



Office of the Chief Investigator  
Transport Safety

**Rail Safety Investigation  
Report No 2010 / 07**

**Tram to Tram Collision  
The Arts Centre, Stop 14  
St Kilda Road, Melbourne  
2 June 2010**





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## **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. In conducting investigations, the Chief Investigator will apply the principles of 'just culture' and use a methodology based on systemic investigation models.

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.



## **EXECUTIVE SUMMARY**

On the morning of 2 June 2010, 'D' Class Combino Tram 3510 was approaching Tram Stop 14 opposite The Arts Centre on St Kilda Road, when it collided with another tram at the stop.

The investigation found that when Tram 3510 arrived at the stop, the driver looked into his rear view mirror and did not notice that the tram ahead of his had slowed down. By the time he looked ahead again, the distance between the trams had closed and Tram 3510 could not be stopped in time to avoid collision.

The investigation also found that Yarra Trams has not actioned previous recommendations made by the Chief Investigator following similar tram-to-tram collisions. This report recommends that Yarra Trams reviews the safe speed of trams when approaching a stop and conducts a comprehensive analysis of previous tram collisions, with a view to implementing appropriate safety defences.





# **1. CIRCUMSTANCES**

## **1.1 The incident**

On the morning of 2 June 2010, 'D' Class Combino Tram 3510 was being operated on a Route 16 service from Kew to Melbourne University, Carlton. The tram departed Kew Terminus at 1008<sup>1</sup>. At 1027 the tram stopped outside Malvern Tram Depot where there was a change of driver.

Tram 3510 then travelled along its appointed route and turned left onto St Kilda Road from Fitzroy Street at about 1058. From there the tram travelled along St Kilda Road towards Melbourne University.

AVM (Automatic Vehicle Monitoring) Polling Data, recorded at the Yarra Trams Fleet Operations Centre indicates that at about 1110 Tram 3510 caught up with Tram 133 at Stop 19 at the Dorcas Street intersection. Tram 133 was also heading towards Melbourne University. The trams departed the stop and continued travelling in tandem towards the city.

At about 1111, the trams stopped at the intersection of St Kilda Road and Southbank Boulevard, opposite the National Gallery of Victoria. While they were stopped, Tram 143 turned from Southbank Boulevard into St Kilda Road ahead of them and stopped at Stop 14.

When the tram traffic signal changed to 'proceed', Trams 133 and 3510 resumed passage to Stop 14. Tram 133 stopped behind Tram 143 while Tram 3510 was some way back still approaching the stop.

At about 1112, just as Tram 3510 was entering the platform, Tram 143 departed the stop and Tram 133 started moving to the head of the platform. At that time the driver of Tram 3510 took his eyes off the road to look into his rear-view mirror. When he looked forward again, a few seconds later, he saw that Tram 133 was very close ahead and collision was imminent. Tram 3510 collided with Tram 133 at a speed of about 23 km/h.

## **1.2 Consequences**

There were a total of 15 passengers in the two trams. One passenger in each tram received injuries that required transport to hospital by ambulance. The driver of Tram 3510 suffered minor bruising.

Tram 3510 suffered damage to its front panel and windscreen.

The rear end of Tram 133 suffered broken panels and windscreens and the driving console was pushed in.

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<sup>1</sup> All times are in Australian Eastern Standard Time.



## **2. FACTUAL INFORMATION**

### **2.1 Driver, Tram 3510**

The driver of Tram 3510 had about four years experience driving trams, having joined Yarra Trams in May 2006. He was stationed at the Malvern Tram Depot. The driver qualified to drive 'Z' Class trams in June 2006 and 'D' Class trams in September 2006. His last medical examination was conducted in June 2006 at which time he was declared fit for duty.

The driver completed the mandatory tram drivers defensive driving course in June 2006 and his latest refresher training course was undertaken in December 2009. The course syllabus included discussions on fatigue awareness and driver concentration. The driver also underwent the six-monthly follow-up tram driver check trip in April 2010 and was deemed competent.

In the days preceding the incident, the driver was on rostered leave on 30 and 31 May. On 1 June, he worked from 0527 to 1409. In his evidence he stated that he relaxed at home after his shift on 1 June and he went to bed at about 2130. He awoke the next morning at about 0200 due to a pain in his inflamed right wrist and at about 0430 he took an anti-inflammatory tablet prescribed for him by his GP.

The driver commenced his shift at 0521 on 2 June 2010, driving a Combino tram on Route 72. At 0857 he had a meal break. He was still feeling some pain in his wrist so at about 1000 he took another tablet. After his meal break he commenced driving Tram 3510 on Route 16, heading towards the university. He stated that he was feeling well and refreshed. The pain in his wrist had subsided and he was not feeling any discomfort.

The trip towards the city was uneventful and was running on time. The driver stated that he did not encounter any interference from other road vehicles or pedestrians during the trip. He became aware of Tram 133 ahead of him when he was approaching Stop No 19 at the intersection with St Kilda Road and Dorcas Street.

Tram 3510 followed Tram 133 through the intersection of St Kilda Road and Southbank Boulevard, towards Stop 14. As Tram 3510 approached the stop, the driver noticed Tram 133 stop behind another tram and he started the process of slowing his tram by bringing the throttle to 'neutral'. He then noticed Tram 133 about 20 metres ahead of him start moving forward. The driver stated that at about that time, he looked up into his rear-view mirror to check on the passengers.

When he looked forward again, after about two to three seconds, the driver said that Tram 133 was not moving as fast as he had expected it to, and that he was very close to it. He stated that he was probably travelling at about 20 km/h. He applied the service brake but realised that it was too late to avoid collision so he applied the emergency brake; but the tram hit the tram ahead.

Following the incident the driver was breath tested and found to have a zero blood-alcohol reading.

## 2.2 The Trams

### 2.2.1 Tram 133 specifications



Figure 1 Tram 133

Tram 133 is a double bogie tram of the 'Z1' class and is driven by four 57 kW ASEA motors, giving it a service speed of 65 km/h. The tram has driver consoles at both ends. Tram 133 is 16.64 metres in length and has a tare weight of 21.8 tonnes and can carry a maximum of 114 passengers.

'Z' Class trams are fitted with AVM polling equipment but are not fitted with a data logger.

### 2.2.2 Tram 3510 specifications



Figure 2 Tram 3510 side view and front view, photographed at different times during its lifespan.

Tram 3510 is a Combino D1 3-part-tram built by Siemens, Germany. The tram commenced service in September 2003 and was assigned to the Malvern Tram Depot. Tram 3510 has an overall length of 20.04 metres, an extreme width of 2.65 metres and weighs 26.8 tonnes. The tram is driven by four 100 kW Siemens motors giving it a maximum service speed of 70 km/h. It is configured to carry a maximum of 168 passengers of which 36 are seated.

The tram was up to date with its schedule of maintenance and servicing.

Tram 3510 is equipped with a Journey Data Evaluation (Darec) logger built by Messma GmbH Germany, for Siemens. Darec is evaluation software that continuously records critical operating systems on the tram into graphics and tables.

Post incident, the data logger was downloaded and its diagnostic memory statistics were retrieved. The data indicated that the tram's driving, braking and general operating systems were operating normally until the time of the incident.

The data logger also identified that as Tram 3510 approached Stop 14, the driving throttle was put into 'neutral' and the tram kept moving forward under its own (built-up) momentum at 23 km/h. The service brake was activated a few seconds before collision and just after the collision the emergency brake was activated.

### 2.2.3 Tram 3510 driver's cabin

A driver's cabin is located at each end of the tram. The adjustable driver's seat is equipped with an armrest and is situated on the centre line of the tram. The chair can be adjusted so that the driver can operate the driving control and at the same time reach the console controls with minimum movement in the chair. Forward of the driver's chair is the main operating console and to the right is the driving console.

The windows around the driver's cabin are of laminated glass, giving the driver about 180° field of vision, with minimum obstruction to the line of the corner frames. Rear-view mirrors are installed outside the cabin on each side, to provide the driver sight along the sides of the tram and to the rear.

The driver's cabin is secluded from the passenger section. The windows are of fixed glass and the egress door to the passenger section is maintained closed and locked when the tram is in service. The cabin is air conditioned with recirculated air but the sliding window on the egress door may be opened to permit fresh air.

### 2.2.4 Tram 3510 driving control

The driving control (see Figure 3) on the right-hand side of the driving console controls the forward movement and braking of the tram. When the control is in the upright position the driving motors remain in neutral with the brake disconnected. When the control is pushed forward the tram accelerates, commensurate with the amount of movement applied to the control.



Figure 3 Tram 3510 Driving console

The service braking system is engaged when the control is pulled backwards from the upright position. The braking effect is commensurate with the amount of movement

applied to the control. The service brakes have an average deceleration rate of 1.35 m/s<sup>2</sup> and a maximum of 1.61 m/s<sup>2</sup>.

When the driving control is pulled backwards to its extremity, the emergency brake is applied. The emergency brake can also be applied by depressing the red button on the main operating console. When in emergency braking mode, the deceleration rate is 3.40 m/s<sup>2</sup>.

## 2.3 Infrastructure



**Figure 4 Stop 14**

Tram Stop 14 on St Kilda Road (see Figure 4) is opposite the Melbourne Arts Centre, about 156 metres north of the Southbank Boulevard intersection. This tram ‘superstop’ was built in June 2008. The tram track runs in a straight line from Stop 17 to Stop 14 (about 600 metres) and continues in a straight line to the next stop at Flinders Street. The track in this section slopes upwards by about 150 mm from the Southbank Boulevard intersection and is level across the ‘safety zone’ and tram platform stop.

The length of the ‘safety zone’ on the inbound track is about 83 metres and is separated from the road by a protective metal fence on a concrete barrier. The length of the platform on this track is about 63 metres.

An inspection of the track infrastructure found that it was in a satisfactory condition for the operation of trams, at the time of the incident.

## 2.4 Environment

At the time of the incident the sun was about 37° to the right of the driver’s vision when travelling towards the city and about 28° above the horizon. The sky was partly cloudy (less than 4 octas). The temperature was about 15° Celsius and the visibility was greater than 10 km. There were no weather induced impediments affecting the driver’s visibility or adverse track conditions that would have affected vehicle traction or braking. The track was dry and clear of debris.

## **2.5 Yarra Trams**

### **2.5.1 Safe operating procedures**

'Yarra Trams' is the trading name for the Melbourne Metropolitan Tram Network franchise that operates the trams and maintains and manages the infrastructure. The current operator of the franchise took over on 30 November 2009.

Yarra Trams has developed and implemented '*General Operational Rules and Procedures*' for the operation of its trams. The current operator is required to update and upgrade the procedures as may be required from time to time. The manual provides guidelines on operational procedures, tram operations, safe interaction with traffic, interaction with the public and general road rules.

Drivers are only assigned the types of trams that they have been trained to drive, on routes where they have undergone familiarisation training. The management of driver working hours is primarily monitored by depot administration staff. Each depot is also required to have a fatigue management plan, which complies with the Public Transport Safety Code of Practice<sup>2</sup> and WorkSafe Victoria safety requirements.

Yarra Trams driver policy requires each driver to report to the Starter's Office at their respective depot before signing the register that they are fit for driving trams. The Starter conducts a preliminary impairment assessment (in accordance with the Code of Practice) to ensure that the driver is fit to carry out his or her duties.

Any medication consumed by a tram driver must be reported to the Depot Manager prior to the driver commencing duties for that shift. The Depot Manager will check whether the stated medication is on the list of approved medications prior to assigning driving duties. In this incident, it was noted that the driver of Tram 3510 had consumed approved medication.

### **2.5.2 Safety Zones and speed limits**

Up until 4 August 2008, Yarra Trams' '*General Operational Rules and Procedures*', Rule 78(g) mandated a maximum speed of 10 km/h through designated safety zones which includes tram terminals and stops.

The Rule was amended effective 4 August 2008 to state that "Trams entering or leaving a safety zone or platform stop must proceed with caution, consistent with the conditions at the time and maintaining appropriate control of the vehicle, unless otherwise specified".

In addition to the above, Rule 104 states that "When a Tram is slowing down or stopped, the Driver of the following Tram must proceed with caution and be prepared to stop not less than one metre from the Tram in front".

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<sup>2</sup> Code of Practice for Health Assessment of Rail Safety Workers, July 2004, adopted from the National Standard for Health Assessment of Rail Safety Workers.

## 2.6 Tram to tram collisions

### 2.6.1 Statistics

The following table shows the number of end-to-end collisions between trams in service that have occurred in the previous five years up to the time of this incident, all of which occurred when the leading tram slowed down / stopped at a tram stop or traffic signal.

Occurrence Area	2006	2007	2008	2009	2010
Melbourne Metropolitan Area	16	20	29	27	15
St Kilda Road	2	6	3	4	4

**Figure 5 5-Year tram to tram collision statistics up to the time of the incident**

There have been three collisions at the Arts Centre Stop - on 10 September 2008, 1 July 2009 and this incident.

### 2.6.2 Previous safety recommendations

Schedule 2 of the *Rail Safety Regulations 2006* requires Yarra Trams to implement processes to ensure that corrective action is taken in response to any safety risks identified following any inspections, investigations, testing or audits and that the corrective action is monitored by them.

Since 2008 the Chief Investigator has investigated five end-to-end tram collisions and made several safety recommendations to Yarra Trams. The recommendations that are relevant to this investigation are listed below:

1. Report No 2007/11 Recommended Safety Action 2008037 -- Yarra Trams should extend its systemic review of incidents to complete the remaining phases of its project with the independent consultant namely:
  - o inspection and familiarisation visit to examine equipment, view routes, driving tasks, etc;
  - o discussions and information from key personnel in a focus group setting; and
  - o assessment and evaluation of current defences.

Yarra Trams has informed the investigation that the systemic review in accordance with this recommendation has not been undertaken.

2. Report No 2008/08 Recommended Safety Action 2008043 -- Yarra Trams carries out a comprehensive review and analysis of Tram to Tram collision data and adopts a strategy to isolate contributory factors in order to minimise the number of incidents.



Yarra Trams have reported that this recommendation is under consideration. The investigation found that Yarra Trams has collected statistics regarding the number of collisions that have occurred but have not done a review of those statistics with a view to identifying and isolating the contributory factors.

The investigation noted that where corrective action was taken, such corrective action was taken in isolation (for example, “driver stood down”) for individual incidents.

3. Report No 2008/08 Recommended Safety Action 2008044 -- Yarra Trams sets up a program to monitor tram speeds on approach to tram safety zones including all tram stops.

Yarra Trams has informed the investigation that this recommendation has not yet been actioned.

## **2.7 Human factors research**

### **2.7.1 Driver attention and reaction time**

Attention is a complex process that refers to the capacity of an individual to maintain some level of alertness during their activities. It involves a narrowing of an individual's focus. Failures of attention can occur when distracting or unnecessary information intrudes on processing. Under such conditions the road users' attention can potentially become narrowly focused on information that is unrelated to the driving task.

Muttart<sup>3</sup> (2005) has suggested that there are appropriate and inappropriate contributors for inattention to a road hazard. Inappropriate attention may take the form of talking on a mobile phone or adjusting radio settings. Examples of appropriate forms would include checking the speedometer reading. However, directing attention to those tasks may lessen the likelihood of detecting a road hazard.

A driver's reaction time is used to assess the swiftness with which they respond to a potential hazard. Reaction time encompasses the time from when the object is first detected and identified, through interpretation of the objects meaning, determination of how to respond, and the execution of the response actions.

A reaction time of 2.5 seconds is generally used in the road design context as the majority of drivers unalerted to a more urgent situation are able to respond in that time frame (Austroads<sup>4</sup>, 2003; Lay<sup>5</sup>, 1985). Reaction time does not include the time taken for the vehicle to respond (for example, brake lag times), or complete the action the driver intended (for example, come to a complete stop).

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<sup>3</sup> Muttart, J.W. (2005). Estimating driver response times. Handbook of Human Factors in Litigation (pp. 14-1 – 14-25).

<sup>4</sup> Austroads. (2003). Guide to traffic engineering practice: Part 7 – traffic signals.

<sup>5</sup> Lay, M. (1985). Source book for Australian roads. Australian Road Research Board.



### **3. ANALYSIS**

#### **3.1 The incident**

Tram 3510 approached Stop 14 at a speed of about 23 km/h. When the driver noticed the trams ahead start moving, it appears that he assumed that the tram directly in front of his was also departing the stop. He brought the driving control to neutral but let the tram roll ahead under its own momentum, expecting Tram 133 to start increasing speed and that his tram would have an additional 15 to 20 metres of track before having to stop.

At that same time he took his eyes off the tram ahead to look into his rear-view mirror. This action prevented him seeing that Tram 133 had only moved to the head of the stop. By the time the driver looked ahead again, the distance between trams was closing very rapidly and collision was imminent.

Tram 133's brake was released at the time of collision, which probably reduced the force of impact and therefore the damage suffered by both trams.

#### **3.2 The tram driver**

The driver's schedule of work and rest for the days preceding the incident indicates that fatigue was not an issue in this incident. It is also noted that at the time of the incident he was not in any pain and it is unlikely that the medication he consumed impaired his driving ability.

The task of driving a tram can be relatively complex requiring an individual to allocate cognitive resources to manipulating the vehicle's controls, scanning the external and internal environment whilst maintaining a safe distance from the tram ahead and also being prepared to stop immediately for interfering road traffic and/or pedestrians.

While it is an 'appropriate form of distraction' to check the rear-view mirror from time to time, in hindsight, the driver should not have checked his rear-view mirror when he did, but should have waited until his tram had come to a complete stop or until he had first verified conclusively the status of the tram(s) ahead.

#### **3.3 Tram braking capability**

According to the driver, he was about 20 metres away from the tram ahead when he looked into the rear view mirror. Tram 133 then moved ahead by about 16 metres (one tram length) to the head of the stop.

Tram 3510 at that time was travelling at 23 km/h (or 6.4 metres per second) so in the time that the driver looked into the mirror (about two to three seconds), the tram would have travelled between 13 and 19 metres. Therefore, when the driver looked forward again, his tram would have been about 20 metres from the tram ahead and still travelling at about 23 km/h.

Allowing for a reaction time of 2.5 seconds before the driver activated the brake, the tram would have travelled a further 15 metres before the braking system would start reducing the speed of the tram. At a speed of 23 km/h and a braking deceleration rate of  $1.35 \text{ m/s}^2$ , the tram should have stopped within about 15 metres and in just under 5 seconds once the brake was activated.

Had the driver applied the service brake when the tram first entered the Stop or had the driver been properly aware of the movement of Tram 133, collision should not have occurred. However, although there initially appeared to be a sufficient distance off to start reducing speed preparatory to stopping, the driver's act of looking into the rear view mirror "for about two to three seconds" resulted in him having insufficient time and distance within which to bring the tram to a stop.

### **3.4 Safety zone speed**

Travelling at a higher speed requires a quicker reaction time. There is also a higher risk of damage, personal injury and associated consequences in case of a collision. Prior to 4 August 2008 drivers had to reduce the tram speed to 10 km/h as soon as they entered a safety zone. From 4 August 2004, Rule 78(g) was amended and in effect transferred the responsibility for selecting a safe speed to the tram driver.

The fenced zone of a tram stop is called a 'Safety Zone', the reason being that this is an area where passengers will congregate, potentially causing a heightened risk of contact with trams approaching the stop. A slower approach speed will provide the driver more time to assess the situation when entering the safety zone and be able to stop the tram very quickly. It would also, in most cases, reduce the severity of injury should there be any contact with a pedestrian.

In this incident, if Tram 3510 had entered the Stop at 10 km/h, a distraction of two to three seconds would have seen it travel between 5.5 and 8.5 metres in that time and be stopped within three metres in about two seconds. Even allowing for a reaction time of 2.5 seconds, in this instance the collision in all probability would not have occurred. Even if the trams had collided, the slower speed would have reduced the amount of damage suffered to both trams.

### **3.5 Previous investigations' recommendations**

It appears that Yarra Trams has not conducted a systemic review and analysis of tram to tram collisions as recommended by the Chief Investigator's previous investigations.

Safety Recommendation 2008037 recommended that Yarra Trams conduct comprehensive research into the driving conditions and situations faced by tram drivers and therefore the risks faced by tram drivers and the defences required to mitigate those risks. The result of such research could provide Yarra Trams with an understanding of the risks encountered by tram drivers and whether their current defences would mitigate those risks.

Safety Recommendation 2008043 supplements 2008037 in that it recommended that Yarra Trams investigate and analyse the contributory factors to collisions. Such analysis would provide Yarra Trams with the knowledge of why collisions occur and thereby, what may be done to mitigate the chance of such collisions recurring.

Removing a person from driving trams (or "driver stood down") does not provide an answer as to why trams are colliding. There was no evidence of a strategy to identify the factors contributing to an incident and then applying systemic safety actions.

Safety Recommendation 2008044 recommended that Yarra Trams monitors tram speeds on approach to tram safety zones. The intent of this recommendation was to determine whether the change to Rule 78 was as safe an option (if not safer) to the earlier requirement to approach a safety zone at not more than 10 km/h.

Stop 14 was converted into a 'superstop' in June 2008 and the 10 km/h safety zone speed rule was amended in August 2008. Statistics indicate that although the number of collisions on St Kilda Road reduced by about 50%, there has also been one collision every year at Stop 14 since September 2008. Furthermore, statistics for the whole tram network indicates that the number of tram collisions increased by 50% in 2008 and has remained steady in the ensuing years.

If Yarra Trams implements a program to monitor tram speeds on approach to safety zones, it would help to determine whether there is any correlation between the removal of tram maximum speed restrictions and the increase in collisions overall. It may also provide some insight into why there has been one collision a year at Stop 14 since it was converted to a 'superstop', and none before.



## **4. CONCLUSIONS**

### **4.1 Findings**

1. The driver was appropriately qualified to drive Tram 3510.
2. The driving and braking systems of Tram 3510 were operating normally prior to the incident.
3. Each tram driver is responsible for determining the safe speed of his/her tram when approaching a stop.
4. The medication consumed by the driver did not present any known impairment to the driving ability of the driver.
5. The fact that Tram 133 was moving at the time of impact reduced the severity of the impact and the resultant damage to the trams.
6. Yarra Trams has not actioned the Chief Investigator's previous Safety Recommendations 2008037, 2008043 and 2008044.

### **4.2 Contributing Factors**

1. Tram 3510 did not slow down sufficiently when approaching Stop 14.
2. The driver of Tram 3510 allowed himself to be distracted at the time his tram entered Stop 14.
3. When the driver of Tram 3510 applied the brakes, there was insufficient distance available to stop the tram.





## **5. SAFETY ACTIONS**

### **5.1 Safety Actions taken**

Yarra Trams have advised the investigation that they “have made some changes to the corrective action process within their safety management system to pick up the current liability of the Chief Investigator’s safety recommendations that still require attention”.

### **5.2 Recommended Safety Actions**

#### **Issue 1**

Compliance with the Chief Investigator’s previous safety recommendations could have provided Yarra Trams with an insight into the circumstances surrounding tram-to-tram collisions and thereby, of appropriate defences to implement to mitigate the risk of future collisions.

#### **RSA 2011006**

That Yarra Trams extend its systemic review of incidents to complete the remaining phases of its project with the independent consultant namely:

- inspection and familiarisation visit to examine equipment, view routes, driving tasks, etc;
- discussions and information from key personnel in a focus group setting; and
- assessment and evaluation of current defences.

#### **RSA 2011007**

That Yarra Trams carries out a comprehensive review and analysis of tram-to-tram collision data and adopts a strategy to isolate contributory factors in order to minimise the number of incidents.

#### **RSA 2011008**

That Yarra Trams sets up a program to monitor tram speeds on approach to tram safety zones including all tram stops.