



INDEPENDENT
TRANSPORT
SAFETY AND
RELIABILITY
REGULATOR

Model of risks of driver incapacitation



Table of Contents

1	Introduction	3
	1.1 Background.....	3
	1.2 Structure of this report	3
2	Methodology	5
3	System Definition	6
	3.1 Definition of Driver Incapacitation	6
	3.2 Representative Rail User Groups	6
	3.3 Estimate of Train Kilometres for User Groups.....	7
	3.4 Driver Safety Systems	8
4	Likelihood Analysis.....	10
	4.1 Fault Tree Analysis	10
	4.2 Likelihood of driver incapacitation	10
	(a) Medical Incapacitation	11
	(b) Incapacitation due to fatigue	12
	(c) Incapacitation due to drugs or alcohol	13
	(d) Incapacitation due to missiles etc	13
	(e) Overall incapacitation rates.....	14
	(f) Failure of Driver Safety Systems.	14
	(g) Failure of Guards or others to take action.....	16
5	Escalation Analysis	18
	5.1 Average Consequences.....	19
6	Risk Results and Sensitivity Analysis.....	21
	6.1 Risk Results.....	21
	6.2 Sensitivity Analysis	24
7	Discussion and Conclusions	25

Model of risks of driver incapacitation



Summary

A model of the relative risks of driver incapacitation has been created that is representative of the types of railway operations in NSW and is sensitive to key parameters. While produced in a data-poor environment, sensitivity analysis has shown that only around a dozen parameters make a significant difference to results and these parameters are either uncertain by nature (and will always be difficult to quantify), or reasonably well understood. Further research should be preformed to reduce uncertainty in these key parameters.

The most significant contribution to driver incapacitation is due to fatigue and the model produced is sensitive to shift patterns.

For passenger services the model shows the combination of controls such as vigilance device, deadman device and train stops for trains on the RailCorp network reduce risks of incapacitation considerably. The most effective driver safety device is the vigilance system, which provides the bulk of the risk reduction. When considered relative to other categories of railway operations, passenger operations are one of the lowest risks according to the model. In particular when considered on a per track kilometre basis, passenger operations are the lowest category.

In combination the Freight categories of Metro freight, Interstate Freight, Grain Freight and Coal Freight operations show the highest relative risks of driver incapacitation on a total annual kilometre basis. However on a per kilometre basis Freight is relatively lower than Track Maintenance Vehicles. Freight operations have already adopted what appears to be the most effective currently available driver safety device for incapacitation which is vigilance controls, and back this up with a second person. This therefore highlights the need for the current arrangements provided for incapacitation for Freight operations, and if practical and cost effective additional controls are discovered they should be considered for adoption.

Track machines have been identified as often not having vigilance devices nor room for a second person. The absence of these controls is reflected in the risk results, with track machines the highest relative risks on a per kilometre basis. This suggests that operators of track machines should reconsider their risk assessments, consider networks minimum standards and look at what options for further risk reduction are available to them.

Model of risks of driver incapacitation



Tourist and Heritage operations on the main line have relatively low risks of incapacitation. Although this supports continuation of current practices, operators should monitor developments in driver safety technologies with a view to adopting practical and reasonable solutions should they emerge.

1 Introduction

1.1 Background

Waterfall SCOI recommendation 31 on Driver Safety Systems states:

“All trains must be fitted with a minimum of two independent engineering defences to minimise the risk of derailment or collision in the event of train driver incapacitation”

In their response the NSW government supported this principle for further review. ITSRR has clarified its expectation with the following:

“ITSRR currently requires through the existing accreditation process all driver-only trains (i.e. one person in the drivers cab) to be fitted with two independent engineering defences. ITSRR to develop and lead a review of the need for a second engineering defence in non-driver only trains.

ITSRR to establish position following review.”

Following this commitment to lead a review ITSRR has prepared a quantitative risk model to establish the relative risks of driver incapacitation for a range of different railway operations in NSW.

This report presents the risk model developed through this study, its results and what they suggest.

1.2 Structure of this report

Section 2 provides an overview of the methodology used in the study.

Model of risks of driver incapacitation



Section 3 of the report defines the system under analysis. It provides a short description of the nature of operations for eight types of rail user groups operating on NSW networks. For each user group it also establishes the type of measures that are in place to prevent, control or mitigate the risks of driver incapacitation.

Section 4 describes the analysis of the likelihood of driver incapacitation which is established through fault tree analysis. Parameters used in the fault tree analysis are described.

Section 5 describes the analysis of escalation of driver incapacitation events using event tree analysis. This shows how initial driver incapacitation events could ultimately lead to consequences such as collisions with other trains, derailments, striking of track gangs, collisions at level crossings, overturning etc.

Section 6 provides an analysis of the risks calculated using the models of fault tree analysis and event tree analysis. A sensitivity calculation is also performed to determine what parameters the model is most sensitive to.

In *Section 7* of the report the results are discussed and conclusions made.



2 Methodology

The intention of the model developed by ITSRR is to enable a comparison of the risks of driver incapacitation between different types of railway operations in NSW. This model has been developed in an information poor environment where data for a number of parameters relevant to the issue is not available. Additionally some aspects of the problem are very difficult to quantify as they are largely behavioural such as the probability a guard will identify driver incapacitation and take appropriate action. Even given some experiential data such parameters would remain very uncertain. As a result a technique has been followed where a robust logical model is developed and is quantified with a combination of robust data and group estimates.

The logic model developed is a combined fault and event tree, where the range and progression of events that must occur that lead to uncontrolled incapacitation (incapacitation of the driver and failure of driver safety systems to bring the train under control) is modelled using a fault tree. Then the escalation of the uncontrolled incapacitation event to a range of possible outcomes has been modelled using an event tree. The resulting logic model is applicable to all of the eight railway operation categories chosen to represent operations in NSW.

For each of the eight railway operation categories, the logic model has been populated with a combination of accurate data and estimates verified by a group voting technique. The model was tested to see if intermediate results (such as incapacitation rates) were close to the perceived experience. It was also tested to see if it gave expected results when parameters were varied –i.e. if the probability of a train stop functioning on demand increased, did risk subsequently decrease? A sensitivity analysis was performed to determine which parameters the model was most sensitive to.

The results of the model are in two forms. One is the relative risk between railway operation categories for the total number of train kilometres that each category covers each year. As the number of track kilometres increases the risk is expected to increase. The other result is relative risk between railway operation categories per track kilometre. It should be understood that the results of the model are to be viewed in relative terms as looking at absolutes is only meaningful once more accurate data is available.



3 System Definition

3.1 Definition of Driver Incapacitation

The working definition of driver incapacitation for this study is “a situation where the driver was unresponsive to the situation of the train for a period exceeding five seconds”. The types of driver incapacitation examined below include sleep, changed mental state due to drugs or alcohol, health conditions such as heart attacks, assault on the driver and driver suicide. This definition precludes events as micro-sleep and momentary attention distraction from the assessment scope.

3.2 Representative Rail User Groups

In order to model the risks of driver incapacitation eight separate user group categories were defined, with the aim of providing good representation of the specific types of railway operations on NSW networks. The eight user groups are defined as *Table 3.1*.

Table 3.1 Representative User Groups

Rail User Group	Definition
General Interstate and regional freight	General containerized freight outside of the RailCorp network with an interstate or regional destination. For the purpose of definition such operations involve the NSW safeworking methods such as Rail Vehicle Detection and Train orders or Electric staff in Non Rail Vehicle Detection Territory (as well as contingent safeworking operations - degraded working)).
Coal Freight	Coal freight in the Hunter Valley region but excluding coal coming onto the RailCorp network. For the purpose of representation the safeworking arrangements are predominately Rail Vehicle Detection (as well as contingent safeworking operations - degraded working).
Grain freight	Grain freight in NSW outside of the RailCorp metropolitan network. Operations will be on the regional country network and the DIRN. For the purpose of definition such operations will involve the NSW safeworking methods such as Rail Vehicle Detection and In Non Rail Vehicle Detection Territory safeworking methods will involve Train orders, Electric staff or Staff and Ticket (as well as contingent safeworking operations - degraded working).
Metropolitan Freight	Coal, Wheat, Minerals and General Container Freight on the RailCorp network. For the purpose of definition safeworking is Rail Vehicle Detection (as well as contingent safeworking

Model of risks of driver incapacitation

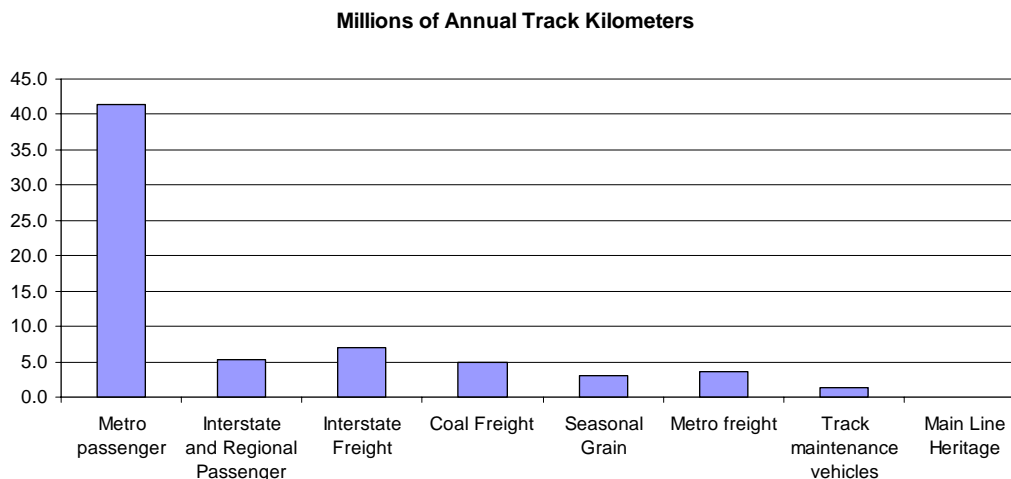


	operations - degraded working).
Metropolitan Passenger	Passenger services on the Railcorp network. For the purpose of definition safeworking is Rail Vehicle Detection (as well as contingent safeworking operations - degraded working).
Interstate and regional Passenger	CountryLink and other interstate passenger services outside of the RailCorp network. For the purpose of definition such operations will involve the NSW safeworking methods such as Rail Vehicle Detection and Train orders, Electric staff and Staff and Ticket in Non Rail Vehicle Detection Territory (as well as contingent safeworking operations - degraded working).
Track Maintenance Vehicles	All forms of track maintenance vehicles travelling on the three networks between work sites.
Main line Heritage	Tourist and Heritage operations on all three networks (Railcorp, DIRN and residual). For the purpose of definition locomotives are steam, as operations with diesel locomotives and railcars are considered to be covered in the "interstate and regional passenger" category.

3.3 Estimate of Train Kilometres for User Groups

An estimate of the annual train kilometres travelled by each of the 8 user groups in NSW is presented as *Figure 3.1*.

Figure 3.1 Estimate of Annual Train Kilometres





3.4 Driver Safety Systems

The driver safety systems (i.e. deadman, vigilance, 2nd person etc) considered in the model for each of the user groups are summarised as *Table 3.2*. This information is based on a survey completed by ITSRR in 2005, and RailCorp's Minimum Operating Standard for driver safety systems¹.

Table 3.2 Driver Safety Systems for Representative user groups

Rail User Group	Definition
General Interstate and regional freight	Non Speed Dependent Task linked or Time cycle vigilance Second person in cab Maximum time for brake penalty 94s
Coal Freight	Task linked or Time cycle vigilance Second person in cab Maximum time for brake penalty 94s
Grain freight	Non Speed Dependent Task linked or Time cycle vigilance Second person in cab Maximum time for brake penalty 94s
Metropolitan Freight	Non Speed Dependent Task linked or Time cycle vigilance Second person in cab Maximum time for brake penalty 94s
Metropolitan Passenger	Deadman pedal or handle Speed dependent Task linked vigilance Guard with emergency brake (not in cab) Trainstops (not provided at some signals) Maximum time for brake penalty 60s Minimum time for brake penalty 35s at > 110 km/hr
Interstate and regional Passenger	Deadman pedal or handle Task linked vigilance Guard with emergency brake (not in cab) Maximum time for brake penalty 60s Minimum time for brake penalty 35s at > 110 km/hr

¹ RailCorp, Rolling Stock Engineering Standards, Minimum Operating Standards for Rolling Stock RSS0001, Driver safety system, RSU Appendix D, Version 3.0 – October 2005.

Model of risks of driver incapacitation



INDEPENDENT
TRANSPORT
SAFETY AND
RELIABILITY
REGULATOR

Track Vehicles	Maintenance	Non Speed Dependent Task linked or Time cycle vigilance Maximum time for brake penalty 94s
Main line Heritage		Fireman Guard with emergency brake (not in cab)



4 Likelihood Analysis

4.1 Fault Tree Analysis

The likelihood of driver incapacitation events has been established through fault tree analysis. The fault tree has three main sub components:

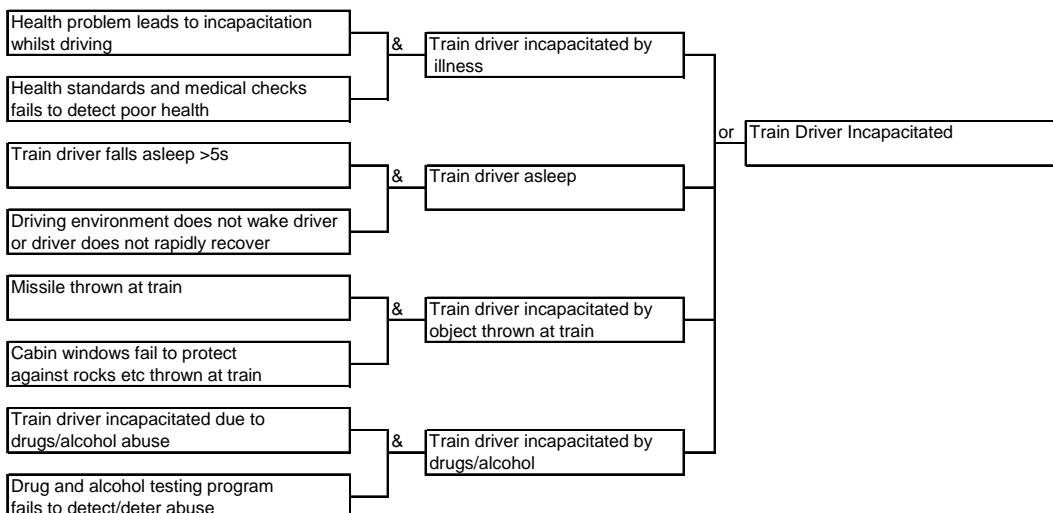
- Likelihood of driver incapacitation;
- Likelihood of driver safety devices failing to intervene following driver incapacitation and the train continuing to accelerate or coast; and
- Likelihood of guards or others failing to activate the emergency brake following driver incapacitation.

Explanation of the logic and data inputs to each of these components is provided under the following separate sub headings.

4.2 Likelihood of driver incapacitation

The section of the fault tree addressing the likelihood of driver incapacitation is shown as *Figure 4.1*. The Figure shows four causal areas of incapacitation of health problems, fatigue, missiles and drugs and alcohol.

Figure 4.1: Fault Tree Section on driver incapacitation



Model of risks of driver incapacitation



Quantification of the causes of incapacitation has been determined from a per driving hour basis. Estimates of the driving hours are based on the track kilometres estimate and an average speed estimate.

(a) Medical Incapacitation

For health problems leading to sudden medical incapacitation a rate of incapacitation per 100,000 driving hours has been determined based on medical data for airline pilots as presented by DeJohn et al² and Mitchell and Evans³. The most frequent categories of incapacitation identified in these studies were loss of consciousness, gastrointestinal, neurological, cardiac and urological. The rate calculated by DeJohn et al and other studies is presented as *Table 4.1*.

Table 4.1: Comparative rates of incapacitation

Source	Rate per 100,000 flight hours	Data period
DeJohn et al –US civil pilots	0.045	1993 to 1998
Martin-Saint-Laurent et al, Air France pilots and flight engineers *	0.044	1968 to 1988
U.S. Air Force	0.019	1978 to 1987
Mitchell & Evans – UK civil pilots	0.014	1990 to 1999

* includes some events that would be categorized as “impairments” rather than “incapacitations”

As the DeJohn work is expressed as a rate per 100,000 driver hours it was necessary to determine an estimate of the driver hours for each type of train operation category. This was done by determining an average speed for each train operation category from timetables, section running times and estimates. This average speed is the total time taken to cover a certain distance, so includes time stopped at signals and stations etc.

² DeJohn, C.A Wolbrink, A.M, Larcher J.G, “In-Flight Medical Incapacitation and Impairment of US Airline Pilots: 1993 to 1998, October 2004, US Department of Transportation, Federal Aviation Administration.

³ Mitchell, S.J and Evans, A.D, “Flight Safety and Medical Incapacitation Risk of Airline Pilots”, Aviation, Space and Environmental Medicine, Volume 75, No. 3, March 2004.

Model of risks of driver incapacitation



Amongst the Transport Safety Board of Canada's reportable incident categories for railways is the category "Crew Member Incapacitated". This is defined as "any crew member whose duties are directly related to the safe operation of the rolling stock is unable to perform the crew member's duties as a result of a physical incapacitation that poses a threat to the safety of any person, property or the environment". For the period 2000 – 2004 a rate of 0.026 per million train kilometres can be calculated from the recorded data. This compares favourably to the DeJohn et al rate (when converted to per train kilometres for RailCorps passenger operations) of 0.012 per million train kilometres.

(b) Incapacitation due to fatigue

The work of Harma et al⁴ on the effect of shift systems on sleepiness at work in train drivers and railway traffic controllers provides percentages of occurrence of "severe sleepiness" for shift categories of night, early morning and day. In this study "severe sleepiness" was defined as the Karolinska Sleepiness Scale rating of 7 or greater. The Karolinska Sleepiness Scale (KSS) is presented as *Table 4.2*. The occurrences of severe sleepiness are presented as *Figure 4.2*.

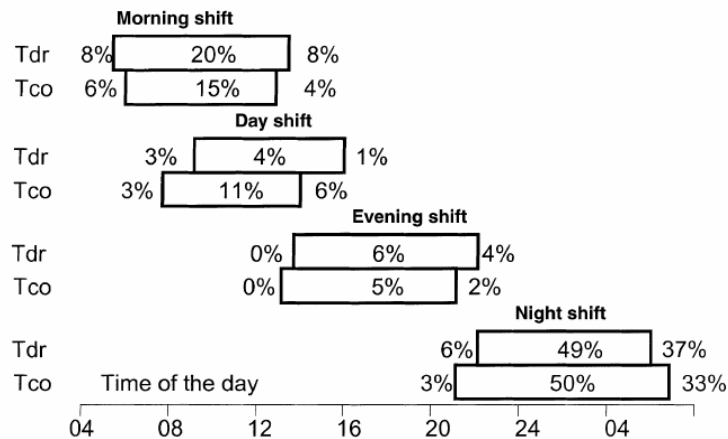
Table 4.2 Karolinska Sleepiness Scale

- 1) extremely alert
 - 2) very alert
 - 3) alert
 - 4) rather alert
 - 5) neither alert nor sleepy
 - 6) some signs of sleepiness
 - 7) sleepy, but no effort to keep awake
 - 8) sleepy, some effort to keep awake
 - 9) very sleepy, great effort to keep awake, struggling against sleep
 - 10) extremely sleepy, can't keep stay awake
- (from Akerstedt 1990)

⁴ Harma M, Sallinen, M, Ranta R, Mutanen P and Muller K, "The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers", *Journal of sleep research*, Vol 11, pp 141-151, 2002



Figure 4.2 The occurrence of severe sleepiness (KSS 7 or higher)¹



The occurrence of severe sleepiness or greater was converted to annual rates of severe sleepiness or greater by estimating the proportion of day, evening, night and morning shifts for each rail user category. Given rates of severe sleepiness or greater, the proportion of these events that lead to “dozing off” has been estimated, based on the research of Sallinen et al⁵. This ultimately produced a rate of fatigue related incapacitation, that is sensitive to shift patterns.

(c) Incapacitation due to drugs or alcohol

Incapacitation due to drug or alcohol use was assumed to occur at an equivalent rate to medical incapacitation.

(d) Incapacitation due to missiles etc

ITSRR collects data on incidents of missiles being thrown at trains or objects positioned in the train path. These incident reports were distributed amongst the operator categories in proportion to annual track kilometres. A probability was estimated for driver windscreens and cab failing to protect drivers from missiles and objects.

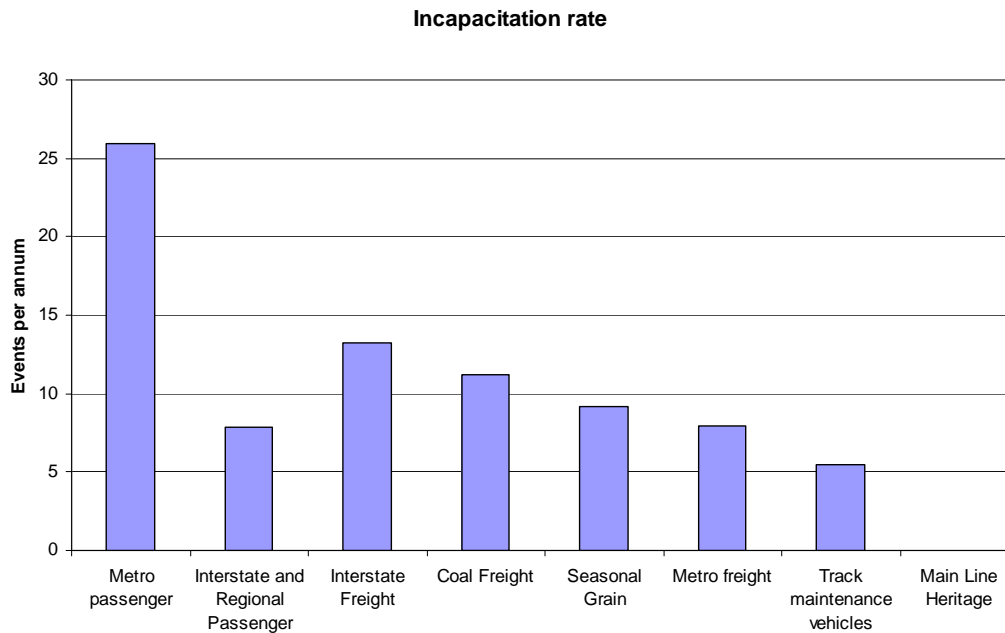
⁵ Sallinen M, Harma M, Mutanen P, Ranta R, Virkkala J and Muller K, “Sleep –wake rhythm in an irregular shift system”, Journal of Sleep Research, Vol 12, pages 103-112, 2003



(e) Overall incapacitation rates

A comparison of the incapacitation rate between the different operator categories calculated using this section of the fault tree is shown as *Figure 4.3*. A useful validation exercise would be to determine if operators are experiencing incapacitation events at rate comparable to what the model is predicting. An indication of such rates could be how often penalty braking events occur for vigilance devices.

Figure 4.3: Comparison of incapacitation rates between operator categories

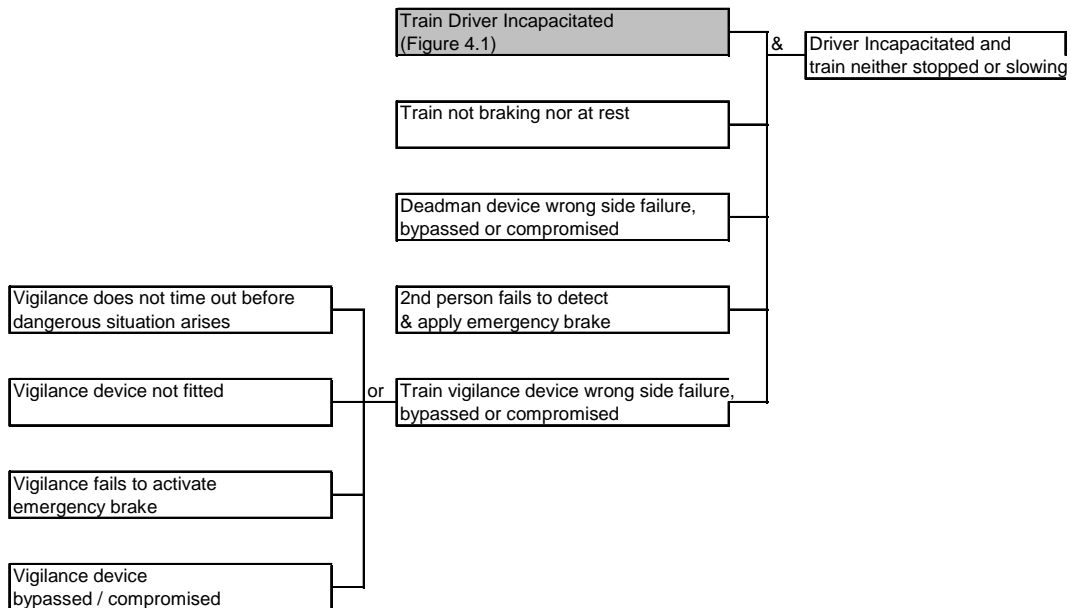


(f) Failure of Driver Safety Systems.

The section of the fault tree addressing the likelihood of driver safety systems failing following driver incapacitation is shown as *Figure 4.4*.



Figure 4.4: Fault Tree Section on failure of Driver Safety Systems



An explanation of the inputs to this section of the fault tree follows:

- “Train not braking nor at rest” accounts for where incapacitation may occur when the train is stopped or is braking which in most circumstances should lead to a safe situation.
- “Deadman device wrong side failure, bypassed or compromised” allows for situations where the device fails to activate the emergency brake when required, where the device has been bypassed by propping the pedal down or where the device is compromised by poor design. The major failure mode for foot pedals is where driver weight may result in their legs being heavier than the return force of the pedal.
- “2nd person fails to detect and apply emergency brake” applies to operations where a second person is present and they fail to detect driver incapacitation or fail to take appropriate action.
- “Vigilance does not time out before dangerous situation arises” allows a factor for the vigilance system not intervening before a dangerous situation, such as signal with a restrictive aspect (eg at stop) or a sudden speed restriction is encountered.
- “Vigilance device not fitted” accounts for the proportion of rollingstock without a vigilance device.

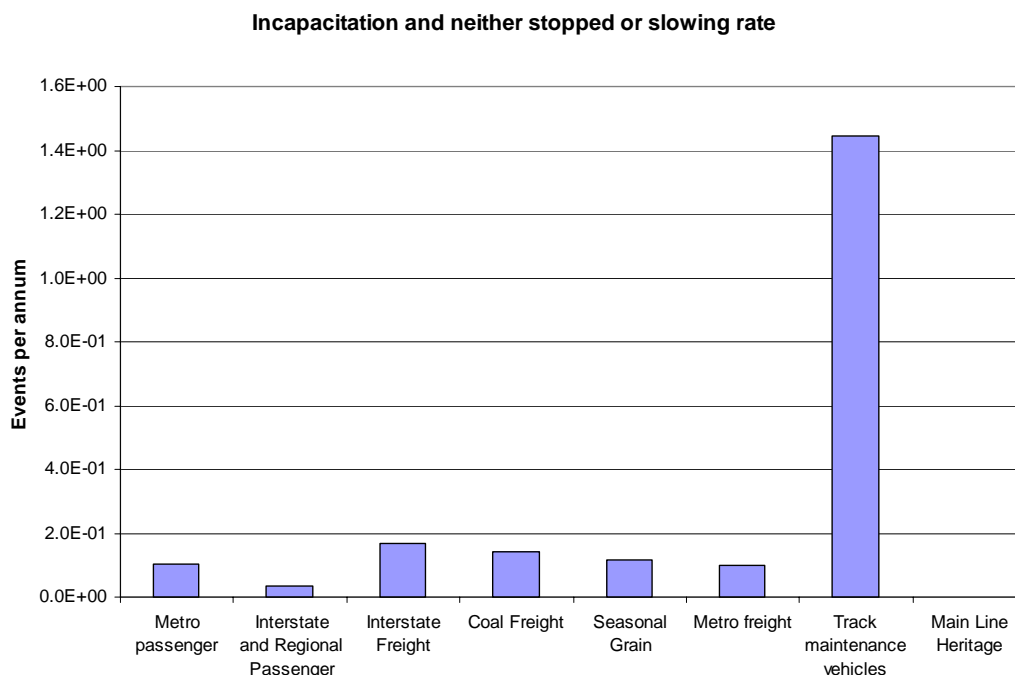
Model of risks of driver incapacitation



- The input “Vigilance fails to activate emergency brake” accounts for a system failure where given an incapacitation event, a fault in the system leads to it not activating the emergency brake.
- “Vigilance bypassed / compromised” accounts for a case where the device has been compromised through tampering or some artificial aid.

A comparison of the incapacitation rate between the different train operation categories calculated using this section of the fault tree is shown as *Figure 4.6*. This figure shows track machines having a high rate of incapacitation with the vehicle not stopped or slowing, which is mostly attributable to their low level of installation of driver safety systems. Also note that passenger services which have high relative base incapacitation rates have dropped considerably due to the influence of the two independent safety systems provided.

Figure 4.6: Comparison of incapacitation and neither stopped or slowing rates between operator categories

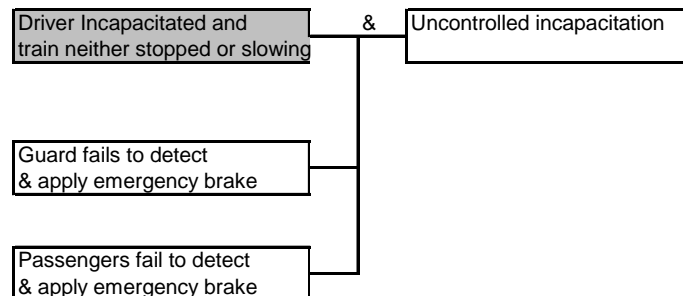


(g) Failure of Guards or others to take action

The last section of the fault tree models the possible intervention by guards or others following driver incapacitation and failing to stop or slow. The relevant section of the fault tree is shown as *Figure 4.7*.



Figure 4.7: Fault Tree Section on failure of Guards or others to take action



In cases where there is a guard, an input has been provided for the probability that the guard will detect there is a problem with the train and so activate the emergency brake. While the fault tree considers the possibility that passengers will activate the emergency brake, this functionality is not present on RailCorp passenger trains, so its value is set to one, removing its influence.

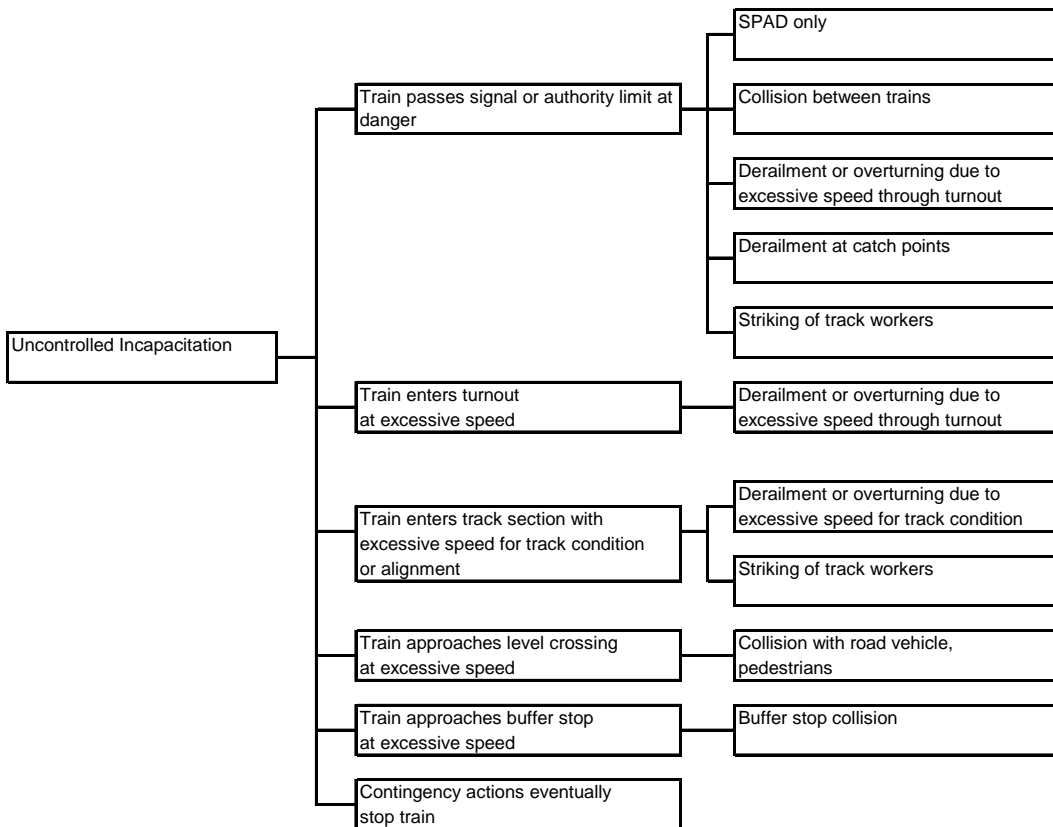
The “top event” of the fault tree is “uncontrolled incapacitation” as incapacitation has occurred and it has not been brought safely under control. Now the train is potentially travelling at excessive speed for an approaching signal, authority limit, track condition, turnout, level crossing, buffer stop, track gang etc. From this point onward outcomes are calculated using event tree analysis.



5 Escalation Analysis

This section describes the analysis of escalation of events following the top event established in the likelihood analysis. It considers a number of outcomes that could result following driver incapacitation and failure of driver safety systems to bring the situation safely under control (uncontrolled incapacitation). The pathways and outcomes considered that the uncontrolled incapacitation event could escalate to are shown as *Figure 5.1*.

Figure 5.1: Escalation pathways and outcomes following incapacitation and failure of driver safety systems



It should be understood that the train is not restricted to following just one accident sequence and could follow a number of pathways before an incident eventuates. For example following incapacitation the train could pass a signal at danger without colliding with other trains or track workers or derailing, pass through a turnout without derailing or overturning, pass through a number of track sections requiring a speed reduction without derailing or overturning, approach a level crossing at excessive speed but still fail to collide with road vehicles or pedestrians before reaching a

Model of risks of driver incapacitation



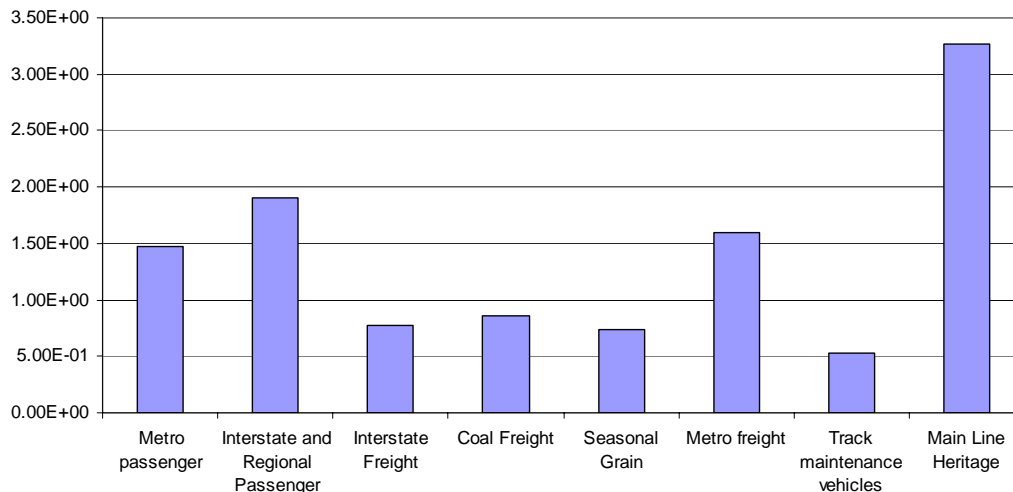
terminal and colliding with a buffer stop. The event tree used to model the possible outcomes of incapacitation and failure of driver safety systems allows for such possibilities, but does not consider variations in the order of events (a time dependence limitation of event trees). More sophisticated simulation, if warranted, could address this short coming.

5.1 Average Consequences

Given an outcome such as a collision, derailment, buffer stop collision etc average fatalities for the outcome have been determined, recognizing that in some cases higher impacts may result and in other cases lower impacts will result. The values for metropolitan passenger services are based on the study by Qest consulting for StateRail⁶, which have then been modified for the user groups other than metropolitan passenger services.

Combining the event tree split fractions and the consequences for each type of event tree outcome provides a combined average consequence for each type of railway operation category. This is presented as *Figure 5.6*.

Figure 5.6: Combined Average Consequence Given Uncontrolled Incapacitation



Examination of *Figure 5.6* shows that according to the model Tourist and Heritage operations will lead to the highest fatalities following uncontrolled incapacitation. This can be explained by the incompatibility of rollingstock with train stops, crash worthiness, carriage of passengers, and operation

⁶ Qest Consulting Engineers, "Risk Assessment of Train Protection Systems for StateRail", Rev B, November 3, 2003.

Model of risks of driver incapacitation



INDEPENDENT
TRANSPORT
SAFETY AND
RELIABILITY
REGULATOR

on metropolitan networks. Metro Freight average consequences also are high, due to incompatibility of rollingstock with train stops and operation on metropolitan networks with passenger services. Metro Passenger is lower than Country passenger due to the influence of train stops in RailCorp's Network. Non metro freight is lower in consequence primarily due to less passenger traffic and freight trains only having crews of two.

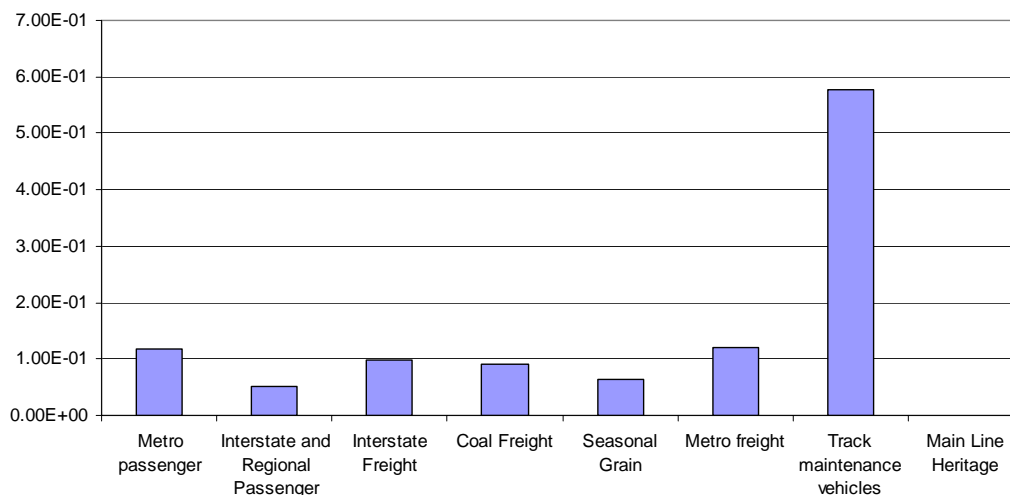


6 Risk Results and Sensitivity Analysis

6.1 Risk Results

The likelihood of uncontrolled incapacitation determined by fault tree analysis and its possible consequences determined by event tree analysis have been combined to give an indication of relative risks of each type of railway user categories according to the total train kilometres each group covers in NSW each year. These relative risks are presented as *Figure 6.1*.

Figure 6.1: Relative Risks of incapacitation each user category



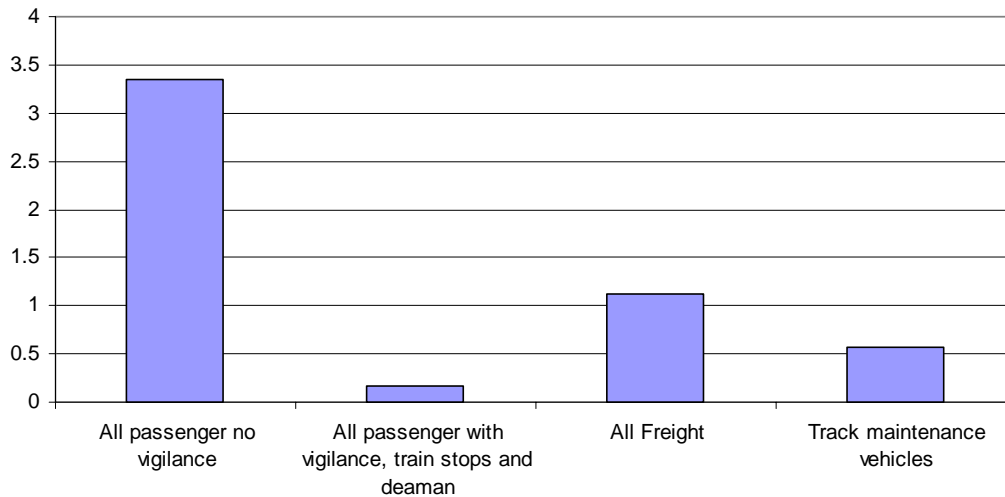
Relative to other risks track maintenance vehicles are significantly higher, which is primarily due to some of these vehicles not being provided with driver safety devices and not having a second person. Each of the Freight operation categories are relatively low, but when combined become a larger risk than track maintenance vehicles, as Shown by *Figure 6.2*.

The relative risk of passenger railway operations in NSW without vigilance devices is also shown on *Figure 6.2*. It can be seen that this is far higher than Freight operations, and that according to the model, the introduction of vigilance devices to passenger services has produced a significant risk reduction. Therefore the relatively higher risks of the combined Freight operations should be viewed in the context that until recently passenger services without vigilance were a much greater contributor to risk.

Model of risks of driver incapacitation

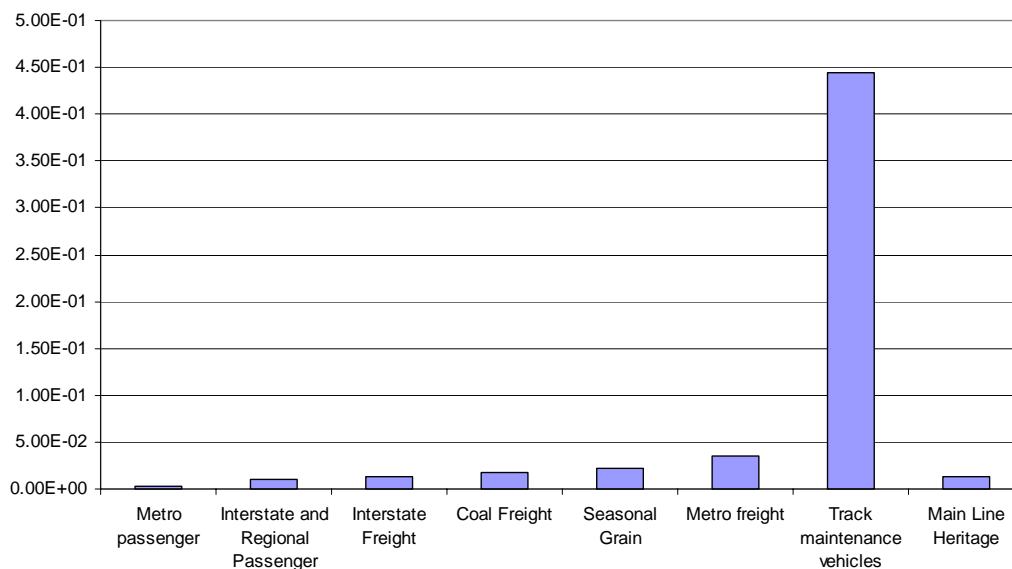


Figure 6.2 Relative risks of Passenger, Freight and Track Maintenance operations.



A comparison of risks per million train kilometres for the 8 representative operator groups is shown as *Figure 6.3*. A similar pattern to *Figure 6.1* appears differing with a higher contribution by Tourist and Heritage operations on the main line. This can be attributed to Tourist and Heritage being more vulnerable given an uncontrolled incapacitation event largely due to it carrying passengers and not compatible with train stops.

Figure 6.3: Relative incapacitation risk per million train kilometres



On a per million train kilometre basis Track Maintenance vehicles are relatively a higher risk than the total combined freight risk, which is not the

Model of risks of driver incapacitation



INDEPENDENT
TRANSPORT
SAFETY AND
RELIABILITY
REGULATOR

situation on a total annual kilometres basis, where freight is a relatively higher risk.

The guidance of the model suggests that track maintenance vehicles are currently a high contributor to risk, both in terms of annual train kms and per million train km basis. As the risk of the combined freight categories is significantly lower on a per million kilometre basis it is of less concern, even though in terms of total risk it is the greatest contributor. The combination of freight operations being the highest contributor is a recent situation as previously passenger services without vigilance devices were a far greatest risk, according to the model.



6.2 Sensitivity Analysis

Analysis has been performed to determine which of the total 45 parameters the model is most sensitive to. The results of this analysis are summarized as *Table 6.1*. Note that the most sensitive parameters are either numbers that are well understood and therefore reasonably certain, or numbers that will always be very uncertain regardless of the amount of data available. This is encouraging as it suggests that estimates of a few uncertain and difficult to measure numbers in combination with that already measured can provide a good appreciation of driver incapacitation risks.

Table 6.1: Top 15 Most Sensitive Parameters

ID	Parameter
22	Train stop present, rolling stock compliant, train stop functions
11	Vigilance does not time out before train encounters dangerous situation
15	Train not braking nor at rest
16	Deadman device wrong side failure, bypassed, compromised
17	2nd person fails to detect & apply emergency brake
18	Guard fails to detect & apply emergency brake
19	Passengers fail to detect & apply emergency brake
5	Train driver falls asleep >5s
6	Driving environment does not wake driver or driver does not rapidly recover
12	Vigilance device not fitted
32	Train overturns or derails due to excessive speed
39	Average Consequences for Overturn
27	Train nearby in adjacent block to SPAD
40	Average Consequence for Collision between trains
20	Train passes signal or authority limit at danger



7 Discussion and Conclusions

A model of the relative risks of driver incapacitation has been created that is representative of the types of railway operations in NSW and is sensitive to key parameters. While produced in a data-poor environment, sensitivity analysis has shown that only around a dozen parameters make a significant difference to results and these parameters are either uncertain by nature (and will always be difficult to quantify), or reasonably well understood. Further research should be preformed to reduce uncertainty in these key parameters.

The most significant contribution to driver incapacitation is due to fatigue and the model produced is sensitive to shift patterns.

For passenger services the model shows the combination of controls such as vigilance device, deadman device and train stops for trains on the RailCorp network reduce risks of incapacitation considerably. The most effective driver safety device is the vigilance system, which provides the bulk of the risk reduction. When considered relative to other categories of railway operations, passenger operations are one of the lowest risks according to the model. In particular when considered on a per track kilometre basis, passenger operations are the lowest category.

In combination the Freight categories of Metro freight, Interstate Freight, Grain Freight and Coal Freight operations show the highest relative risks of driver incapacitation on a total annual kilometre basis. However on a per kilometre basis Freight is relatively lower than Track Maintenance Vehicles. Freight operations have already adopted what appears to be the most effective currently available driver safety device for incapacitation which is vigilance controls, and back this up with a second person. This therefore highlights the need for the current arrangements provided for incapacitation for Freight operations, and if practical and cost effective additional controls are discovered they should be considered for adoption.

Track machines have been identified as often not having vigilance devices nor room for a second person. The absence of these controls is reflected in the risk results, with track machines the highest relative risks on a per kilometre basis. This suggests that operators of track machines should reconsider their risk assessments, consider networks minimum standards and look at what options for further risk reduction are available to them.

Model of risks of driver incapacitation



INDEPENDENT
TRANSPORT
SAFETY AND
RELIABILITY
REGULATOR

Tourist and Heritage operations on the main line have relatively low risks of incapacitation. Although this supports continuation of current practices, operators should monitor developments in driver safety technologies with a view to adopting practical and reasonable solutions should they emerge.