested as part of the tram maintenance program to ensure they are adequate for tram detection on track circuits. The results of post-incident testing of Tram 3535 found that the wheel-to-wheel resistance on all axles was outside specified limits. This would have increased the likelihood of the tram not being detected on the network. In relation to the St Kilda Junction occurrence, this was not a factor as the following tram had waited clear of the points selection zone.

4. FINDINGS

4.1 Context

The following findings are made with respect to the collision of Tram 3535 with Tram 3532 at St Kilda Junction on 13 February 2019. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

A safety issue is an event or condition that increases safety risk and:
(a) can reasonably be regarded as having the potential to adversely affect the safety of future operations; and,
(b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

4.2 Contributing factors

- The driver of Tram 3535 probably either did not select a left-turn command or selected the command when the tram was not over the detection loop.
- It is likely that the driver of Tram 3535 either did not see or misread the points signal indicator and the lay of the points.
- The left-turn signal for outbound trams at St Kilda Junction provided permission to proceed for the turn when the points were set for the straight**. [Safety Issue]**

4.3 Other factors that increased risk

- Traffic signals on the network that provide a proceed indication independent of the setting of the points increase the likelihood of a tram movement in conflict with other trams or other road users. **[Safety Issue]**
- The secondary points indicator was not functional.
- Tram 3535 wheel-to-wheel resistances were outside specified limits.

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 Independence of traffic signals at St Kilda Junction

Number:	2019-01-001
Issue owner:	Yarra Trams

Safety issue description

The left-turn signal for outbound trams at St Kilda Junction provided permission to proceed for the turn when the points were set for the straight**.**

Proactive action taken by Yarra Trams

Yarra Trams instructed two independent Human Factors assessment for signalling standards and Driver rules, this resulted in a proposal to simplify lantern design which is currently undergoing a review.

Safety action recommended by the Chief Investigator

The Yarra Trams review and associated design proposal was concerned with points signals only without accounting for the drivers' interaction with both tram and road traffic signals.

Accordingly, is recommended that Yarra Trams undertakes a full human factors review of several hotspot locations including the tram and road traffic signals that a driver is expected to interpret and respond to and develop improvements to reduce collisions caused by off-route trams.

5.2 Independence of traffic signals at other locations

Number:	2019-01-002
Issue owner:	Yarra Trams

Safety issue description

Traffic signals on the network that provide a proceed indication independent of the setting of the points increase the likelihood of a tram movement in conflict with other trams or other road users.

Proactive action taken by Yarra Trams

An off-route mitigation program is ongoing which focuses on the antecedents to human error and infrastructure arrangements at known locations for driver off route.

Driver training has been updated for passing through signals and points

Safety action recommended by the Chief Investigator

Yarra Tram's proactive safety actions are acknowledged however as noted above, the Yarra Trams review and associated design proposal was concerned with points signals only without accounting for the drivers' interaction with both tram and road traffic signals.

Accordingly, is recommended that Yarra Trams undertakes a full human factors review of several hotspot locations including the tram and road traffic signals that a driver is expected to interpret and respond to and develop improvements to reduce collisions caused by off-route trams.