OVERLAPS ON REGIONAL LINES

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1 Summary

The paper adopts a risk based approach in determining what factors are important in setting the length of overlaps in the context of regional lines.

Initially, the purposes for which overlaps are provided are considered in relation to how these purposes can have an impact on the occurrence of train to train collisions. Historic collision incidents are reviewed and lessons extracted.

A risk model is presenting showing the causal links between trains overrunning signals at stop and deaths from collisions.

For each step in the causal chain, quantitative evidence is presented on the probability of each adverse outcome occurring. This allows a detailed exploration of the risk factors for which overlaps are provided as a control. A link is also drawn between the operational pattern, the type of infrastructure and the influence of each on final risk.

The risk model is then puts the collision risk into the context of the “tolerable risk” concept and the “costs” of providing incremental increase in overlaps are explored.

The position is put that (1) the marginal benefit of providing incremental increase in length of overlap is very small beyond an intermediate length; and (2) a “one size fits all” approach to overlaps is often not appropriate.

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2 Introduction

The occurrences of SPADS (Signals Passed at Danger) is a major source of operational risk for any railway. Australian research suggests that an average of fewer than 1 stop signal in every 10,000 encountered will be passed at danger [17].[1]

Of these, the vast majority will involve simple misjudgement of stopping distance. The driver wrongly assesses the track condition, the train braking characteristics, or simply misjudges distance. Typically the train then overruns the signal be a distance less than 100m.

On regional lines, an overlap which can typically be 300m in length is provided to control this risk.

More serious are the 1 – 6% of SPADS where the driver does not respond to the signal. These are termed “signal disregards” and can be further subcategorised; the most frequent being “Start on Stop” incidents, the less frequent but perhaps more hazardous being “signal disregards in running” which are often associated with secondary factors such as fatigue.

On suburban lines, enforcement devices such as trainstops ar typically provided to limit the maximum overrun distance in these cases. An overlap distance is set sufficient to support the needs of the enforcement system.

On regional lines, such enforcement devices are typically not used.

This paper investigates the causes of SPADs with a view to assessing whether, in the absence of enfarcement systems, a significant safety improvement can be obtained by increasing the overlap beyond the nominal length generally used.

What are the risks associated with relying on the nominal overlap for regional lines?

3 Review of current situation

3.1 Standards

3.1.1 General Principles

Overlaps are provided by most railways around the world.

The IRSE textbook “Railway Signalling” [18] states the purpose of an overlap as follows:

> *“The overlap is provided as a nominal distance which may be regarded as a protection for the driver against overrunning a signal at stop in foggy weather or when the rails are slippery, assuming that the brake application has been made at or before the train passed the first warning signal”.*[2]

The appropriate length of overlap and the need for supervisory equipment varies between Rail Authorities dependent on a number of factors as follows:

- <u>The level of traffic on the line.</u>

  Victorian Passing Lanes traffic of up to 20 services per day compares with 150 services per day for a typical Melbourne suburban line. As the level of traffic increases, the probability of conflict increases leading to an increase in the need for supervisory equipment. Queensland Rail sets a threshold traffic level of 75 trains per day above which ATP[3] equipment is

[1] Nikandros (2007), Measuring railway signals passed at danger, para 4.2.

[2] Nock O.S (ed) (1980): “Railway Signalling – A treatise on the recent practice of British Railways”; p.4

[3] Automatic Train Protection

fitted[4].[1] Trainstops are utilised on the Melbourne Metropolitan network.

- <u>The type of traffic on the line.</u>

  Victorian Passing Lanes traffic is predominantly freight. This compares with a typical Melbourne suburban line or country VLP line which is predominantly commuter[5]. The "exposed population" is higher for commuter lines than for freight lines.

- <u>Train speed on the line.</u>

  Line speed on Victorian Passing Lanes is 115 km/hr for freight and up to 130 km/hr for passenger. This compares with a typical Melbourne suburban line which has line speeds varying typically from 60 km/hr to 115 km/hr depending on the line. On the ARTC network, line speed of 160 km/hr is accommodated in NSW.

  On VLP lines where Vlocity trains run at 160 km/hr, special supervisory measures (ie mandated incorporation of TPWS into RFR schemes with fitment to passenger trains only) are utilised. TPWS support is not found on VLP lines operating at 130 km/hr line speeds and less (eg Seymour corridor).

The setting of overlap length is generally risk based taking into account the above factors. For British Rail/ Network rail, where intercity passenger trains operate routinely at 200 km/hr at close headways, the following approach was taken in setting overlap length:

> *"Statistics show that overrunning seldom exceeds 90m. In 1978 British Railways reviewed the matter and decided that, in future, all overlaps should be 183m except where the line speed is 97km/hr or less when the length may be progressively reduced[6]." [18]*

3.1.2 European Practice

Similar values and tradition in providing safety can be found in the remainder of Europe. The following are maximum overlap allowances are provided in each European country[7]: [8]

Table 1: European Maximum Overlaps

Railway	Country	HS Overlap	Freight	Supervised
OBB	Austria	50m	Yes	Yes
NMBS/ SNCB	Belgium	100m	Yes	No
SBB	Switzerland	100m	Yes	No
DB AG	Germany	200m	Yes	Yes
RENFE	Spain	50m	Yes	No
SNCF	France	100m	Yes	No
BR	Great Britain	183m	Yes	No
FS	Italy	100m	Yes	Yes
CFL	Luxembourg	200m	Yes	No
NSB	Norway	400m	Yes	Yes
NS	Netherlands	NA	Yes	Yes
BV	Sweden	200m	Yes	Yes

It should be noted that in all cases at minimum an audible indication is provided when the train passes a warning signal. If the driver does not respond to the

[4] QR STD/0076/SWK, quoted from ATSB investigation, Signal MR5 passed at danger, freight train Y245, Murarrie, Queensland, 28 June 2004, p.35.

[5] ARTC NE supports approx 20 services per day, 4 of which are passenger. This compares with, for typical RFR, 62 services per day, 60 of which are passenger. For typical suburban line, 150 services, all passenger, are run.

[6] Nock O.S (ed) (1980): "Railway Signalling"; p.5

[7] Bailey C. (ed) (1995): "European Railway Signalling" pp 7-8.

indication by operating a vigilance control, the brakes are applied automatically[8]. [8]

It can be seen from these figures that maximum non-supervised overlap prescribed for a European railway is 200m. As in Britain, train speeds are 160 – 200 km/hr for passenger trains and operations are at close headways.

3.1.3 Victorian Practice

Draft VRIOG Standard

In Victoria, the Victorian Rail Industry Operators Group Standard VRIOGS 012.0.1 – 2008[9] is a recent statement of Victorian Practice. This states, under requirements for "Nominal Overlaps" (lines where trainstops, TPWS, or similar are not fitted):

> *"On lines carrying passenger trains with speeds up to 40 km/h a minimum nominal overlap distance of 100 metres shall be provided.*
>
> *"On lines carrying passenger trains with speeds greater than 40 km/h a minimum nominal overlap distance of 200m shall be provided. In addition, at junctions in order to further mitigate the residual collision risk an additional control measure shall be introduced. The standard control measure shall be the introduction of an unconditional medium speed warning aspect. Additional or alternative control measures may be introduced by the designer with the agreement of the infrastructure manager. Where the standard control measure is not used, evidence of the risk management process used for the treatment of residual risk shall be documented by the infrastructure manager.*
>
> *"On freight only lines the minimum nominal overlap distance shall be 100 metres unless directed otherwise by the Infrastructure Manager."*[10] *[27]*

Example of additional control measures currently in service can be found in both the ARTC and the Melbourne Metropolitan networks.

The Connex overlap protection guidelines issued in 2004 involve the setting of flank protection beyond the end of the overlap without increasing the overlap itself (Connex 100m overlap remained applicable with trainstop protection). This additional protection was applied on a "risk" basis only.

The ARTC network (North East and Western lines) provide point trapping for opposing trains at crossing loops. Such trapping is also incorporated in the design for Passing Lanes.

Passing Lanes design incorporates minimum overlaps of 300m.

Observed Victorian Practice

While Victorian Principles as they relate to suburban networks are included in the former PTC document, "PTC-ENG-SPE-001", practices related to the regional rail network have not previously been well documented. The most recent statement of Regional Victorian principles is found in the SKM review of Victorian Signalling Principles[11].[24] This stated that nominal

[8] Ibid: chapter 9. It should be noted that AWS is not used in Australia for reasons which are now historical. The cost of retro-fitting of AWS to existing networks now is similar to progressing straight to ATMS, ETCS or similar system.

[9] Quoted from VRIOGS 012.0.1 – 2008, "Victorian Signalling Principles – Overlaps". Dated 10 July 2008. [draft - uncontrolled when printed]. Note that current status of this document, including ARTC endorsement of it, is not clear.

[10] VRIOGS 012.0.1 – 2008, p10.

[11] SKM (2002): Victorian Signalling Principles Review

overlaps of 200m apply for regional CTC network.

This standard can be seen to derive from the Victorian Rule Book which states that a train may be signalled into a section with no train 400m in advance of the stop signal at the end of that section[12]. Many signalled schemes built around this rule and the derived principles remain in service.

A typical scheme of this type is illustrated:

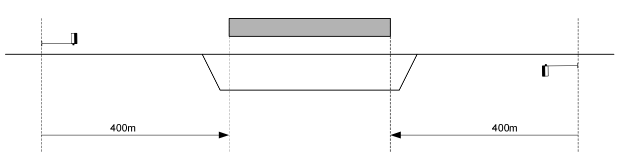

Figure 1

With this arrangement, trains can approach the station from either direction with one being received into the station. Thus a shared overlap of 400m (or 2 non-shared overlaps of 200m) is implied.

On the ARTC network, more recent resignalling works at Newport and Maroona have incorporated main-line junctions with nominal overlaps from conflict points of 249m and 300m respectively.

For the existing North East CTC line, overlaps are provided for following trains by means of "floater track" circuits. These track circuits have no defined length, feed and relay being co-located, but are generally regarded as being effective for a train of poorest shunt for a minimum distance of 100-200m.

Trapping or Flank Protection

In addition to the overlap track, additional protection is provided on existing CTC lines by use of "point trapping" or "flank protection". This method sets the points at the far end of the loop away from any train entering without authority, thus avoiding the possibility of a head-on collision within the passing loop.

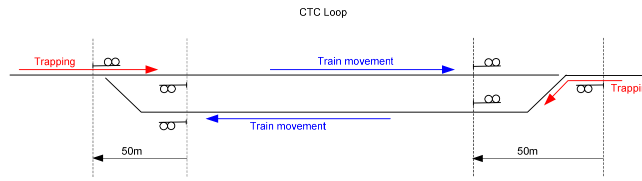

Figure 2

This method of main line protection, though widely practised in Victoria, is not prescribed in either the PTC written standard or the more recent VRIOG standards. In British schemes, its use is included in Network Rail Group Standards. It is discussed briefly in section 5.3 below.

3.2 Signals Passed At Danger (SPADs)

3.2.1 General Principles

Data on SPAD occurrences are maintained by many Rail Operators and Safety regulators.

SPAD occurrences are recognised to be of a number of types:

- Driver misjudgement

  This is the type which provision of an overlap can effectively control. The 300m overlap incorporated in the passing lane design controls this risk.

  Incidents of this type[13] are reviewed in section 4.3.

- Restored in front of train (RIFOT)

  This is typically caused by a failure in the signalling system, but can also be caused by signaller error. It is a significant causal factor in SPADs. The

[12] Refer PTC 1994 Book of Rules and Operating Procedures; Section 20, Rule 6..

[13] Murarrie & Gloucester

overlap has no role in protecting against this type of SPAD. Protection is provided by the "Approach Locking" facilities within the interlocking.

Incidents of this type are not further reviewed in this report.

- Driver disregard

  This type of SPAD occurs when the driver fails to be able to practically respond to the signal at stop. Typical reasons for disregarding the signal are that the driver is incapacitated or asleep. This may also be due to the driver disregarding the previous warning signal such that limits the driver's ability to practically respond to the stop signal. A special case "starting against signal" (where a driver starting from a station accepts advice to proceed from station staff or otherwise, is distracted, and fails to observe that the signal is at stop or otherwise restrictive). Once past the signal, the driver will continue until (a) stopped by a supervision device, (b) he/she becomes aware that he/she is travelling against authority, or (c) he/she sees and/or collides with an obstruction.

  Incidents of this type[14] are reviewed in section 4.1.

  Overlaps are found to play no more than a chance role in this process. Overlaps are not considered an effective control against driver disregard.

In addition to these SPAD occurrences, incidents involving driver actions after stopping at a signal at stop should also be considered. Driver expectation about the road ahead can and has in several instances led to behaviour resulting in collisions with injury and fatality.

Incidents of this type[15] are considered in section 4.2. It is found that the length of overlap can be a contributing factor to such incidents in that provision of a long overlap can encourage the expectation that the line ahead is clear when it is actually blocked.

3.2.2 Statistics on SPAD occurrences

SPAD statistics are collected by many rail authorities and Safety Regulators. Because the definition of what constitutes a SPAD differs between jurisdictions, figures are difficult to readily compare between Rail Authorities. Within given Rail Authorities, the extent of the overrun in metres is often not recorded against each incident.

National Express, the former Melbourne suburban rail operator, included "overrun by more than 200m" as one of the categories in their SPAD reporting statistics. Their experience, which could be expected to be typical, was recorded in the investigation report to the collision at Footscray:

> *"A SPAD report covering the NXB operations for the period 1 January 2000 to 31 May 2001 showed that 107 SPAD had been reported. Two of the 107 SPAD resulted in an overrun of more than 200 m, and none had involved injuries to either passengers or employees."*[16] *[26]*

[14] Violet Town, Benalla, Beresford, Fisherman Islands, Adelaide, Footscray & Epping

[15] Holmesglen, Syndal & Glenbrook

[16] ATSB report into incident at Footscray, pp17-18

The same report noted that 39% of the recorded SPADs were "start against signal" incidents.

SPAD rates in the UK are available from their Safety Regulator:

> *"SPADS network wide (approx 7500 km of track) are recorded at a rate of about 300 per month (0.6 per thousand signals). The most serious category (about 10%) involve drivers failing to observe a signal on starting."*

This corresponds to a probability of SPAD (to any cause) per signal per journey of around 1 in 10 million[17]. Overruns by more than 200m are perhaps 1 in 50 of these[18].

For Victoria[19], historical data shows about 30 SPADS per month (2002 data). Allowing for the differences in network dimensions, this rate (per unit track/ signal/ traffic) is comparable with the British experience.

A small number of these occurrences evolve into a more serious incident resulting in a collision and/or an investigation report. A number of these incidents, selected due to relevance to the discussion of controls against overruns, are presented in the next section.

These are divided into 3 sections:

- Disregard incidents (including one "start against signal") (section 4.1)
- Violation incidents following stopping at a stop signal (section 4.2)
- Misjudge incidents (section 4.3)

[17] Note that these are average figures. Individual "high risk" signals will have higher SPAD probabilities associated.
[18] Refer Railtrack and Victorian Safety Regulator reports for base SPAD rates, Bayside study for overruns by more than 200m.
[19] Whole of state data. Thus includes Connex, Vline and ARTC networks. Excludes areas where safeworking is other than by fixed signals

The Human Factors considerations applicable to such occurrences are discussed in section 5 following.

4 Review of incidents

4.1 "Disregard" incidents

4.1.1 Violet Town: 07:05 hrs, 7 February 1969[20]. [14]

The Southern Aurora (passenger express) travelling south, was planned to cross a northbound freight train at Violet Town loop. The Southern Aurora arrived first and was set for the straight.

The crew comprised a driver (who, according to the inquest, was dead at the time the first warning signal was passed) together with an observer in the cab whose task was to call each signal aspect to the driver, receive a response, and apply the emergency brake in any unsafe situation. The crew also included a guard, located at the rear of the train, whose tasks included observing the signals and applying the emergency brake in any unsafe situation.

The train was fitted with a vigilance device (though not of a type which operated the brakes) which the driver was required to acknowledge. This vigilance device operated with the train still past the warning signal approaching Violet Town loop. The inquest found that the observer had acknowledged the vigilance device on behalf of the now dead driver.

The train passed the warning signal (Y/R aspect), the running "C" light at the start of the loop (R/R with white "C" light), then the stop signal at the far end of the loop (R/R) without any emergency brake application being made by the observer.

[20] Ref: Ian MacFarlane account (2004): Railway Safety – Interlocking and Train Protection; p.268

The train collided with the slowing northbound freight train mid section. No brake application was made prior to the collision. 7 passengers and 2 crew (including the driver who had died prior) died.

The inquest found that if the observer had applied the emergency brake, even as late as the loop departure "stop" signal, the accident could have been averted.

Violet Town is an example of a pure disregard. In a case such as this where no brake application was made at any stage, the length of the overlap had no impact on the final outcome.

4.1.2 Benalla: 06:44 hrs, 2 June 2006[21] [3]

A PN freight service (5SM5) travelling south, was planned to cross Interail freight service 5MB7 at Benalla loop. The Interail freight service arrived first and was set for the loop.

The Interail train crew comprised a driver and a co-driver. The co-driver was responsible to call each signal aspect to the driver as was the case at the time of the Violet Town accident.

The train was fitted with a vigilance device which was connected directly to the brakes. This was reset 5 times in quick succession starting just two minutes prior to the derailment. The final acknowledgement occurred with the train just 350m from the entry signal to the loop.

The train passed the warning aspect (Y/R), then, 120m from the running "C" light at the start of the loop (R/R with white "C" light) made an emergency brake application.

The train, travelling at an estimated 106 km/hr, derailed whilst traversing the 40km/hr loop entry points. Benalla loop is 800m in length. Had the train not derailed, braking according to GW40 would have brought the train to rest approximately 1km into the next section beyond the exit from the loop. The investigation did not find whether a collision could have been avoided in that case. In the event, no lives were lost.

Benalla is a further example of a disregard. In this case the train derailed, thus potentially avoiding a collision such as that which occurred at Violet Town.

ATSB investigation recommended as follows[22]: [3]

- "… that the ARTC consider the benefits of pre-briefing or warning train crews (by radio) about timetabled and also non-scheduled train crosses.
- "… that Chicago Freight Car Leasing Australia review the effectiveness of their current fixed time based train driver vigilance systems with a view to ensuring that drivers maintain an optimal state of alertness at all times while performing driving duties.
- "… that Interail monitor and review processes in place to ensure that train crews are competent to undertake work at their designated level of responsibility and that this is acknowledged and recorded within the employee files. (For example, evidence that demonstrates requisite driver safeworking and route knowledge skills)
- "… that Interail monitor and review processes in place to ensure that driver re-certification is regularly reviewed and recorded.

[21] ATSB report into incident

[22] Ibid p.40

- "… that Interail review their current crew resource management practices with a view to ensuring that a co-driver is sufficiently alert and actively participating in the operation of the train, particularly during periods of high risk operation.
- "… that Interail's training strategies clearly articulate and communicate mentoring responsibilities and what that entails …
- "that Interail should review opportunities to improve its systems that identify weaknesses in driver safeworking and route knowledge skills and improve fatigue management to ensure drivers are fully fit for duty."

One observation is that none of these recommendations requests a review of the signalling infrastructure itself. Rather the human factors elements were found of prime importance.

4.1.3 Beresford: 06:32hrs, 23 October 1997[23] [12]

A coal train (MT304) travelling towards Port Waratah (NSW) was standing on the line. A second coal train (DR396) was scheduled to follow.

Both coal train crews comprised a driver and an observer. The observer was responsible to call each signal aspect to the driver.

The train was fitted with a vigilance device which was connected directly to the brakes. This was acknowledged up to 1 minute prior to the collision.

DR396 was found to have travelled in a manner consistent with a well controlled train for the section in a situation where the signals were green. This section of line is on a downhill grade and dynamic brake was selected. The train passed a warning signal (Y aspect – single light) with no air brake application being made. It then passed a stop signal (R aspect – single light) still with no air brake being applied. Approximately 370m from the point of collision travelling at approx 62 km/hr, the driver of DR396 sighted the coal train ahead and applied the emergency brakes.

A collision occurred. There were no fatalities, but the crew of DR396 were seriously injured.

Beresford was a further example of a disregard. The investigation found that the first response initiating emergency braking was not brought about by the signalling system, but by the sighting of the coal train ahead. In this case the 445m overlap provided was of little relevance to the final outcome of the incident.

The independent inquiry report found[24]: [12]

"The shift pattern worked by the driver and observer of DR396 resulted in a level of work related fatigue, due to sleep deprivation, of sufficient dimension to impair hand-eye co-ordination and reaction/response times, and to adversely affect awareness …

"The vigilance control did not adequately protect against reduced driver awareness."

As at Benalla, the human factors elements surrounding the incident were found to be of more significant than the technical aspects. The report concludes with a comment that more emphasis needs to be put onto these aspects of incidents when designing safety accident databases[25]. [12]

[23] Independent Inquiry Report: Coal Train Collision, Beresford NSW, 23c October 1997.

[24] Ibid, p.32

[25] Ibid, p.33: "… *many transport safety incident databases focus on technical malfunctions rather than the human factors which underlie many accidents and incidents*. …"

4.1.4 Adelaide: 07:01 hrs, 28 March, 2006.[26] [6]

The following is quoted from the abstract of the incident report:

"At 0701 on 28 March 2006, TransAdelaide passenger train H307 passed signal 161 at Adelaide Railway Station while it was displaying a red stop aspect. Train H307 then travelled the wrong direction along the Up track for approximately two minutes before stopping about 600 m past signal 161.

> *"At the same time, Great Southern Railway's Indian Pacific passenger train (1PA8) was approaching Torrens Junction where TransAdelaide's broad gauge line crosses the standard gauge Defined Interstate Rail Network (DIRN). The investigation found that the signalling system could not provide an appropriate indication to both trains and thus neither train driver was aware of the potential for a collision. Had train H307 continued on for a further 1000 m the two trains may have collided.*
>
> *"The investigation also concluded that driver distraction, conflicting signal indications (hand and fixed), and inexperience contributed to the occurrence."*

This incident was a classic "start against signal" disregard incident. The driver was given a green "right of way" indication by platform staff at the scheduled departure time. The driver started based on this indication and did not check departure signal 161 which was showing red. In the context of this paper this was a disregard incident. The suburban train travelled "wrong line", trailing through one set of points and damaging them, for about 600m.

The train eventually stopped as the driver realised he was on the wrong line supported by the TransAdelaide controller's radioed instruction. The instruction for the India Pacific Train to stop was relayed through the ARTC controller.

Line speed in this area is low (less than 30km/hr achieved by train in area). Thus the time involved was about 2 minutes. There were no fatalities or injuries.

The provision of overlaps had no bearing on the outcome of this incident.

The report found[27]: [6]

"*It is possible that the departure procedures at Adelaide station could increase the risk of 'Starting Against Signal' SPADS due to expectation error.*

"Platform coordinators give RoW at the scheduled departure time regardless of any delay to the clearing of the departure signal. Under these conditions, it is possible that drivers would move off and slowly approach the signal with the expectation that it would clear as they approached, increasing the risk of an error if the signal remained red."

4.1.5 Fisherman Island: 07:38 hrs, 20 September 2004[28] [7]

The following is quoted from the executive summary of the incident report:

> "At 0738:061 on 20 September 2004 train 8868 passed signal FS66 when it was displaying a stop aspect. Train 8868 was a freight train from central Queensland bound for Fisherman

[26] ATSB: Signal 161 Passed at Danger; TransAdelaide Passenger Train H307; Adelaide SA, 28 March 2006.

[27] Ibid, p.31

[28] ATSB: Signal FS66 Passed at Danger, Freight Train 8868, Fisherman Islands Qld, 20 September 2004.

Islands and was crewed by a driver who had signed on at Maryborough at 0050 the same day. Signal FS66 is about five kilometres from Fisherman Islands and about 100 metres from a busy road crossing at Pritchard Road.

"Train 8868 reached Lytton Junction at about 0736 and was routed onto the Fisherman Islands branch line for the final section of the journey. The driver recollects passing through this junction and setting one of the train radios to the Fisherman Islands local control channel. He thinks he then fell asleep, as he remembers little until sensing that the train was travelling too slowly. The driver then applied full power until about 15 metres from signal FS66, by which time the train was travelling at 49 km/h. Being momentarily unaware of where he was, applying full power, noticing the cars on the level crossing before realising (when 15 metres away) that the signal was red, indicate only a partial state of arousal. A service rate reduction2 of the brake pipe failed to stop the train from passing the signal and proceeding through the Pritchard Road crossing. Because of the rate of reduction and because the brake pipe pressure reduced to 229 kPa, well below the 350 kPa equalised pressure of a full service application, it is concluded that the brake handle was placed in the 'handle out' position and not in the emergency position. The 'handle out' position is the notch immediately before the emergency position.

"As train 8868 passed signal FS66 the protection cycle for the level crossing was only partially complete and the boom barriers were not horizontal. Train 8868 stopped about 175 metres beyond signal FS66 and 74 metres beyond the level crossing."

This incident can be classified as a disregard or a misjudge, depending on which aspects of the incident are focussed on. The train stopped within the relevant overlap distance and there were no fatalities. The length of overlap had no bearing on the outcome of this incident.

Of particular interest is the time of occurrence: 07:38 hrs. This compares with the other disregard incidents identified: 07:05 hrs for Violet Town, 06:44 hrs for Benalla, 06:32 hrs for Beresford.

The common factor in all the incidents discussed to this point (apart from Adelaide) is that of driver fatigue combined with the observation that in each case the driver/ observer generally passed multiple warning signals and became aware of the danger primarily by observing something other than a signal.

The reasons underlying such behaviour are discussed in section 5 below which covers the Human Factors research into SPAD incidents.

Two further Melbourne suburban examples follow a similar pattern, but with medical causes found rather than fatigue.

4.1.6 Footscray: 08:28 hrs, 5 June 2001[29] [2]

The following is quoted from the executive summary of the incident report:

"An empty suburban electric express train collided with the back of a suburban passenger train at number 4 platform Footscray station just after

[29] ATSB: Collision between suburban electric passenger train 6369 and the empty express electric train 6371, Footscray, Victoria, 5 June 2001.

0828 on 5 June 2001. The passenger train had about 20 people on board.

The driver of the empty train suffered an injury to his left elbow. Two passengers were taken to hospital for observation but were released with no serious injury.

The evidence available to the investigation suggests strongly that the driver's performance was impaired by a medical condition leading to him being unable to recall events for a period of less than two minutes, between the Maribyrnong River bridge and the point of collision. The driver was taking a course of prescribed medication, which combined with the early start to his working day on the morning of the accident and a history of chronically disturbed sleep, may have resulted in a sleep period (apnoeic episode) while he was driving the train.*"*

This incident was a further example of a driver disregard.

Between the stop distance at which the train tripped and the train in the platform was 230m. The trains slowed from 77km/hr to 30km/hr in that distance consistent with the braking characteristics of the Comeng train after tripping. The driver himself made no brake application.

Prior to tripping at the stop signal, the train had passed two warning signals (showing Y/G and then R/Y aspects in order) without driver response. In fact, rather than slowing, the train had sped up from 50 km/hr to 80 km/hr consistent with the change in line speed between these signals. If the driver had observed the red signal when it was in sighting and applied the brakes even at that late stage, the train would have stopped safely.

In the event the trainstop mechanism stopped the train rather than the driver who passed the stop signal without response. In the absence of the trainstop, the 200m overlap would have been expected to have little bearing on the outcome of this incident.

4.1.7 Epping: 09:14 hrs, 18 June 2002[30] [4]

The following is quoted from the executive summary of the incident report:

"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

[30] ATSB report.

by Melbourne Transport Enterprises, through Connex Trains Melbourne (CTM) and Alstom Melbourne Transport Limited (AMTL).

"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."

This incident is an example of a "start against signal" combined with a driver disregard.

Between the stop signal and the collision was a distance of 155m. The train needed 270m to stop from line speed. Thus, to stop safely, the driver needed to apply brakes 120m ahead of the signal. This did not occur. The driver reported that he did not observe the stop signal at all and that the train first braked on tripping at the signal.

Prior to tripping at the stop signal, the train had started from Epping platform (terminal station) on a medium speed warning signal (showing R/Y aspect). without driver cautionary response. In fact, rather than proceeding with caution the train had sped up from stop to 80 km/hr at close to the best acceleration available to the train. Even taking into account the quick acceleration, if the driver had observed the red signal when it was in sighting and applied the brakes even at that late stage, the train would have stopped safely.

In the event the trainstop mechanism stopped the train rather than the driver who passed the stop signal without response. In the absence of the trainstop, the length of the overlap would not have been expected to have a bearing on the outcome of this incident.

4.2 "Violation" incidents after stopping at red signal

The incidents reviewed in this section are examples of trains which had stopped at a stop signal in accordance with all rules and procedures. In signalling design the curtain in the analysis is usually drawn at this point. The train is regarded as stopped and safe.

However, in all railways the question must then be asked: "What happens next?" How the train proceeds forwards, the assumptions the signalling system encourages in the driver and the safety culture of the railway itself then becomes the major determinant of safety for the passengers on the train.

4.2.1 Holmesglen 14:32hrs, 26 July 2000[31] [26]

The following is quoted from the introduction of the incident report:

"At 14:32 on Wednesday 26 July 2000 the 14:22 Glen Waverley train (No 2020) to Flinders Street collided with the 14:11 hours Glen Waverley train (No 2018) to Flinders Street which was stationary at Holmesglen Railway Station. Train 2018 was carrying passengers. Train 2020 was a scheduled express to Flinders Street Station and was not carrying passengers.

[31] Vic DOI Office of the Director of Public Transport, Safety and Technical Services Branch; Final Report, Investigation into the Collision between Connex Passenger Trains at Holmesglen Station on Wednesday 26 July 2000.

Each train consisted of six cars and both trains were severely damaged. The track rail head was damaged and ballast was disturbed at the point of collision.

"Ten (10) passengers and both train drivers were transferred to hospital. Other passengers requiring attention were treated at an emergency medical centre established at Holmesglen TAFE College International Centre *adjacent to the site of the incident."*

As part of the investigation, the driver was interviewed. Why did he crash into the train ahead?

"*He recalled that on approach to Jordanville, automatic signal (DG526) indicated clearance to proceed at normal speed subject to being prepared to stop at the next signal. The next signal was DG484 which he recalled was indicating stop.*

"*He stated that after stopping his train at the signal, he waited for around 40 seconds. As he could not observe any train ahead he moved the train forward, passing the signal at stop. The trip apparatus on the train was activated. This discharged all brake pipe air pressure, automatically applied full emergency brakes and brought the train to rest. He then reset the trip and recharged the brake pipe. He indicated that he moved the master controller into the first notch for about five seconds in order to gain momentum. He then moved the master controller to the 'Off' position and stated that he thought the speed at the point of collision was at least 20 km/h*."

As the report continues, it is clear that the driver had not judged his speed correctly:

"Analysis of the speed of train 2020 at the point of impact is set out in Appendix 1. It indicates that the train was travelling at a speed in excess of 44.5 km/h, possibly as high as 65 km/h."

The high speed with which the train proceeded was informed by his belief about whether he was facing a clear track ahead of a failed signal, or an actual train. His experience with encountering signals at stop in the past then led him to assume the former:

"The Driver of train 2020 indicated that he believed that Signal DG484 was defective and stated that after proceeding beyond signal DG484 he reached into his bag to obtain a pen and his roster book to write down the number of the signal for the purpose of reporting it to Metrol. He stated that the reason why he thought the signal to be defective was that he could not see a train in the track section ahead.

"The site inspection … revealed that it is not possible to see the entire track section from DG484 to the next signal at Holmesglen Station owing to the curve in the track on the approach to the Station."

The "fully braked" overlap provided at this location had no impact on the outcome of this incident. Holmesglen was found not to be an isolated example. The report went on to discuss four previous collisions which had occurred in similar circumstances over a period of about 15 years.

These included the incident at Syndal.

4.2.2 Syndal 20 November 1989[32] [26]

The incident is described in the Holmesglen report as follows:

"*On 20 November 1989 a suburban electric passenger train collided with another which was stationary in the Up platform at Syndal*

[32] Quoted in part from Holmesglen report. Original report was on paper.

Station resulting in 75 injuries. The Board of Inquiry found that the collision was due to human error in that the Driver of the second train after exercising train brake tripping procedures at Automatic Signal DG660 proceeded at a speed which was inappropriate to the conditions. The Driver concerned first observed the stationary train when it was approximately 50-60 metres away. The estimated speed on impact was 40 km/h. The impact pushed the stationary train forward approximately two to three metres.

"*The Board of Inquiry recommended that more on the job supervision of drivers be provided by Electric Running Supervisors, that strict enforcement of Regulation 74 be applied by all Supervisory Officers and that foliage on the left hand curve approaching Syndal Station be removed and a program be implemented for its continued maintenance*.

"Regulation 74 has since been superseded by Section 3 Rule 1 in the Rule Book."[33]

One aspect of this incident was the relationship between the overlap of the signal passed at stop and the timetabled running of the following train.

At the time of the incident, two trains were timetabled to depart Glen Waverley (the terminal station) approximately 4 minutes apart. The track past the signal (DG660) is a downhill grade around a blind corner to Syndal Station. The overlap of the signal stretches more than 1 km up the hill beyond Syndal most of the way to the next station. The transit time for the overlap is 1 – 2 minutes.

Thus the second train was operating at close to signal headway interval. The train regularly encountered the signal DG660 at stop, the result of any timetable disruption and the long overlap. After tripping past the signal, the driver was accustomed to find the train ahead well gone on reaching Syndal.

This expectation on the part of the driver – that the signal was regularly at stop, but Syndal platform was clear when reached – clearly influenced his behaviour in the moments leading up to this incident. In this case, the provision of the very long overlap, in combination with all the other factors, may have been contributory to building the driver expectation that the line ahead was clear. The provision of the overlap did not act as a control protecting against the incident.

To control this effect, measures needed to be taken to ensure that signal DG660 was generally clear when reached by the following train. Measures available were either (a) shorten the overlap to that required (allows clear aspect earlier), or (b) increase the timetabled interval between trains.

In the event, the timetabled interval between trains was increased. The consequent effective loss of line capacity remains with us today and causes transfer of travellers to road travel.

4.2.3 Glenbrook: 08:22, 2 December 1999[34] [25]

The outcome of the two incidents above was influenced by the driver's beliefs about the signalling system. If he believed there were always two red signals between his train and any obstruction, he would feel safe to proceed at a higher speed up to the

[33] Holmesglen report, p 27.

[34] Special Commission of Inquiry Into the Glenbrook Rail Accident, Interim Report June 2000

second stop signal. If he believed overlaps to be long, he could proceed faster for the first part of the journey past the red signal.

If he knew for certain that the signal was failed, he assumed he could proceed safely at speed to the next signal.

The existence of such thinking in any rail network is a source of real danger. This is no better illustrated than at Glenbrook.

Glenbrook is on a winding stretch of outer suburban track in the Blue Mountains leading into Sydney.

On the morning of 2 December 1999, a power supply unit failure affected two track circuits. This caused two signals to revert to stop.

The India Pacific train approaching Sydney was the first train to encounter the first of the signals (signal 41.6) at stop. Its driver called Penrith signal box in accordance with safeworking unit 245 and obtained permission to proceed to the next signal (signal 40.8) at “extreme caution”. The train travelled at a maximum 18 km/hr and reached signal 40.8, also at stop, after 7 minutes and 45 seconds. The rules then required the driver to communicate again with the Penrith Signal Box (by post phone) to gain permission to proceed with “extreme caution” to the next signal.

The report includes the following diagram illustrating the situation and aspect sequence at that time.

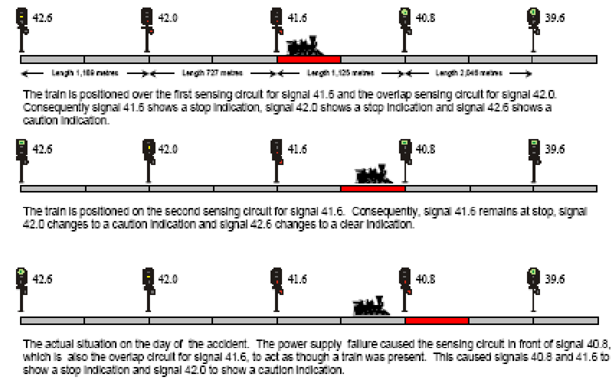

Figure 3

A following suburban train was catching up to the India Pacific at this time.

The signal maintainer informed the driver of the suburban train over the train radio that there was a track circuit failure in the section. Thus the driver was aware of the presence of a signal failure but not of a train.

As can be seen from the diagram, in spite of the provision of “fully braked” overlaps in this section of the CityRail network, the suburban train and the India Pacific were separated by a single red signal.

The driver of the suburban train contacted Penrith Signal box by radio at signal 41.6 in accordance with safeworking unit 245 and also obtained permission to proceed to the next signal (signal 40.8) at “extreme caution”.

The expectation on the part of the driver of the track ahead is clear from the radio transcript and subsequent comment[35]: [25]

“Mr Mulholland[36]:	*Yeah, 534?*
“Mr Sinnett[37]:	*Yeah, who have I got there, matey?*

35 Glenbrook interim report 1, p46.
36 Signaller at Penrith
37 Driver of suburban train

"Mr Mulholland:	*Penrith, mate.*
"Mr Sinnett:	*Yeah, it is 41, 41.6, I'm right to go past it, am I, mate?*
"Mr Mulholland:	*Yeah, mate, you certainly are. Listen, can you get back to us? What was the previous signal showing?*
"Mr Sinnett:	*Yellow.*
"Mr Mulholland:	*Yellow, okay, and what's that signal exactly showing, just red or…?*
"Mr Sinnett:	*Yeah, two reds, mate.*
"Mr Mulholland:	*Two reds, no worries. All right mate, can you just let us know what the signal in advance says when you get to it, thanks?*
"Mr Sinnett:	*Okay, matey.*
"Mr Mulholland:	*Okay, thanks*

"There are a number of significant aspects to that conversation. The fact that Mr Sinnett's mind was conditioned to believe that the line was clear is supported by his expectation that he could pass the signal at stop. He indicated that he was at signal 41.6 without reporting it at stop, as one would have expected him to have done. He assumed, correctly, that the signaller at Penrith knew it was at stop and furthermore it was indicated to him that it was a failure. The evidence that his mind was so conditioned was the way in which he sought authority to pass it with the words: "I'm right to go past it, am I, mate?"

"This expectation was confirmed by the immediate and definite reply "yeah mate, you certainly are"."

The suburban train then proceeded into the occupied section which was on a 1 in 60 downgrade. Expert evidence was that the train reached 50 km/hr before sighting the rear of the India Pacific at a distance of 135m. The collision occurred at approx 32 km/hr.[38] [25]

The collision resulted in 7 fatalities and a many seriously injured. The "fully braked" overlap provided at this location had no bearing on the outcome of the incident.

4.3 "Misjudgement" incidents

4.3.1 Murarrie: 19:31 hrs, 28 June 2004[39] [1]

Freight train Y245 had departed the Brisbane port of Fisherman Islands 18 minutes prior en route to North Queensland. It was planned to stop to allow a grain train to cross its path ahead.

This train was operating with a driver only.

The driver had passed a warning signal MR1 (Y aspect – single light indication) when he saw signal MR5 displaying stop (R aspect – single light indication) when about 200m away. The driver made a brake application and stopped 81.8m beyond the stop signal.

A SPAD alarm operated at Mayne Control centre. 20s following the alarm, an emergency call was made by the control centre to the freight train to stop.

[38] Glenbrook interim report 1, p.63.

[39] ATSB: Signal MR5 Passed at Danger, Freight Train Y245; Murarrie, Queensland 28 June 2004.

In the event, since the crossover was 580m beyond the signal, no collision occurred.

The inquiry found that the call itself was not effective as it occurred 20 seconds after the SPAD (controller was out of position and "boom failure" alarm had occurred moments before) and the 580m could be traversed in that time. The radio exchange with the driver took a further 22s.

This incident is an example of a driver misjudge.

The driver reported he had observed the yellow MR1 signal but was distracted by the radio handset falling to the floor followed by the need to slow the train to a curve speed.

MR5 is a signal rarely at stop (it was at proceed 94% of the time in the 3 months prior) and the driver reported he had never needed to stop at it previously. It was found that he had slowed from 70 km/hr to 50 km/hr after passing MR1 but subsequently "forgot" that MR5 could be at stop.

On observing MR5 at stop beyond the curve (260m sighting), he first applied the service brake but quickly concluded this would not be sufficient and applied emergency braking.

The driver involved had been involved in 5 prior SPAD incidents and was suffering from various medical conditions. He died in October the same year after suffering a heart attack.

QR has in place a "safe driving" program in mitigation of SPADs. This program involves the use of a driving technique taking the train in structured stages from the observing of the warning signal to stop just ahead of the stop signal. The inquiry found that if this technique had been used in this case, taking into account the distractions which occurred and the sighting distance of the stop signal available, the train would have stopped approx 50m before the signal.

The investigation made the following observations concerning the Human Factors aspects of the incident[40]: [1]

"*Various agencies have conducted research regarding causal factors that ultimately lead to a SPAD occurrence. Generally, this research has concluded that the driver at the approach of a warning signal will prepare the train for a stop at the next signal. Failure to do this is usually a conscious decision on the part of the driver.*

"*Such a decision can be termed a routine violation and is often made with a mental model that presents a picture of having scope to delay braking action because of the distance and/or grade to the stop signal, braking capabilities of the train, or the perception that the signal may be clear to proceed. As the train continues between the warning signal and the red signal, the driver is vulnerable to losing concentration and forgetting about the yellow signal just passed. The risk of forgetting increases with time*.

Studies show that short term (or working memory) is limited in capacity, decays rapidly and is affected by distractions or competing interests. As the red signal comes into sight or increasing prominence, the driver will often identify the mistake. At this point an attempt will be made to bring the train to a stop before the red signal, often successfully. However, when there is an inability to recover due to speed, signal sighting distance or late identification, a SPAD results."

40 Ibid, para 2.3.4, p.25

The provision of a longer overlap would not have influenced the outcome of this incident.

4.3.2 Gloucester: 07:50hrs, 11 March 2008[41] [5]

Freight train 2WB3 was approaching Gloucester (NSW) where a track worker had in place a TOA. At Gloucester, a distant and outer home signal protect the location. In this instance the outer home was held at stop.

The train was crewed by a driver and an observer.

Visibility at the time was reduced to 100m – 150m in places due to fog.

The run on approach to Gloucester was characterised as "normal". When the train passed the distant signal the driver applied the service brakes. This was increased to full service and then finally, with the train about 100m from the outer home, to emergency. In spite of these applications, the train overran the outer home signal by 140m.

The investigation found that the distance between the distant and the outer home (547m with line speed 70 km/hr) was insufficient to bring the train to a stand from line speed. Restricted visibility (at the distant) may have contributed, but recent SPADs had occurred previously at this signal in better weather[42].

This incident was a further example of a driver misjudge combined with insufficient signal spacing. The provision of a longer overlap would not have influenced the outcome of this incident.

[41] ATSB report
[42] For instance by 20m on 16 September 2007 in fine weather.

5 Human Factors Research

5.1 Human Factors studies

5.1.1 Human Factors Review

Between 1968 and 1974, a number of important studies were carried out by the International Union of Railways (U.I.C) and Swedish State Railways (SJ) to assess the Human Factors considerations relevant to railway signalling. This work was an early step in the process towards what has since become the European Train Control System (ETCS).

The studies addressed lineside signs and signals. They involved both review of earlier Human Factors work and extensive simulation specific to the railway environment. An important part of this work was published in book form in 1974[43]. [16] This section summarises some key findings from these studies and subsequent work relevant to this risk assessment.

5.1.2 Misjudgement or Disregard

The author considered that many events categorised as "disregards" are actually symptoms of inherent limitations in the human cognitive system[44]. [16]

"In spite of the great differences in luminance between the threshold stimulus and the light signals, the latter are sometimes detected late or not at all. Such cases are sometimes classified as "disregard of signals". Although disregard of signals cannot be wholly excluded it is not clear how the phenomenon can be verified. What can be observed is the overrunning of restrictive stop signals, but whether the cause is "disregard of" or failure to detect

[43] Mashour M. (1974): "Human Factors in Signalling Systems – Specific Applications to Railway Signalling"
[44] ibid p 162.

the signals remains to be determined by reliable method."

The author goes on to demonstrates the limitations of the human cognitive system (by simulation studies) and the inevitability of a level of "detection failure" unless signals possess certain characteristics. These characteristics involve simplicity of presentation and attention-grabbing nature demanding immediate, clear responses (eg "commence brake application now").

5.1.3 Signs vs warnings

The study went on to investigate why certain aspects (particularly red) are consistently responded to more quickly and more reliably than other warning aspects and wayside signs. A link was found between reliability of detection and

(1) urgency of message (immediacy of response needed and urgency perceived by driver);

(2) complexity of message provided (more complex message detected less reliably);

(3) impact of message (ability to stand out against background and other messages).

The study found that people assess warning signs in one of two ways[45]: [16]

<u>General search:</u>

This method is used to detect signs and familiar objects in the environment. The attention used in this detection must compete with other sensory inputs and other objects apart from signs in the environment. Subjects were found to be limited to detecting 3 – 5 objects per second by search. Tests showed that subjects missed detecting approx 1 in 6 objects presented in a simulated train run. This finding was independent of the familiarity of the driver with the route or knowledge of the position of the objects.

<u>"Interrupt" Detection:</u>

This method is used to detect signals of high importance requiring immediate attention. "*Where the signal possesses sufficient stimulative power and importance, the signal gains access to a central cognitive mechanism for bypassing the general search process".* Such signals are detected with high reliability[46]. [16]

The study found that the key signal in the signalling sequence to avoid SPAD was the warning signal (Y) at which the driver must commence action to slow the train.

These factors were also investigated by the report by the IRSE "Human Factors Working Group"[47]. This group found that driver response to signals depend in part on unconscious mental models built up around various locations and situations[48]. [16] An illustration of experience supporting particular model driven behaviours in the UK context is presented as follows:

<u>Diluting the message</u>

"*When looking at what factors lead to the driver developing false expectations, the results of a west coast mainline cab riding study are quoted. Thus revealed that 86.14% of signals were green, 8.13% were double yellow 3.14% were yellow and 2.32% were red*."[49] [13]

Based on these numbers, to the driver "double yellow" means: "*30% chance of*

[45] ibid pp 162 - 4

[46] ibid p 163.

[47] IRSE Signalling Philosophy Review, April 2001

[48] ibid, report of working group 2, sect 12.3.4

[49] IRSE (2001): *Report of Working Group 2: Human Factors* (p.13) [Railtrack data]:

having to stop in 2 signals". In human factors terms, this is similar to "*ignore*".

To the driver "yellow" means "75% chance of having to stop at next signal". In human factors terms this is better though still falls short of an imperative.

For our signal system, the difference between our intention and the human factors outcomes can be summarised in the following table:

Aspect	Intended meaning	Actual meaning ("4 aspect" accounting for human factors)
Y/G	Reduce speed to diverge at next signal (100%)	50% (perhaps) chance of needing to diverge at next signal (slow before points) or 30% chance of needing to stop in 2 signals (do nothing now)
Y/R or R/Y	Stop at next signal (100%)	75% chance of needing to stop at next signal (can I see the next signal?)
R	Stop at signal (100%)	Stop at signal

Where the aspect sequence changes to use approach operated yellows widely, the table potentially looks as follows:

Aspect	Intended meaning	Actual meaning (accounting for human factors)
Y/R or R/Y	Stop at next signal (100%)	1 in 5 chance of needing to stop at next signal (even if I can see the next signal)
R	Stop at signal (100%)	Wait to see if signal will clear up in front

The net effect, unintentionally, is the training of drivers that it is ok to "do nothing" at more than half the warning signals. In the worst case there is the expectation developed that not even the red signal is absolute. These are negative safety impacts.

The following recommendations are quoted from "*Human Factors: findings from Ladbroke Grove" by Dr Deborah Lucas, HSE, UK*":

HF5: Complex signal and track arrangements impose higher demands on drivers' route knowledge and attention. … Presenting information in a consistent and straightforward manner, avoiding anomalies, and avoiding other visual distractions at signals should be normal good practice for all signals. It should always be possible to identify a signal directly and uniquely. …"

HF7: The use of existing warning devices to warn of other situations must be considered very carefully (eg using AWS to warn of other non-signal situations such as speed restrictions) since this may reduce its effectiveness as a primary warning to the driver of the need to stop the train. …"

Taking account of these considerations, the recommendations which came out of the Ladbroke Inquiry[50] [9] included one for Railtrack to consider converting the existing four-aspect signalling to three-aspect signalling in the area to enhance safety.

<u>Improving Signal Impact</u>

Mashour (1974) [16] went on to consider what characteristics a signal should have to ensure optimum visual impact to the driver. On this it stated[51]:

"The driver generally knows where the signals are;

"But he is also occupied with other tasks such as scanning the track for unexpected dangers, as well as controlling the machine;

"Thus the signal is sometimes on the periphery of perception. The chance of the signal being missed is greater if the Engine Driver relies solely on "search";

"Therefore signals should possess sufficient stimulative effect so that they

[50] Report of Ladbroke Inquiry, recommendation 10 (ii)(i), p.128.
[51] Mashour (1974), p 166

impose themselves on the eye receptors for detection and thus obtain "priority processing" or attention."

The study finds that simplicity of sequence is key here. It is important that the warning signal requires a response and it is important that the driver is aware of it as he passes. It finds[52]: [16]

"Both the size and apparent brightness of a signal increase as the observation distance decreases, and so, consequently does the probability of detection …

"This significant factor – shortening of observation distance – should be employed as far as possible to promote safety. The most effective way of doing this is to install simple foresignals (SF)[53] at braking distance. Detection of SF signal at 50m or even less would not be too late or dangerous for safety, since the adjustment of speed should begin at SF signals, not before."

Fog, background light, etc can be controlled at these distances. At long distance these factors cannot be controlled and judging distance is difficult.

Put another way: what is important for a yellow signal is not that it is visible at 1000m, but that it is "in your face" and clearly understood at 50m. This is the principle behind AWS and other similar systems which work by generating an audible warning in the driver's cab as the SF signal is passed by the train.

The above principles can be found embodied in the Railtrack Group Standard on Signal Sighting[54]. [22] This standard makes provision for the "normal" height of the most restrictive aspect to be 3.35m above rail level (5.03m when gantry mounted) and centre of beam focussed to a point 3m above the left hand running rail at a distance 183m from the signal.

The IRSE Human Factors Working Group[55] [13] also sets an outer limit of 800m "*as being the point where the signal starts to provide valid information to a driver and thus becomes the target signal*". Outside that distance the signal is treated as background at uncertain distance and cannot compete effectively with other extraneous sources of light.

It should be acknowledged that ARTC practice differs from this Railtrack standard in a number of respects and there may be valid reasons for such differences[56].

In particular, it is argued that long distance viewing are required at any Distant Signal due to train management and train braking practicalities for long train operations. Some of the issues driving a desire for long sighting distances are discussed in section 5.2 below.

The view of Mashour (1974) [16] and the framers of the Railtrack Group Standard is that for long freight trains, the driver must expect that "seeing yellow means the train will have to stop". Making a partial brake application and hoping that the signal will clear in time is not practical in the context of

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52 ibid p 176

53 "simple foresignal" translates to a normal speed warning (Y/R) in Victoria or a distant signal (Y) in NSW.

54 GWRT0037, Issue 3

55 IRSE Report, Working Group 2, para 6.4, p.19

56 GWRT0037 states that "signals normally be positioned to give drivers an approach view for a minimum of 7 seconds and an uninterrupted view for at least 4 seconds". This compares with Australian practice which seeks to provide an uninterrupted view of 6 seconds or broken view of 10 seconds. Referring to the Railtrack standard, the report of the Ladbroke inquiry (section 11.7, p.179) stated that "good practice is to ensure that twice the minimum distance is available where this can reasonably be achieved". Australian practice better aligns with this view than the quoted Railtrack Group Standard. Note that Mashour (1974) found that the maximum detection time for any signal was 2 seconds.

practical stopping distances. Hence the focus in the Human Factors research is on giving the yellow signal high impact.

5.1.4 Combined Forewarning Signals (4 aspect signalling and/or approach operation)

The studies looked at the effectiveness of the signalling system in preventing overruns in relation to the complexity of the aspect sequences.

Mashour (1974) [16] found[57]:

"… there is almost nothing about C-indications[58] that, as regards safety, makes them superior to S-indications[59]. On the contrary they are either risky or superfluous depending on the type of signal – distance arrangement …

"And even if both indication types were equivalent with regard to signal-distance arrangements, S-indications would be preferable since, being easier as "meanings", they contribute less than C-indications to errors."

In the simulation studies, Mashour (1974) [16] confirmed that the more complex signals were missed or misinterpreted more often and took longer to recognise[60].

The studies also found that the driver's ability to recall the need for actions where the action was not immediate was reduced[61].

The study looked specifically at the comparison between 4-aspect (referred to as C-signals in the study) signal sequences and 3-aspect signal sequences (referred to as S-signals in the study) in the context where there is braking distance between each signal. It found[62]:

"*The use of C-Signals in railway signalling practice has been justified on the grounds that they develop expectancy (a warning) about the indication of the next signal ahead. But to my knowledge it has not been shown empirically to what extent C-signals do in fact develop this "expectancy". According to the present results, however, C-Signals constitute the potential source of most recognition errors; furthermore, their indications are often forgotten. These threats to safety could be avoided by replacing C-signals … with S-signals with proper spacings*."

It can be concluded from these studies that the introduction of 4-aspect signals or approach released intermediate signals (a variant of C-signals in the terms presented) are not effective additional controls for Passing Lanes. The studies suggest that safety would be reduced rather than enhanced by such measures.

5.1.5 Approach Operated Warning Signals

It has been suggested that an alternative approach to complex aspects is the successive approach operation of warning signals. Where this is done, the system builds the expectation in the driver that Stop signals generally are not required to be stopped at. The driver expects that the signals will "clear up" on approach and drives accordingly.

The result of this effect is a clear SPAD risk.

[57] Mashour (1974) p 50
[58] In the text "C-indication" means "Combined indication" corresponding in the Victorian case to the first warning signal in a 4-aspect sequence (Yellow over green) (or green over yellow in Metropolitan Sydney)
[59] In the text "S-indication" means "Simple indication". Relevant here is the "SF-indication. This is the "Simple forewarning signal – Distant or Yellow as referred to above.
[60] Ibid chapter 8.
[61] Ibid p 168 with empirical data chapter 14.
[62] Ibid p 314.

The following is just one Human Factors reference which discusses the impact of false warnings on operator response[63]: [11]

"*There are a number of Human Factors considerations which the system designer will need to consider. The first is that system reliability is paramount because credibility will be lost if a crew member has come to expect false warnings. This has been confirmed in findings of investigations into aircraft accidents and incidents. It has been estimated by ALPA that some 65% of the GPWS warnings before 1982 were unnecessary and greatly reduced the credibility of the system. Even when actuation of the caution is technically (though not operationally) justified, excessive appearance of an alerting signal will reduce the response to it and also create a nuisance*.

"*In other words, it should not appear in normal operation*.

"*The interpretation of multiple …[aural] warnings requires learning and it cannot be expected … that this learning will be retained adequately to ensure immediate response* … ."

The issue of approach clearing signals was also considered by the IRSE Human Factors Working group[64]. [13] It looked at issues of expectation and anticipation at such signals:

"… *Mental models reduce the mental workload and allow the driver to drive to their upper limits by being able to anticipate certain events or circumstances. However, two types of error may result from over-reliance on mental models. A driver approaching a red signal may anticipate the signal clearing on the basis of past experience and fail to stop appropriately. Alternatively the driver may look at the signal but actually believe the aspect is showing something different: a model-induced illusion.*

"The OPC research … gives two examples of problems created by mental models and anticipation:

"A) Approach [operated] signals usually step up to green on the approach of the train and as a result drivers have a tendency to approach the signal at a speed more aligned with the intention to move forward rather than stop.

"B) Flashing yellows at route junctions are commonly interpreted as a sign to "keep the train moving", and this, combined with the expectation that the signal at the end of the sequence will clear increases driver expectation and so increases likelihood of a SPAD.

"Both types of error (anticipation and driver-induced illusion) occur because using these mental models, and driving in autopilot as it were, means attention levels are limited. Changes in the environment, for example a signal change, require active attention. Drivers are known to get stuck in autopilot and cannot shift mental gears from automatic, unconscious processing to active attention.

"The disadvantage is that such mental models are difficult to override so that information, which should suggest that the normal set of conditions do not apply, is ignored … .

[63] Hawkins (1993): "Human Factors in Flight", 2nd edition, p.256.
[64] IRSE (2001) Report, section 12.3.4, pp 63-4

The report [13] goes on to observe[65] that such signal sequences "… *build particular expectations of certain sequences of timing and events at particular localities and drivers anticipate such events based on previous experiences. Thus when approaching a particular junction past a yellow signal, if 9 times out of 10 the junction signal clears for his route of approach, he will anticipate it doing so on the tenth.*

"The risk is greatest when it doesn't."

The use of 4 aspect signalling unnecessarily is rated in Network Rail guidelines as a "minor" risk factor. The literature suggests that use of Systematic Approach Clearing of aspect sequences is at a higher level of risk.

5.2 Stopping on sight

The Human Factors research supports the concept of keeping the signalling as simple as possible. The simplest form of signalling is 2- aspect (Red and Green) as is used, for instance, on the London underground.

This can be an effective approach in some circumstances which depends largely on the braking characteristics of the train in question. The risk of attempting to apply this approach (eg by providing 2km sighting distances to red signals) in the context of Passing Lanes is discussed in this section.

The Victorian rule book allows that for line speeds up to 80km/hr, 2-position signalling may be put in place without the need for distant signals. The basis for this is that, for such areas, provided that the stop signal is sighted from a distance of 400m, a loco-hauled passenger train can be expected to be able to stop on sight of that signal.

For much of the Melbourne Metro area, where line speeds are 80km/hr or less, and sighting of 400m is typically available, "stop on sight" capacity becomes a viable backup of last resort where warning aspect signals have not been observed.

The sighting distance needed for "stop on sight" varied according to the line speed and the braking characteristics of the train. Modern EMUs and DMUs have better braking than loco-hauled passenger trains. GW40 represents a significantly lower braking rate than any passenger train.

For passenger trains, a rough guide to "stop on sight" distances needed for various line speeds and braking rates is given in the following table:

Table 2: Braking distance to stop from various line speeds with various braking rates

Braking Rate ->	**0.6 m/s/s**	**0.7 m/s/s**	**0.9 m/s/s**	**1.0 m/s/s**	**1.2 m/s/s**
Line Speed					
LS- 80 km/hr	410m	350m	270m	250m	210m
LS - 100 km/hr	640m	550m	430m	390m	320m
LS - 115 km/hr	850m	730m	570m	510m	430m
LS - 130 km/hr	1090m	930m	720m	650m	540m
LS - 160 km/hr	1650m	1410m	1100m	990m	820m

Within this range, VLP loco hauled brakes at 0.6m/s/s, EMU and Sprinters brake at 0.8 m/s/s, XPT brakes at 0.9 m/s/s, Vlocity brakes at 1.1 m/s/s Freight trains (GW40) generally brake at approx 0.23 m/s/s[66].

Taking account of the typical sighting distance for Passing Lanes together with the 300m overlap allowance, a passenger train having not responded to the warning signal (disregard) generally stops within the

[65] IRSE (2001) Report: p. 34

[66] Various sources including VRIOG 012.0.1 – 2008 and GW braking curves.

overlap after responding to the red signal alone.

While supervision systems which respond to the train approaching a red signal too fast are available, their application to passenger trains only is little more effective than relying on the "stop on sight" allowance discussed above. A more cost effective strategy is to ensure that the driver is unable to pass the yellow signal without being aware of it. This approach has the added advantage that it is applicable to all classes of train.

5.3 Point Trapping

Point trapping or flank protection is a control measure against SPAD events which relies on the use of points and/or derails to separate authorised train movements from unauthorised train movements. This form of protection is utilised today in Victorian CTC passing loops and planned Victorian Passing lanes as a control against approximately half the collision opportunities found in those layouts. A brief description with diagram is found in section 3.1.3 above.

The concept of point trapping/ flank protection is illustrated in the following diagram:

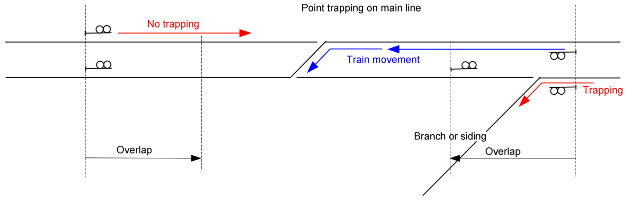

Figure 4

In this diagram, the authorised train movement (in blue) is protected against some unauthorised train movements by setting points towards a branch line or siding and away from the potential collision point with the authorised train movement. The conditions under which trapping is set varies between rail administrations. In the example shown, the point of collision is taken to be beyond the end of the overlap of the conflicting train movement. It should be noted that not all potential conflicts are necessarily removed by implementation of trapping principles (in the diagram above, unauthorised train movements from the left are not trapped)

This type of flank protection is found in:

- Victorian CTC Crossing Loops and Passing Lanes
- Connex Overlap Protection Guidelines (guidelines for additional protection introduced to high risk locations on "risks" basis following the incidents at Epping and Footscray).

As part of the Ladbroke inquiry in Britain, there was discussion as to whether provision of additional flank protection could have prevented the collision.

It was stated[67]: [9]

"*Railway Standard SSP 49, which appeared in its first version in June 1988, provided for this as follows:*

" ' Set and lock points in the converging route in a position to divert an unauthorised movement away from the legitimate route where this can be achieved without restricting other permissible movements'.

"The standard stated that this should be used "only where the application is both simple and effective. Each case must be decided on its merits". This last sentence was deleted in the revised version of the

[67] Ladbroke Inquiry: para 7.19, p. 107

standard which was issued in November 1990".

Concerning the particular design, it was stated[68]: [9]

"*Mr Harman told the Inquiry that flank protection should have been considered by engineers at the development stage of the layout. It could have been provided "relatively simply" but "at some operational disbenefit". All that he could say was that at the time the designers thought flank protection pursuant to SSP 49 was "not necessary" or "inappropriate". It appears that when he took up his post in May 1992 he did not see reason to investigate this*."

The recommendations from the inquiry (recommendation 10 (ii)(ii)) included one that additional flank protection be considered for the location.

Flank protection / point trapping is more widely practiced in some other rail jurisdictions than in Victoria. In the example provided above, the additional protection can be provided by adding a "runoff track" or derail as shown in the following diagram:

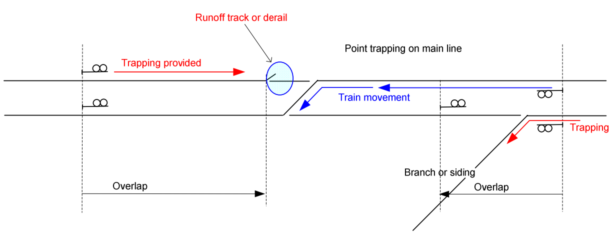

Figure 5

Such a control measure was proposed in the risk assessment under this item 24-C.

Concerning the proposal, the following comments can be made:

- The Ladbroke inquiry found that provision of such flank protection was an effective control measure against signal disregards.
- The control measure as proposed introduces a new derailment risk which would need to be balanced against the risk of collision it avoids.
- Runoff tracks providing similar protection have been installed at some locations in Victoria (eg at Ringwood).
- Due to the cost and (potential) operational dis-benefit of additional flank protection, it is utilised at "high risk" locations only in the Melbourne Metropolitan area. Additional runoff points as shown above have not to date been considered for installation as part of the program addressing the high risk locations.
- Main line runoff tracks and derails are standard features of the ARTC network at "high risk" locations outside Victoria. There is one included in the proposed scheme for the Wodonga bypass.

In the context of this risk assessment, provision of additional trap points is considered more effective than either providing a longer overlap or providing an alternate aspect sequence. It is not considered to be as effective as provision of an advanced protection system such as ATMS.

6 Quantified collision scenarios – the underlying Passing Lanes risk

In this section the risk associated with infrastructure of the type used for ARTC Passing Lanes (Victorian signal aspects)

[68] Ibid, section 7.21

with proposed design is quantified. Train overrun signal at end of “loop line”

This scenario is illustrated in the following diagram:

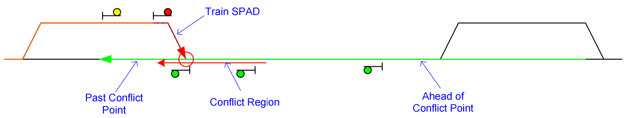

Figure 6

According to this scenario, the SPAD-ing train first enters the Passing Lane across the 80km/hr points in the reverse position. It will pass the approach signal at “Y/R(80)”, then the signal at the points at “R/G(80)”. If the train “disregards” these signals, the lateral forces associated with travelling over-speed over the points reverse should provide a distinct jolt to any fatigued train crew. This jolt is not expected to be sufficient to derail the train.

Operationally, the first train to arrive at the Passing Lane will be directed to the “loop line” (estimated more than 90% of cases based on experience with NSW Passing Lanes). The train crew will thus expect that there will be a need to stop at the signal at the other end of the Passing Lane.

With the signal at the far end of the Passing Lane held at stop, the train will first pass a “Y/R” warning signal approximately 3.5 km after passing over the points reverse before reaching the “R/R” stop signal at the far end of the Passing Lane.

Thus, prior to stopping at the stop signal, the train will have passed 3 signals showing restrictive aspects and passed over a set of points reverse.

Provided the driver is aware, these warnings will be reinforced by the operational expectation that the train will is scheduled to cross, and that it will be required to wait at the far end of the crossing train.

Due to the above circumstances, a “disregard” SPAD at the far end of the Passing Lane is considered less likely than the average generic rate at this location.

<u>Position of conflicting train</u>

Should a “disregard” SPAD occur, the conflicting train can be in one of three general locations relative to the SPAD. These are as follows:

<u>Location 1(a): Approaching the Passing Lane at distance</u>

The location of the conflicting train in this case is generally in the Single Line between Passing Lanes as far back as the next Passing Lane.

When the SPAD train passes the signal at stop, the Single Line Vital Circuits will restore all signals on the single line and the departure signals from the adjacent Passing Lane to stop. Thus, the conflicting train will see the next signal approach at stop (no “Y” approach warning signal). The driver of the conflicting train will apply brakes from that point. Provided this train has not yet passed the “distant” signal approaching the Passing Lane, applying the brakes provides the possibility of avoiding the collision or reducing its severity substantially.

Based on the relative locations of Passing Lanes, the probability of this scenario given the initial “disregard” SPAD is expected to exceed 0.8.

<u>Location 1(b): Entering the Passing Lane in Conflict on Main Line</u>

For this conflict to occur, the conflicting train must be inside the “distant” signal at the time of the SPAD but not yet passed the points at the entry to the Passing Lane. The opportunity for collision will also depend on the speed and length of the conflicting train. It will be less for a passenger train (being shorter and faster) than for a freight train (being longer and slower).

The probability of the train being in this position as the SPAD occurs is put at approximately 0.1.

<u>Location 1(c): Already entering the Passing Lane and clear of the conflict point.</u>

This situation covers the remainder of situations. In this case, the conflicting train will be already passed the conflict point and no collision will occur.

The probability of the train being in this position as the SPAD occurs is put at approximately 0.1.

A special case of this scenario is where Train Control has planned that a simultaneous entry occurs following simultaneous entry from each end of the Passing Lane. This situation is currently not common and estimated to occur for 1-2% of all crosses (based on experience of NSW Passing Lanes currently in service).

At this level of occurrence, train drivers will remain aware of the probability of the need to attempt simultaneous entry on a regular basis, even though this mode is not the most common.

Probability of collision

Assessing this scenario as a special case, the expected rate of collision is 6.80×10^{-8} per hour.

6.1 Train overrun signal at end of "main line"

This scenario is illustrated in the following diagram:

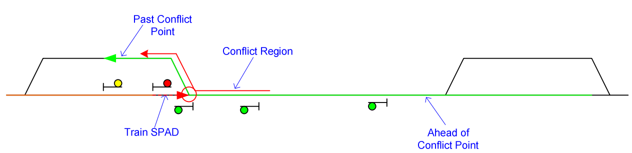

Figure 7

According to this scenario, the SPAD-ing train first enters the Passing Lane across the 80km/hr points in the normal position. It will pass the approach signal at "G/R", then the signal at the points at "G/R".

Operationally, the first train to arrive at the Passing Lane will be directed to the "loop line" (estimated more than 90% of cases based on experience with NSW Passing Lanes). In only 10% of cases, the train crew entering the Passing Lane on the straight will need to stop at the signal at the other end of the Passing Lane.

With the signal at the far end of the Passing Lane held at stop, the train will first pass a "Y/R" warning signal approximately 3.5 km after entering the Passing Lane and before reaching the "R/R" stop signal at the far end of the Passing Lane.

In this case, the train will pass 1 signal showing a restrictive aspect prior to the "stop" signal. In this respect, the situation is the same as for a train on "plain track" which is estimated to encounter approximately 5% of headway signals at stop protecting the train ahead.

The driver will be aware of the need to stop at the end of the Passing Lane after entering on the Main Line at about twice the rate of the average signal. This expectation will be reinforced by the practice of attempting simultaneous entry movements on a regular basis (1-2% of train movements).

Due to the above circumstances, a "disregard" SPAD at the far end of the Passing Lane is considered about the same as the average generic rate at this location.

Position of conflicting train

Should a "disregard" SPAD occur, the conflicting train can be in one of three general locations relative to the SPAD. These are as follows:

Location 2(a): Approaching the Passing Lane at distance

The location of the conflicting train in this case is generally in the Single Line between Passing Lanes as far back as the next Passing Lane.

When the SPAD train passes the signal at stop, the Single Line Vital Circuits will restore all signals on the single line and the departure signals from the adjacent Passing Lane to stop. Thus, the conflicting train will see the next signal approach at stop (no "Y" approach warning signal). The driver of the conflicting train will apply brakes from that point. Provided this train has not yet passed the "distant" signal approaching the Passing Lane, applying the brakes provides the possibility of avoiding the collision or reducing its severity substantially.

Based on the relative locations of Passing Lanes, the probability of this scenario given the initial "disregard" SPAD is expected to be about 0.3.

Location 2(b): Entering the Passing Lane in Conflict on Main Line

For this conflict to occur, the conflicting train must be inside the "distant" signal at the time of the SPAD but not yet passed the points at the entry to the Passing Lane.

The opportunity for collision will also depend on the speed and length of the conflicting train. It will be less for a passenger train (being shorter and faster) than for a freight train (being longer and slower).

The probability of the train being in this position as the SPAD occurs is put at approximately 0.3.

<u>Location 2(c): Already entering the Passing Lane and clear of the conflict point.</u>

This situation covers the remainder of situations. In this case, the conflicting train will be already passed the conflict point and no collision will occur.

The probability of the train being in this position as the SPAD occurs is put at approximately 0.4.

A special case of this scenario is where Train Control has planned that a simultaneous entry occurs at the Passing Lane. This situation is currently not common and estimated to occur for 1-2% of all crosses (based on experience of NSW Passing Lanes currently in service).

At this level of occurrence, train drivers will remain aware of the probability of the need to attempt simultaneous entry on a regular basis, even though this mode is not the most common.

<u>Probability of collision</u>

Assessing this scenario as a special case, the expected rate of collision is 2.27×10^{-8} per hour.

6.2 Train overrun signal for "head to tail" collision

This scenario is illustrated in the following diagram:

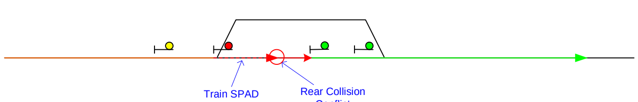

Figure 8

According to this scenario, the SPAD-ing train enters the Passing Lane following a train which has already entered and is protected by the signal at the entry to the Passing Lane.

Operationally, the first train may be in either the "main" or the "loop" line. The more likely situation will be for it to be on the "main" line.

With the signal at the near end of the Passing Lane held at stop, the train will first pass a "Y/R" warning signal approximately 2.5 km ahead the "R/R" stop signal.

Thus, prior to stopping at the stop signal, the train will have passed 1 signal showing restrictive aspects. In this respect, the situation is the same as for a train on "plain track" which is estimated to encounter approximately 5% of headway signals at stop protecting the train ahead.

The probability of this situation in a Passing Lane is expected to be comparable to the same situation on plain track. Guaranteed overlap will be 400m, though in practice the train ahead will usually be further ahead.

<u>Probability of collision</u>

Assessing this scenario as a special case, the expected rate of collision is 6.15×10^{-9} per hour.

7 Quantified risk analysis

There are a number of distinct risk scenarios which can result in collisions in the context of Crossing Loop and Passing Lane infrastructure.

The risk levels associated with these risk scenarios are discussed in the following subsections.

7.1 Overlaps and flank conditions

7.1.1 Base information

The following information formed the basis of the analyses[69]:

<u>Traffic Levels</u>

Traffic levels proposed for the corridor are 20 trains per day (10 in each direction)[70].

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[69] In providing base parameter estimates for the analysis, the data has generally justified a range of estimates. The figure used for the analysis has in each case been the "high risk" edge of the range. As a result, the estimates presented tend (intentionally) to overstate the risk rather than present an unbiassed estimate.

[70] Ref: ARTC report (unpublished)

At each crossing place (crossing loop or passing lane), an average 1.6 crosses will occur per day[71].

A “3 train cross” (2 fleeted trains waiting for a counter-direction train to arrive at the loop before proceeding) occurs on the network on average once in 1 month. This translates to one event per year per crossing place[72].

Transit times are also relevant for the discussion. With the infrastructure in place, a train will pass through an average 3 crossing places per hour (participating in up to one cross per hour).

<u>Generic fault information</u>

Studies show that on average a driver will experience a SPAD once in each 7600 signals approached at stop.

The majority of these SPAD events involve overruns of less than 100m. 2 - 6% of SPADs involve distances greater than 200m. In the AVA submissions it was assumed that 6% of SPADs involve overruns greater than 300m.

Trains are sometimes stopped due to breakdown. In this discussion, it is assumed that a train will be stopped due to breakdown on average once in 10,000 hrs.

<u>Consequence data</u>

In the calculations it is assumed that 2 fatalities occur in the average accident. This is higher than the average rate determined in empirical British studies[73]. [10]

<u>Note regarding data bias</u>

The data used in the calculations is based on estimates expressed over a range of values. In the analyses presented in AVA submissions it has been consistent practice to present the edge of the range expressing the highest risk.

This results in an intentional bias towards high expressed risk levels. Compared to an unbiased estimate (acceptance of centre of range), these expressed risk levels are 1 – 3 orders of magnitude (depending on specific scenario) higher. Thus the risk levels quoted in this section are expected to be conservative.

7.1.2 Opposing movements

<u>SPAD at Starter Signal (300m overlap)</u>

This scenario involves risk of a collision with a crossing train entering the passing lane (this risk scenario is not applicable for crossing loops).

The control proposed was a 300m minimum overlap.

It was found that, per passing lane, this risk could result in a fatality between once in 390 years and once in 1180 years.

<u>Crossing loop – Three train cross</u>

The risk during such a cross was regarded as the highest potential risk for crossing loop configuration. In particular, the reliance on an overlap of 100-150m in infrequent circumstances required analysis.

The control in place is a 100-150m minimum overlap together with the flank protection which is in place for normal train crossing scenarios, but not the “three train cross” scenario.

Detailed analysis shows that, per crossing loop, a collision could be expected on average once in 63,000 years.

[71] Ref: ARTC report (unpublished)
[72] Ref: ARTC report (unpublished)
[73] Ref: Evans A W (2004): Rail safety and rail privatisation in Britain (draft); Centre for Transport Studies, Imperial College London

Crossing loop – Trains held at Home Arrival signals (separated by 2km[74])

This risk involves both trains signalled up to Home signals SPAD and simultaneously overrun by more than 300m (the base overlap).

The control in place is the approx. 2000m separation provided by the length of the crossing loop.

Based on the traffic patterns (assuming no flank protection in place) for the line a collision per crossing loop due to this risk can be expected on average once in 24,000,000 years.

7.1.3 Follow-on movements

Collision risk associated with follow-on moves was provided for two main scenarios as follows:

SPAD at home arrival (train ahead held at mid-lane)

This risk involves the SPAD of a train at the entry signal to a Passing Lane. The train ahead is standing at the mid-lane signal and a collision may occur.

The control in place is a 300m minimum overlap.

Detailed analysis shows that, per passing lane, the average rate of collision is once in 27,000 years.

SPAD at starter signal colliding with train ahead

This risk involves the SPAD of a train at the starter signal departing from the lane. The train ahead is stopped (typically due to an event such as a breakdown) just ahead and a collision occurs.

The control in place is a 300m minimum overlap.

Detailed analysis shows an average rate of collision is once in 1,400,000 years.

7.1.4 Summary of collision outcomes

The following table summarises the risk findings from the scenarios presented in the above sections:

Risk scenario	Mean time between collisions
SPAD at starter – collision with opposing train (300m overlap)	780 – 2300 years
SPAD at starter – collision with train ahead (300m following overlap)	1,400,000 years
SPAD at home arrival – collision with train ahead (300m following overlap)	27,000 years
SPAD at home signal – three train cross scenario	63,000 years
SPADs at home signals (simultaneous) – 2km separation	24,000,000 years

In the following sections, the SPAD risks shown as accepted in the above table will be regarded as acceptable for design purposes.

7.1.5 Relationship with tolerable risk

The above sections address the issue of average fatality rate for each collision type for trains using the infrastructure.

[74] Note that for the purposes of this calculation, it is assumed that a train, having passed 300m beyond the stop signal, will stop within 2000m. As discussed earlier in this paper, this assumption is weak.

When assessing "tolerable risk" the relevant question is the risk of fatality to an individual travelling on the train. To the analysis already carried out, the following must be incorporated:

- Passenger loading for average train

  This varies between operators. For this analysis a figure of 100 will be used

- Average fatalities per collision

  For the British context, Andrew Evans[75] has analysed all accident data between 1967 and 2002/3 and concluded that an average 4.0 fatalities occurred in that period per fatal accident involving collision, derailment or overrun. He notes that non-fatal accidents are 2 orders of magnitude more frequent than fatal accidents. This would imply 0.04 fatalities per accident as a non biassed estimate.

  For the purposes of this paper, the average number of fatalities per collision will be assumed to be 2.

With this additional information, and accepting the conservatism of the risk components used, the individual risk of fatality to the exposed individual can be estimated at between $8x10^{-6}$ and $2x10^{-5}$ per year.

This compares with a tolerable risk level of $1x10^{-4}$ per year for a passenger and $1x10^{-3}$ per year for an employee.

Again in the British context, RSSB[76] has calculated current actual risk for passengers at $5x10^{-6}$ per year and train drivers at $6x10^{-5}$ per year. Their analysis is based on actual records of accidents and fatalities.

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Abbreviations

ALPA: Airline Pilots Association

ARTC: Australian Railtrack Corporation

ATMS: Advanced Train Management System

ATP: Automatic Train Protection

ATSB: Australian Transport Safety Bureau

AVA: Application to Vary Accreditation

AWS: Automatic Warning System

CTC: Centralised Traffic Control

DIRN: Defined Interstate Rail Network

DOI: Department of Infrastructure

ETCS: European Train Control System

GPWS: Ground Proximity Warning System

HSE: Health and Safety Executive

IRSE: Institution of Railway Signal Engineers

NSW: New South Wales

OPC: Occupational Psychology Centre

PTC: Public Transport Corporation

QR: Queensland Rail

RIFOT: Restored in Front of Train

[75] Evans A W (2004): Rail safety and rail privatisation in Britain (draft); Centre for Transport Studies, Imperial College London
[76] RSSB (2006): Overview of the Risk Profile Bulletin, issue 5

RFR: Regional Fast Rail project

RSSB: Rail Safety and Standards Board

SA: South Australia

SKM: Sinclair Knight Mertz

SPAD: Signal Passed at Danger

TOA: Track Occupancy Authority

TPWS: Train Protection and Warning System

VLP: Vline Passenger

VRIOG: Victorian Rail Inndustry Operators Group Standard

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[3] ATSB: Derailment of train 5MB7, Benalla, Victoria 2 June 2006.

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[5] ATSB: Signal passed at danger, Gloucester, NSW 11 March 2008.

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[21] Rail Safety and Standards Board. GE/GN8537 Guidance on signal positioning and visibility, 2003;

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[23] RSSB: Overview of the Risk Profile Bulletin, issue 5; 2006

[24] SKM: Victorian Signalling Principles Review; 2002

[25] Special Commission of Inquiry Into the Glenbrook Rail Accident, Interim Report June 2000

[26] Vic DOI Office of the Director of Public Transport, Safety and Technical Services Branch; Final Report, Investigation into the Collision between Connex Passenger Trains at Holmesglen Station on Wednesday 26 July 2000

[27] Victorian Rail Industry Group Standards. VRIOGS 012.0.1 – 2007 Standard for signalling design and documentation. Melbourne: Director of Public Transport, 2007.

Figures from text

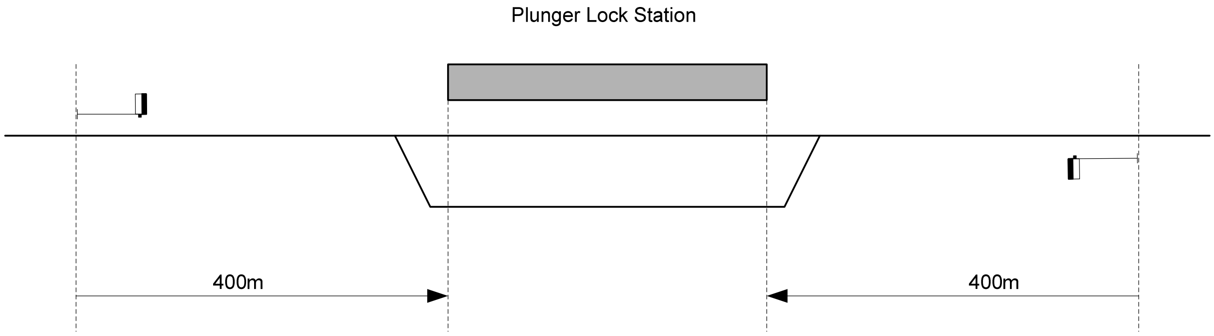

Figure 1 (page 5)

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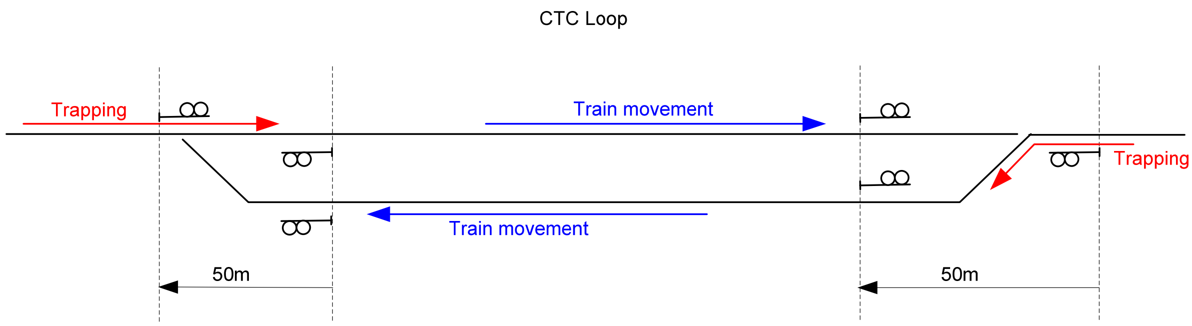

Figure 2 (page 5)

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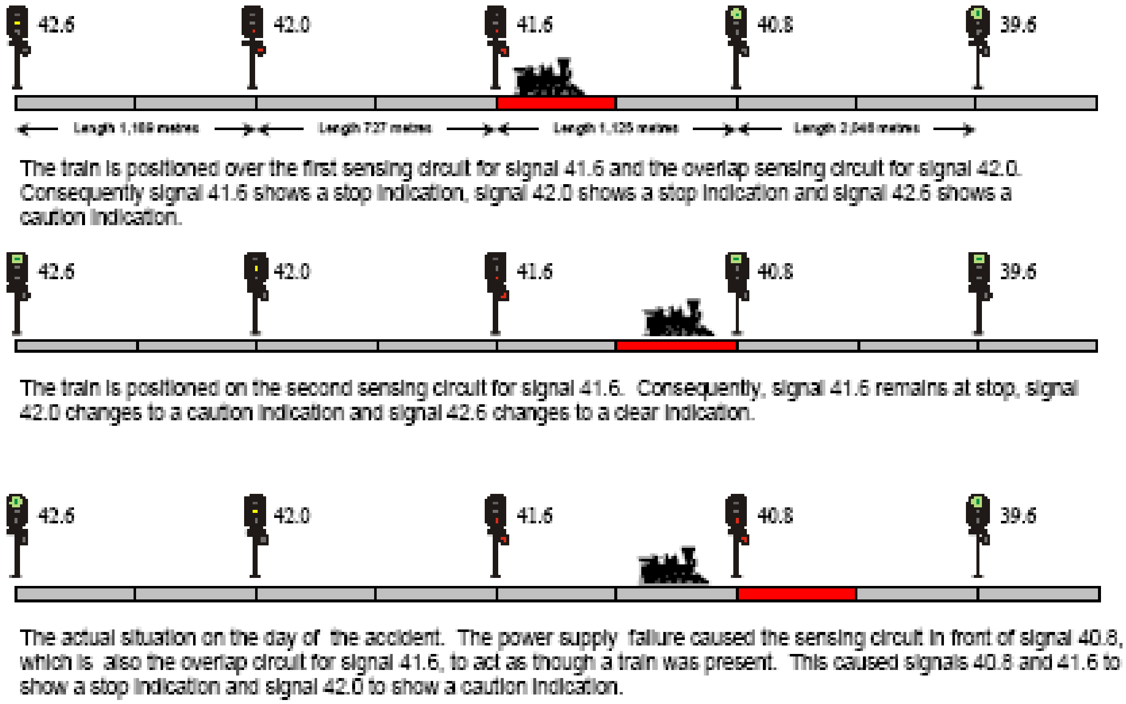

Figure 3 (page 16)

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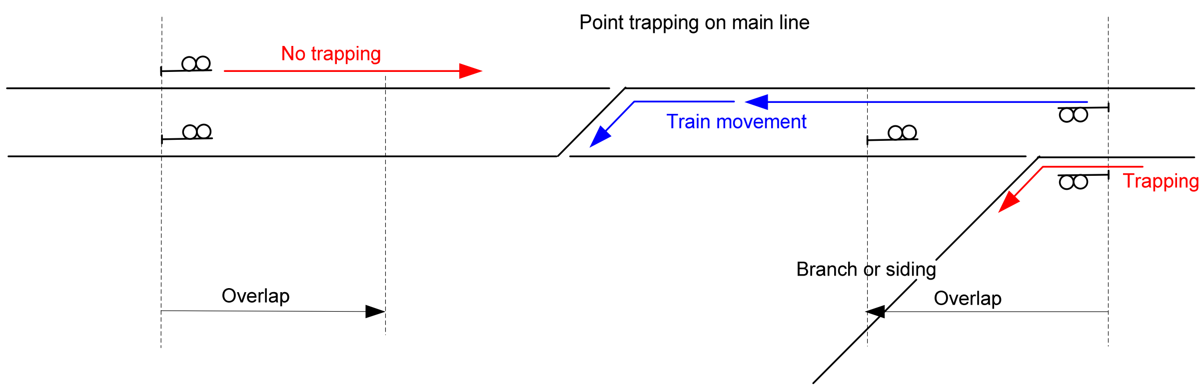

Figure 4 (page 26)

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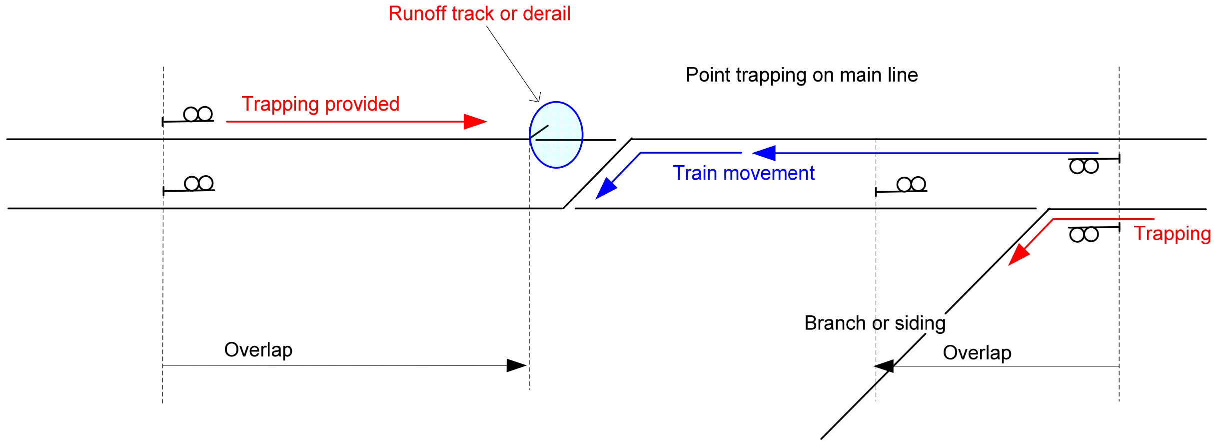

Figure 5 (page 27)

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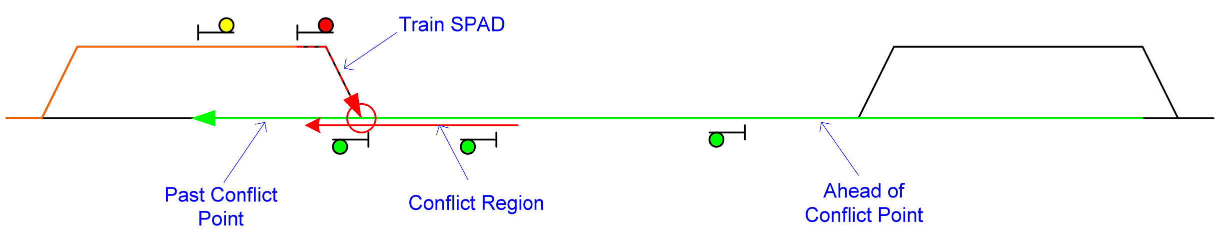

Figure 6 (page 28)

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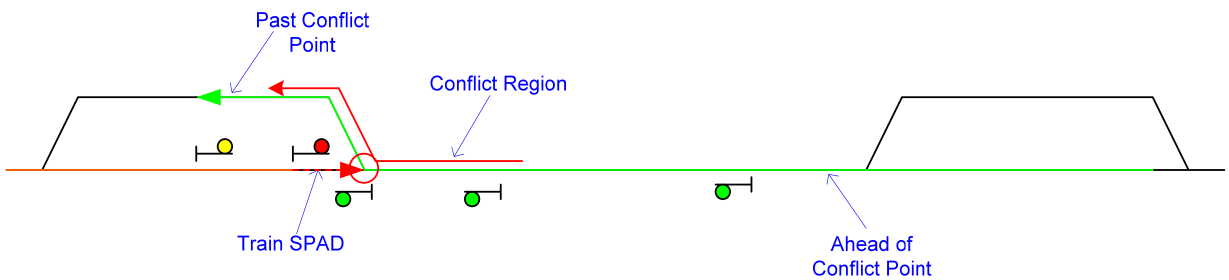

Figure 7 (page 29)

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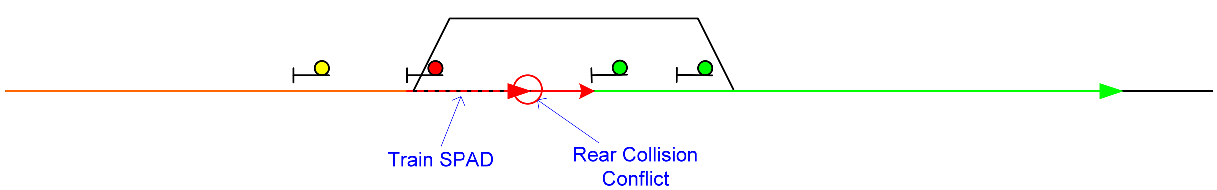

Figure 8 (page 30)

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