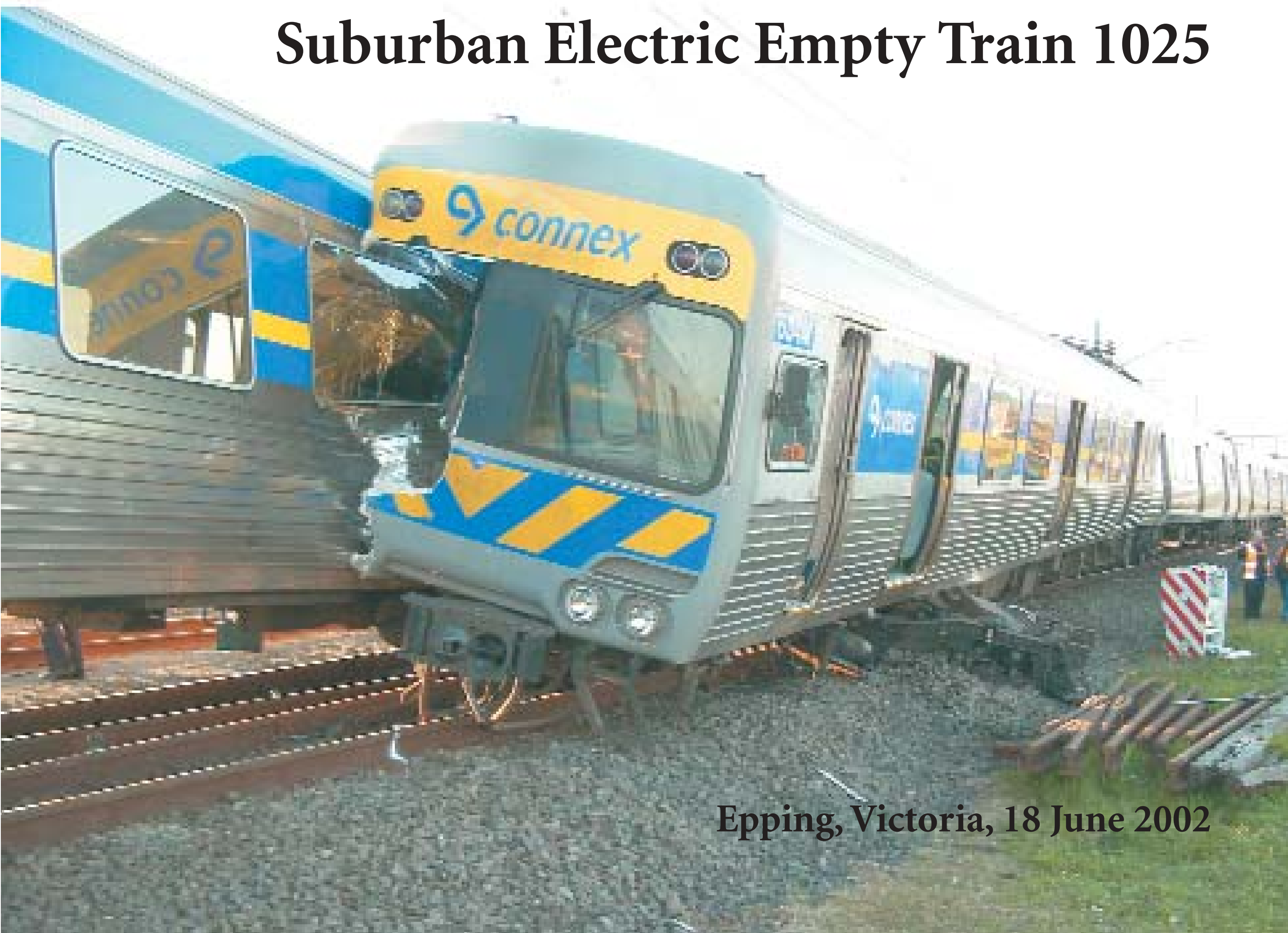
AUSTRALIAN TRANSPORT SAFETY BUREAU

RAIL SAFETY INVESTIGATION
2002/001

Collision Between Suburban Electric Passenger Train 1648 and Suburban Electric Empty Train 1025



Epping, Victoria, 18 June 2002

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Department of Transport and Regional Services

Australian Transport Safety Bureau

RAIL INVESTIGATION REPORT
No. 2002/001

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The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Commonwealth Department of Transport and Regional Services. The ATSB's objective is safe transport. It seeks to achieve this through: open and independent no blame investigation; safety data analysis; and safety communication and education.

As the ATSB believes that safety information is of greatest value if it is passed on for the use of others, readers are encouraged to copy or reprint for further distribution, acknowledging the ATSB as the source.

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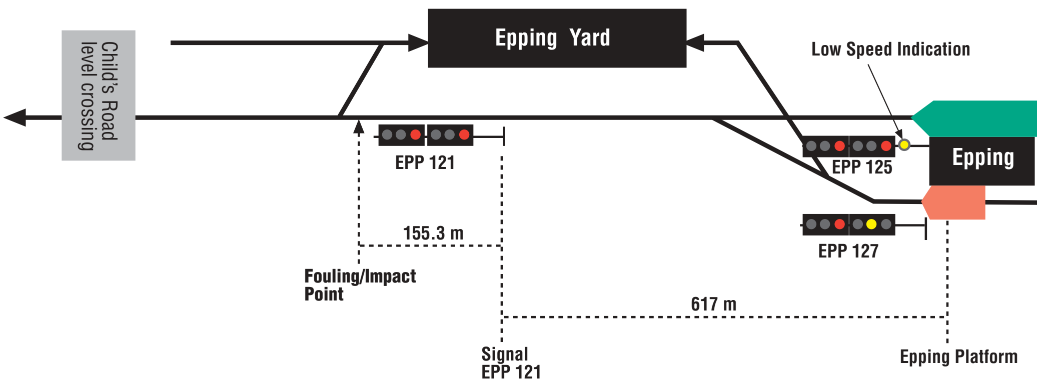
EXECUTIVE SUMMARY

At about 0914 on Tuesday 18 June 2002 a scheduled suburban electric passenger train number 1648, on an up journey, collided with an approaching scheduled suburban electric empty train number 1025, on a down journey, on a section of single line, 772.3 metres south of Epping Railway station. Passenger train 1648 had a driver and 16 passengers on board, while the empty train 1025 had a driver and two other drivers travelling as passengers with the train. Train 1025 was traversing a single line section and crossing into Epping Yard at the time of the collision. The leading cab on train 1025 had just traversed a set of points and passed the fouling point for both the main line and the crossover line into Epping Yard, moments prior to the collision. Train 1648 had departed Epping platform and was advanced into the single line section on a restricted indication, and had subsequently passed signal EPP121 that was indicating stop. Both trains and infrastructure, including signalling and tracks, were operated by Melbourne Transport Enterprises, through Connex Trains Melbourne (CTM) and Alstom Melbourne Transport Limited (AMTL).

Emergency services, including the Police, Fire and Ambulance services attended the scene. The driver of the passenger train suffered bruising to his right upper arm, but was discharged from hospital on the day of the collision. Minor injuries to passengers were reported. No passengers were hospitalised.

The evidence available, including an expert medical assessment, suggests that the driver of train 1648's performance was impaired by his physically 'unwell' condition. He could not recall events between the departure from Epping station on the up journey and the point that the train passed signal EPP121 at stop, a period of about one minute. As a result, signal EPP121 was passed at stop and a collision occurred. Train 1648 was travelling at about 60 km/h and train 1025 at about 12 km/h, at the point of initial impact.

FIGURE 1:
Signal distances at Epping



There are safeguards or defences to protect against such an accident. On this occasion the defences in place failed to prevent the accident. A number of defences were identified as being inadequate in terms of design or application.

The investigation established that train maintenance was not a factor in the accident. In addition, the signalling system, which incorporates automatic train stops, operated within its design criteria. However, the design criteria of the signalling system was such that it could not maintain a minimum safety margin to prevent the collision, given the speed of the passenger train involved.

Trains are fitted with pilot valves (including a dead man's handle), so that in the event that a driver becomes incapacitated the train should be brought to a halt. On this occasion the driver of train 1648 had become incapacitated but the pilot valve did not activate by applying the train's emergency brakes.

The performance of the driver of train 1648 was impaired by migraine symptoms, and possibly treatment, and the effect of stressful personal circumstances. The driver's history of migraine had been declared during regular medical assessments but the medical guidelines did not address the symptoms or treatment for a potentially incapacitating illness. The report also addresses factors that contribute to the driver working when he was unwell.

The Investigation Team has also reviewed the factors surrounding the Footscray collision on 5 June 2001 (ATSB rail investigation report no. 11-01) and considers this event to contain some similar safety issues.

A number of safety actions have been taken or are underway through the Victorian Department of Infrastructure.

The report's recommendations on pages 41 and 42 relate to:

- the design of the signalling system;
- the train working procedures for trains operating on single line sections of track;
- the medical fitness/assessment guidelines;
- the medical conditions that can impair or incapacitate a train driver;
- driver sign-on procedures;
- sick leave policy;
- emergency procedures; and
- recommendations contained in the ATSB Footscray investigation report.

1 INTRODUCTION

1.1 Terms of reference

The Victorian Minister for Transport, the Hon Peter Batchelor, requested the Australian Transport Safety Bureau (ATSB) to undertake an independent investigation into the collision between an empty suburban train and a suburban passenger train near Epping railway station on 18 June 2002. The investigation was conducted in accordance with the provisions of the *Transport Act 1983 (Victoria)* as amended.

The Terms of Reference for the investigation are as follows;

The Investigation will examine all relevant matters including:

1. The events leading to the collision, including determination of the relative contribution of rolling stock, infrastructure and operating procedures.
2. Train maintenance systems.
3. Signal maintenance systems.
4. Training and re-training procedures for relevant staff.
5. Operating procedures and effectiveness of such procedures.
6. Medical condition of the rail safety workers involved in the collision.
7. Post collision emergency management arrangements and procedures.
8. Relevance (if any) to the recommendations from the ATSB Investigation into the collision at Footscray railway station on 5th June 2001.
9. Final report format to follow the model Draft AS Guidelines for rail safety investigations.

2 INVESTIGATION METHODOLOGY

The purpose of this investigation was to enhance rail safety in the Melbourne Metropolitan network, by determining the sequence of events which led to the accident and the factors which may have influenced those events. Of particular importance is the need to understand what the accident revealed about the environment in which this particular rail operation was being conducted, and to identify deficiencies with the potential to adversely affect future safety.

The analysis of this accident is based on the Reason model[1] of accident causation in modern technological systems. The report was written using the format contained in the Australian Standard 5022-2001 'Guidelines for rail safety investigation' and in accordance with the terms of reference.

During the investigation, information was obtained and analysed from a number of sources, including:

- visits to the accident site;
- inspection and analysis of the rollingstock involved in the derailment;
- recorded train and train control information;
- track and rolling stock maintenance records, procedures and standards;
- the history of organisational and infrastructure changes associated with the accident site;
- interviews with personnel directly associated with the accident;
- interviews with management and safety personnel of organisations relevant to the accident;
- a review of the driver medical assessment and management system;
- a review of organisational documentation;
- staff training curriculum for Safeworking employees; and
- the ATSB Footscray investigation report.

In addition technical analysis and reports were provided from relevant experts on aspects of:

- brake systems and pilot valves;
- signalling and infrastructure; and
- transport medicine.

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

1 REASON, J. 1990, *Human Error*, (Cambridge University Press: Cambridge) ; REASON, J. 1997, *Managing the Risks of Organisational Accidents*, (Ashgate Publishing Limited: Aldershot).

3 FACTUAL INFORMATION

3.1 Background

Epping is located approximately 22.5 kilometres from Spencer Street station, north of the Melbourne CBD. The station is classified as a premium station[2]. Epping is the terminal station on the Clifton Hill – Epping line.

There is a maintenance yard facility adjacent to Epping station on the western side of the line between the Child's Road level crossing and the station platform. The maintenance yard consists of 26 tracks, six of which are under cover inside the maintenance shed, in addition there is a dedicated wash road and 19 stabling/ marshalling roads. Entrance to the yard is via Epping platform, or the southern entrance between Child's Road level crossing and Epping platform.

The Clifton Hill – Epping section of line is a double line from Clifton Hill to Keon Park, then 4.7 kilometres of single line to Epping, with a platform crossing loop at Lalor. The signalling system is a combination of three and four aspect signals, both controlled and automatic. The safeworking system[3] operated over the section Keon Park – Lalor is Automatic[4] and Track Control[5], the section from Lalor to Epping is Station Limits[6].

The maximum permissible line speed is 80 km/h for electric trains in the Clifton Hill – Epping section. Traction power is 1500 volt DC supplied by suspended overhead wiring.

The collision involved two suburban electric trains operating on the Melbourne Metropolitan network. The trains and infrastructure, including signalling and track, were all operated and maintained by Melbourne Transport Enterprises, through principle contractors Connex for train operations, and Alstom for maintenance.

The accident site was 772.3 metres south of Epping station, in the Epping – Lalor section of single line. The first point of contact was at the fouling point[7] on number 22 points.

Connex suburban train operations included the Epping, Hurstbridge, Lilydale, Belgrave, Alamein, Glen Waverley lines via the City Loop, and Flemington Race course. During the peak hours (first train–0900, 1530–1830, Monday to Friday), and for most off-peak periods, this service was operated on a regular 20-minute frequency.

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2 Premium stations are staffed first to last train seven days a week, full booking office facilities, bright lighting, Closed Circuit TV monitoring, public telephones, enclosed waiting areas, and toilets open first to last train.

3 Safeworking systems are an integrated system of operating procedures and technology for the safe operation of trains and the protection of people and property on or in the vicinity of the railway.

4 Automatic, signals operating independently.

5 Track Control, all points and signals operated remotely from Epping signal box.

6 Station Limits, all points and signals operated from Epping signal box.

7 The fouling point is the point between two (or more) lines which cause obstruction to the other line(s) passage.

At the time of the accident the trains scheduled between Epping and Clifton Hill were:

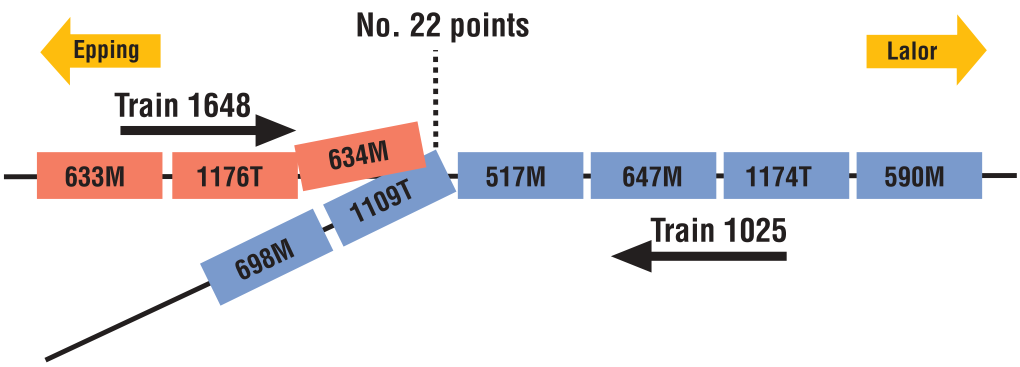
	Mon-Fri	*Sat*	*Sun*	*Total*
Up Trains[8]	60pass, 5mt	50pass	38pass, 1mt	148pass, 6mt
Down Trains[9]	58pass, 8mt	50pass	39pass	147pass, 8mt
Total	118pass, 13mt	100pass	77pass, 1mt	295pass, 14mt

Pass = passenger service, mt = empty train[10]

Train 1648 was a single three car unit, scheduled to depart at 0913[11] from Epping platform one, southern end, to the City Loop.

Train 1025 was scheduled to depart Flinders Street platform 1 at 0836, as a two unit consist, and then run empty directly into Epping yard. Normally running on mostly restricted signal indications train 1025 would directly follow another down passenger service to Epping.

FIGURE 2:
Layout of carriages at the accident scene.



3.2 Sequence of events

Train 1025, the 0836 empty service, left platform 1, Flinders Street, Melbourne at 0850:21, almost 15 minutes late and was due at Epping Yard at 0913. In addition to the driver, there were two other Connex drivers travelling as passengers in the driver's compartment. From Flinders Street the train had an uninhibited passage through to Lalor platform. The train passed Lalor, down end, at 0912:35, some two minutes and 35 seconds behind the scheduled passing time of 0910, before slowing for a low speed signal indication to proceed across Child's Road level crossing into Epping Yard.

Train 1648, the 0913 passenger service, left Epping platform 1 at 0913:15 on a Medium Speed warning indication displayed from signal EPP 127. The train increased speed

8 Up Trains refer to trains travelling from an outer station to the city.

9 Down Trains refer to trains traveling from the city to an outer station.

10 Empty trains on the down may travel directly into the Yard, empty trains on the Up may depart directly from the Yard.

11 All times shown in this report are in Eastern Standard Time.

over 617 metres and passed the next signal, EPP121, displaying a stop indication at 0914:19, at or near full line speed (80 km/h). The signal activated the emergency braking system on the train. The driver indicated that he had noticed the restricted signal indication displayed from signal EPP127, but could not recall anything beyond that point, until hearing the emergency brake activate as the train passed signal EPP121.

At 0914:23 the leading axle on the first carriage of empty train 1025 passed over number 22 points leading into Epping Yard. The driver, and driver passengers, noticed the oncoming train and recognised the danger. The driver decided to apply the throttle just prior to impact, hoping to move the crew compartment out of the impact zone.

At 0914:33 train 1648 collided with train 1025, both trains coming to a stop about three seconds later.

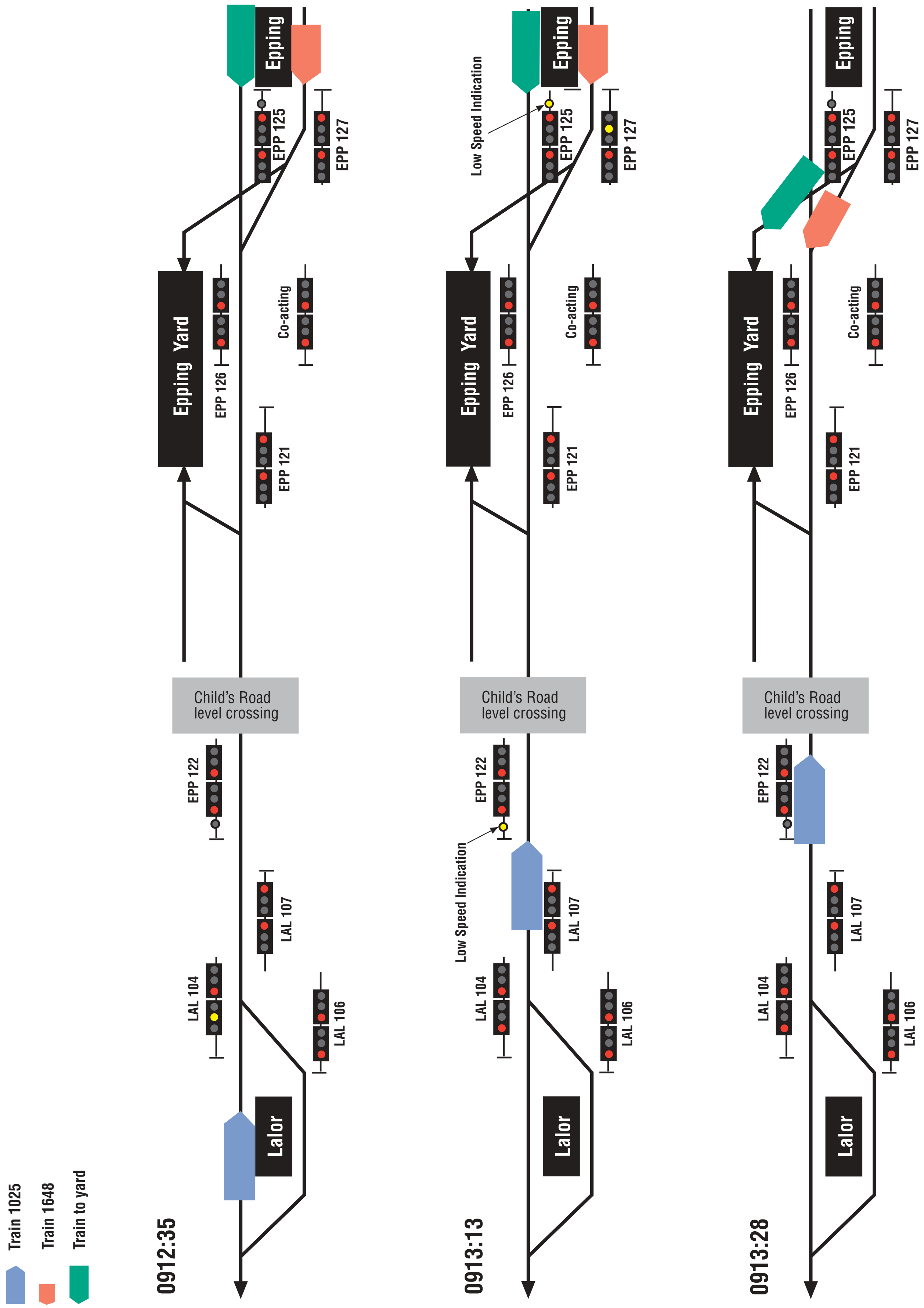
The leading carriage on passenger train 1648 made first contact on the leading carriage on train 1025, approximately 12 metres from the front of the train, skidding along the first carriage and into the second car of the empty train.

The driver of the train 1648 had braced himself just prior to the impact, but sustained an injury to his upper right arm. The leading carriage of his train, lurched to the side on impact with the empty train causing the leading bogie to rotate 90° clockwise and shear off under the carriage. The leading carriage came to rest on the ballast shoulder canted to an angle of 15–20°. Carriage 1109T from the empty train derailed the leading bogie.

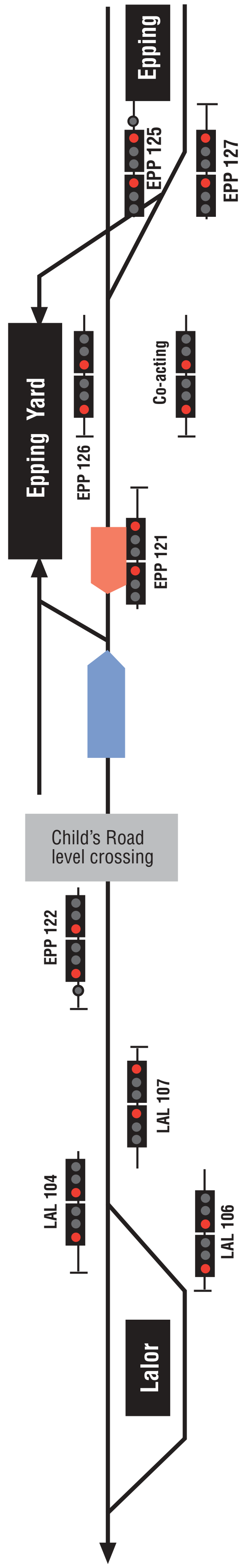
The initial report of the collision was made to the train control centre, Metrol[12], at 0915 by the driver of train 1648.

12 Metrol – The Metropolitan Train Control Centre.

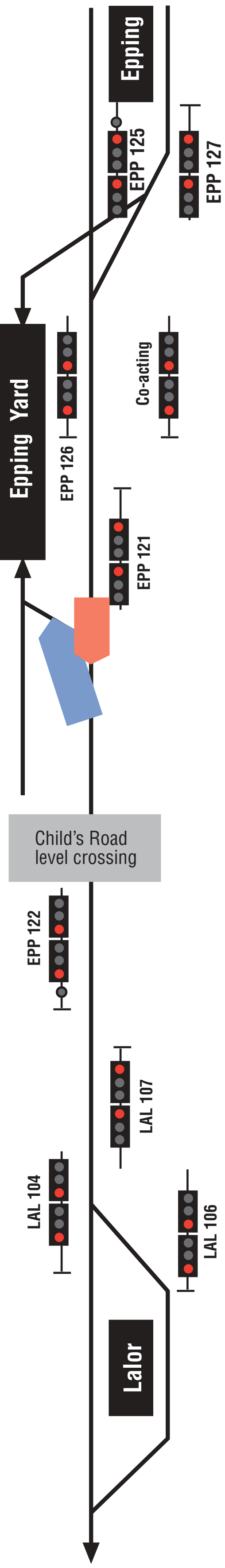
FIGURE 3:
Sequence of events



0914:19



0914:33



3.3 Injuries

The driver of passenger train 1648 suffered bruising to his right upper arm and was taken to hospital for observation, he was discharged at 1445 that day. The next day he visited his general practitioner and reported that he had a sore neck.

No passengers were hospitalised, however, several passengers reported receiving minor injuries and consulted their respective doctors. No further injuries have since been reported.

3.4 Damage

3.4.1 Damage to train 1648

Train 1648 was a suburban electric multiple unit train, consisting of three carriages, (one trailer and two motor cars), with car 634M (motor) leading, then 1167T (trailer), and 633M (motor) at the rear.

Leading car 634M sustained major undercarriage and bulkhead damage as a result of the collision. The driver's control area was relatively intact with shards of shattered glass scattered throughout the cabin, the offside of the cabin was severely damaged. The outer steel skin was peeled back from the bulkhead and pushed back past the crew compartment door. Internal fittings and fixtures were smashed and dislodged. Inside the passenger compartment there was evidence of panel buckling on the offside behind the crew access door.

Undercarriage damage sustained by car 634M included major leading bogie damage, compressor, main reservoir, and supplementary reservoir, including other miscellaneous under body equipment.

FIGURE 4:
Damaged carriage 634M

FIGURE 5:
Damaged carriage 634M

3.4.2 Damage to train 1025

Train 1025 was a suburban electric multiple unit train, consisting of six carriages, (two trailer and four motor cars), with car 698M (motor) leading, then 1109T (trailer), 517M (motor), 647M (motor), 1174T (trailer), and 590M (motor) at the rear.

The outer skin of leading car 698M was severely scored. The second car (1109T) sustained major damage to its saloon area. The damage extended from the leading bulkhead through to the central doors of the carriage. The passenger seats on the right hand side of the carriage in way of the impact were torn from their floor mountings and thrown across the carriage, internal panelling was fragmented throughout the carriage. Undercarriage damage included serious impact damage to the leading bogie and other secondary equipment. Additionally, the Scharfenburg coupler between cars 698M and 1109T was bent as a result of the leading bogie on car 1109T derailing.

FIGURE 6:
Internal damage to carriage 1109T

FIGURE 7:
External damage to carriage 1109T

3.4.3 Crashworthiness of trains

Some items had broken loose in the driver's cabin of car 634M as a result of the impact. The restraint system holding the wheelchair ramp had failed.

Each Comeng type carriage has anti-collision posts fitted in the front vertical centre of the carriage that are designed to prevent carriages telescoping. These posts are designed to carry a force of 540 Kn[13] up to a height of 1650 mm above rail level, which is up to 440 mm above floor level, in the vertical centre of the carriage. In this accident the impact was sustained on the outer corner of the carriage where no such posts were situated to prevent or deflect an intrusion into the passenger saloon.

3.4.4 Damage to infrastructure

The collision caused the leading bogie of car 1109T (train 1025) to derail. The bogie was struck and forced over the field side rail into ballast, coming to a stand clear of the sleepers. The force applied to the field side rail caused the rail to roll outwards lifting securing spikes, pandrol clips, and sleeper plates from the timber sleepers, over a distance of about two metres. The timber sleepers showed superficial damage consistent with wheel flange impacts. All track fastenings were replaced following the accident but no sleepers were replaced. Both the turnout and main lines had wheel impact marks on the gauge faces as a result of the hard contact with the wheel flanges.

3.5 Train crew details

The driver of train 1648 was rostered to commence his morning shift on 18 June 2002 at 0545, signing on at Upper Ferntree Gully depot. That morning the driver of train 1648 had driven from his home directly to Bayswater station, bypassing the published sign-on procedures for Upper Ferntree Gully depot. He commenced his shift at Bayswater by preparing[14] a set of empty passenger cars before leaving Bayswater at 0708, driving an empty train to Ringwood. He then drove a passenger service to the city where he joined another train, service 1021 to Epping which departed at 0815.

TABLE 1:
Summary of driver details

	Driver 1648	*Driver 1025*	*First passenger Driver 1025*	*Second passenger Driver 1025*
Gender	Male	Male	Male	Male
Classfi cation	Driver	Driver	Driver	Driver
Medical status[15]	Medicallyfi t	Medicallyfi t	Medicallyfi t	Restricted
Continuation training	Current	Current	Current	Current
Time on duty	3 hours 28 minutes	0 hours 55 minutes	0 hours 55 minutes	0 hours 45 minutes

13 Kn denotes a kilo newton, a unit of force.

14 'Preparing' refers to a driver's duties ensuring a train is 'fit for travel' prior to entering service.

15 Assessed according to the Public Transport Corporation's '*Medical Examination Guidelines*'.

3.6 Train information

Both trains involved in the collision were suburban multiple unit electric trains built by Comeng (Victoria) Pty Limited at Dandenong between 1981 and 1989. Each unit had been refurbished, which involved interior fit outs and new bulkheads for motor cars, and the fitting of windows to trailer car bulkheads. Train 1648 was equipped with Knorr type brake equipment, utilising disc type brakes.

Each train was made up of three-car units. Train 1648 consisted of a single three car unit with an overall length of 71.2 m. Train 1025 consisted of two three car units with an overall length of 142.4 m. Both trains were operated as driver only trains, referred to as single person operated trains (SPOT).

Records of recent maintenance on the three units involved in the collision indicated that the units had been inspected and maintained in accordance with Alstom's procedures. There had been no significant defects recorded against any unit in the previous 400 days.

After the collision, both trains were inspected by a train brake expert. The units were subjected to a full series of brake integrity tests. The report on those tests indicated that all the brake modes on all units operated correctly. In addition, an inter-unit continuity test confirmed that all brake modes were continuous through to the end couplers on all carriages. The brake test report concluded that the air braking systems were functioning correctly at the time of the accident (see further detail below).

Due to accident damage, in particular to electrical cables and wiring, the standard brake tests were unable to be conducted on the leading carriage of train 1648 (634M), and second car of train 1025 (1109T). Therefore components from car 634M were removed and independent bench tests were conducted on the driver's brake valve, triple valve, and train trip valve. The bench test on those components concluded that each component was considered to be operating correctly at the time of the accident.

The hand and foot pilot valves in the leading carriage of train 1648 (634M) could not be tested due to the damage sustained in the collision. The valves were inspected and found to be in a normal operating condition. Additionally, these valves are tested regularly by drivers in preparation for the initial run or during cutting in[16] procedures whilst in service. If a faulty pilot valve is detected, the fault would normally be listed as critical and the train removed from service with a fault record logged by the driver.

The hand pilot valve is a mechanically operated valve, whereas the foot pilot valve is an electrically operated solenoid valve, both of which are 'fail safe'. Therefore, if one or both of the pilot valves should fail, or be activated, the brake pipe air is exhausted to the atmosphere. Traction power is disconnected at the same time via an interlock and the emergency brakes are applied to bring the train to a stop. The pilot valves may be circumvented by a secondary circuit and vigilance button with a 30 second timer. There was no evidence to suggest that the secondary circuit had been activated.

No fault records had been logged by the driver prior to the collision, suggesting that the pilot valves were operating correctly.

16 'Cutting in' is a term used to describe a procedure for preparing a drivers workstation for operation, normally after changing ends at terminal locations such as Epping.

The train brake expert's report concluded that train 1648 on 12 June prior to the accident was:

> in an acceptable operating condition, capable of meeting or marginally exceeding the standard brake performance requirements for a Comeng suburban train.

3.7 Track and other infrastructure

3.7.1 Track

The 1.5 kilometres of track between Lalor and Epping is a single line section within the Melbourne suburban network and has a gauge of 1600 mm, classified as 'broad gauge'. In the up direction from Epping, the track curves left, (323 metre radius) through a crossover then transitioned into a long right curve (497 metre radius) around the Epping Yard boundary, before a straight section passing signal EPP121. Beyond signal EPP121 the line curves to the left (550 metre radius) and straightens, before the crossover into Epping Yard, then rises to cross the Child's Road level crossing and continues to Lalor platform.

The sleeper spacing in open track is nominally 685 mm and the bearer spacing through number 22 crossover was in accordance with its design plan. From Epping platform through the crossovers into Epping Yard the sleepers and bearers were timber, then concrete to the approach of number 22 crossover, returning to timber construction through number 22 crossover to Childs Road level crossing. From Lalor the rail weight is 47 kg/m increasing to 53 kg/m, then 60 kg/m from number 22 crossover through to Epping platform. The main line rail is continuously welded. The nominal track speed is 80km/h, except as displayed otherwise.

The design and condition of track infrastructure is not considered to be a contributing factor to the collision.

3.7.2 Electrical infrastructure

Melbourne suburban electric train services are powered by a 1500 V direct current (DC) overhead system. The overhead wires are supported by structures at intervals of about 70 m to 90 m. The contact wire height is between 4.7 m and 5.8 m above rail level.

During the collision the leading pantograph on car 634M did not disengage from the overhead wiring. The pantograph was isolated soon after the accident. The Electrical Control Room (Electrol) 'event list' for the day showed no record of a DC circuit breaker opening.

Electrol was advised at 1030 that there had been no damage to the overhead equipment and that overhead power was not required to be switched off in the section between Keon Park – Lalor, for maintenance purposes.

The electrical overhead equipment is not considered to be a contributing factor to the collision.

3.7.3 Signalling infrastructure

There are eight main line controlled signals on the single line between Lalor and Epping, four signals for the down direction into Epping platform, and four signals for the up direction into Lalor platform[17].

Departing Lalor platform in the down direction there were 'home' signals, LAL104 (platform 1) and LAL106 (platform 2), situated on the departure end of Lalor platform entering the single line section. Next is signal EPP122 ('home') protecting Child's Road level crossing and number 22 points entering Epping Yard. Finally, 'home' signal EPP126 protects the entry into Epping platforms one and two. Additionally signal EPP126 has a 'co-acting'[18] signal, to allow easier signal sighting for down trains placed adjacent to the main signal post on the other side of the line.

Departing Epping platform in the up direction, there are 'home' signals EPP125 (platform 2) and EPP127 (platform 1) controlling the entry into the single line section or Epping Yard. Next is 'home' signal EPP121 protecting number 22 trailing points and Child's Road level crossing. Approaching Lalor platform is 'home' signal LAL107 controlling the entrance into either platform one or two at Lalor.

All signals are classified as controlled signals, operated by the Signaller at Epping Signal Box. The total distance between Epping and Lalor platforms is 1,577 metres. The relevant signal spacings are listed below for both up and down direction signals.

TABLE 2:
Signal distances

Up signals	*Distance*	*Down signals*	*Distance*
Epping platform 1 to signal EPP127	10m	Lalor platform to Signals LAL104 & LAL106	19 m
Epping platform 2 to signal EPP125	19m	Signals LAL104 & LAL106 to EPP122	546m
Signal EPP127 to EPP121	607m	Signal EPP122 to EPP126	773m
Signal EPP121 to LAL107	741m	Signal EPP126 to Epping platform	238m
Signal LAL107 to Lalor platform	219m		

Note: Distances were quoted from Connex signalling diagram number 33/01, a one metre discrepancy exists between up and down direction measurements.

An independent signalling consultant[19] inspected the track and witnessed testing of the signalling system and provided the investigation team with a report on the signalling system. The report noted:

> The train-stop arm at signal EPP121 was gauged in the stop position and found to be operating to specification.

17 Refer to figure 3 on pages 8 and 9.

18 'Co acting' signals are used to mimic signal indications from the main signal. They are used to resolve signal sighting issues.

19 Sinclair Knight Merz Pty Limited (SKM)

All the track circuits were within specification. Several of the relay boxes had additional wiring modifications carried out on them such as an additional power supply, protection varisistors, and additional resistors added. However those modifications were not considered to have had any effect on the safety of the signalling.

FIGURE 8:
Signal EPP121

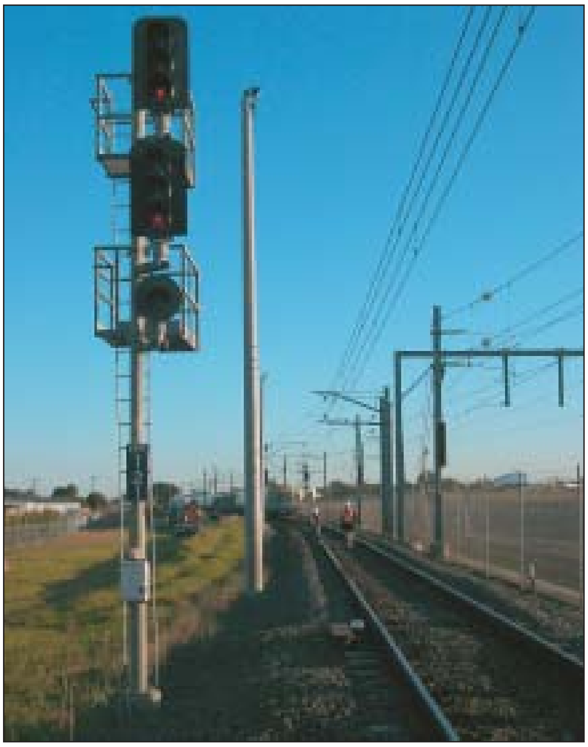


FIGURE 9:
Signal EPP121 train stop showing an impact mark

The signal circuitry, aspects, and the train-stop arm were determined to have been working as designed at the time of the train collision.

3.8 Train control

Local train control in the Epping area is controlled by the signaller at Epping signal box. Overall train control is managed by a train controller located at Metrol.

Recorded train control data indicated that following its departure from Epping platform, train 1648 passed signal EPP127 while it was showing a red – over – yellow aspect. That restricted signal required the driver to pass at medium speed, 40 km/h, to the next signal (EPP121),which displayed a stop indication. The Victorian Public Transport Corporation *(Book of Rules and Operating Procedures, 1994)* (Section 2-16, Rule 13, clause (e)) provides that 'the driver may proceed at medium speed (40 km/h) and must be prepared to stop at the next signal'. It also states that 'the speed restriction applies to the whole section up to the next fixed signal'. The next signal, EPP121 was at stop, showing a red – over – red indication.

After the initial report of the collision, all trains were terminated at Keon Park and formed up services towards the city, except the following down passenger train that had already entered the Keon Park – Epping section. That train was terminated at Lalor and returned towards Flinders Street station. After that time, the overhead power supply was de-energised from Keon Park to Epping at 0949.

3.9 Environmental factors

3.9.1 Weather and light conditions

The accident occurred in fine weather, with clear visibility and a dry track. At the time of the collision the sun had an azimuth[20] of 43½ degrees and an elevation[21] of about 14½ degrees. Based on the geometry of the track and the time of the collision, the sun would have been behind the driver.

The investigation team noted that on a following day at 0913, in similar light conditions to that of the accident, the sun was shining on signal EPP127 and EPP121 but did not significantly affect the sighting of the signal indication.

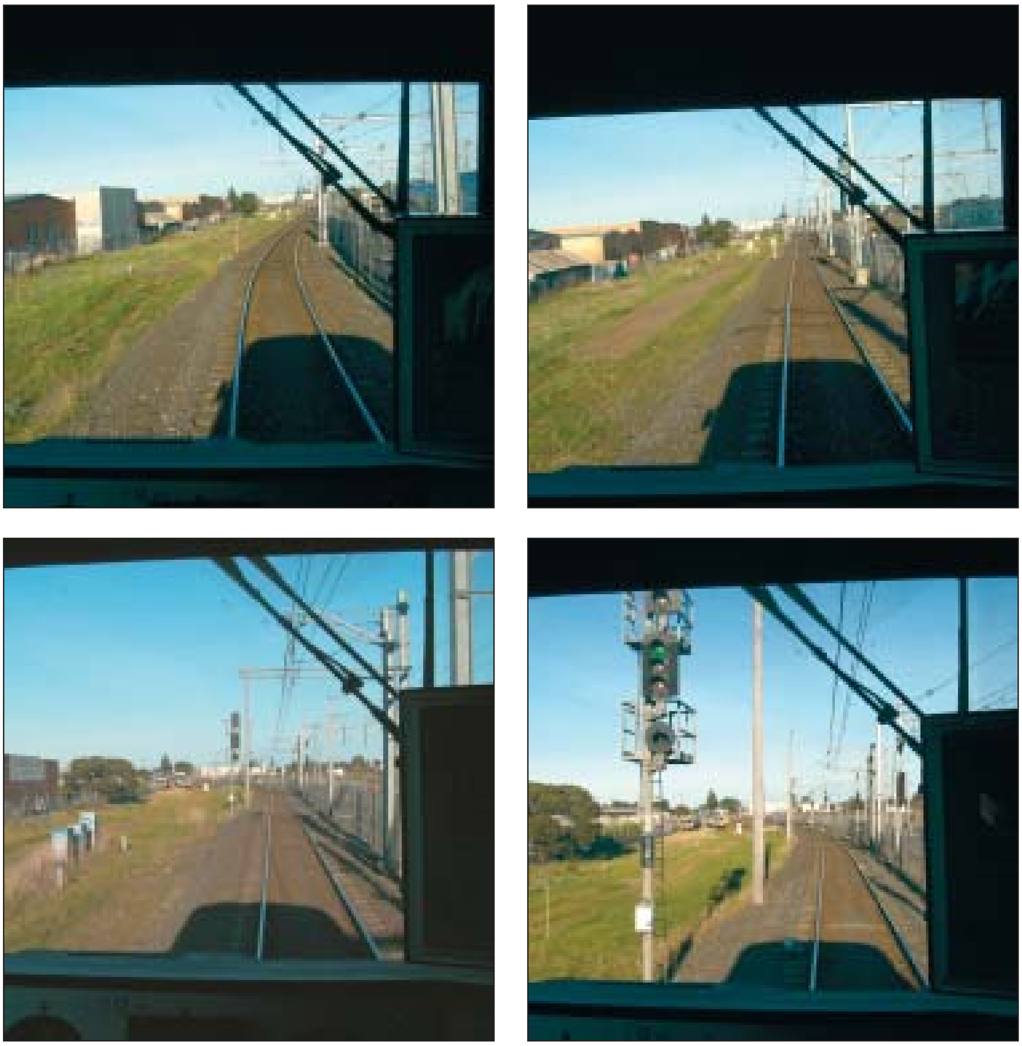
The weather conditions at the time were not considered to be a contributing factor in the collision.

The pictures below were taken from a driver's cab, at 0913 towards signal EPP121, and would closely represent the view from the driver's cab of train 1648.

20 Azimuth is the clockwise horizontal angle (in degrees, minutes, and seconds) from true north to the sun.

21 Elevation is the vertical angle (in degrees, minutes, and seconds) from an ideal horizon to the sun.

FIGURE 10:
View of signal EPP121 from a driver's cab



3.9.2 Potential distractions

There were no other obvious potential distractions other than the driver's mobile phone.

The driver's mobile phone record was also examined to establish whether or not he was distracted while making or receiving a phone call. Those records indicated there was no telephone call in the relevant period.

3.10 Toxicology

After the incident, the driver submitted to a breath and illicit drug analysis by Victoria Police. That analysis returned a zero reading.

3.11 Organisational context

3.11.1 Background

On 29 August, 1999, the Public Transport Corporation (PTC) ceased operating the rail network in Victoria as a public utility, transferring operations to Melbourne Transport Enterprises (Connex Trains Melbourne, Alstom Melbourne Transport Limited) and

National Express Group Australia (M>Train), both of which are private sector companies. Connex entered into an agreement with the Victorian Government for a period of 15 years.

As part of the agreement, Melbourne Transport Enterprises (MTE) is required to maintain train services within certain parameters. Service levels are monitored and measured principally against punctuality, reliability, and customer satisfaction. All performance is measured by Passenger Weighted Minutes (PWM), any below standard performances are converted into monetary penalties, by formula, for not meeting the standards. The efficient running of the trains therefore relies on serviceable trains, efficient infrastructure and an adequate supply of suitably qualified and fit staff.

At the time of the accident Connex employed about 264 drivers. Discussions with Connex personnel revealed that in the period before the accident the company was short of approximately 15 drivers, meeting the shortfall by overtime or service reductions/cancellations.

3.11.2 Accreditation and audit

The Victorian Rail system operates on the principle of 'co-regulation'. The state regulatory body, the Department of Infrastructure (DoI), accredits rail operators based on the regulator's approval of a company's Safety Management System (SMS). The SMS is contained in the MTE Management Safety Manual (MSM). The MSM is a general safety policy manual supported by other more detailed operational documents covering the various areas of operation including engineering, maintenance and train operation. The SMS provides MTE's principal contractors with documentation detailing the rail safety requirements for the safe operation of trains, and the maintenance standards for infrastructure and rolling stock.

MTE is an accredited operator and is audited for compliance with the MSM and other safety procedure documentation supporting that manual.

Audits assess compliance with an approved or accredited SMS or standard. The audit, as a defence against an accident, is only effective as far as the standard or procedure is effective in itself. Hence an audit of the existing and long-standing signalling system would usually only measure compliance with its design. It would not normally identify unsafe conditions within the signalling system. Similarly, an audit of the medical standards would measure compliance against the PTC Medical Standards, but would not normally identify any shortcomings in the standards themselves.

MTE is an accredited organisation, through its principle contractors Connex and Alstom, and is essentially a vertically structured organisation. Alstom has its own workshops and maintenance regime. Under provisions of the *Transport Act 1983 (Victoria)*, there are requirements that accredited operators should be audited at least on a yearly basis, with a provision for special audits and 'unannounced' compliance inspections.

3.11.3 Shift and fatigue management

At the time of the incident, Connex operated a cyclic 24–hour roster including morning, afternoon, and nightshift. Each driver was designated a roster number, or shift, for each day up to twelve months in advance depending on operational requirements. The roster or shift sign-on times nominated could be varied by the rostering section, two hours either side of the original sign-on time, with not less than 48 hours notice.

Connex requires a minimum of two hours notice for drivers who report sick[22], otherwise there would be insufficient time to arrange a replacement driver. A number of 'standby' drivers are placed around the Connex network, primarily at Flinders Street station, to manage short notice absences. Generally there is insufficient time to deploy a standby driver to an outstation depot, causing train services to be delayed or cancelled. Under the driver's award, drivers who did not give the two hours notice may not receive sick leave entitlements, based on the discretion of their supervisor.

There is a consultative process in place between management and local drivers regarding rostering issues. Drivers may exchange shifts with other drivers providing the request complies with award rostering procedures and was approved by rostering management. All rostering is monitored by rostering management.

3.11.4 Single person operated trains[23]

Connex operates in a Single Person Operated Trains (SPOT) environment. The SPOT system was introduced to the Victorian rail network in 1993 after extensive research and testing of the method of working.

Prior to the introduction of SPOT working, a number of modifications were made to rollingstock, infrastructure, rules, and operating procedures. Signals not already equipped, were fitted with train stops[24] and rolling stock fitted with associated passenger movement equipment and foot pilot valves to allow the driver to operate the additional equipment.

The introduction of SPOT trains, with the modifications to drivers' controls and driver retraining, was assessed as not increasing the risk to train safety. The system has relied on, and continues to rely on: trained, fit and alert drivers; a speed signalling system; 'train-stops'; and the pilot valve system.

3.11.5 Signals and train stops

The Victorian railway signalling system is a speed based system, modelled on the US Rhea-Rudd signalling system. Signals are separated by distances that allow train drivers adequate time to stop, provided that the speed at which the train is travelling is consistent with the speed permitted by the signalled speed aspect.

The signal colour combinations indicated will depend on whether the signal is a 'three aspect' or a 'four aspect' signal.

22 Stage 1M of the Induction Manual

23 Single Person Operated Trains are also referred to as Driver Only Operated trains

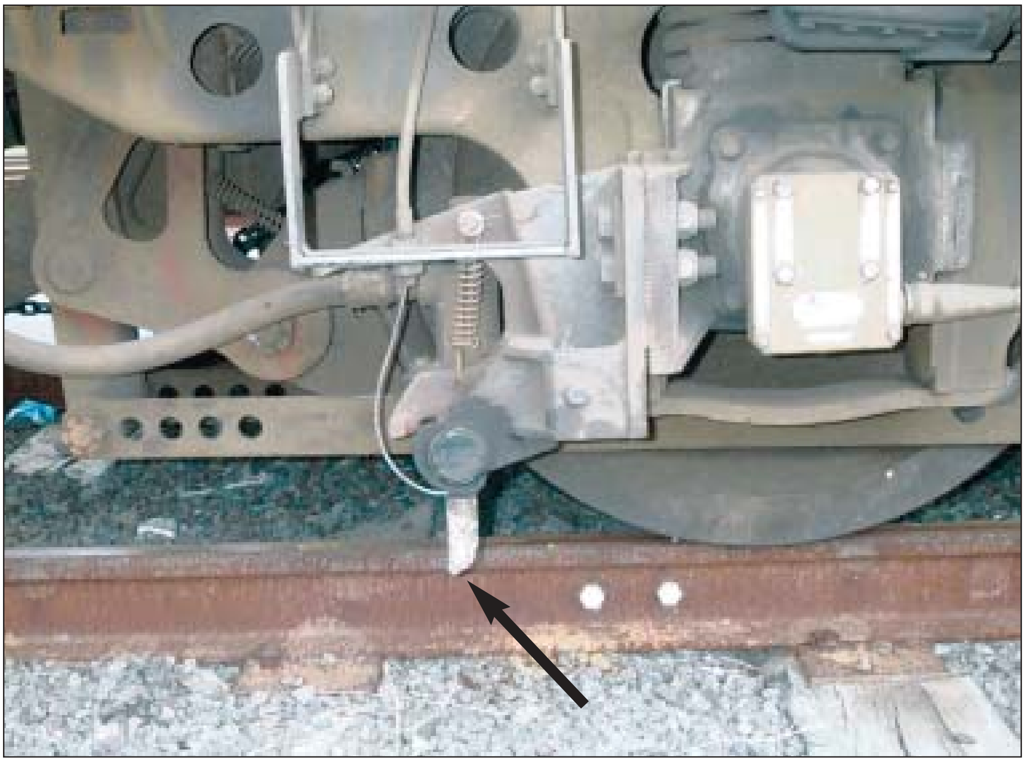
24 Train stops are devices interlocked to the signalling system that apply the brakes of a suburban train should it pass the signal at stop

TABLE 3:
Three and four aspect signal indications

Three Aspect Signalling			*Four Aspect Signalling*		
Green/red	🟢 🔴	Line Speed	Green/red	🟢 🔴	Line speed
Yellow/red	🟡 🔴	Normal speed & warning next signal at stop.	Yellow/green	🟡 🟢	Reduce to medium speed speed by next
			Red/yellow	🔴 🟡	Medium speed and warning next signal at stop
Red/red	🔴 🔴	Stop	Red/red	🔴 🔴	Stop

Most signals in the Victorian suburban network are equipped with an automatic train stop, which consists of an electric or air operated tripping arm. When the signal is at proceed, the tripping arm is below rail level and does not interfere with the normal running of trains. However, when the signal is at stop, the arm moves to above rail level. When a train passes over it, the arm strikes a lever attached to the train trip, causing the brake pipe to exhaust to the atmosphere thereby applying the emergency brakes and bring the train to a stop.

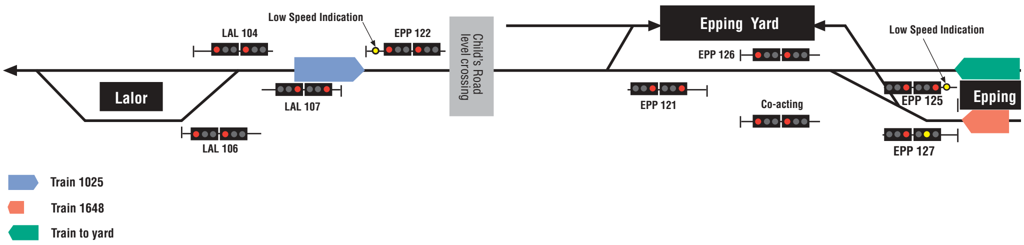
FIGURE 11:
Train trip[25] mechanism



[25] A train trip is a safety device that works in conjunction with signal train stops. It is fixed to the bogie under the driving position, on the left hand side.

With train 1648 preparing to leave Epping platform, and train 1025 departing Lalor platform, the signalling system displayed the following indications:

FIGURE 12:
Displayed signalling



A train driven at the cautionary speed of 40 km/h would require about 75 m to stop under emergency braking conditions[26], given good track and weather conditions. If a train is not driven at the cautionary speed, but at full line speed, the stopping distance is much greater. In the case of the suburban line between Keon Park and Epping the full line speed is 80 km/h. A train tripping on the signal trip arm at 80 km/h would require approximately 280 m to 320 m in which to stop, the actual distance being subject to weather and line condition, brake condition and type, and the consist[27] of the train.

3.11.6 Signals passed at danger (SPAD) occurrences

Recorded data indicated that train 1648 passed signal EPP121 while it was displaying a stop indication. Such an occurrence is known as a 'signal passed at danger' (SPAD).

The signalling system, 'train stops', the pilot valve (foot or hand) and driver alertness and training are the four main defences against rail collisions. SPAD occurrences are a key safety concern in rail operations worldwide and such instances are recorded and analysed in varying degrees throughout Australia.

SPADs may occur during the following situations:

- departing a platform (leaving before the signal permits);
- leaving a siding;
- on line, in a section of track;
- arriving at a station; and
- leaving a loop.

A frequent cause of a SPAD is for the signal to be restored to the danger configuration (stop) as a train approaches, providing the driver with limited time to react and stop the train before the signal.

26 Based on the standard emergency braking curve of 0.83 ± 0.05 m/s^2

27 'Consist' refers to the types of carriages within a train unit.

An analysis and summary of SPAD occurrences in the Connex Network was undertaken, for the period 9 July 1996 to 29 May 2002 (70 months). During that period there were 107 SPADs, of which:

- 21 were main line signals completely missed;
- 11 were main line signals misjudged by the driver[28];
- 68 were main line signals restored as the train approached;
- 4 were siding signals completely missed;
- 2 were siding signals misjudged by the driver; and
- 1 was a siding signal restored as a train approached.

Of the SPADs analysed, four occurred in the Epping area, all within the Epping Yard during shunting operations. No SPADs were recorded for the main line between Epping and Lalor during the analysed period.

Connex did not categorise the severity of each SPAD, although a system of categorisation was being considered.

Interviews with other drivers indicated that it was normal to arrive at Epping on the down journey and depart on the up journey with a full line speed indication of green – over – red from the platform signal.

3.11.7 Driver medicals

Train drivers fall under the category 'A' requirements of the Public Transport Corporation's '*Medical Examination Guidelines*'. At the initial examination a driver is subject to an Electro Cardio Graph (ECG). The requirement for a periodic physical and vision examination includes a full medical history as well as urinalysis and height/weight index. Under those guidelines drivers are required to undergo a medical examination every four years until they are 39 years of age, then at two-yearly intervals between the ages of 40 and 49, and thereafter annually until retirement. From the age of 40, drivers are subjected to an ECG at each medical. Therefore the driver of train 1648 was required to undergo a medical examination every year, which included an ECG.

Since June 1993, drivers of single-person operated trains were not required to meet medical standards that were more rigorous than trains with two drivers or multiple crews (driver and guard). In May 1993, the Public Transport Union (PTU) expressed concern at the different standards apparently being applied to SPOT drivers at certain depots. The Public Transport Corporation (PTC) replied in June 1993 that no additional medical standards were required for drivers associated with the SPOT project.

Drivers from both trains were current with their medical examinations and were assessed as medically fit for duty.

[28] The driver has obeyed the signal indication but misjudges distance resulting in a minor overrun

3.11.8 Train 1648 driver history

3.11.8.(i) Background

The driver of train 1648 was a 53 year old male. He had worked within the Victorian rail industry for about 31 years. He started work as a cleaner before being appointed as a locomotive driver. In 1979, he transferred to Melbourne as an Electric Train Driver and had remained in that capacity until the day of the accident. He described himself as a conservative driver, but indicated that he was experiencing serious personal issues that disrupted his sleep patterns.

Periodic internal audit reports noted that the driver's train handling skills were of a high standard, for example, his utilisation of the master controller and brake controller ensured passenger comfort. He had successfully completed all of the continuation training[29] modules.

3.11.8.(ii) Personal medical history

The driver of train 1648 was medically examined in accordance with the PTC Medical Examination Guidelines as an employee of the PTC. Medical records dating back to February 1989 were examined by the investigation team. The driver had undergone regular medical examinations according to PTC guidelines. According to the medical practitioner's examination reports, there were no adverse findings apart from the following:

> A report in February 2002 notes a 'moderate high frequency hearing loss' and a 'body mass index of 31'.

The driver indicated to the investigation team, and commented on several self assessment forms filled out prior to medical examinations, that he had a history of migraine.

The driver of train 1648 indicated that he was suffering from a severe migraine headache on the morning of the collision. He also indicated that on occasions he suffered serious migraines resulting in nausea and vomiting. On the day of the collision prior to signing on, he indicated that he self administered two capsules of pain reliever, at about 0500 for relief of the migraine symptoms. The investigation was unable to conclusively establish the type of pain reliever used. The driver recalled feeling unwell and vomiting in the commuter car park of Bayswater station prior to commencing duty. The driver indicated that he did not report in sick because of insufficient time to meet the minimum two hours notice required by Connex. Additionally the driver indicated that he intended ceasing duty, due to illness, once he had completed service 1648 into Flinders Street station.

3.12 Emergency response

The time of collision was correlated between the Position of Train System, carriage security CCTV[30] recordings, and the Interlock[31] log report for the area, that time being 0914:33.

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[29] Continuation training is an ongoing (refresher) training regime for drivers. The training covers all modules of initial driver training.

[30] CCTV denotes Closed Circuit Television security cameras.

[31] The Interlock report is a computer generated report of signalling equipment condition and status.

Metrol received the initial notification by radio from the driver of train 1648 at 0915 advising of a major collision, however the radio signal dropped out. A second radio call was immediately made by the driver of train 1648 to Metrol confirming that a collision had occurred between two trains on the main line at Epping. Metrol immediately advised the Victoria Ambulance Service at 0915, followed by Victoria Police at 0916, then worked through an emergency contact list for company notifications.

Connex implemented their emergency response plan which involved notifying relevant personnel and organisations, alternative transport arrangements, and public awareness. All stations on the Keon Park to Epping line were attended by staff to facilitate the above requirements.

Up to five emergency calls were received by '000', emergency hotline, from people claiming to be passengers on the affected train.

Victoria Police officers from the Epping station were the first emergency services to arrive on site at 0925, closely followed by the Victoria Ambulance Service, Metropolitan Fire Brigade, and Police officers from the Reservoir station. A senior Police Officer assumed command of the site until relieved by the Alstom Manager Fleet Maintenance who then handed over command of the site to the Connex Emergency Services Liaison Officer.

The Metropolitan Fire Brigade asked one of the drivers on the empty train whether the overhead power had been de-energised. One of the passenger drivers passed the query to Metrol and Electrol. The overhead wiring section between Lalor and Epping was de-energised at 0949.

The recovery phase commenced at 1640 and was completed at 0310 on 19 June, with normal train operations restored.

3.13 Passenger questionnaire

Sixteen passengers were asked by ATSB investigators to complete a questionnaire relating to the accident. Thirteen passengers responded to that questionnaire. From those responses, it was established that three passengers were in the front car, six were in the middle car, and four in the rear carriage of passenger train 1648.

The majority of respondents indicated that they travelled regularly on the Epping Line.

Four of the respondents were males ranging in age from 31 to 75, and nine were females ranging in age from 12 to 75, no passenger noted a physical disability. All passengers surveyed were seated facing forward and recall a severe jolt at the time of impact. A number recalled hearing and/or seeing the other train. The majority of passengers were offered medical assistance at the scene, with most declining, electing to see their family doctor at a later date.

All passengers left the train within a short time, with very few requiring assistance. Generally, all respondents found the response staff were easily identified, emergency response to be above average, with indications that most had been contacted by Connex at a later time.

4 ANALYSIS

4.1 Introduction

Safeguards (defences) in the rail system are designed to prevent such accidents or minimise the consequences. Factors that were considered relevant to this accident include:

- Personal health and medical fitness;
- Medical examinations;
- Shift roster;
- Pilot valve – hand (deadman's handle) and foot pedal;
- Signalling system and train stops;
- Train control;
- Driver sign on procedures;
- On time running, reliability, and performance; and
- Emergency response.

It was considered that there were significant similarities between this accident and the collision at Footscray on 5 June 2001 and the findings and recommendations of that report were therefore reviewed.

4.2 Personal health and medical fitness

An expert in transport medicine was engaged by the investigation team to review, investigate, and report on all medical aspects relating to the investigation.

The driver of train 1648 was an experienced driver with over 31 years of service. Following the accident he stated that he could not recall driving or sighting any signal, or any actions from the time he left Epping to the time the train tripped past signal EPP121. His failure to recall the signal or any other part of the track between 0913 and 0914:19 (Epping to signal EPP121) could be explained if the driver was:

- affected by prescription medicine, self administered medicine, illicit drugs or alcohol;
- daydreaming or being distracted for a period of one minute;
- falling asleep, or otherwise losing situational awareness; and/or
- being unwell or medically unfit to drive.

Testing for alcohol and illicit drugs immediately after the accident registered a zero reading. Impairment through the influence of alcohol or the intentional abuse of illicit drugs can be discounted as a factor contributing to the accident.

The medical expert's report indicated that the driver had a history of migraine that had not responded to prescribed medical treatment. The report notes:

> At the time of the accident, he was probably medically impaired by the symptoms of a severe migraine and other factors.

Medical impairment would have manifested itself by degradation of:

- Alertness and vigilance;
- Concentration;
- Arousal state (sleep and wakefulness);
- Cognitive function; and
- Reaction time.

His overall situational awareness would have been adversely affected by the factors contributing to his impairment.

A severe migraine attack such as the driver described, may have momentarily interfered adversely with his central, peripheral and colour vision. It is likely that he was completely incapacitated by these symptoms for a brief period of time measuring seconds or longer.

During the night preceding the accident, his sleep was disturbed by the onset of a severe migraine. The possibility that he fell asleep at the controls for a brief period, as a result of his disturbed sleep, cannot be excluded. Similarly, a transient period of complete or partial loss of consciousness cannot be excluded.

The possibility of the driver suffering some form of epileptic seizure just prior to the impact cannot be excluded, however in the context of the history of events, it is unlikely.

The possible adverse effects of medication used by the driver prior to the accident, to treat his migraine cannot be accurately determined.

This was because there were a number of discrepancies noted by the investigation team. The driver was unable to accurately recall if he had taken Panadeine Forte, Panadeine, Panadol or other medication to treat his migraine. Panadeine Forte, and to a lesser extent Panadeine, are capable of interfering adversely with human performance.

The driver usually self-medicated with pain reliever during migraine attacks, and rarely sought additional medical treatment. This attack was no exception.

The adverse medical circumstances affecting a close family member of the driver materially contributed to his stress levels and in part to his impairment. The family member's serious medical condition was a significant distraction to the driver's performance, disturbing sleep patterns affecting his off work time, and additional to the adverse effects of the migraine.

4.3 Medical examinations

The driver's medical condition (migraine) had been declared on self assessment forms at the previous four PTC medical examinations. He had indicated the frequency, severity and nature of these episodes at two of those examinations. The self assessment report had not been further investigated by any medical practitioner performing the PTC medical assessment in the context of public safety.

At the time of the accident, the PTC medical examination guidelines used for the assessment of medical fitness to drive a train were not adequate in the context of public safety. The medical expert's report notes:

> As best can be determined the guidelines in use at the time to assess his medical fitness were the *PTC Medical Guidelines For Authorised Practitioners July 1997*. These guidelines lack specificity and detail on the acceptability of a number of serious medical conditions and medication in the context of rail safety and in that regard are inadequate for use as medical standards.

Medical conditions that can impair or incapacitate a train driver must be rigorously investigated and assessed. This is particularly important with conditions such as migraine and epilepsy that can occur with little or no warning. Similarly, medications used to treat those conditions must also be evaluated very carefully if they are to be permitted for use during driving and other hazardous activities associated with rail operations.

Revised medical guidelines must address these issues and provide clear details on the actions to be taken by authorised medical examiners when conditions such as migraine and medication are declared or detected at examination. During the course of investigations for these conditions, drivers will need to be removed from driving duties temporarily. If abnormal investigations (e.g. abnormal EEG) are revealed in the medical assessment of a driver for another condition, the driver should not be returned to full duties until the significance of the abnormal investigations are determined by competent medical specialists and the determination of fitness is made by an independent and senior rail medical examiner.

In aviation medicine, migraine sufferers are referred by a designated aviation medical examiner to the Civil Aviation Safety Authority (CASA) Aviation Medicine Section for individual consideration. The CASA publication *Designated Aviation Medical Examiner's Handbook* explains the two main types of migraine, common and classical, shown below:

Headache

Nearly all applicants have experienced headache. Mostly these headaches will have been mild and benign, but it is important to assess the nature and cause of significant headache, whether the problem was an isolated, past event, or is recurrent and continuing.

Migraine

There are two main types of migraine — common migraine and classical migraine.

Common Migraine

More than 80 per cent of migraine sufferers experience 'common' or 'non-classical' migraine, which is not associated with sharply defined neurological disturbances.

Assessment of 'nonclassical' migraine depends on:

- Severity of symptoms
- Frequency of occurrences
- Degree of control required and achieved, and
- Presence of psychiatric or neurological symptoms.

Classical Migraine

Classical migraine is accompanied by transient focal neurological phenomena that may include:

- Ophthalmoplegia
- Hemiplegia
- Retinal phenomena, such as scotomata
- Basilar artery phenomena, and
- 'Facial' migraine.

Such migraines are characterised by long periods of remission and capricious onset, and may completely incapacitate the sufferer.

The Aviation Medicine Section considers all cases individually.

The medical expert's report also comments:

> Medical fitness to operate a train should only be determined by suitably trained, qualified and competent medical practitioners. With conditions such as migraine, self-determination of fitness for duty by the affected driver should be reviewed.
>
> Specified medical conditions which are detected or declared during 'fitness for duty' medical assessments (e.g. migraine) should be further referred to a designated independent reviewing medical authority for the ultimate decision regarding medical fitness to drive a train. Drivers detected with these medical conditions should be placed on a recovery regime, which includes the classification of the severity of the condition, and the suitability of medication prescribed for that treatment, in the context of 'fitness for duty'. A recovery matrix should be developed to assist employees, and medical examiners, to manage absence from duty in a safe manner.

4.4 Shift roster

4.4.1 Fatigue

Fatigue may be described as a reduction in physical and/or mental capability as a result of physical or emotional exertion which may impair nearly all physical abilities including, strength, speed, reaction time, coordination and decision making. Fatigue may be described as acute or chronic. Acute fatigue occurs in a matter of hours as the result of excessive mental or physical activity and may be cured by a period of rest or sleep. A state of chronic fatigue is reached when the 'normal' period of rest or sleep is insufficient to restore an individual's working performance to its usual level. Chronic fatigue is insidious and usually happens over a period of time. Individuals suffering from chronic fatigue always perform below their personal best but are often unaware that their performance has been significantly degraded. In the worst case, chronic fatigue can drive an individual to sleep while at work often in the form of a momentary event or 'micro-sleep' which may last a few seconds or several minutes.

4.4.2 Fatigue analysis

The driver's work and rest routine was analysed using Fatigue Audit InterDyne (FAID) software developed in conjunction with the Centre for Sleep Research at the University of South Australia. Research by the Centre for Sleep Research suggests that a fatigue score of 40–80 is moderate, 80–100 is high with scores 100–120 being very high. High fatigue scores of 80–100 have been shown to produce individual performance impairment equivalent to a blood alcohol concentration over 0.05 per cent. The FAID software enables the quantitative assessment of an individual's level of fatigue at a point in time based on work hours for the previous seven days. It cannot measure the emotional or other psychological causes of fatigue, neither can it differentiate in terms of the level of physical exertion. The resultant individual fatigue 'score' may be used as a guide to indicate what effect fatigue may have had on an individual's performance.

The FAID software was used to analyse the driver's rostered work hours from 26 May to the time of the accident on 18 June. The FAID program gave a maximum fatigue score of 65.5 at 0600 on the 7 and 8 of June.

Based on work hours, and the assumption that the individual's time off duty included an appropriate period of recuperative sleep, the driver was in the mid range of moderate fatigue. However, he was also experiencing considerable emotional stress, of which the migraine was possibly a manifestation. It is probable that on the morning of 18 June the driver's judgement, actions and situational awareness were severely affected by chronic fatigue, if indeed he was awake and cognisant in the cab in the time leading up to the collision.

What ever the fatigue level of the driver, based on the FAID rostering principles, the Connex master work roster was considered not to be a factor in this incident.

4.5 Pilot valve – hand (deadman's handle) and foot pedal

Suburban trains are equipped with a pilot valve, which should apply the train brakes automatically if a driver fails to maintain the pilot valve handle in a set position.

Alternative systems, such as vigilance controls, may prove to be more problematic in a metropolitan rail system, given the density of traffic, the time gap between trains and the workload of train drivers.

Drivers on suburban trains are required to maintain a certain pressure on a hand pilot valve, or a foot pedal. These are often referred to as the 'deadman' or vigilance devices. The system was predicated on the principle that any release in pressure on the pilot valve handle would apply the train brakes and stop the train within an established safety margin. With the introduction of single-person operated trains and because of the extra functions a driver was required to undertake, a foot pilot valve was introduced in addition to the hand pilot valve. At any given time while running a driver must maintain pressure on either the foot pedal or hand pilot valve control.

Many drivers had adapted to using the foot control in preference to the hand control. The driver of train 1648 was one such driver.

A number of reports[32] have identified areas of concern with the foot pilot valve system. Concerns such as circumventing the foot pilot valve and the dead weight of the lower limbs maintaining foot pedal position were highlighted.

Examination of the driver's cab of train 1648 on 18 June, found no evidence that the pilot valve had been intentionally circumvented. Given the design of the pilot valve system, there is a strong possibility that the driver was able to instinctively maintain adequate foot and/or handle pressure.

On the morning 18 June 2002 the pilot valve system on train 1648 did not operate although the driver was incapacitated between 0913 and 0914:19.

4.6 Signalling system and train stops

The efficient operation of the network depends upon minimum train separation consistent with safety. The safety and separation of trains is controlled by the signalling system, which allows trains in adjacent track sections[33], but does not allow trains to occupy the same block section of track. Therefore short block sections allow more intense use of the network. The train stop system, and the 'overlap'[34], reduces the risk of a train occupying the same track section as another train.

The signalling system and train stop system operated as designed. However, these two inter-related, and critical defences did not prevent the collision.

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32 Chaffin and Anderson, 1984, *Occupational Biomechanics.* Viner Robinson Jarman Pty Ltd, 1992, *Report On Vigilance Control.*

33 For the purpose of this report a track section is taken to be the length of track between two sequential signals.

34 'Overlap' In this report an overlap refers to a length of track on the departure side of a signal which must be clear before a train can be signalled to pass the previous signal, in order to provide a safety margin.

The driver did not respond to the signal aspects at signal EPP121. The train stop, however, did operate but due to the trains speed at signal EPP121 the train did not stop within the designed safety margin, or overlap.

The 'worst case' in establishing an overall safety margin, based on an automatic train stop, is the distance required to bring a train to a halt at maximum achievable speed, plus an allowance for adverse track conditions.

Given constant deceleration under emergency braking of -0.83 m/s^2, the distance required to bring a suburban electric train to a halt from full line speed (80 km/h) is between 280 m and 320 m. The actual distance is subject to factors including weather and line condition.

The distance between signal EPP121 and the fouling point at number 22 points crossing into Epping Yard is about 155.3 m. The safety-margin for train operations appears to be predicated on a driver obeying all signals except the stop signal and driving through the signal at the prescribed reduced speed of 40 km/h. It does not take into account a driver who has been incapacitated for some reason and has not reacted to signal indications.

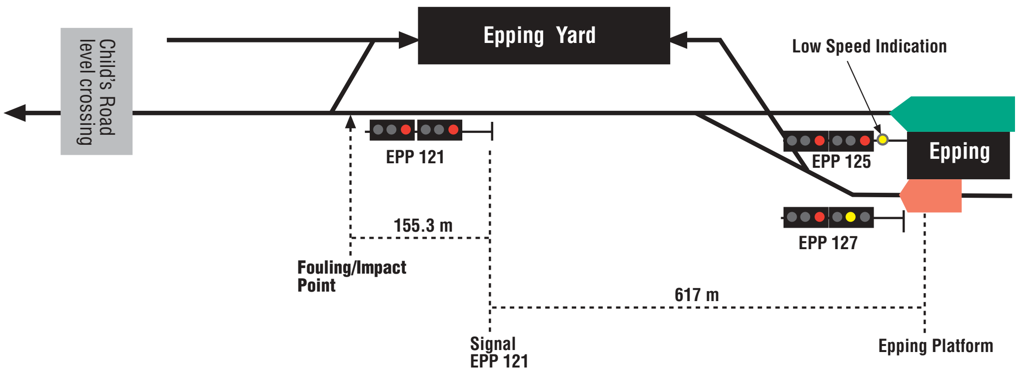
In this case the train had accelerated over a distance of 617m, from Epping platform to signal EPP121, before passing signal EPP121 at stop.

There are signalling systems that, together with train stops, regulate the train's speed consistent with the signal aspect. Such a system is used in the underground rail system in the Melbourne Metropolitan area, in Sydney and other areas of Australia, whereby a train exceeding the designated speed between any two signals will activate an intermediate train stop, regardless of the aspect of the signal.

The signalled movement from Epping platform one to signal EPP121, whilst there was an approaching train from the opposite direction crossing into Epping Yard, was allowed by the signalling system. Although this was an allowed move, it only offered a single signal protection of an opposing movement entering/exiting a single line section of track. The control of train movements into a single line section is critical to safety, to prevent 'head on' collisions. In this case a 'head on' collision was narrowly averted by the driver of train 1025. Other control systems in use include:

- Automatic Train Protection (ATP), a system that supervises train speed and target speed, and enforces braking when necessary;
- Automatic Warning System (AWS), a system that has audible and visual alarms to alert the driver;
- catch points/derailers, to prevent unsafe movements of trains by diverting the movement away; and
- two signal protection.

FIGURE 13:
Signalling layout at Epping



To determine an approximate impact speed, a series of brake tests were conducted using a three car Comeng unit similar to train 1648. The tests were conducted on a fine dry day from Epping platform one to Lalor passing signal EPP121 at stop to reflect the conditions experienced by train 1648. The following table represents the test results:

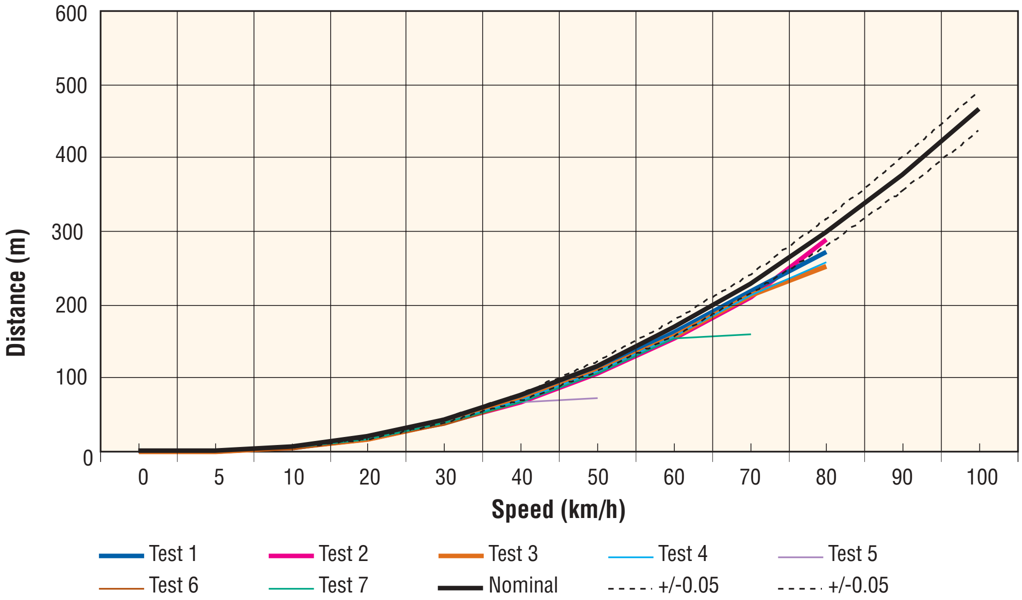
TABLE 4:
Brake test results

Test	*Conditions*	*Actual Speed at signal EPP121*	*Stopping Distance*	*Speed at Fouling Point*	*Braking Effort*
1	Maximum speed	78 km/h	271.65m	61 km/h	-0.86 m/s²
2	Maximum speed	82 km/h	288.05m	64 km/h	-0.90 m/s²
3	Maximum notch 3[35]	76 km/h	248.45m	57 km/h	-0.90 m/s²
4	Maximum notch 3	77 km/h	249.35m	58 km/h	-0.92 m/s²
5	Speed 40 km/h	42 km/h	82.15m	N/A	-0.83 m/s²
6	Speed 40 km/h	40 km/h	76.40m	N/A	-0.89 m/s²
7	Speed 60 km/h	61 km/h	162.55m	22 km/h	-0.88 m/s²

Allowing for the variation in driver technique, the probable impact speed would have been between 57 and 64 km/h at the impact/fouling point, in addition to the speed of train 1025 in the opposite direction of 10–15 km/h. If train 1648 had departed from platform two at Epping the speed at signal EPP121 and the fouling point would have been marginally higher, due to the straight departure as opposed to the turnout via platform one.

35 Notch 3 designates a throttle position on the master controller. Notch 1, or shunt, being the lowest, notch 2 or series, notch 3 or series parallel, and notch 4, or weak field, being the highest setting.

FIGURE 14:
Braking Curves



The distance from signal EPP121 to the fouling point between the main line and number 22 points was 155.3 metres. A train travelling in excess of 55 km/h would not stop within the safety margin.

The design distance of the overlap was insufficient for the train stop to bring the train to a halt from the speed the train was travelling at the time of the accident.

4.7 Train control

The train control system covering the Epping area worked as designed.

Once cleared from the platform on a caution signal the signaller at Epping had no way of influencing the outcome of the accident. The signaller at Epping had advanced train 1648 off the platform to signal EPP121, to maintain an on time departure from the platform.

After the collision, the driver of train 1648 attempted several radio calls to Metrol but having initially made contact the transmission failed. The issue of whether or not the emergency radio call worked as designed is not clear. The emergency transmission to Metrol should have remained connected, until terminated by Metrol or the driver. There is a history, however, of areas of unreliable communication in the train system radio network. Some drivers carry mobile phones as these are considered to be more reliable.

4.8 Driver sign on procedures

The sign on procedures at Upper Ferntree Gully, as with other attended depots, involved drivers attending and physically signing on at the depot, checking for special working information, then proceeding to their designated duties for the day. On occasion, drivers may ring from an out station depot to notify staff that they are in attendance without physically signing on. Connex document 13 WI MO 49 requires drivers signing on at unattended stations to contact the Train Crew Allocation Officer, (TCAO) and advise that office of their attendance.

Stage 2M of the driver training manual comments that:

> it is necessary to sign on in order to ascertain that drivers are in position for duty, are in a fit condition, in proper dress, and any alterations to rostered duties or special instructions can be issued.

Once the driver has signed on they must report to the officer in charge of the station for further directions, this is also a screening process. The manual also notes that 'drivers must sign on with a zero blood alcohol level', there is no other definition for 'fit for duty'.

On this occasion the driver of train 1648 did not sign on as required at Upper Ferntree Gully, bypassing the sign on procedures, reporting direct to Bayswater station for duty.

It is doubtful that even if the driver had reported in person to the officer in charge at Upper Ferntree Gully, his 'unwell' condition would have been noted or reported by the driver. Maintaining scheduled times, particularly in peak periods, depends on drivers signing-on on time.

The issue of 'late notice' absences is difficult to manage. A scheduled driver reporting sick at short notice has the potential to delay or cancel train services, putting extra workload on colleagues or leading to inconvenience for customers. The risks involved in a driver signing on when unwell against the possibility of a small number of drivers abusing a system is a matter for management to assess.

Connex has estimated that the amount of 'late notice' sick leave, in a period of 18 months, is 0.024 per cent. Additionally the driver sick leave average in 2002 is 12.5 days per annum, of the 15 days provided.

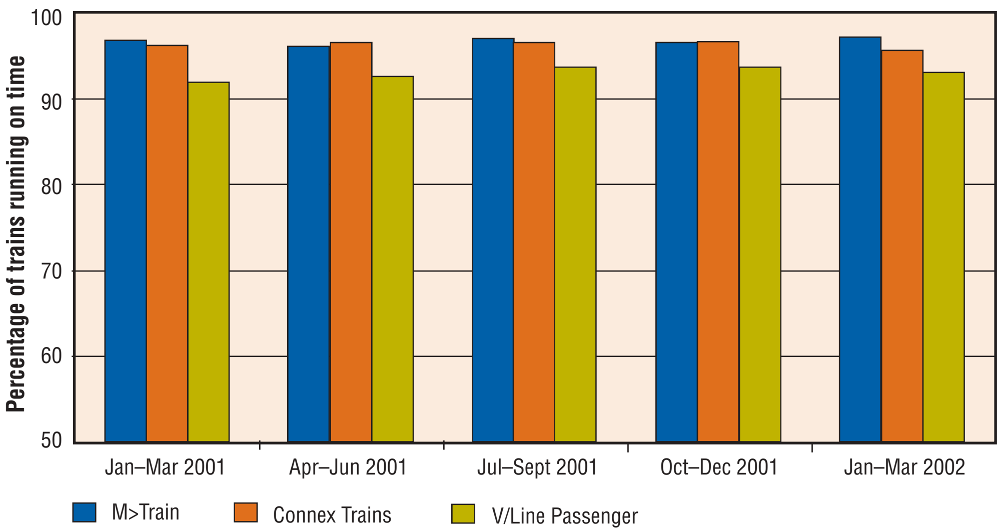
4.9 On time running, reliability, and performance

On 29 August, 1999, Connex entered into an agreement with the Victorian Government for a period of 15 years. As part of the agreement, Connex were required to maintain train services levels within certain parameters. Monitoring of performance is based on maintaining scheduled times at originating and destination stations. Any performance that exceeds the standards is awarded an operational performance incentive.

Over the period from April 2000 until March 2002 Connex consistently exceeded the threshold of 92 per cent on time running performance. Over the same period Connex reliability consistently exceeded the 95 per cent threshold.

Discussions with Connex staff have indicated that they were aware of the penalties imposed for below target level performance. Most staff commented that they felt that on time running was the most governed and monitored performance indicator.

FIGURE 15:
Excerpt from Victorian Department of Infrastructure publication Track Record 10



Discussions with various signallers at Epping signal box have indicated that movements from Epping platform into the single line section of track, while there is an oncoming movement into Epping Yard, was not uncommon. Signallers have commented on their reluctance to perform this movement, but had to maintain on time departures from Epping platform. Connex management has not been provided with comments regarding the signaller's concerns.

The movement from Epping platform one to signal EPP121 is a strategy to allow an on time departure and thus maintain the on time running criteria.

4.10 Emergency response

The overhead power had not initially been isolated to guarantee the safety of the site. Without any first hand knowledge of the situation, the risk of electrocution, electric shock, or other damage could not be discounted. Emergency services liaised with the first passenger driver from train 1025 to ascertain if the overhead power had in fact been de-energised. The first passenger driver off train 1025 liaised with Metrol. The overhead power was eventually de-energised at 0949, 35 minutes after the collision. The overhead power supply should have been isolated as soon as possible and not restored until a positive report that it was safe to do so. There is no formal procedure for isolating the overhead power supply as soon as possible.

Other than the issue of the monitoring of the overhead power supply, the general response to the accident was effective.

4.11 Footscray accident

On Tuesday 5 June 2001, an empty suburban electric train collided with the rear of a suburban passenger train at number 4 platform at Footscray station. The report into the collision highlighted a number of deficiencies, as a result a number of recommendations were made. The Epping collision is similar in many aspects.

4.11.1 The signalling system and overlap

Following the recommendations from the Footscray report, a risk assessment was undertaken by the Victorian Department of Infrastructure to survey the signalling and overlap system in the Melbourne metropolitan rail network. That survey may have identified Epping as a potential risk, and may have recommended actions to prevent overlap over runs. That survey was partially completed at the time of this accident.

4.11.2 Rail accident response plans

Rail organisations were asked by the Victorian Department of Infrastructure to review their response plans as a result of Footscray. Reviews included staff training, rapid deployment of staff to unmanned stations to ensure adequate response procedures are in place, and ensure immediate safety of the track infrastructure. The emergency response at Epping was adequate, although the overhead power was not immediately de-energised to provide site safety.

4.11.3 Hand and foot pilot valves

Advice was sought from suppliers by the Victorian Department of Infrastructure regarding the use of vigilance devices on suburban type operations. Indications were that the use of a vigilance device is not widely supported.

A risk assessment was in the process of being conducted to determine whether the present system on Hitachi and Com Eng vehicles could be improved.

The new Siemens train was fitted with a twist type deadman's device, that was the current accepted European standard. A twist type pilot valve may have activated, during the driver's incapacitation, to stop the train before overrunning the safety margin, therefore preventing the impact.

4.11.4 Medical issues

Following the recommendations from the Footscray report, the Victorian Department of Infrastructure have amended the *Transport Act 1983*. The amendment expanded the scope of the *Transport Act 1983* to control the use of prescription and over the counter drugs by rail safety workers. Tenders have also been invited for a review of medical examination and standards, and development of a health assessment and certification standard.

5 CONCLUSIONS

5.1 Findings

1. Train 1648 accelerated from Epping platform passing signal EPP121 at danger at 0914:19, at a speed of about 77 to 82 km/h.
2. Train 1648 collided with train 1025, which was approaching on a single line section of track turning out into Epping Yard, at 0914:33, at a speed of about 57 to 64 km/h.
3. The driver of train 1025 applied throttle to move the leading compartment out of the impact zone and across the turnout at a speed of about 10 to 15 km/h.
4. The driver of train 1648 had not followed published sign on protocols.
5. The driver of train 1648 had been on duty for about 3½ hours.
6. The signaller at Epping signal box had advanced train 1648 from Epping platform, into the single line section to signal EPP121, to maintain an on time departure of the train.
7. Once signalled from the platform, the signaller at Epping had no means of preventing the collision.
8. The signalling system and train stop operated as designed.
9. Electrical and track infrastructure was not considered a factor to this accident.
10. Train 1648 was in an acceptable operating condition prior to the accident.
11. The restraint systems holding several fixtures in the driver's cabin on train 1648 failed.
12. Train maintenance was carried out in accordance with requirements and no pre-existing faults were identified.
13. The overhead power supply was not isolated as soon as possible after the accident.
14. The Connex emergency management plan was implemented and operational within 10 minutes of the collision.
15. The response of the emergency services was effective and appropriate to the accident.

5.2 Significant factors

1. The performance of the driver of train 1648 was impaired by migraine symptoms and stress associated with medical circumstances affecting a close family member.
2. The pilot valve did not activate, although the driver was incapacitated.
3. The track 'overlap' provided an insufficient 'safety-margin' to a train exceeding the authorised speed limit, because a train travelling in excess of 55 km/h cannot stop within the standard safety margin, entering an occupied single line section, in this case.
4. At the time of the accident, the medical guidelines for the assessment of medical fitness to drive a train were not adequate in the context of public safety. Those guidelines lacked specificity and detail on the acceptability of a number of serious medical conditions and medication in the context of rail safety and in that regard are inadequate for use as medical standards.

6 RECOMMENDED SAFETY ACTIONS AND SAFETY ACTIONS INITIATED

6.1 Recommended safety actions

6.1.1 Victorian Department of Infrastructure

RR20020001 The ATSB recommends that the Department of Infrastructure review the implementation of recommendations contained in the risk assessment conducted on the signalling system in the Melbourne Metropolitan rail network following the ATSB Footscray investigation report.

RR20020002 The ATSB recommends that the Department of Infrastructure review the design of the signalling system, including the safety margin and route interlocking, particularly on single line sections of track with only one signal protection from oncoming movements.

RR20020003 The ATSB recommends that the Department of Infrastructure review the train working procedures for trains operating on single line sections of track, to prevent unauthorised train movements entering a single line section of track.

RR20020004 The ATSB recommends that the Department of Infrastructure review the design and/or application of hand and foot pilot valves.

RR20020005 The ATSB recommends that the Department of Infrastructure review PTC medical fitness examination guidelines so that medical fitness to operate a train should only be determined by suitably trained, qualified and competent medical practitioners.

RR20020006 The ATSB recommends that the Department of Infrastructure review and assess medical conditions that can impair or incapacitate a train driver.

RR20020007 The ATSB recommends that the Department of Infrastructure revise the medical guidelines to provide clear details on the actions to be taken by authorised medical examiners when conditions such as migraine and medication are declared or detected at examination.

RR20020008 The ATSB recommends that the Department of Infrastructure review specified medical conditions which are detected or declared during 'fitness for duty' medical assessments (e.g. migraine). Such conditions should be further referred to a designated independent reviewing medical authority for the ultimate decision regarding medical fitness to drive a train.

RR20020009 The ATSB recommends that the Department of Infrastructure monitor the implementation of the recommendations in this report, and determine implications to other train operating companies.

6.1.2 Melbourne Transport Enterprises

RR20020010 The ATSB recommends that Melbourne Transport Enterprises review driver sign-on procedures.

RR20020011 The ATSB recommends that Melbourne Transport Enterprises review policy on sick leave generally, in particular, existing processes dealing with 'last-minute' declarations of unfitness and capability to deploy reserve crew to 'trouble-spots' when sudden illness affects a driver.

RR20020012 The ATSB recommends that Melbourne Transport Enterprises review the emergency procedures to provide protection to the accident site as soon as possible including isolation of overhead power.

RR20020013 The ATSB recommends that Melbourne Transport Enterprises assess the train radio system for radio reliability.

6.2 Safety actions already initiated

Following the collision the Victorian Department of Infrastructure held a number of meetings with Connex and M>train, the two suburban train operators, to discuss a number of ideas to mitigate risk and additional controls to improve train driver assessment and health protection measures. Additional safety actions underway are detailed on page 36.

7 SUBMISSIONS

A copy of the draft report was provided to five individuals or organisations who were considered to be a 'directly interested party'. Of those parties, two responses were received, and the final report has been amended to reflect the submissions where appropriate.

7.1 The Department of Infrastructure

The Department of Infrastructure made a number of comments and observations on the draft report issued to directly interested parties. The comments and observations have largely been incorporated into the body of the report.

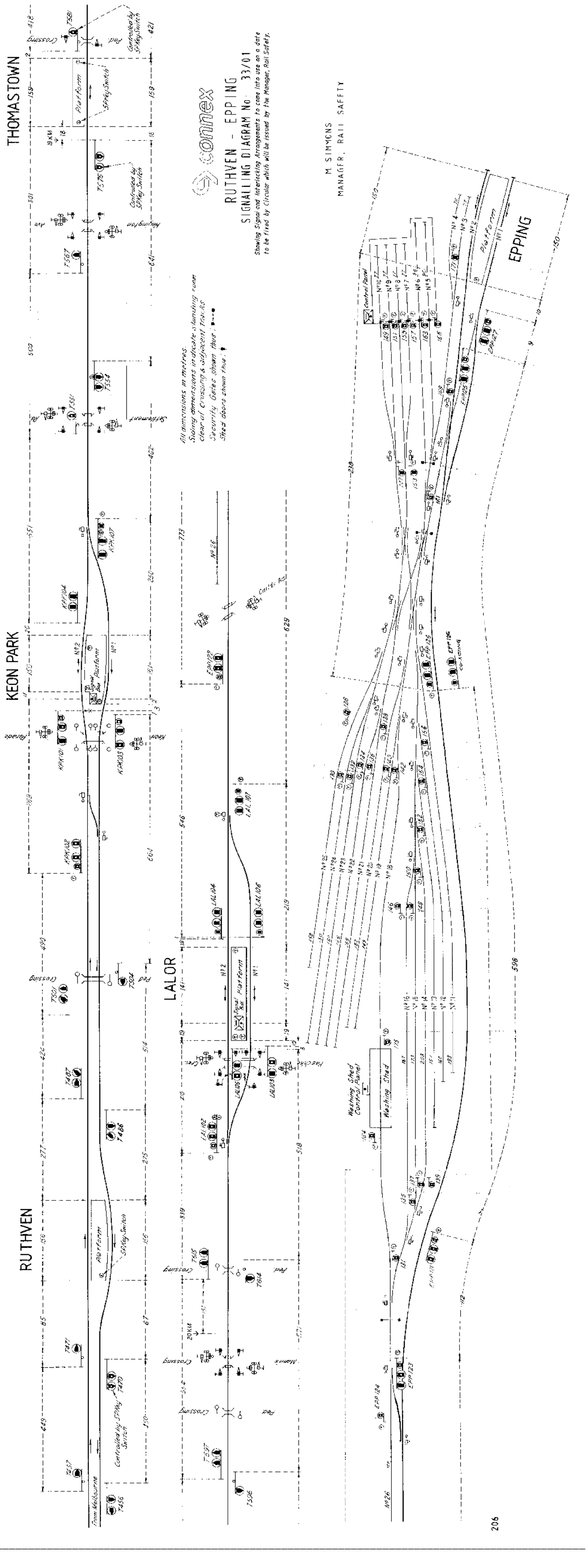
7.2 Connex Trains Melbourne

Connex Trains Melbourne made a number of comments and observations on the draft report issued to directly interested parties. The comments and observations have mostly been incorporated into the body of the report.

8. Appendix

8.1 Melbourne suburban rail network map

8.2 Ruthven to Epping signalling layout



Collision Between Suburban Electric Passenger train 1648 and Suburban Electric Empty train 1025