

Independent Transport Safety and Reliability Regulator (ITSRR)

International Search & Review
of Engineering Safety Devices

March 2006

Halcrow

Independent Transport Safety and Reliability Regulator (ITSRR)

International Search & Review
of Engineering Safety Devices

March 2006

Halcrow

Halcrow
Level 22, 68 Pitt Street Sydney, NSW 2000
PO Box R1573 Royal Exchange NSW 1225
Tel +61 2 9250 9900 Fax +61 2 9241 2228
Email: sydney@halcrow.com.au

Halcrow Pacific Pty Ltd has prepared this report in accordance with the instructions of their client, Independent Transport Safety and Reliability Regulator (ITSRR), for their sole and specific use. Any other persons who use any information contained herein do so at their own risk.

© Halcrow Pacific Pty 2006

Halcrow

Level 22, 68 Pitt Street Sydney, NSW 2000
PO Box R1573 Royal Exchange NSW 1225
Tel +61 2 9250 9900 Fax +61 2 9241 2228
Email: sydney@halcrow.com.au

www.halcrow.com

Independent Transport Safety and Reliability Regulator (ITSRR)

International Search & Review of Engineering Safety Devices Utilised On Rail Systems

Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Prepared by	Checked by	Authorised by
1	A	Draft	24/11/2005	AP	KM	GJD
1	B	Draft	1/12/2005	AP	SB	PH
1	C	Draft	21/12/2005	AP	PH	GH
2	0	Draft	01/03/2006	KM	KM	CA
3	0	Draft	06/03/2006	KM	CA	
4	1	Final draft	23/03/2006	KM	CA	
Final	Issued	Issued version	28/03/2006	KM	CA	CA

Contents

1	Executive Summary	3
1.1	<i>Scope of study</i>	3
1.2	<i>Methodology</i>	3
1.3	<i>Engineering devices</i>	3
1.4	<i>Results and comparison</i>	4
1.5	<i>Conclusions</i>	5
2	Scope of Project	6
3	Methodology & Research	7
4	Train Safety Systems	8
4.1	<i>Deadman's systems</i>	8
4.2	<i>Vigilance Systems</i>	10
4.3	<i>Combined Deadman's and Vigilance systems</i>	12
4.4	<i>Additional methods to enhance safety</i>	12
4.5	<i>Train Protection Systems</i>	13
4.6	<i>Multiple driver operation</i>	15
4.7	<i>Management control measures</i>	16
4.8	<i>Defective Equipment - Degraded Modes of Operation</i>	18
5	Findings of Review	20
5.1	<i>Passenger trains</i>	20
5.2	<i>Freight trains</i>	24
5.3	<i>Heritage Vehicles</i>	26
5.4	<i>Infrastructure maintenance vehicles</i>	27
6	New Concepts for Driver Safety Devices	28
6.1	<i>Ocular Measurement Monitors</i>	28
6.2	<i>Brain Activity Monitors</i>	30
6.3	<i>Head Nodding Monitors</i>	31
6.4	<i>Vehicle Control Behaviour</i>	32
6.5	<i>Aids to Driver Alertness</i>	32
7	Deadman's Systems Issues	33
7.1	<i>Deadman's Systems – advantages</i>	33
7.2	<i>Deadman System's - disadvantages</i>	33
7.3	<i>Comparison – 4D/Tangara and the Victorian Footplates</i>	34
8	Vigilance System – Issues	35
8.1	<i>Vigilance Systems – Advantages</i>	35
8.2	<i>Vigilance Systems – Disadvantages</i>	35
8.3	<i>Task-linked systems</i>	36
8.4	<i>Other issues with Drivers Safety Devices</i>	37
8.5	<i>Comparison of Deadman's to Vigilance systems</i>	38
8.6	<i>Conclusion</i>	39

9	Glossary	40
10	References	41
11	Appendix A	42
	<i>11.1 Review of Relevant Accidents</i>	<i>42</i>
12	Appendix B	46
	<i>12.1 GO/RT3251 Train Driving, Appendix A, Medical Standards</i>	<i>46</i>

1 Executive Summary

1.1 *Scope of study*

Halcrow was engaged by the Independent Transport Safety and Reliability Regulator (ITSRR) to undertake an international review of current practices with the purpose of providing a report that identifies and establishes the type of driver safety devices currently utilised on a number of rail systems around the world.

1.2 *Methodology*

In order to identify the variety of safety devices available within the global railway industry two main approaches were used:

- Interviews / surveys with representatives of rail organisations
- Literature search / review

1.3 *Engineering devices*

The primary objective of the engineering devices is to mitigate the risks arising from incapacitation. The review has identified two core systems – vigilance and deadman's, which are widely utilised across the operators surveyed.

1.3.1 *Vigilance system*

A vigilance system seeks to establish that the driver is both present and conscious by requiring an acknowledgment of a warning. This warning can be either;

Visual (warning light), or **Audible** (bell or horn sounding in the driving cab), or a combination of both.

1.3.2 *Deadman's system*

In a similar way to the vigilance systems, a deadman's system seeks to establish that the driver is present. A deadman's system is generally configured as a foot pedal or a handle. The system requires a continuous input from the driver through an application of force to the handle or pedal.

1.4 *Results and comparison*

1.4.1 *Passenger and freight*

The international review identified the engineering safety devices utilised by twelve (12) railway operations across nine (9) countries

1.4.2 *NSW comparison – passenger*

It was found that on-board safety systems employed on multiple-unit trains in NSW combine the use of a deadman's device and vigilance systems¹. This combination compares favourably with the other operators identified in the international survey, and the specific details of the NSW operation (such as lower time to brake application) are likely to deliver marginally higher levels of risk mitigation when compared to other operators.

Where NSW compares less favourably (to a small number of the other railway operators surveyed) is in the utilisation of more advanced levels of train protection equipment, such as ATP, to mitigate against failure of one of the on-board safety systems. There is no ATP system currently installed on heavy rail in NSW, whereas ATP is installed on some of the higher speed passenger networks included in the survey.

1.4.3 *NSW comparison – freight vehicles*

It was found that on-board safety systems employed in NSW on freight vehicles are currently limited to vigilance systems. This is consistent with other railways in Australia, and offers a lower level of train protection than is employed by all of the overseas railways reviewed for this report - with the exception of North America - which use additional measure in the form of deadman's devices, AWS or TPWS. This means that NSW operations may deliver marginally lower levels of risk mitigation when compared to the operators reviewed for this report.

Where NSW compares less favourably (to a small number of the other railway operators surveyed) is in the utilisation of more advanced levels of train protection equipment, such as TPWS and ATP, to mitigate against failure of one of the on-board safety systems. There is no ATP system currently installed in NSW, whereas ATP is installed on certain freight lines in Queensland and Western Australia.

¹ Locomotive-hauled passenger trains are fitted with the same systems as on freight locomotives, ie. vigilance equipment.

1.4.4 *NSW comparison – Heritage vehicles*

There was insufficient information available in the survey to be able to provide a meaningful comparison, but where data has been received the NSW system compares favourably with other operators.

1.4.5 *NSW comparison – Infrastructure maintenance vehicles*

Whilst it is common practice worldwide to have two devices fitted for both freight and passenger trains, as well as on a number of heritage trains, many maintenance vehicles in NSW are equipped with either one or no system at all.

1.5 **Conclusions**

All of the Passenger operators surveyed utilise a combination of deadman's and vigilance systems worldwide. Of the five freight operators surveyed three used a combination of deadman's and vigilance. However, the level of safety can be further enhanced if these systems are combined with a track-side train protection system and appropriate control measures.

In addition to train-based engineering driver safety devices, a range of track-based systems and rules/procedures further increase the safety and reliability of trains in service. Track-based systems include train stops, ATP, ATO, ETCS, and TPWS. Technical arrangements are also increasingly supplemented by enhanced training, assessment and coaching.

There is a range of additional measures being developed and trialled both within and outside the railway industry for monitoring arousal and fatigue. These systems, combined with currently used task-linked vigilance systems, have the potential of improving operating reliability within the rail environment to enhance safety further.

2 Scope of Project

Halcrow was engaged by the Independent Transport Safety and Reliability Regulator (ITSRR) to undertake an international literature review with the purpose of providing a report that identifies and establishes the type of driver safety defences currently utilised on a number of rail systems around the world.

This report provides an overview of the performance and functional specification of each type of Driver Safety System (DSS) reviewed. Consideration is also given to situations where systems are used in conjunction with other train safety devices and whether the systems are used in areas where the train is operated with only one driver in the cab or two-driver operations.

The types of vehicles considered within this study are:

- Passenger Trains
- Freight Trains
- Heritage Vehicles
- Infrastructure Maintenance Vehicles

The findings and conclusions of this report are based on the data retrieved during the literature search and the information gathered in the survey of operators. The number of operators prepared to provide information during the survey was also limited. It has not been possible to validate the accuracy of the data and information collected.

3 Methodology & Research

In order to identify the variety of Driver Safety Systems (DSS) available within the global railway industry two main approaches were used:

- Interviews / surveys with representatives of rail organisations
- Literature search /review

The interviews / surveys included technical specialists in the field of train safety as well as representatives from rolling stock manufacturers and train operators. For this purpose a questionnaire was sent to a number of operators to assist in identifying comparable systems.

To ensure a comprehensive overview of current systems and approaches, a literature search was also undertaken. The literature search used available documents from within Halcrow's technical library, historical records and information gathered from sources such as:

- IMechE published technical reports;
- Transportation Research Board of the National Academies;
- Local Railway Authorities;
- International publications from railway operators such as the DB (German Railways), OEBC (Austrian Railways), SBB (Swiss Railways), SNCF (French Railways) and a number of UK railway operators;
- Survey into the configuration of Driver Safety Devices on overseas passenger and freight trains;
- Vigilance Device standard for rail vehicles operated in Germany as provided by the German Railways (BN 411 007);
- International Rail Journal publications;
- Conference documentation from the InnoTrans² and CORE 200-2004; and
- RSSB Railway Group Standards³.

² Europe's largest Railway Conference and Exhibition on Passenger and Heavy Haul, Berlin/Germany

³ The organisation responsible for the setting of standards and industry research for the UK rail industry.

4 Train Safety Systems

This chapter outlines the functional specification of the identified safety systems based on technical (engineering) and operational systems. The primary objective of such systems is to mitigate the risks arising from driver error or incapacitation. Examples of these are shown below;

Engineering systems

- Vigilance system
- Deadman's system
- Automatic Train Protection

Operations systems

- Two Man Operation
- Supervision of staff
- Methods of safe working

The two most common generic types of DSD are:

- The constant pressure device; the deadman's system; and
- The intermittent action reset device; the 'vigilance' system.

Both deadman's and vigilance systems require a regular or continual physical input. The detection of an absence of this input is then used to indicate driver incapacitation.

The following section discusses these areas in more detail.

4.1

Deadman's systems

4.1.1

A Definition

'Requires constant presence and control is monitored by demanding a feedback signal from the driver. Most operate through means of a pressure device that has to be operated by the driver – absence of operation signals a lack of presence and control, and so the train is designed to be arrested'⁴.

4.1.2

Types of Deadman's systems

(a) Deadman's handle

Deadman's handles are generally incorporated into the master controllers in the driving cab, the types include:-

- T-Bar with the handle being twist activated;
- T-Bar with the handle having to be depressed;
- Handle with a button that must remain depressed;
- Control arm or lever that must be depressed;

⁴ Alara 1997:12



Figure 1 Example of Deadman's Handle

(b) Deadman's footpedal

The most common form of footpedal is a two-position pedal. This requires the driver to apply pressure to hold the pedal down. When no pressure, or insufficient pressure, is applied the brakes will not normally release.

If sufficient pressure has been applied and is subsequently removed the brakes will apply. The forces required to activate and deactivate the footpedal differ due to the spring mechanism used and the hysteresis of the microswitch.

Typically, in Victoria and NSW, the driver's footpedal must be depressed to a "middle zone" to trigger the microswitch located under the footplate and as a result suppress the activation of the deadman emergency braking system. Once the footpedal is in this zone, the deadman can be activated by either releasing the footpedal or pressing the footpedal to the bottom of its travel. The forces required to activate and deactivate the footplate differ due to the spring mechanism used and the hysteresis of the microswitch. When operating the footpedal from the top down position, the deadman system is suppressed once position L1 is reached. The deadman system would activate the brakes if the footpedal is released to the L2 position or pushed to the H3 position. During normal driving, the footpedal can be maintained anywhere between positions L2 and H3 to suppress the operation of the deadman system.

Figure 2 shows the activation and deactivation positions, L1, L2, H3 and H4 for the footplate during its travel.

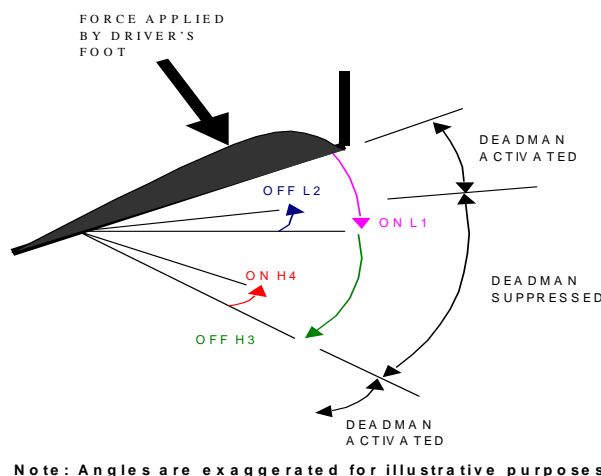


Figure 2 Footpedal Operation and the Activation and Deactivation Positions

The footpedals employed by RailCorp are similar in operation to the Melbourne footpedals. The only exception being the forces required to activate the footplates in the Melbourne system are approximately half of those required on RailCorp trains. Again this type of operation can lead to RSI. It was noted in discussions with the Melbourne operators that drivers continually complain about the sensitivity of the footpedal. When the footpedals were originally fitted in Melbourne they had to be modified to have a foot rest fitted next to them, so that the driver could balance their foot on the footrest whilst using the deadman's footpedal.

4.2 *Vigilance Systems*

4.2.1 *A definition*

'Comprises a cycle time device that requires periodic re-initiation by the driver to avoid a penalty brake application and maintain tractive power. Vigilance devices operate on the principle that a periodic action (or motor response) by the driver, timed to coincide with a system prompt (such as visual or audible warning) provides confidence in the awareness(or vigilance) of the driver'.⁵

4.2.2 *Types of vigilance systems*

Vigilance Systems in Australia comprise buttons supported by warning lights and alarms. There are differing modes on systems fitted to all varieties of rolling stock fitted in each state.

⁵ Alara 1997:12

The differences are the timing cycles, the warning periods and whether the system timing is dependent on train speed, and whether they are task-linked.

(a) Set Time or Basic System

This is the most basic system in use and is reliant on the system being reset after a constant time period has passed.

(b) Time Speed System

This system monitors the speed of the train from a feed from the Speedometer or an independent speed sensor and increases the frequency of the alarms based on the speed of the train i.e. the faster the train is travelling the more frequent the warnings.

These systems are either electro-mechanical or in the case of the newer systems electronic. It operates in a similar way to the time-time based system; with the difference that braking is initiated based on a time versus speed basis.

Distances travelled before the initiation of braking ranges from 75m to 1200m, depending on type of rolling stock and travelled speed.

(c) Time-Time Based System

This system is based on an electronic device and is currently the system which operators in Europe are installing as their preferred system. It functions in a way that braking is initiated if the driver fails to acknowledge a signal within a given period. The time between acknowledgements can be programmed at the time of installation and varies between operators and type of vehicle, and is generally dependent on maximum speed and track layout within the network.

The time interval between activations and the requirement for the driver to acknowledge is random between a set range and ranges from 25 to 90 seconds after which a light, sound or voice signal is given to the driver. The time a driver has to acknowledge the vigilance signal by either pressing and releasing, or releasing a button, handle or pedal ranges from 3 to 15 seconds.

This differs from the set time system in that the system operates with random timings rather than the set time intervals of the system described in (a) above.

(d) Task-Linked Vigilance Systems

Task based systems can be incorporated into the systems discussed above in that they can supplement the functionality of time based systems. A task based system will monitor the items listed below and the vigilance device timer is automatically reset every time one of the following systems is activated:

- Brake Controller;
- Power Handle;
- Radio;
- Horn or bell, or
- Light switch.

4.2.3

Reset after system-initiated braking

There are two ways of configuring the vigilance device timer. It can either be reset immediately after a penalty brake was initiated, or the train has to be brought to a standstill in order to reset the timer and operate the power controller. Most systems worldwide allow for immediate reset to avoid delays and disruption of service through an enforced stopping of the train. The second system requires the train to stop in order to reset the vigilance timer.

4.3

Combined Deadman's and Vigilance systems

Such systems combine the attributes of both the deadman's and vigilance DSDs, by requiring continual application, as with the deadman's system, while monitoring alertness by prompting as with the vigilance system.

Systems that are currently in use in the United Kingdom and Germany require the periodic release of pressure to discourage circumvention or detect a case in which the driver has maintained pressure on the control after losing consciousness.

4.4

Additional methods to enhance safety

Driver safety systems must be viewed in the context of the other methods that are available to enhance safety, and may include, but not limited to, the engineering solutions, as discussed in section 4.5, and the training, standards, procedures and processes which support safe operation of the system.

These measures are in place in each railway operation and, depending on the level of controls employed, together with traffic densities and the size of the railway operation, determines which type and combinations of safety devices are fitted to the rolling stock.

These measures are integral elements, which have the ability to complement or counter the effectiveness of the rolling stock engineering solutions provided. Such measures can be split into two main groups:

- Technical solutions i.e. electronic and electro-mechanical systems including Train Stops, TPWS, ATP and AWS, which are discussed in section 4.5.
- Management solutions, these include procedures, processes and rules, including medical requirements for Rail safety workers, drugs and alcohol policies and competence assessments⁶.

When considering the requirements for additional solutions, consideration must be given to other control methods which are either in place or could be used to further enhance safety.

4.5 *Train Protection Systems*

4.5.1 *Automatic Train Operation (ATO)*⁷

An ATO system allows for automatic operation of trains through the control of acceleration and braking, including terminal braking at specified station-stop positions, using operating management information and location information received from trackside equipment. ATO uses an onboard database containing trackside data to control train acceleration and braking to suit the relevant conditions (such as the track gradient and curvature) at each station.

ATO controls all phases of train operation, from acceleration to precise stopping. Currently, ATO is installed mostly in monorails and linear metro. Combined with the Platform Gates, ATO helps the train operators to realize driverless operation.

4.5.2 *Automatic Train Protection (ATP)*

ATP describes systems that monitor the actual speed of the train against that which is allowed on a particular section of the railway. ATP intervenes automatically to apply the brakes if a train is detected as going too fast; and the driver has taken no action, or insufficient action, to slow the train.

⁶ Also included in this category are arrangements provided for degraded modes of operation during failure of electronic and electro-mechanical systems and or failure of driver engineering defences e.g. the vigilance equipment.

⁷ In some countries, 'ATO' is also called 'ATC (Automatic Train Control)

ATP ensures that trains comply with speed restrictions and prevents higher speed SPAD's, whilst mitigating the risk of slow speed SPAD's by ensuring the train stops within the overlap distance. However, ATP may not prevent incidents caused by signalling failures, or by defects in the train or track equipment associated with the operation of ATP.

There are many rail routes in Western Europe equipped with an ATP system. In the UK, ATP is installed on the Great Western Main Line (between London and Bristol), the Heathrow Express, and the Chiltern line. In Australia, ATP is used on Perth's suburban network and some Queensland Rail routes; with most of its freight locomotives fitted with ATP as well as the mainline of the BHP Iron Ore Railroad.⁸

4.5.3 *ATS (Automatic Train Stop)*⁹

Automatic Train Stop is a system that operates in conjunction with equipment installed on the vehicle to apply the brakes at designated speed restrictions, and block signals in case the driver fails to acknowledge a signal. Once actuated, the brakes are applied until the train has been brought to a standstill and the ATS system is reset.

4.5.4 *AWS (Automatic Warning System)*

AWS omits an audible and visual indication of the status of upcoming signals. Where the signal is showing a restrictive indication the driver receives a warning tone and when the driver responds (on release of push-button) a distinct visual indication is received. The train brakes are automatically applied unless the driver acknowledges the warning within 3-7 seconds.

4.5.5 *European Train Control System (ETCS)*

ETCS is the automatic train control system for the European railways, it has three levels of operation. Level 1 ETCS is the most basic and is placed at desired locations with the option to fit infills. Level 2 is fitted with infills and has the capability of in-cab signalling. The most advanced is level 3 which is based on continuous track data communicated through GSM-R (including voice communication between driver, station master, trackside maintenance staff, controller, etc). GSM-R provides the data for ETCS as part of ERTMS (the European Rail Traffic Management System).

⁸ Jane's world Railways 2005-2006

⁹ This is the system currently used by Railcorp.

4.5.6 *Train Protection Warning System (TPWS and TPWS+)*

TPWS is a further enhancement to the existing AWS system. It is seen as a cost-effective control measure by providing the majority of the risk mitigation that ATP provides for significantly less investment.

TPWS automatically initiates braking if the train approaches a signal fitted with TPWS too fast, fails to stop at a signal at danger, or is traveling too fast on the approach to certain speed restrictions and buffer stops that are fitted with TPWS. It therefore reduces the risk of derailment and collisions between trains and of derailment through overspeeding.

4.6 *Multiple driver operation*

Dependent on the type of operation, passenger or freight, as well as the country involved the number of drivers staffing trains varies.

The same control facilities and therefore driver safety devices are common for both one-driver and two-driver operations.

Where there are two train crew in the leading cab, the main objective of having the second person is to: provide backup to the driver and assist in the operation of the train.

Staffing of trains can be grouped in to the following categories.

4.6.1 *Single driver,*

This is where a train has only one driver on board. In Europe the majority of passenger and freight trains are operated with one driver. On Commuter passenger and freight trains it is often the case that there are no other members of staff on the train.

On intercity passenger trains it is not unusual for there to be customer services or revenue protection staff on the train. These staff may, or may not be trained to assist the driver in carrying out certain duties.

The majority of passenger services in NSW are operated with a single driver in conjunction with a train guard.

Whilst other states allow limited single driver operation, in NSW, with the exception of a few specific locations, normally yards, freight trains are not permitted to have single driver operation. Freight trains must normally be manned by two drivers

4.6.2 *Double manned*

In Europe where two drivers are utilised on passenger trains this is mainly on speeds in excess of two hundred and one (201) km per hour, or over extended distances.

In Australia and North America, on some freight trains, the crew is made up of two drivers. This is normally due to the length of the working day of the driver or the distance being traveled without a break.

4.6.3 *Multiple crewing*

Elsewhere in North America and parts of Australia long distance freight trains are manned with up to two complete crews to enable the train to continue to operate for the whole journey without stopping to change crews. The crews alternate, with one crew resting while the other crew drives, to overcome fatigue issues

4.6.4 *Manning during Degraded operation*

A second driver, or in some cases persons not fully competent as drivers are utilised to enable the train to remain in service with one or more of the engineering-based driver safety systems in a failure mode in order to allow the train to remain in service and continue until it can be removed from service for repair.

Exceptions do occur on some passenger, heritage and freight trains where derogations by the duty holder and 'grandfather rights'¹⁰ have been claimed to allow the running of such vehicles under specific conditions.

4.7 ***Management control measures***

4.7.1 *Medical requirements*

It is a standard requirement in modern railway systems for staff involved in safe-working to undertake a periodical medical examination. This periodicity is dependent on both age and previous medical conditions. An example of these arrangements can be found in the *UK Railway Group Standard GO/RT3251 Train Driving Appendix A* This is attached as Appendix B. NSW operators also employ medical standards for staff involved in safe-working, These have been reviewed by operators following the accident at Waterfall to provide further assurance that staff involved in safe-working are fit to carry out their duties.

¹⁰ This is a term used to allow a company to continue to operate in a manner in which it has historically operated until such time as they make a significant change. It is used in very limited circumstances.

4.7.2 *Drug and alcohol testing*

As with medical requirements it is now a standard requirement to have drugs and alcohol testing undertaken on a random, but regular basis. This includes testing in the following circumstances.

- At point of employment;
- On promotion or transfer;
- Following an incident; and
- Randomly - as defined by management.

4.7.3 *Training (skill and job based)*

To ensure that risk is reduced it is imperative that staff who are involved in rail safety working are not only technically competent to carry out their role but are also assessed in an appropriate risk based manner. As well as being aware of the role they have in managing the risks of the environment in which they work. This should include an awareness of the issues related to lifestyle, fatigue and safety culture.

4.7.4 *Fatigue management processes for fatigued drivers*

Whilst the intention is to prevent fatigue from entering the workplace it must be accepted that as a result of operational disruption fatigue of staff may occur. This is particularly true in relation to long distance freight services where staff are likely to be in remote locations when they become fatigued. In this instance it is more difficult to provide a relief driver or crew. These instances require a robust fatigue management process.

4.7.5 *Human behaviours during degraded methods of operation*

When discussing engineering solutions consideration should be given to the manner in which normal operations take place as well as the consequence of one or more safety systems failing while a train is in service.

When trains are operating in a state of degraded mode following equipment or system failure, the network is at its most vulnerable. The staff involved in the failure may become anxious for the need to rectify the problem in a timely manner particularly in Metropolitan or high traffic areas. In these circumstances human error is more likely to occur. In this state of mind and with engineering solutions removed there is increased potential for human errors to be made and incidents to occur.

To assist in overcoming this problem robust guidelines for staff action during degraded modes of operation are required.

4.8

Defective Equipment - Degraded Modes of Operation

In accordance with the UK Group Standard defective on-train equipment is defined as: “on- train equipment which is not performing its intended safety function, either fully or in part, or is isolated or missing, with the result that risks to safe inter working or to the safety of passengers and the railway workforce are increased”.¹¹

A degraded mode of operation is regarded as being any circumstance in which one or more of the above systems fails or deviates from the specified performance requirements. A planned and agreed approach to managing these degraded modes of operation will assist during failures and provide a consistent and risk based approach to the identified defect(s).

The UK *Railway Group Standard GO/RT3437 Defective on Train Equipment* sets out the requirements relating to the production of contingency plans, which have to be applied when on train equipment becomes defective and, in its defective state, could result in increased risk to safe inter-working, the safety of passengers or the railway workforce.¹² The Austrian railways has set out a table of action in case one or more of the existing driver safety systems fail to operate. The table below shows which action is required in case one or more of the engineering based DSS fails while a train is in service.¹³

¹¹ United Kingdom Railway Group Standard GO/RT3437 Defective on Train Equipment December 2004 Part B3 Definitions.

¹² United Kingdom Railway Group Standard GO/RT3437 Defective on Train Equipment. December 2004. Part B1 Purpose.

¹³ OEBC, Austria, Zugsicherheit in Oesterreich, 2004, www.oebb.at, accessed: February 2006

If DSS operational				Allowed V _{max} (kph)	
LZB (linear train control)	PZB (spot train control)	Task linked Vigilance	Basic Vigilance	One-Man Operation	Two-Man Operation
Y	-	Y	-	*	-
Y	-	-	-	*	-
-	Y	Y	-	160	-
-	-	Y	-	100	-
-	-	-	Y	80	100
-	Y	-	Y	80	160
-	Y	-	-	50**	160
-	-	-	-	50***	100

Table 1: Table of action for degraded mode of operation – OEBA Austria

* Speed in accordance with speed signal sent to the driver's station

** Operation to nearest station with siding or storage facilities only

*** Operation to nearest station only

The table above which is produced from OEBA Austria shows that as the protection provided by engineering systems are removed due to failure, two control measures are used in a staged process. These are the reduction in speed of the train and the second is the provision of the second person to assist the driver.

At the present time RailCorp has similar requirements documented.¹⁴ These instructions are comparable with the practices and controls established in Europe.

¹⁴ NTR410 Network Rules Railcorp Defective Equipment, Driver Safety Systems.

TWP 122 Train Operations Manual, Railcorp, Failure of the Drivers safety systems.

5 Findings of Review

This chapter sets out the findings of the review of engineering safety devices. Types of vehicle considered within this study are divided into four main categories:

- Passenger trains
- Freight trains
- Heritage vehicles and
- Infrastructure maintenance vehicles

5.1 *Passenger trains*

The review identified the engineering safety devices utilised by nine (9) railway operations across eight (8) countries. The passenger systems were collated together.

Table 2, on the next page, sets out the main findings from the survey of railway operators.

Operator – Country		Vigilance System				Deadman's System		Additional train protection system	Single driver operation?
		Time to first alert	Alert signal	Time to braking ¹⁵	Reset options	Deadman's Handle	Deadman's Foot-pedal		
Australia NSW – Railcorp Electric and Diesel Fleet	<75kph	45 sec	Acoustic and visual	15 sec	Once train has stopped	Y	Y	ATS	Y
	75-90kph	35 sec		15 sec					
	>90kph	25 sec		10 sec					
Germany – DB		30 sec	Acoustic and visual	5 sec	immediate	Y	Y	Indusi (LZB, PZB) Limited ATP ETCS trial	Y
Austria – OEBB		30 sec	Acoustic and visual	5 sec	immediate	Y	Y	Indusi (LZB, PZB) Limited ATP ETCS trial	Y
Switzerland – SBB		30 sec	Acoustic and visual	5 sec	immediate	Y	Y	Indusi (LZB, PZB) Limited ATP ETCS trial	Y
Spain – RENFE		30 sec	Acoustic and visual	5 sec	immediate	Y	Y	ATS	Y
UK – Operators		60 sec	Acoustic	4 sec	Once train has stopped	Y	Y	AWS / TPWS (limited ATP)	Y
US – MTA (LIRR)		60 sec	Acoustic and visual	3-5 sec	immediate	Y	N	ATC	Y
Australia – VIC (Hitachi and Comeng)		30 sec	Visual	5 sec	immediate	Y	Y	ATS	Y
New Zealand		50 sec	Acoustic and visual	20sec	-	Y	N	Mechanical trainstops on critical signals in Wellington suburban area only	Y

Table 2: Driver Safety Systems on Passenger Trains – Worldwide

¹⁵ The time, in seconds, from when the alert is issued to the point at which a brake application is automatically initiated

5.1.1

Comparison and analysis - passenger

1. All operators surveyed utilise a combined Vigilance and Deadman's system.
2. With the exception of Australia and New Zealand who use a three position deadman's pedal all other countries surveyed use a two position pedal.
3. In general passenger operators are utilising a similar combination of Vigilance and Deadman's system.
4. Time to first alert varies between 25 and 60 seconds.
5. Time to braking is between 3 and 20 seconds with the highest values being on trains in NZ followed by trains in NSW.
6. The Vigilance alert signal to the driver is provided by either a visual or acoustic signal and in the majority of cases visual and acoustic are combined to deliver both an audible and visual advice.
7. If a brake application is initiated by the Vigilance system, most operators allow the driver to override the application immediately, thus minimising train disruption. However in UK and on RailCorp the train must be brought to a complete standstill before normal operation of the train can resume.
8. All the operators surveyed utilise some form of Deadman's handle or footpedal.
9. All the operators surveyed generally operate trains with only one driver in the leading cab in normal operation
10. All of the operators surveyed utilise some form of train protection system ranging from AWS / ATS through to a comprehensive ATP system. The coverage in each country varies and tends to be installed on the highest speed and/or more frequently used lines.
11. Less than 40% of the operators surveyed have a comprehensive ATP system installed on any of the routes they run trains over. The routes fitted with ATP tend to carry high speed passenger services.

5.1.2

NSW comparison - passenger

It was found that on-board safety systems employed in NSW multiple unit trains combine the use of a deadman's system and vigilance device. This combination compares favourably with overseas railways and the specific details of the NSW operation (such as lower time to brake application) are likely to deliver higher levels of risk mitigation. It should be noted that on locomotive-hauled rolling stock there is only a vigilance system.

The main differentiator between NSW and the majority of the other railways surveyed is the utilisation of more advanced levels of train protection equipment, such as ATP, to mitigate against the failure of one of the train safety systems. It should however be noted that the level of coverage of these systems is variable between countries and tends to concentrate on the highest speed or more heavily utilised routes.

5.2 *Freight trains*

The review identified the engineering safety devices utilised by five operations /countries.
The table below sets out the main findings from the survey of freight railway operators.

Operator – Country	Vigilance System				Deadman’s System		Additional train protection system	Single driver operation
	Time to first alert	Alert signal	Time to braking	Reset options	Deadman’s Handle	Deadman’s Foot-pedal		
UK	60 sec	Acoustic	4 sec	Once train has stopped	N	Y	AWS / TPWS	Y
North America – Norfolk Southern	Not provided	Acoustic and visual	15 sec	10 seconds	N	N	AWS / ATS (new stock only)	N
New Zealand – Toll	50 sec	Acoustic and visual	20sec	immediate	Y	N ¹⁶	None	-
Australia - generally ¹⁷	70 sec (50 sec for DOO)	Acoustic and visual	20 sec (10 sec for DOO)	-	N	N	State/operator dependent	Limited
Zimbabwe	60 sec	Acoustic and Visual	5 sec	-	N	Y	None	Y

Table 3: Driver Safety Systems on Freight Trains – Worldwide

¹⁶ Some older rolling stock is fitted with deadman system and no vigilance controls.

¹⁷ In NSW there is no single driver operation other than for specifically approved yard operations. All freight trains in NSW must have a driver and a second person.

5.2.1

Comparison and analysis - freight

1. With the exception of North America and Australia operators surveyed utilise a combined Vigilance and Deadman's system.
2. In general the difference between freight and passenger systems is the timing of the vigilance system to first alert and the timing of the vigilance system to braking, both of which tend to be higher in freight than passenger trains.
3. Time to first alert varies between 50 and 70 seconds.
4. Time to braking is between 4 and 20 seconds.
5. The vigilance alert signal to the driver is provided by either a visual or acoustic signal and with the exception of the UK visual and acoustic are combined to deliver both an audible and visual advice.
6. If a brake application is initiated by the Vigilance system, operators have differing requirements. For example, in New Zealand the driver is able to override the application immediately, thus minimising train disruption. However in UK and on RailCorp the train must be brought to a complete standstill before normal operation of the train can resume and in North America Norfolk Southern require a 10 second delay before reset.
7. Three out of five operators surveyed utilise some form of Deadman's handle or footpedal.
8. Single driver operation is not as common in freight operations as it is in passenger.

5.2.2

NSW comparison - freight

It was found that on-board safety systems employed in NSW use a vigilance device, but there is no use of a Deadman's system in NSW. This is not an uncommon situation for freight operators. However NSW does require a second person to support the driver. The utilisation of a driver and second person in the cab is also apparent in North America.

5.3 *Heritage Vehicles*

Heritage vehicles are vehicles which have previously been in revenue earning service and are operated, in the majority of cases, by volunteer groups or individuals. These not only include Steam Locomotives but increasingly they include diesel and electric traction. It was found during this study that while the sample size was small, the majority of traction in this category operate with the same safety equipment as was in place at the time of their revenue earning operation with no additional equipment fitted since. In terms of manning, the trains are at least manned to an equivalent level as they were historically. This is often then supplemented with additional managers or supervisors. Some exceptions to these arrangements are shown below.

5.3.1 *UK*

Until 2003 it was acceptable for heritage rolling stock to operate on the UK Network Rail with AWS only. It has now become mandatory for diesel and electric heritage rolling stock to operate with TPWS fitted in addition to a deadman's device. However, there are some exceptions for very old rolling stock such as steam locomotives. If these vehicles are not fitted with TPWS, portable TPWS systems are available and are fitted to the traction unit whilst operating on Network Rail controlled infrastructure.

It is also a condition of operating on the public rail network to have a second suitably qualified person overseeing the performance of duties. This person is normally a supervisor or manager who has had driving experience, although they are not required to be competent to drive the class of traction they are observing. Heritage railways that operate on their own infrastructure are exempt from most of the rules and regulations that govern heritage rolling stock operating on Network Rail infrastructure. In these circumstances the owner operator put in place sufficient processes to operate safely and with in the conditions of any safety case or operating license issued.

Most heritage operations in the UK operate as two-man system with two drivers, driver and fireman or a driver and a train guard.

5.3.2 *New South Wales*

The rail motor society in New South Wales previously operated a deadman's safety device, which was not interlinked with the braking system (audible alarm only). It has recently undergone a series of modifications, such that the deadman's pedal is now linked to the braking system.

5.3.3 *NSW comparison*

There was insufficient information available in the survey to be able to provide a meaningful comparison, but where data has been received the NSW system compares favourably with other operators.

5.4 *Infrastructure maintenance vehicles*

5.4.1 *UK*

An Infrastructure Maintenance Vehicle (IMV) also known as a Rail Mounted Maintenance Machine (RMMM) or OTM (On track machine) in the UK is a vehicle that can travel on-rail under its own power system. Such vehicles are not allowed to operate, work or travel outside possessions without prior authorisation.

When authorisation is given for operating outside possessions IMV's are considered effectively to be trains and therefore should meet the safety criteria of driver safety systems as set out in the Railway Group standards (GM/GN2575 Issue 2)¹⁸. On the London Underground the IMV's are (as a minimum) fitted with ATS and a deadman's handle.

5.4.2 *Singapore*

Singapore track maintenance vehicles comprise locomotives, wagons and self-propelled specialist vehicles. On the North East Line the locomotives are fitted with Deadman handles and full ATP to permit operation during normal service. On the SMRT system (North South and East West Lines) ATP equipment was fitted to locomotives but this is not used at present.

On the North East Line if a self-propelled vehicle is required to run on the main line then it must either be coupled in a consist with a locomotive at each end or run only under possession. SMRT only operated engineers' trains within possessions.

5.4.3 *Victoria*

IMVs in Victoria generally operate with a vigilance control system. However, some older IMVs do not have vigilance installed, but are run as two-man operation. Discussions with operators have indicated that all machines which operate wholly on rail are fitted with a fail safe braking system, so if the brakes bleed a parking brake is automatically applied.

5.4.4 *New South Wales*

Within controlled conditions it is currently permissible for a permanently rail mounted infrastructure machine to operate without the provision of either a Vigilance device or a deadman's system.

5.4.5 *NSW comparison*

There was insufficient information available in the survey to be able to provide a meaningful comparison, but where data has been received the NSW system appears to have less safety devices fitted than other operators surveyed.

¹⁸ The standard stipulates that the vehicle control system shall be capable of initialising a brake application with a retardation equivalent at least to a full service brake application as a result of an input from safety and emergency systems such as AWS, TPWS, DSD, and Vigilance.

6 New Concepts for Driver Safety Devices

The study to this point has focussed on the traditional DSD systems.

Are there any new concepts or developments that can be adapted to the rail industry to replace the current DSD systems?

A review of a number of possible new concepts for driver safety devices shows that most focus on methods for monitoring driver fatigue and alertness.

6.1 *Ocular Measurement Monitors*

6.1.1 *Aim*

Ocular measurement monitors are systems that are able to monitor and record the movement of the human eye and eyelid. It is possible to calculate the frequency and duration of eye closures; a measure that has been shown to be directly related to driver alertness and fatigue.

6.1.2 *Systems*

Existing methods for monitoring eye movement employ either a set of goggles worn by the user or a video camera trained on the subject. A very precise method is based upon monitoring small reflections on the eyeball made by infrared lights. However, infrared monitoring is subject to noise, distortion and tracking problems with head movement.

One company called Seeing Machines have developed a system using two small video cameras and stereo processing to monitor and track eye movement. The monitoring cameras would typically be mounted on a vehicle dashboard. The system can provide a number of outputs:

- Locate drivers head
- Locate the eyes
- Measure gaze direction
- Measure eyelid closure

According to the Seeing Machines the system is able to “simultaneously measure enough facial information to provide estimates of high-level human cognitive factors, such as attention, inattention, fatigue and boredom.”

The human factors product developed by Seeing Machines, faceLAB (refer to Figure 3), is at present a laboratory baseline that can be developed further into applications such as driver monitoring in the automotive, airline and rail industries (Edwards, T). At present it seems only to be at the development stage but has been taken on board for further development by a number of leading automotive manufacturers. Volvo founded the Seeing Machines Company in partnership with

the Australian National University. Current research and development using the Seeing Machines system is focused on drowsiness, workload management and distraction. These measures could have direct applicability in the rail environment.



Figure 3. Seeing Machines faceLAB product.

The University of Surrey UK prepared a report, commissioned by the UK Railway Safety body, on a Pilot Study of 'Train Drivers' Eye Movements'. The research paper addressed the feasibility of using eye-movement recording as a way of assessing how train drivers sight signals as they approach them. The report found that it is possible to record eye movement; in this case using a custom designed face-mask which contained a video camera to track head position and a modified visor which continuously detected the position of the driver's pupil using infra-red technology. The accuracy of such a system is dependent on the accuracy of calibration. The calibration procedure for this study consisted of making repeated fixations by the user on targets. The calibration procedure ended when the eye position could be recorded across the full visual field with accuracy better than one degree.

The research carried out by the University of Surrey was specifically related to the sighting of signals rather than driver alertness. It noted that Automatic Warning Systems (AWS) appear to serve to initiate a large proportion of first-time-looks at signals – especially cautionary signals. The UK AWS works in conjunction with magnets in between the two running rails on the approach to a signal. If the signal is showing a green aspect, a bell sounds in the cab and a visual indicator in the cab shows all black. If, however, the signal shows two yellows, one yellow or a red aspect as the train passes over the magnet, then a horn sounds in the cab and the driver must press a cancellation button within 2.2 seconds. Failure to do this initiates an emergency brake application.

Although it is intended to operate as a support device to re-confirm details of signals already passed, frequently signals were not looked at until the AWS had sounded. There were, however, a number of points made in the research that can be related to driver alertness. The research found that it is possible to record and

analyse train drivers eye-movements in a robust and reliable manner. The report noted that although attention can be independent of eye-movements, there is good reason to assume they are highly interrelated.

Railway Safety believes that more work in this area will be of great benefit to the rail industry and lead to improvements in signal sighting. Follow-on research in this area is being commissioned and will further develop eye-movement measurement to investigate train driver visual strategies.

Pacific National are also trialling an Australian developed system¹⁹ which was developed for the road industry. This system also monitors movement of the eyes and eyelids. Trials of this system are progressing at the time of writing.

6.2

Brain Activity Monitors

6.2.1

Aim

Human consciousness and psychological states (among which fatigue belongs) are closely related to brain activity. Variations in the subject's alertness cause changes in the types of electrical signals processed by the brain. In states of fatigue and close to sleep the electrical signals differ from those of someone who is well rested and alert. It is these differences in the level of electrical activity in the brain that can be monitored.

Spectral EEG analysis is the most appropriate method for detecting the onset of different stages of sleep and therefore fatigue. However, in practice, automatic monitoring of driver alertness and fatigue levels failed. This can be explained by the fact that the EEG of an alert person has proved to be very individual and influenced by a number of psychological factors.

6.2.2

Systems

A company based in California, Advanced Brain Monitoring (ABM), have developed a drowsiness monitoring device that can be housed in a cap worn by the user and which includes two electrodes that pick up EEG signals (refer to Figure 4). The EEG data is transmitted via radio to a processor located within 10 metres of the user.



Figure 4. ABM head mounted EEG monitor.

ABM's drowsiness monitoring device is currently on the market for about US\$500 per unit. The company has developed an EEG-severity index to help quantify levels of vigilance and attention based on previous research data. In addition to

¹⁹ Optalert Drowsiness detection, <http://www.optalert.com/home.html>

the sensor headset, ABM markets a range of assessment software and a sleep risk evaluation system.

As with the faceLAB product, the system needs to be accurately calibrated to ensure reliability of the results. It is also likely that the system may require calibration for each individual user. Although the ABM system is well developed the company is currently looking to secure equity financing to fund beta site testing, market development, and product launch.

A Driver Vigilance Telemetric Control System (DVTCS) has been developed by a company called Neurocom, founded by the institute of Radio Engineering and Electronics of the Russian Academy of Science (IRE RAS). The state of the driver is determined through continuous measurement of brains activity that is in turn compared against certain thresholds and criteria. Although no mention is made about how the system is setup for different users, there must be a calibration procedure to ensure that the system is accurately set-up for the particular user.

The system comprises of a portable wrist-watch that contains electrodes, the primary processing unit and a radio transmitter (refer to Figure 5). This transfers information to a receiving unit which carries out secondary processing. The state and vigilance level of the driver is displayed on the secondary unit in the form of an illuminated bar of varying length.



Figure 5. Neurocom vigilance driver monitor

A system has been specifically developed for the railway industry and Neurocom are the sole supplier of vigilance control devices used by the Russian Ministry of Railways. For the railway application, provided the normal vigilance level of the driver is maintained, periodic vigilance checks are cancelled. If the driver vigilance level deteriorates beyond the critical point, the system activates automatic emergency braking.

6.3

Head Nodding Monitors

6.3.1

Aim

The development of this type of monitor has been led by the assumption that head nodding is related to the onset of fatigue. Hulbert (1972) has noted that driver alertness often decreases substantially before the head begins to nod. Potentially,

this means that with the onset of head nodding the driver is already fatigued and driving in an unfit state.

6.3.2

Systems

The basic systems are designed to alert drowsy drivers and prevent them from falling asleep. The device itself is relatively simple and attaches to the driver's ear and sounds an alarm if the driver's head should nod, preventing them from sleeping. The alarm activates at a head nod angle of between 15 and 20 degrees from the vertical. The device shown in Figure 6 is commercially available and retails in the USA for US\$50.00. It is therefore a relatively cost-effective solution but relies solely on the driver choosing to use the device.



Figure 6. Napzapper stay awake device

6.4

Vehicle Control Behaviour

Systems are being studied in the road industry that involve comparing the driver's responses to those which are expected. Obviously a system that monitors a large truck weaving from side to side at speed cannot be replicated in a railway environment, however; the concept of a system that monitors the drivers expected responses may provide a more sensitive DSD system.

6.5

Aids to Driver Alertness

There are a number of ways of improving the alertness of the driver, especially over long periods of driving. However, it must be ensured that any system employed does not distract the driver from the primary task of safely operating the train. Possible aids to driver alertness include:

- Low-level background music;
- Driver alert voice recordings warning of upcoming signals;
- Improved cab air conditioning – in particular the ability on cold days to have heating to the legs and body, yet retain a stream of cooler ventilation air to the driver's face;
- Variable intermittent vigilance tests that are not habit forming.

7 Deadman's Systems Issues

7.1 *Deadman's Systems – advantages*

The intended advantages of the deadman DSD's include:-

- Maintaining constant surveillance of the driver;
- Immediate reaction to driver incapacitation;
- Ensuring the driver maintains his position in the driving seat.

7.2 *Deadman System's - disadvantages*

The disadvantages of Deadman DSD's are listed as follows

7.2.1 *All Deadman's devices*

- Usually more intrusive for driver;
- More likely to be circumvented. Both hand and foot deadman systems can be weighed down

7.2.2 *Hand Deadman's devices*

- Not as likely to detect inactivity. Many hand operated systems can be kept maintained although the driver has become inattentive or inactive. It was noted in information from the united Kingdom that a human factors Consultant working for the rail industry identified that someone who is drifting off to sleep can retain muscle tone for up to 2 minutes and not be aware that they have been asleep;
- Holding down a Deadmans handle over a period of hours is tedious and difficult because of the requirement for constant pressure.

7.2.3 *Foot Deadman's devices*

- A number of systems can be maintained if the driver becomes incapacitated. For many systems the weight of the lower leg can maintain the set position;
- Systems that are too sensitive and have had a foot rest fitted lessens the effectiveness of the deadman's foot plate. The footrest on the Victorian system is aligned with the middle of the set position.

The ability for an incapacitated driver to maintain pressure on the foot DSD system was highlighted in the waterfall inquiry. Various studies suggest that

“tension in the postural muscles cannot be used as an indicator of perceptual vigilance”²⁰

The forces required to activate and release the differing 3 position DSD footplates in Victoria , Queensland and New South Wales are compared to see their range and suitability for the task.

The 3 position pedal has a middle set position that must be maintained to allow the train to be operated. Because of the middle set position, a study carried out by StateRail, highlighted that there are differing forces to activate and deactivate the DSD pedal at both set position. This is because it takes extra effort to press and activate each of the set points rather than maintain the plate at a set position.

The pressures that are critical to the footplates performance as an effective DSD system are release pressure and the lower deactivation pressure.

7.3

Comparison – 4D/Tangara and the Victorian Footplates

Following some work by the Department of Infrastructure their review into ‘Deadmans and Vigilance Operating Standards’ (DaVOS) found that drivers representaives felt that many of the drivers considered that the 4D / Tangara style footplate was preferred, the reasons discussed were as follows:-

- More reliable, as it is sealed with a rubber cover against dirt etc.
- It is not as sensitive;
- Not as easy to jam objects in the mechanism and is hence less likely to be circumvented;
- More comfortable to use;
- It doesn’t require a footrest to operate.

The Tangara style footplate has proven to be more reliable with very few units changed out each year as compared to the Victorian style. Other issues have to be considered when looking at its advantages, these include its effectiveness as it is heavier to operate and as highlighted in the Waterfall inquiry many had easily been circumvented by jamming a flag between it and the console.

²⁰ Buck 1968

8 Vigilance System – Issues

8.1 *Vigilance Systems – Advantages*

The intended advantages of a Vigilance system include:-

- Less prone to be tampered with or circumvented;
- Allows driver to move from his seat;
- Not as prone to fatigue driver as a badly designed deadmans system, if forces to activate and ergonomics are not good;
- Vigilance systems with shorter periods for either the visual or acoustic warnings require a greater amount of attention to avoid the penalty brake application. The Federal German Railways have 2.5 second intervals between the light to acoustic warning and 2.5 seconds more (5 seconds total) before the penalty brakes are applied

8.2 *Vigilance Systems – Disadvantages*

The ATSB Rail Investigation Report into the Footscray incident, dated 5 June 2001 stated ‘Vigilance systems may prove to be more problematic in a metropolitan rail system, given the density of traffic, the time gap between trains and the workload of train drivers’.

8.2.1 *Train Separation*

The minimum train separation distances of the signalling and safe working system does not always allow for the time cycles within a vigilance system. The worst case in establishing overall safety margins is considered to be:

Max Speed * Vigilance cycle time + penalty brake

Typical stopping distances for a train:

160 kph – 5.09 klm to stop

115 kph – 3.83 klm to stop

80 kph – 3.28 klm to stop.

A report commissioned by the Public Transport Corporation, Victoria²¹ highlighted that train separation and overlaps was one of the greatest risks in the Melbourne metropolitan network. The report concluded that “Driver-only operation involves no less risk than current operations”. The report also concluded that “a 10-10 cycle is a feasible alternative to a continuous acting deadman’s device”.

8.2.2

Automaticity

A 1998 study by the Monash Accident Research Centre concluded that:

“Most current Vigilance systems can be operated in a largely automatic manner and don’t require conscious attention or vigilance to respond to the system”.²²

The main reasons are:-

- Drivers can respond prior to the presentation of the light. The drivers have developed a strategy of pre-emption which removes the requirement of looking at the light. Drivers have reported pressing imaginary buttons while driving their cars. Changes to remove pre-emption of the task may increase the annoyance factor which may encourage circumvention;
- Many vigilance systems are fixed cycle;
- Drivers become used to prompts and merely responds by reflex action;
- Vigilance lights may be less effective as compared to audible warning during daylight hours.

8.3

Task-linked systems

8.3.1

Tasked linked systems – Advantages

- Least intrusive of all systems.

8.3.2

Tasked linked systems – Disadvantages

- Tasked linking may enable the driver to keep acknowledging the vigilance system while being occupied with other functions rather than driving.

²¹ Vinear Robinson Jarman, 1992

²² Haworth, Regan & Larsson, 1998: 1

8.4 *Other issues with Drivers Safety Devices*

8.4.1 *Ergonomics*

Good Ergonomics and cab layout are critical as they are the workspace of the driver. One of the ‘motivational factors’ behind circumvention is that many constant pressure DSD systems are not ergonomically sound. Also, cab layouts that force the driver to adapt to the train can be less safe than trains that are adapted to the driver.

‘When laying out a drivers workspace, the designer should minimise potential safety hazards through good understanding of the capabilities of the user, the duties of the operator, the tasks to be performed, and the potential safety risks’.²³

The location and configuration of handles and foot pedals, warning lights, and cancellation buttons may impact on their use, abuse. Even auditory warnings may differ between cabs or lighting may be at the edge of the peripheral field of the driver who doesn’t respond if engrossed in other visual tasks. Volpe, in their human factors guidelines for train cabs²⁴, also state that “all main controls, including their full range of motions, should be within the zones of comfort with auxiliary controls placed within the larger zones of reach”.

Light brightness of warning of foot set lights may be too bright, it was noted that in NSW many of the footpedal set lights have been covered by stickers or coloured over to dull them.

8.4.2 *Noise Levels*

Excessive noise can be fatigue inducing or contribute to reductions in alertness. The effect of noise upon the level of alertness depends on the nature of the noise. Continuous ambient noise may contribute to reductions in vigilance but noise with information value may help maintain alertness. As could become the case with the introduction of voice-activated vigilance systems.

8.4.3 *2 man crewing*

Multiple crews can provide a distraction as well as an arousal factor. The practice of calling out signals and general activity provide a stimulus for the driver. However, there is also the potential for conversations to distract the driver and decrease vigilance. The Federal Aviation Administration in the United States instituted a “sterile cockpit rule”, all conversations non flight related are not allowed below 10,000feet. This was instituted because of crashes where conversations created distractions.²⁵

²³ Volpe 1998:Ch5.1.2

²⁴ Volpe 1998: Ch5.1.2

²⁵ Volpe 1998: Ch6.2

8.5 *Comparison of Deadman's to Vigilance systems*

The difference between the deadman's and vigilance systems were examined in a risk study carried out by Alara Risk Services (1997). The risk analysis was as a result of recommendation following the investigation into the sprinter train collision that occurred at Spencer Street during 1997. A major part of the risk assessment was dedicated to comparing vigilance systems with deadman's systems. The report concluded that the vigilance control and the pilot valve designs, as reviewed, did not currently present markedly different risks.

The report however detailed the differences of each system and included a detailed risk analysis that summarised the greatest or highest rated risk issues with each type of system, these included:-

8.5.1 *Deadman's Systems*

- Handle/footpedal not released after incapacitation;
- More prone to be deliberately disabled;
- Difficulty in maintaining the pilot valve, too sensitive over certain tracks;
- System does not monitor over speeding.

8.5.2 *Vigilance Systems*

- The timing of the Vigilance system does not arrest train immediately;
- Train can continue powering after driver loss of control;
- Driver can leave the controls;
- Enables driver to drive with less than adequate attention, may lead to over speeding and poor control.

8.6

Conclusion

With an increasing number of safety systems in place, the risk for the overall safety system to fail decreases and overall safety increases. The use of two or more independent systems appears to offer the best defence against accidents arising from driver incapacitation or driver fatigue. Currently the most successful on-board system available is a combination of deadman's system and vigilance device complemented by additional control measures.

There is, however, a range of additional developments, both within and outside the industry, looking at alternative methods of monitoring arousal and fatigue. These systems combined with vigilance have the potential, if proven to be capable of operating reliably within the rail environment, to enhance safety and monitor alternative parameters to current technology.

In addition to engineering-based driver safety devices, a range of management measures further increases the reliability. Other systems include ATO, ETCS, ATP, TPWS and Train Stops. These technical systems are also increasingly supplemented by enhanced training, assessment and coaching. Where it is not practical or appropriate to have a second engineering solution consideration should always be given to the provision of additional crew to supplement the engineering solutions installed.

9 Glossary

ATP	Automatic Train Protection
ATS	Automatic Train Stop
DSD	Drivers Safety Device
IMV	Infrastructure Maintenance Vehicle
LZB	<p>A train Protection system that affords continuous train control signalling which is superimposed on distant and main signals. It provides a continuous cab indication to the train driver and permanently indicates the maximum speed based on the available braking distance. It supervises to both speed restrictions and signals.</p>
OTM	On Track Machine
PZB	<p>This is the main train protection system which is installed throughout Germany, Austria, and Switzerland. The system provides braking curve supervision in the braking distance on the approach to a fitted signal. The brake is applied automatically if a main signal is passed at danger.</p> <p>Additionally the PZB will automatically apply the train brakes if the driver doesn't react to a signal in the warning position. It also prevents a SPAD when a train starts from a platform when the platform starting signal is displaying a danger aspect.</p> <p>While the train is under the supervision of LZB the PZB is automatically passive, however in the event of a malfunction of the LZB the PZB will immediately become active This system is to high speed lines >160kmh in some European countries including Austria and Germany.</p>
RMMM	Rail Mounted Maintenance Machine

10 References

- Alara Risk Services (1997), *Sprinter Collision Risk Assessment for the Public Transport Commission*, Infrastructure Division, Public Transport Commission, Victoria
- Buck, L. (1968) 'Experiments on Railway Vigilance Devices', *Ergonomics*, v11, No.6, pp557-564
- DB (1999), Standard fuer Sicherheitsfahrerschaltungen
- Dept of Transport and Regional Services, Australian Transport Safety Bureau (2001), *Collision between suburban electric passenger train 6369 and the empty express electric train 6371*
www.eisenbahn-bundesamt.de
- Halcrow (2003), *Rail Safety Advisory Group Discussion paper – Deadmans and Vigilance Operating Standards (DaVOS)*, Department of Infrastructure, Victoria
- Haworth, N. Regan, M. & Larsson, T. (1998) *Investigation into Effectiveness of Driver Vigilance Control Systems on Locomotives*. Research undertaken for FreightCorp. Monash University Accident Research Centre.
- Heron, R.M. (1988), *Ergonomics evaluation of C.P. Rail's new road freight locomotive cab design. Montreal, Quebec*: CP Rail System.
- Jane's World Railways, 2005- 2006
- McInerney, A.P. (2005), *Special Commission of Inquiry into the Waterfall Rail Accident Volume 1*: New South Wales Government.
- OEBB (2003), Zugsicherheit in Oestterreich
- Reason, J. (1997), *Managing the Risks of Organizational Accidents*: ASHGATE
- RSSB, (2004), *Guidance on the Engineering Acceptance of On Track Machines*, GM/GN2575 June Issue.
- Sleep Diagnostics Pty Ltd (2006), <<http://www.optalert.com/home.html>>
- Transport Accident Investigation Commission New Zealand (2002), *Express freight Train 533, derailment, near Te Wera*
- Vinear Robinson Jarman, (1992) *Risk Analysis of Train Operations*. Public Transport Commission, Victoria
- Volpe Centre – Mutler, J. Rudlich, R. & Yearwood, K (1998), *Human Factors Guidelines for Locomotive Cabs*. US Dept. Transportation, Federal Railroad Administration. Ch.6.

11 Appendix A

11.1 *Review of Relevant Accidents*

11.1.1 *Footscray, Victoria*

Just after 0828 on 5 June 2001 an empty suburban EMU train collided with the back of a suburban passenger train at platform number 4 at Footscray station. The passenger train had about 20 people on board.

The evidence that came to light after the inquiry 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 (ATSB, 2001).

Drivers of suburban trains in Victoria are required to maintain a given pressure on a deadman's pedal or handle. In the event of a driver becoming incapacitated for any reason, the relaxing, or increase of pressure on the deadman's control should automatically apply the train brakes.

In certain circumstances, the deadman's device can be maintained at the correct pressure just by the weight of the lower leg, whether or not the driver is incapacitated. Recommendation 7 of the report into the incident stipulates that the use of deadman's footpedals should be reviewed, given their limitations, to determine whether the system can be made more effective or whether an alternative, equivalent system might make a better safeguard (ATSB, 2001).

It is clear from the accident at Footscray that there are deficiencies in using a deadman's pedal that does not have a positive reset action and that requires a constant force to operate.

11.1.2

Te Wera, New Zealand

On Friday 26 July 2002, a freight train no 533, was travelling from Auckland to New Plymouth and consisted of a DX locomotive and a DC locomotive in multiple with a load of 30 wagons. The train was operated by a locomotive engineer (Driver) who was assisted by a rail operator.

The crew had taken over the running of Train 533 at Okahukura on Thursday 25 July 2002 at about 2330, after having taken Train 524, a New Plymouth to Auckland express freight train, from Stratford to Okahukura. They departed from Okahukura at about 2355 on their return journey to Stratford.

At about 0147 on Friday 26 July 2002 Train 533 emerged at about 45 km/h from the western portal of Tunnel 2 between Whangamomona and Te Wera and increased speed as it descended a 1 in 51 gradient towards a 45 km/h, speed restricted left-hand curve, which it entered at about 70 km/h. The train had negotiated about 300 m of the curve when the locomotives left the track, became airborne and plunged about 12 m down the side of the track formation (TAIC 2002).

The derailment of Train 533 resulted from the train entering a posted 45 km/h restricted speed curve at excessive speed. The excessive speed was consistent with the locomotive engineer and rail operator's loss of attention and situational awareness consistent with their having fallen asleep (Transport Accident Investigation Commission New Zealand 2002).

The locomotive engineer did not make an emergency brake application immediately before the derailment, but even had he done so it would not have changed the outcome. The report discussed that the existing locomotive vigilance system may not provide an effective defence against microsleeps and the possibility of similar occurrences (Transport Accident Investigation Commission New Zealand 2002).

11.1.3

Waterfall, New South Wales

On 31 January 2003 at approximately 7:14 am, a four car Outer Suburban Tangara passenger train, designated G7 and travelling from Sydney Central railway station to Port Kembla, left the track at high speed and overturned approximately 1.9 kilometres south of Waterfall railway station. The train driver and six passengers were killed. The train guard and the remaining 41 passengers suffered injuries ranging from minor to severe (Special Commission of Inquiry into the Waterfall Rail Accident, 2005).

The driver of the train, Mr Zeides, had a number of risk factors for coronary artery disease. The postmortem examination revealed that he had a 90 per cent blockage of the left anterior descending coronary artery. While this did not establish conclusively that he had a heart attack, the preponderance of evidence was that he was at considerable risk of an incapacitating cardiac event. The inference from the known state of Mr Zeides' health led the Commissioner to find that he suffered a sudden incapacitating heart attack at the controls of G7 (Special Commission of Inquiry into the Waterfall Rail Accident, 2005).

That conclusion led the Commissioner to examine why, in those circumstances, there was a failure of the deadman's system, which was supposed to prevent an accident of this kind if the train driver has a sudden heart attack. The deadman's system was designed to stop the train unless the train driver maintained continuous pressure on either a spring-loaded hand control or a foot pedal. The foot pedal was designed so that if too much or too little pressure was applied, the emergency brakes would be applied (Special Commission of Inquiry into the Waterfall Rail Accident, 2005).

It was clear from the investigation of the accident that the deadman's systems in the Waterfall train were not operating as the design intended. The deadman's was designed to 'turn off' and apply the brakes if a driver became incapacitated. Another key area to review was that this train was two man operation, in that a guard could have applied the emergency brakes.

11.1.4

Berajondo, Queensland

At 2355 Eastern Standard Time on 15 November 2004 the tilt train VCQ5 a 'down movement', derailed 419.493km from Brisbane (Roma Street), north of Berajondo on the Bundaberg to Gladstone line. The lead power car, No. 5403 and all remaining seven trailer cars derailed. The trailing power car No. 5404 was the only unit to remain substantially upright although the leading bogie set (in direction of travel) was partially derailed.

There were 157 passengers and crew on board the train. No one was fatally injured; however, there were some significant injuries (ATSB, 2004)

The drivers' cab consists of two compartments, the forward driving compartment and the rear vestibule containing tea/coffee making facilities. A doorway connects the two compartments. The co-driver told the investigation team that shortly after departing Berajondo he exited the drivers' compartment and entered the rear vestibule to make coffee (this is normal practice for two driver crews). While doing so, at approximately 2355, the tilt train VCQ5 derailed on the first of the 60km/h curves commencing at 419.411km, travelling at a speed recorded on the train's data logger of 112km/h (ATSB, 2004). This particular incident had two man operation and again it highlights that two man operation is not flawless.

12 **Appendix B**

12.1 GO/RT3251 Train Driving, Appendix A, Medical Standards