

Human factors analysis  
of bus rollaways



# Executive summary

## Background

A bus rollaway can be considered the “uncontrolled movement of a bus due to gravity or the motive power of the engine”.

In Victoria, 47 bus rollaways have occurred since 2000 resulting in minor injuries to drivers and passengers, and damage to infrastructure and vehicles. Interstate, bus rollaways have resulted in driver fatalities.

Recognising the risk bus rollaways pose to bus safety, TSV has undertaken a project working with industry to identify ways to eliminate or minimise the risks. This document is the result of that project.

## Aim

The aim of this document is to assist industry to build its capacity to manage the safety risks arising from bus rollaways. This document brings together information from researchers, operators, manufacturers and industry associations and discusses tools and methods that can be applied to manage bus rollaway risks.

## Key findings

The key findings are:

- incident data suggests that rather than technical factors, bus rollaways have been the result of human actions and inactions
- risks posed to each operator from bus rollaways depend on several aspects including fleet size, bus types and scope of operations; these factors vary considerably amongst Victorian operators
- applying human factors<sup>1</sup> tools, methods and standards will help manage these human risk issues and ensure that the risks of bus rollaways posed to each operator is controlled and managed effectively.

## Suggestions

The key suggestions are:

- know what type of rollaway your bus is vulnerable to and where the higher risk operations are for example, shopping centres and depots
- use the human factors tools, methods and standards discussed in this guide to manage errors and violations that cause bus rollaways.

Experience in other industries (including aviation, nuclear and healthcare) has shown that applying human factors is likely to result in significant benefits for bus users and operators. These benefits include increased comfort, productivity and safety, and reduced likelihood of human error.

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<sup>1</sup> The scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applied theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

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# Introduction to human factors / ergonomics

## Why human factors?

Human errors, performance capabilities and limitations appear to contribute to bus rollaways (see sections 2 and 3). As human factors is an area of knowledge dedicated to understanding how to manage these risks/issues, it has been applied in this analysis.

## Definition of human factors

The International Organisation for Standardization (ISO) provides the following definition of human factors (also referred to as ergonomics):

“The scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.”

The International Ergonomics Association uses the same definition.

Human factors is considered a mix of engineering and psychology: understanding human performance capabilities and limitations (psychology) and taking these into account when designing tools, procedures, equipment and controls (engineering).

### Aim of human factors

- > reduce error
- > increase comfort
- > increase productivity
- > increase safety

The diagram below shows the aims of human factors which include:

- understanding the performance capabilities and limitations of people, for example, fatigue, vigilance, memory, concentration
- understanding the interactions between the person and other elements of the system for example, tasks, products, procedures, environment
- applying human factors tools and methods to understand the system
- undertaking these activities with the aim of reducing error, and increasing comfort, productivity and safety.



### **Human factors: a profession with tools, methods and standards**

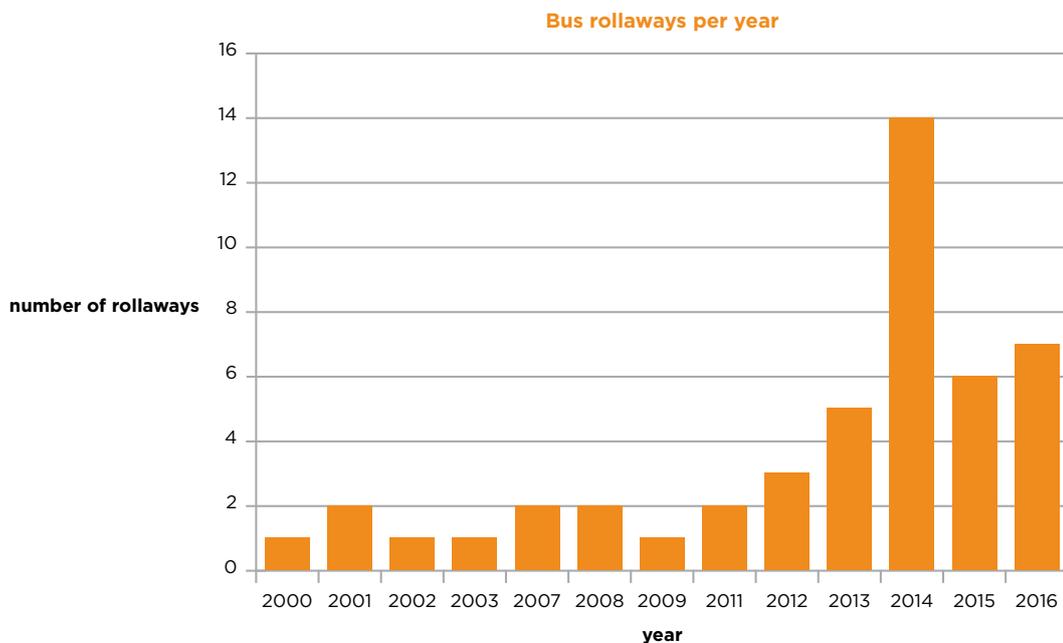
Like engineering, human factors/ergonomics is both a science and a profession. It is a science in which human factors researchers conduct experiments to understand human performance capabilities and how design can take these into account. See for example, the scientific journals *Human Factors* and *Applied Ergonomics*. It is also a profession with ergonomists or human factors specialists who apply tools, methods and standards to design things which are 'human centred'.

# Bus rollaway statistics

## Bus incidents, rollaways and TSAARS

TSV captures all reportable occurrences via the Transport Safety Accreditation Audit and Reporting System ('TSAARS')<sup>2</sup>. From 8 November 1999 to 22 August 2016, there have been 3,332 bus incidents recorded in TSAARS.

Since the first incident recorded on 30 August 2000 to the latest on 15 August 2016, there have been 47 bus rollaways. The data shows a upwards trend of bus rollaway incidents, year-on-year.



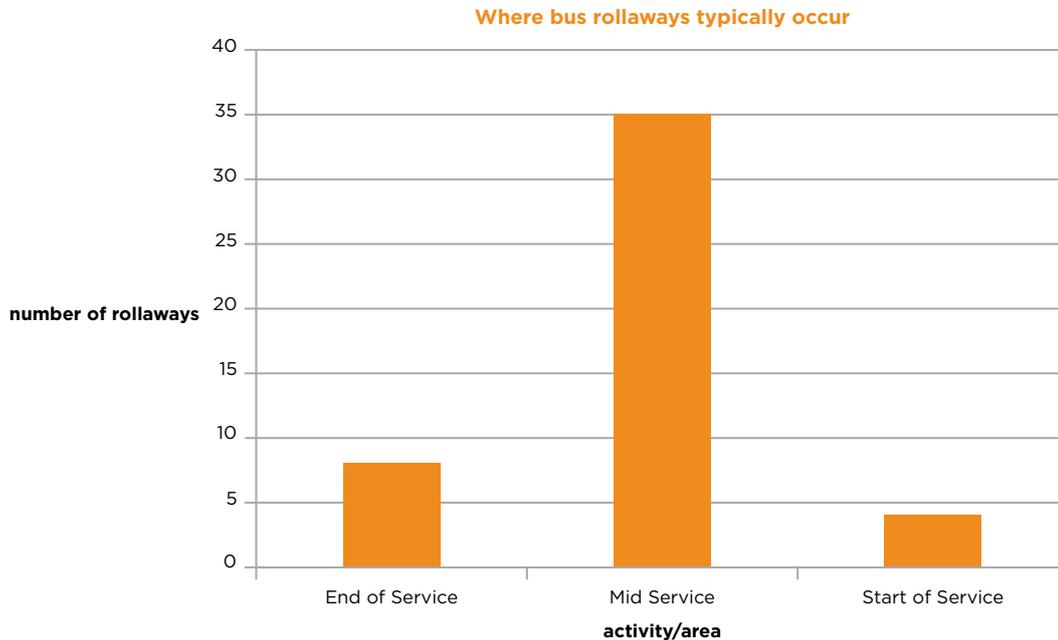
<sup>2</sup> Incidents reported to Bus Safety Victoria must be reported using the *Approved Form* as per Regulation 24 of the *Bus Safety Regulations 2010*.

## Where do rollaways typically occur?

Most rollaways occur within the depot but also occur at shopping centres and terminus'. In the chart below, 'Location' refers to an area of interest such as a school or tourist attraction, 'Road' refers to an insignificant area where a bus has simply broken down.

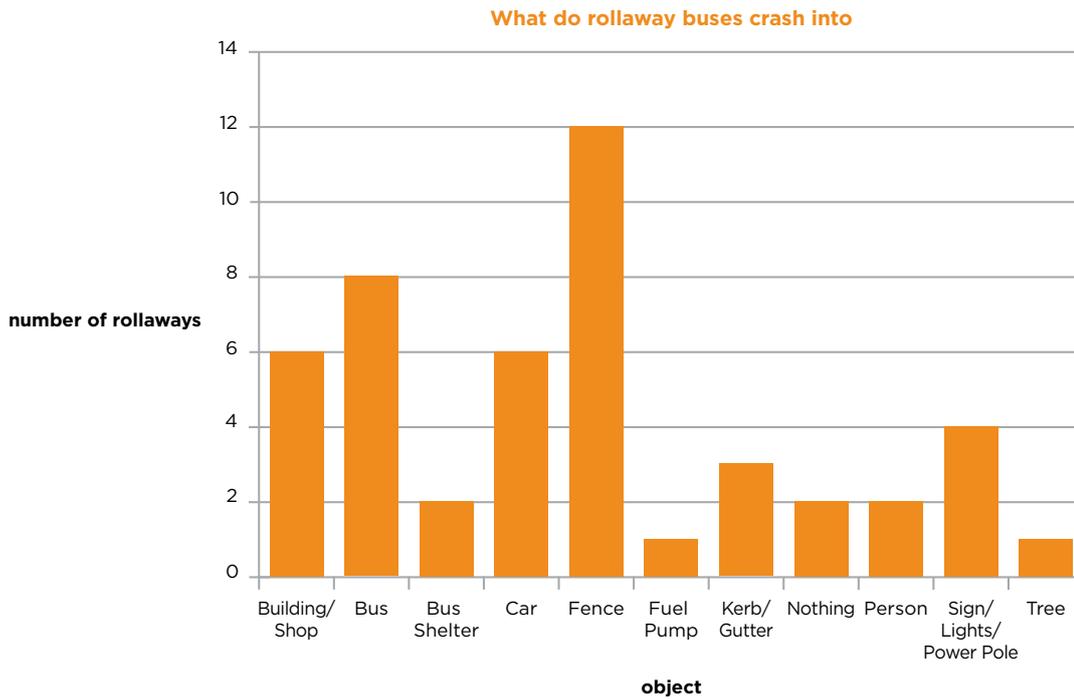


Most bus rollaways occur mid-service, such as when the driver is taking a break. However, they also occur during start up (pre-trip inspections) and at the end of the shift, for example, during the night when the bus is cleaned.



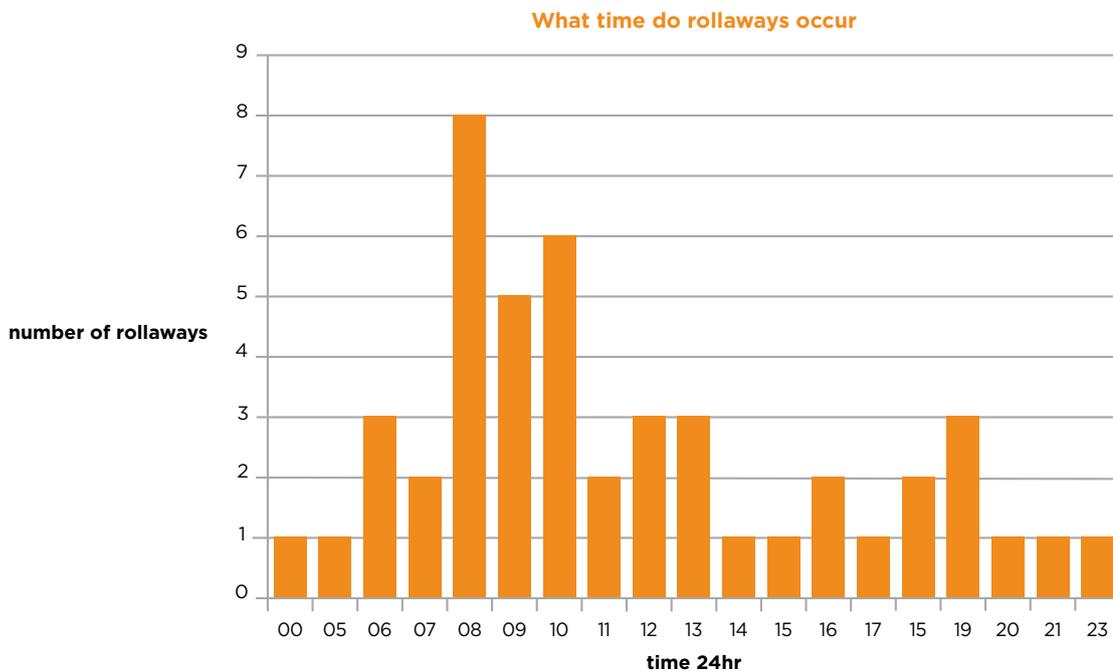
## What do rollaway buses crash into?

The data shows rollaway buses crash into fences (whether at the depot or of a house). Those buses stopped by 'nothing' do not hit anything because someone has pressed the door open button or activated the park brake, or the bus has stopped because of the slope of the road.



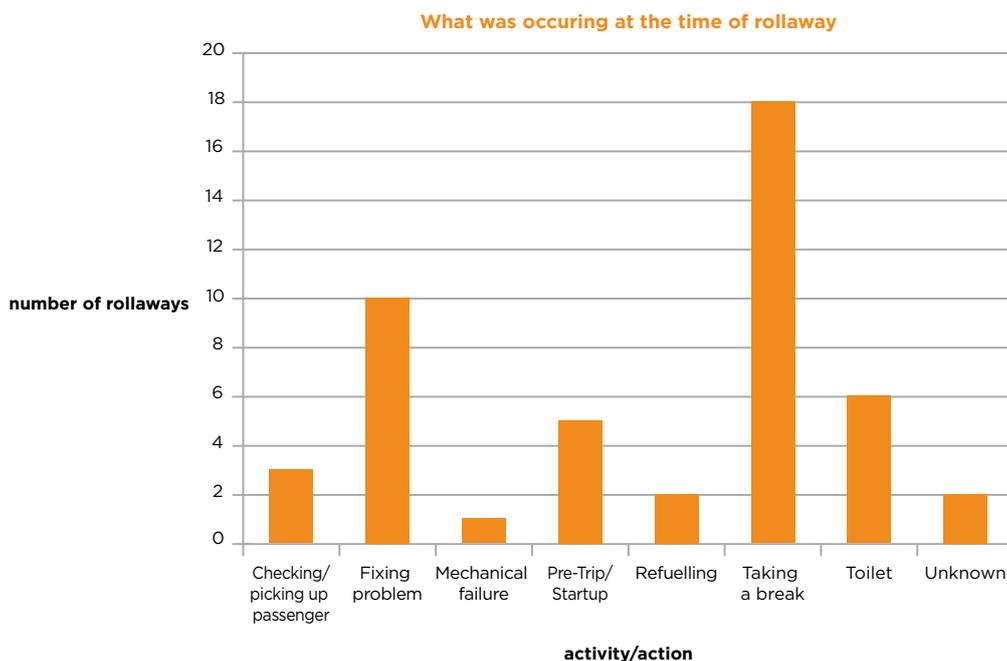
## What time of day do incidents typically occur?

The three hours from 8-11am account for 40 percent of all bus rollaways. The five hours from 7-11am account for 50 percent of all bus rollaways.



## What was occurring at the time of the rollaway?

Most rollaways occur when the driver is taking a break (38 percent) or when the driver is fixing a problem (21 percent). Twelve percent of incidents have occurred because the driver had an urgent need for the toilet.



## How do rollaways typically occur?

### The 'Toilet' incident

Drivers are in need of the toilet and, at the bus stop, they leave the bus running, open the doors using the door console buttons and exit the bus. In their hurry, the park brake is not applied.

If the bus is in neutral and on a gradient, it rolls away. If the bus is in drive, it drives away. There would usually be a three second delay after the doors are closed before the bus rolls away.

### The 'Break' incident

Drivers are taking a break during their shift. They stop at a terminus, for example, a shopping centre. The driver then steps out of the bus and in the process, the park brake is not applied.

The driver walks to the side window, reaches through and closes the doors. If this occurs, the following may result:

- if the bus is in drive, the bus rolls away and may pull the driver, with his hand through the window, with it
- if the bus is in neutral, the bus may roll away if on an incline or decline

It should be noted that drivers have been injured trying to stop the bus by pressing the external open/close door buttons.

### The 'Finish' incident

The driver parks the bus at the depot, does not apply the park brake and switches off the engine. The driver steps out of the bus and closes the doors using the outside door buttons. Once the doors close, the service brake is released. With the engine off however, the park brake will be engaged since there is no air in the brake chamber to cage the spring brake.

The next morning, the oncoming shift driver opens the doors using the outside door buttons and starts the bus. The driver does not realise that the park brake has not been applied. Waiting for the Myki machine to turn on and the bus air-conditioning/heating to reach the set temperature, the driver steps out of the bus and closes the door using the external open/close door buttons. From here, the following can occur:

- once the air pressure builds up and reaches normal bar pressure, the park brake deactivates because the air pressure cages the spring
- with the bus in either neutral or drive, it rolls away
- on buses with a broms brake fitted, the broms brake will pop out preventing air from filling the park brake chamber; this broms brake must be pressed before air enters and therefore cages the spring brake.

### The 'Fixit' incident

In this situation, there is an issue with the bus, for example, noises coming from the engine; ignition not working. The driver may have also stopped the bus to check for something on the road next to the bus stop.

In trying to diagnose the problem, either the driver or mechanic turns on or off several components in an attempt to diagnose or correct the fault. The bus may be alarming (both auditory and visual) which adds urgency to diagnosing the problem.

To diagnose the problem, one of the things that is attempted is activating or deactivating the park brake.

Through the process of diagnosing, the driver may move out of the drivers cab and go to the back of the bus or try the open and close external door switches.

Depending whether it is in on or off, with the door closed, the bus may then either drive away, or roll forward or backward. This can occur also on relatively flat ground some minutes later with wind assistance and with the driver further away from the bus.

# Why do drivers not apply the park brake?

Rollaways occur when the park brake is not applied. The real question is *why* do drivers not apply the park brake? This section highlights some of the factors that contribute to this situation.

## Known factors

### Violations

Violations are deliberate deviations from safe operating procedures, standards or rules<sup>3</sup>.

Rollaways have occurred when drivers put their hand through the driver's side window to close the door. This triggers the bus doors to close, releasing the service brake interlock. If the park brake has not been applied, a rollaway can occur.

### Urinary urge

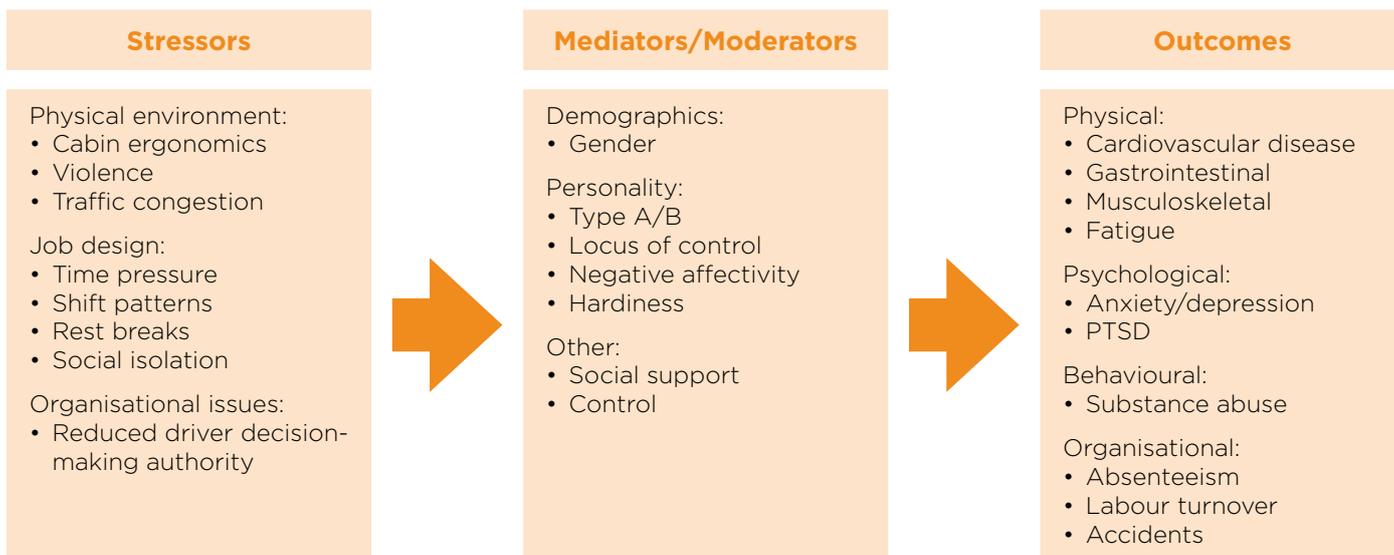
Research has found that urinary urge impairs attentional memory, working memory<sup>4</sup>, and concentration<sup>5</sup>. Reported incidents have occurred where the driver had severe urinary urge and, in the process, did not apply the park brake before leaving the bus.

## Other factors

The incident data does not provide sufficient information to conclusively determine what factors were involved. However, based on research, it is suggested that the following are likely to be contributing factors to bus rollaways:

### Predisposed illnesses associated with the occupation of bus driving

A UK study published in 2006 reviewed research on bus driver wellbeing over the last 50 years<sup>6</sup>. Drivers were found to be predisposed to ill-health including: fatigue, cardiovascular disease, gastrointestinal and musculoskeletal disorders. The stressors that contribute to these health effects, such as increased traffic and violence from passengers, were found to be increasing. The result of these ill-health effects, such as pain or discomfort experienced from cardiovascular disease and musculoskeletal disorders, result in increased fatigue and reduced concentration. The Figure below shows how the stressors of the job (time pressures, traffic congestion) and mediators (hardiness of drivers) contribute to ill-health outcomes which in turn can contribute to reduced concentration and fatigue.



Key to job stressors, mediating/moderating variables, and outcomes of occupational stress for bus drivers.

In terms of bus rollaways, it may be that drivers involved in rollaways have some of these illnesses. As result, they may experience discomfort or pain which expresses itself as fatigue and thus reduced concentration. Both these factors increase the likelihood of the driver forgetting to apply the park brake.

3 Reason, J, 1997, Managing the risks of organizational accidents, Ashgate, Farnham, p. 72.

4 Lewis, MS, et al. 2011, 'The effect of acute increase in urge to void on cognitive function in healthy adults', Neurourology and Urodynamics, vol. 30, pp. 183-187.

5 Fultz N et al. 2005, 'Prevalence, management and impact of urinary incontinence in the workplace', Occupational Medicine, vol. 55, pp. 552-557.

6 Tse, JLM, Flin, R, Mearns, K, 2006, 'Bus driver well-being review: 50 years of research.' Transportation Research Part F: Traffic Psychology and Behaviour, vol. 9, pp. 89-114.

## Fatigue

Fatigue contributes to lower concentration and can increase likelihood of errors. This can include responses becoming mistimed (right action but at the wrong moment) and taking longer to respond to tasks.

The Centre of Accident Research and Road Safety – Queensland (CARRS-Q)<sup>7</sup> found that drivers awake for 17 hours have a driving ability equivalent to a blood alcohol concentration of 0.05. After 21 hours awake, this is equivalent to a BAC of 0.15.

Several factors, found as part of bus driving (on-the-job-factors), contribute to fatigue. A study<sup>8</sup> of Australian metropolitan bus drivers found that the following factors can contribute both positively and negatively to fatigue:

- support from management: how well drivers are supported by managers was seen to determine how much stress drivers feel and thus how fatigued they were
- ticketing and policing: policing passenger entry, checking concessions, handling cash, and the competing priorities to 'get moving' versus policing ticketing and passenger behaviour
- cabin ergonomics: heat and glare, noise and exposure to passenger violence, thermostatic control of driver cabin, and neck, shoulder or back pain associated with layout
- tight route schedules
- distractions and acute stress from interactions with passengers: requests for directions and aggressive passengers (verbal or physical)
- turn-around and shift regularity
- extended shift cycles
- interactions with road users: stress from maintaining route schedules; maintaining safety in the face of unpredictable driver behaviour
- extended commute times: long driver commuting times and distances from home to their place of work.

## Mental wellbeing

Research has found that distraction resulting from depression or mental wellbeing issues can have a significant effect on concentration. A study<sup>9</sup> of 28,902 workers in the US found that most common health conditions—allergic rhinitis (hay fever), migraine and depression—contributed to the largest proportion of lost productive time at work. They found that 71 percent of the lost productive time while at work could be accounted for from workers' health conditions. Hemp (2004)<sup>10</sup> also found that this presenteeism (being at work while unwell) contributed to lost productive time and concentration.

In terms of bus rollaways, drivers may be carrying some of these illnesses and personal issues, which lower their concentration and thus increase the risk of forgetting to apply the park brake.

## Medication

A study<sup>11</sup> of 13,000 road traffic accidents found that car drivers taking certain types of prescribed drugs have an increased risk of being involved in a road accident. Anti-inflammatory drugs were found to somewhat increase the risk; stronger drugs such as anti-depressants and sedatives were found to have a marked increase in risk. Reduced concentration and fatigue largely accounted for this increased risk.

In terms of bus rollaways, drivers on prescribed drugs are likely to have lower concentration and higher fatigue. This is likely to result in an increased risk of drivers forgetting to apply the park brake.

## Post-completion errors

Research<sup>12</sup> has found that another type of error (known as post-completion error) occurs after the main task has been completed. Once the main task has been completed, the following 'clean up' step which should occur soon after is often forgotten.

In terms of bus rollaways, such post-completion errors could include stopping at a terminus after a shift (the normal time when bus rollaways occurs – see above). Once this main task has been complete (stopping safely at a bus stop and opening the doors) the peripheral 'clean-up' step (applying the park brake) may be forgotten.

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7 [http://www.carrsq.qut.edu.au/publications/corporate/fatigue\\_fs.pdf](http://www.carrsq.qut.edu.au/publications/corporate/fatigue_fs.pdf)

8 Biggs, H, Dingsdag, D, & Stenson, N, 2009, Fatigue factors affecting metropolitan bus drivers: A qualitative investigation, *Work*, vol. 32, pp. 5-10.

9 Stewart, WF, et al., 2003, 'Lost productive work time costs from health conditions in the United States: results from the American Productivity Audit,' *Journal of Occupational and Environmental Medicine*, vol. 45, pp. 1234-1246.

10 Hemp, P, 2004, 'Presenteeism: at work-but out of it,' *Harvard Business Review*, vol. 82 pp. 49-58.

11 Engeland, A, Skurtveit, S & Jørg Mørland, J, 2007, 'Risk of road traffic accidents associated with the prescription of drugs: a registry-based cohort study,' *Annals of Epidemiology*, vol. 17, pp. 597-602.

12 LI, Yau Wai, et al., 2005, 'Post-completion errors in problem solving,' *Proceedings of the Cognitive Science Conference*, pp. 1278 - 1283.

## Vigilance decrement or time-on-task effect

Research since the late 1940s<sup>13</sup> has found that sustained attention on a given task results in reduced performance: increased reaction times, variability in reaction times and mental fatigue. These effects are known as 'vigilance decrement' or the 'time on task effect'. Accidents involving truck drivers have been associated with this 'time on task effect': increased sleepiness and fatigue which result in lapses in vigilant attention. Experiments have been undertaken which highlight the extent of the time-on-task effect<sup>14</sup>. Brain imaging studies found reduced blood flow to parts of the brain responsible for sustaining attention; this reduced blood flow was observed during the rest period even after the task ended<sup>15</sup>.

Many accidents have occurred once the driver has completed a run in the mid-morning, after the busy 'high vigilance' peak hour run has been complete. It is at this time, after sustained vigilance, that research suggests the time-on-task effect occurs. This onset of fatigue, a result of the time-on-task effect, may explain why drivers forget to apply the park brake: they are mentally tired and are unable to sustain sufficient attention to remember to apply it.

## Negative transfer errors using different bus types

There are many permutations and combinations of buses in Victoria with the controls and features on each bus varying from one to another<sup>16</sup>. It was observed that larger operators have more than 30 different specifications of buses within their fleet. Research suggests human errors can result when, in a new situation, the person applies the same rule or process. This is referred to as *stereotype takeover*<sup>17</sup> (where a highly skilled act interferes with a task) or negative transfer errors<sup>18</sup> — skills which carry over but serve to inhibit performance and impact on safe operation.

Negative transfer errors are likely to occur where the driver transfers from one bus (with many rollaway controls) to another (with very few controls). In this situation, for example, the driver incorrectly expects park brake warnings or alarms will sound if he/she has not applied the park brake. Not having heard these in this different bus type, the driver is not reminded to apply the park brake.

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13 See Mackworth JF, 1948, The breakdown of vigilance during prolonged visual search. Quarterly Journal of Experimental Psychology, vol. 1, pp. 6-21.

14 Pattyn, N, et al., 2008, 'Psychophysiological investigation of vigilance decrement: boredom or cognitive fatigue?.' Physiology & Behavior, vol. 93, pp. 369-378.

15 Lim, J., Wu, W., Wang, J, Detre, JA., Dinges, DF & Rao, H, 2010, 'Imaging brain fatigue from sustained mental workload: An ASL perfusion study of the time-on-task effect. NeuroImage, vol. 49(4), pp. 3426-3435.

16 Napper, R, 2010, 'Reducing variation not function - lessons from applied route bus design research', Australasian Transport Research Forum 2010.

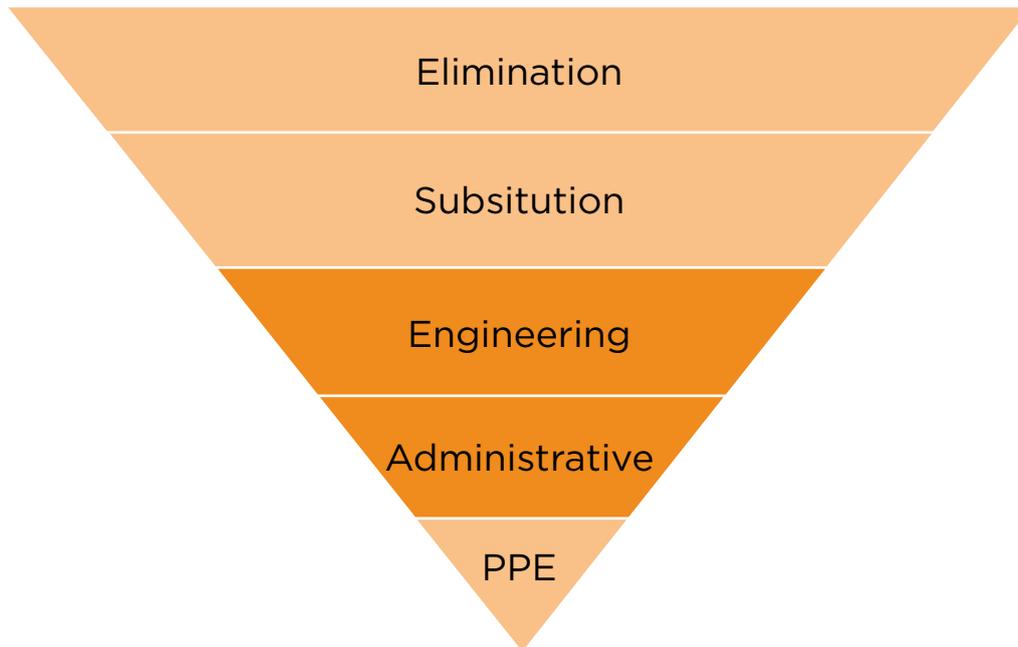
17 Sanders, MS & McCormick EJ, 1997, Human factors engineering and design, 2nd edn, McGraw Hill, New York, p. 659.

18 Besnard, D, & Cacitti, L, 2005, 'Interface changes causing accidents. An empirical study of negative transfer,' International Journal of Human-Computer Studies vol. 62, pp. 105-125.

## Controls currently applied

### What type of controls are out there?

Different controls were examined as part of this research. In terms of the hierarchy of controls, only engineering and administrative controls were observed. Usually a combination of these two controls were put in place by operators to minimise the risk of bus rollaways.



## Administrative controls

### Signs and stickers

Signs and stickers are used to notify the driver:

- that they must apply the park brake
- of the dangers of not applying the park brake
- that the door button must not be accessed from outside the bus through the driver cab window.



View of one side of a double sided warning sticker affixed to the inside of the bus.

In NSW, the purpose of the [Bus Operator Accreditation Package](#)<sup>19</sup> is to assist persons wishing to become an accredited operator. One of the operator requirements in the package under section 4.3 (pp. 28) is the 'runaway bus procedure' copied below:

The operator must ensure that buses are safely and appropriately secured when parked and must provide drivers with a Standard Operating Procedure which shall include the following instructions:

- Before leaving the driver's seat you **must** apply the park brake and check that it is correctly engaged.
- Where a bus is fitted with an external door close control, you must use this to close the bus
- You **must not** close the bus doors by reaching keys, handles, switches levers or other controls from outside the bus through the driver's side window, and
- Under **no** circumstances, should you access the bus controls via the driver's window.

<sup>19</sup> According to the NSW Roads and Maritime Services website (pp. 1), the Bus Operator Accreditation Scheme was introduced on 1 July 2005.

The Runaway Buses Information Procedure is in an appendix (Appendix 7) to the Bus Operator Accreditation Package. It states that bus operators will follow the NSW Roads and Maritime Services safety instruction regarding the correct method of securing a bus.

According to this Runaway Buses Information Procedure, “the requirement to affix the safety stickers to all buses and to distribute the Bus Safety Alert to all drivers forms part of the bus operator accreditation and audit program”(pp. 1).

The sticker must be affixed on the lower half of the driver's side window on all buses. The safety message on the inside of the bus will be:

**“Parking brake must be applied before leaving seat”**

The safety message on the outside of the bus will be:

**“Do not access bus through window”**

**Note:** This instruction applies to all operators and all drivers. No exemptions are available or will be granted.

Operators can purchase the safety stickers from the NSW Bus and Coach Association.



## Notices, newsletters, circulars

Following bus rollaways, operators have released safety alerts on the correct application of the park brake:

### **Urgent Safety Alert :** **Runaway Bus leads to calls for Handbrake Safety Checks**

**Before you leave the drivers seat, always ensure:**

- The bus is in neutral gear and the park brake is applied
- The park brake is correctly engaged
- Never use the bus door interlock as the brake system
- Never reach in through the window to use the door controls

Your ongoing attention to this issue is required to avoid any incidents from occurring in the near future.

## **NOTICE TO ALL DRIVERS** **CLOSING BUS DOORS**

### **ANOTHER BUS ROLL-AWAY HAS OCCURRED IN VICTORIA!**

**This is another warning to all drivers to ensure that they remember to apply the hand brake before leaving their seat. This action will ensure that buses cannot roll away if the door is closed.**

Operators have provided this information in monthly or quarterly newsletters. The example below, from an operator's newsletter, discusses the dangers of rollaways when troubleshooting problems on buses:

### **Reminder: Handbrakes**

From time to time when a bus will not start and the bus is away from the depot, drivers will try different methods to re start the bus.

The important part of the various processes followed to restart the bus must never include releasing the handbrake at any stage.

Recently a bus rollaway occurred as part of a driver attempting to restart another driver's bus, this resulted in damage to two buses.

Your personal safety and the public's safety are paramount at all times.

Remember to never disengage the handbrake until it is safe to do so.

## Driver handbooks and procedures

Driver handbooks state the proper procedure for securing a bus. Handbooks also warn that drivers are not to reach through cabin window to open or close the doors. Below is a sample from three operators' driver handbooks:

### BUS ROLL-AWAY: PREVENTION OF.

Instances have occurred when drivers have not applied the parking brake because a door is open and the brakes are on. They have then either switched off the bus and the rear door automatically closes or they have closed the front door from the outside switch. When bus doors close the brakes will release and buses have rolled away.

- Always select neutral & apply the handbrake before leaving the driver's seat; and
- Never reach through the driver's window to close the door,

Drivers must follow this procedure when stopping the bus engine and securing the bus:

- Apply the park brake
- Turbo engine buses – let engine idle for one minute to allow the turbo to cool down
- Push stop button / lever or turn key to "off" position
- Turn ignition key off
- Turn battery isolator switch off (where fitted)

If securing the bus on a downhill slope, turn the wheels toward the kerb or if securing on an up-hill slope, turn the wheels away from the kerb.

Do not close the bus doors by reaching switches from outside the bus through the driver's side window. Under no circumstance, should you access the bus controls via the employee's window.

### HANDBRAKE<sup>17</sup>

The Handbrake **MUST ALWAYS** be applied whenever the bus stops for more than 3 seconds. Prior to leaving the bus, Drivers **MUST** turn the engine off, place gear in neutral and ensure their bus is secure by applying the handbrake. This is not only a company directive but also a responsibility of all Licence holders by law. The use of other systems on the bus such as doors to hold the bus is irresponsible and negligent.

### DOORS

*When alighting from the bus, the doors must be closed. The Driver's side window is NEVER to be used to open or close doors.*

## Bus timetabling and scheduling

It was observed that operators had organised their timetable to ensure older buses, with fewer rollaway controls, were used on charter or school runs rather than route operations. This was seen as reducing the risk since route operations have more passengers and frequent stops.

## Training

Bus safety training modules were observed to cover the following:

- correct procedure to apply the park brake as listed in the driver handbook
- engineering and functionality of the park brake
- fault and troubleshooting.

An example from the training is shown below:

- The park brake acts on the drive /rear wheels only. When the hand control is in the forward position with the air system fully charged and the blocking valve depressed, the park brake is in the “Released position”
- When hand control is moved backwards, the park brake is gradually applied until it is in its locked position
- To release the park brake from the locked position, lift the ring upwards and move the control handle forwards

**Never leave the bus without applying the park brake**

**Never drive the bus with the warning light activated**

### Assessment

Operators use different methods to assess drivers on their awareness and understanding of bus rollaways and correct procedures for securing buses including:

- written exam involving multiple choice questions
- written exam involving long answer questions
- requiring drivers to sign a declaration that they have read the driver handbook which discusses the correct procedure to secure a bus
- on the job assessment during induction.



# Engineering controls

## Auditory warnings

Different types of auditory alarms (sounds, bells, beeps, chimes, horns, spoken words) were observed on buses. They were interlocked with different components: the cab door, seat, seat belt, ignition, infrared beam. The alarms have either been installed as part of the original build or retrofitted.

Other alarms, seen only on newer buses, are spoken words which notify the driver that the park brake needs to be activated, for example, "Park brake is not activated – please activate park brake".

Such alarms work as follows:

- driver stops the bus
- driver opens the doors using the controls on the driver console
- once the doors open, the service brake is applied.

The following then occurs, depending on the type of interlock:

- **seat belt:** if the driver takes off their seat belt, and the park brake is not applied, an alarm sounds
- **cabin door:** if the driver opens the cabin door and the park brake is not applied, an alarm sounds
- **seat:** if the driver leaves their seat (seat base pressure sensor<sup>20</sup>), an alarm sounds
- **infrared beam (in buses without cab door):** if a driver gets out of their seat and walks across the driver door threshold, he/she trips an infrared beam<sup>21</sup> and thus activates an alarm alerting the driver to apply the park brake<sup>22</sup>.

View of cabin door with sensor that activates alarms if the driver opens the door and the park brake is not applied.



20 The operator who applied this control has since had this removed. Drivers found the base plate protecting the sensor make the seat uncomfortable. The seat sensor was also found to have issues with operational reliability.

21 The infrared beam shines across where the cabin door is normally located.

22 This is a new, mandated rollaway control for buses in South Australia.

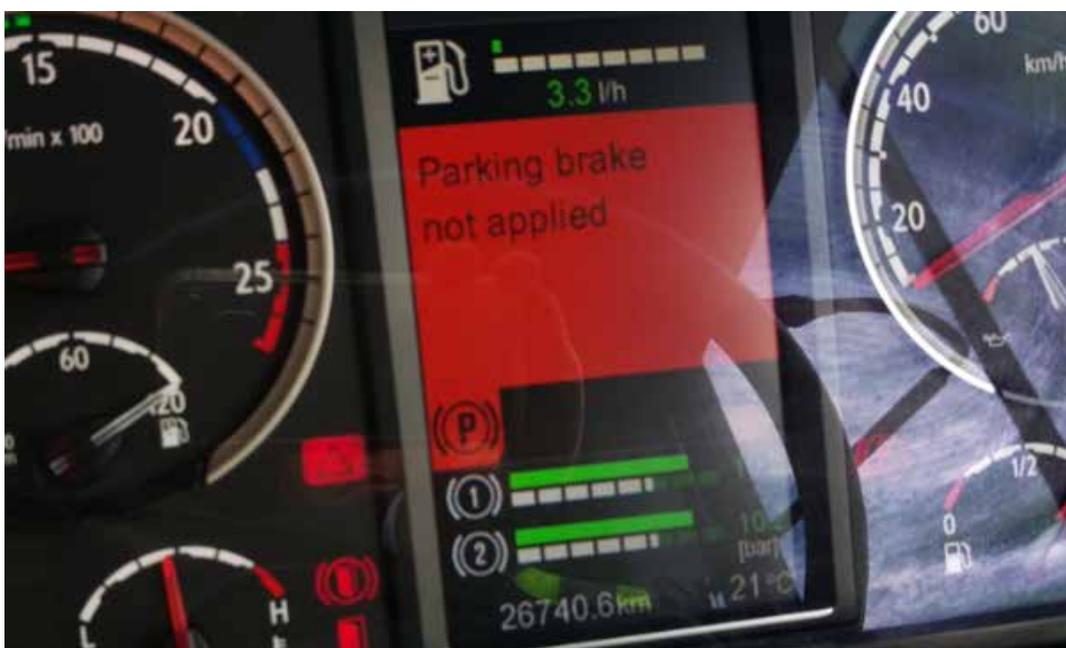
## Visual warnings

Visual alarms for most buses are flashing or solid lights located on the driver console. This was observed as an icon on the driver console, an '(H)', or a written warning message, '(Parking brake not applied)'.

Also observed was a retrofitted visual warning which had been installed above the console. This light flashed repeatedly when the park brake was not engaged.



View of the centre console indicator showing that the park brake has not been applied.



View of centre console notifying the driver that the park brake has not been applied.



View of retrofitted visual warning alarm that activates if the park brake has not been applied.

## Traffic calming devices

### Berms

These berms (pictured below) are placed within the depot. The bus is parked next to them preventing the bus rolling away in the event that the park brake is not applied.



## Speed bumps

Speed bumps are used in the fuel bay to stop the bus rolling away. They have also been used in the depot itself. Three examples are shown below.



Speed bump used in refuelling bay.



View of speed bump installed in refuelling bay.



Concrete speed bumps or chocks installed to prevent the bus rolling away.

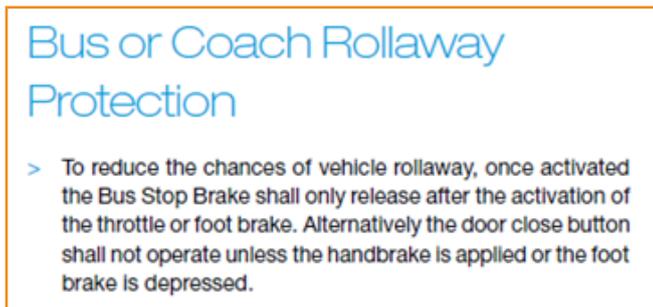
## Park brake interlocks

### Accelerator or brake interlock

Newer buses (built since about 2010) have interlocks between the accelerator or brake, and the doors and service brake. This accelerator or brake interlock works as follows:

- driver stops the bus
- driver presses the door open button from the drivers console (this activates the service brake)
- driver steps out of the bus to close the doors using the outside external open/close door buttons (or reaches through window to press the close door button)
- door closes but service brake holds and bus does not rollaway; the accelerator or brake must be tapped to release the service brake.

This is one of the suggested bus rollaway features according to the [Bus Industry Confederation \*Moving People - Industry Advisory Door Safety Advisory\*](#) ('BIC Advisory') on bus door safety published in October 2012:



### Ignition

In newer buses, the ignition cannot be turned off unless the park brake is applied. This type of ignition interlock works as follows:

- driver comes to a stop and tries to turn off the bus
- ignition key will not turn (and an alarm will sound also)
- driver then applies the park brake
- driver can then turn the ignition off.

### Park brake and operation of external open/close door buttons

Buses were observed to have interlocks such that the external buttons used to open and close the doors will not work unless the park brake has been applied. This type of interlocking feature works as follows:

- driver comes to a stop and opens the doors using the door button on the driver's console
- the doors open which then results in the service brake being applied
- driver walks out of the bus but does not apply the park brake
- the driver cannot close the doors using the external open/close door buttons; because the park brake has not been applied; once the park brake is applied the driver is able to close the doors using the external/open door/close button

This is a the mandated specification for new buses in South Australia and is also recommended in the BIC Advisory: "for doors that can be closed via the external power close button, then these external buttons shall only operate if the park brake is applied".

## Location of external open/close door buttons

### Behind glass panel

In NSW, buses were observed to have the external open/close door buttons located behind a glass panel. The glass panel can be broken to access the buttons in the case of an emergency or it can be opened with a key (such as a T-key) for use by drivers or maintainers during normal situations.



View of glass panel which can be opened in normal situations with a T-key to access the door open close buttons or the glass broken in emergency situations.



View of glass panel which can be opened in normal situations with a T-key to access the door open close buttons or the glass broken in emergency situations.

## Under the bus

Victorian buses had the external door buttons located on the underside of the bus, with variation on where these buttons were located:



Under bumper



Before wheel

## Restrict window access

In an attempt to restrict drivers accessing the open/close door buttons through the driver's window, operators have installed different types of driver windows to make it difficult or impossible to access. Different window arrangements observed include:

- windows located higher up so that it is inaccessible by the driver (see below) from outside
- mesh installed (like a flywire screen) such that the window panel can be opened for fresh air but does not allow the driver to put their hand through.



View of drivers' side window which is elevated to prevent access to the door open buttons from outside the bus

## Broms brake/dual parking brake control

Several buses were observed to be fitted with a broms brake. The broms brake (also referred to as a dual parking brake control) is used in emergency situations and during start up<sup>23</sup>.

When main air pressure is lost, the park brake comes on. Some buses have a separate emergency release reservoir air tank which can be used to fill the park brake chamber and thus release the brakes. This emergency release reservoir air tank is activated by the broms brake valve and works as follows:

- bus engine is on
- bus loses air-pressure
- drop in air pressure causes the broms brake valve to 'pop out'
- driver can 'push in' the broms brake valve; this allows the emergency air to fill the park brake chamber keeping the park brake deactivated for a short period
- driver can then move bus to safe location before this emergency air is exhausted activating the park brake.

During start-up, the broms brake works as follows:

- bus engine is off and with no air in the park brake chamber, the park brake is activated
- park brake control has been moved to the 'off' position while the bus is turned off
- bus is then switched on building air pressure in the lines, chambers and reservoirs
- increase in air pressure causes the broms brake valve to 'pop out' which in-turn, causes air to be bypassed from reaching the park brake chamber, keeping the park brake activated
- driver must then 'push in' the broms brake valve to supply air to the park brake chamber and deactivate the park brake.

The pictures show the broms brake valve:



View of broms brake valve and park brake on chassis



View of broms brake valve and park brake in bus

23 See the 2014-2015 Commercial Driver Handbook of California - State of California - Department of Transport ([https://www.dmv.ca.gov/portal/dmv/detail/pubs/cdl\\_hm/cover](https://www.dmv.ca.gov/portal/dmv/detail/pubs/cdl_hm/cover)) or the 2007 Air Brake Manual Training and Reference Guide - Department of Transport - Northwest Territories transport Canada ([http://www.dot.gov.nt.ca/media/ec5c8e43-112d-4e6d-b459-8904c0489be0/k66ufQ/DMV/Air\\_Brake.pdf](http://www.dot.gov.nt.ca/media/ec5c8e43-112d-4e6d-b459-8904c0489be0/k66ufQ/DMV/Air_Brake.pdf))



View of brooms brake valve next to park brake lever (above)

It is clear that a wide variety of controls are being used to eliminate or reduce the risk of bus rollaways<sup>24</sup>. In the next section, human factors tools, methods and standards are discussed which can be used to:

- assess the effectiveness of current rollaway controls
- assist in the effective design of new rollaway controls.

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<sup>24</sup> As Napper (2010) points out, such diversity results in a 'raft of solutions to the same or similar problems'.

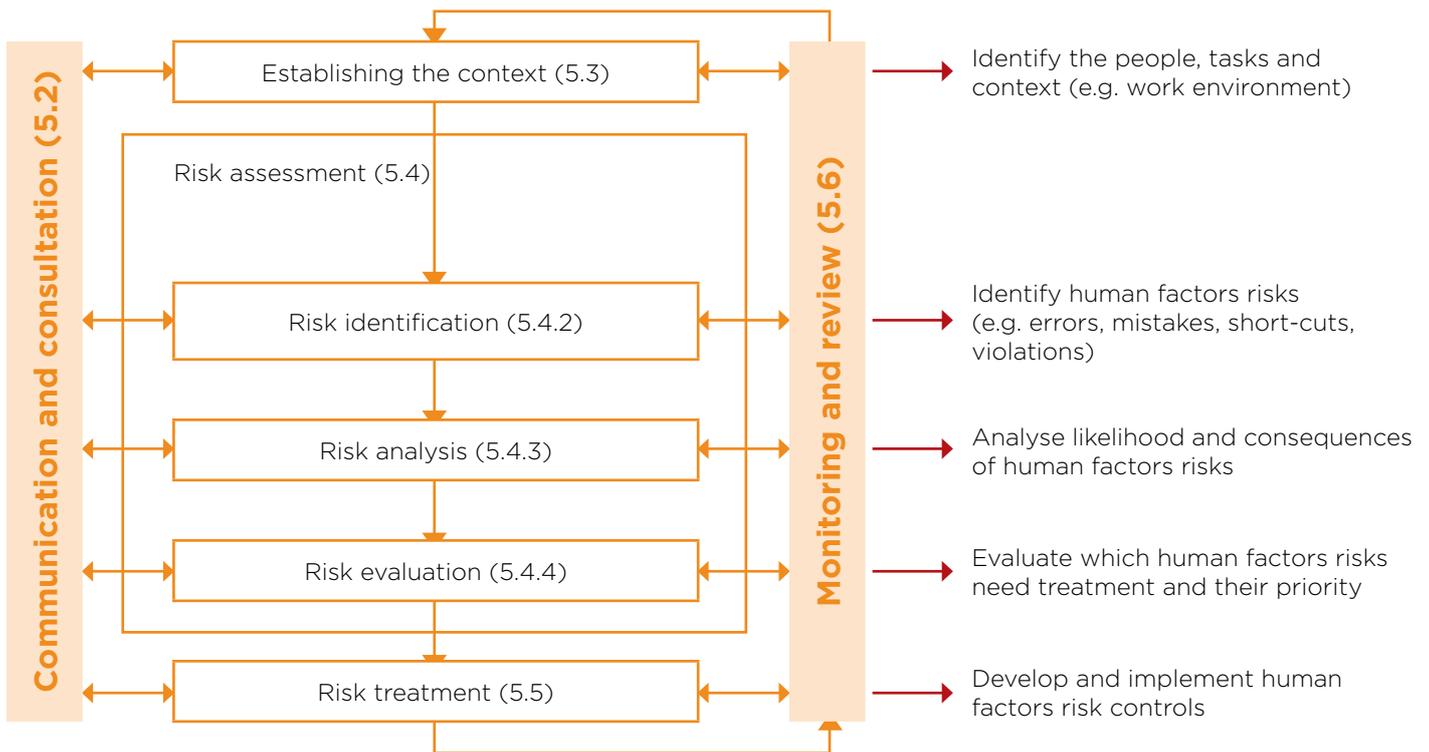
# Applying human factors to risk management

## Benefits of integrating human factors

Given that the incident data suggests that human capabilities and limitations (errors, fatigue, urinary urge) cause rollaways, human factors should be included as part of the risk assessment process. Human factors integration is defined as the<sup>25</sup>:

“systemic approach to the identification tracking and resolution of human-system issues in order to ensure the balanced development of both the technological and human aspects of operational capability”.

Below is the risk assessment process of ISO 31000 *Risk management—Principles and guidelines*. This is the process that underpins the 2015 guidance *Managing the Risks to Bus Safety*. The diagram shows how human factors can be integrated at each step of the risk management process.



## Establishing the context (clause 5.3)

This step requires an understanding of the internal and external context, and defining the ‘activity, process, function, project, product or service’. Integrating human factors as part of this step involves identifying the people and tasks that are being performed, for example:

- who will be affected using the particular controls (e.g. maintainers, cleaners, drivers)
- what tasks will they be doing when using the particular controls (e.g. refuelling, moving the bus into the depot)
- when will they be performing these tasks (e.g. at night, in the early morning).

## Risk identification (clause 5.4.1)

This step includes identifying the sources of risk:

- what elements of human performance will impact controls
- where could errors occur
- where could violations occur?

## Human performance factors

Human performance elements include fatigue and reduced concentration associated with:

- urinary urge
- predisposed illnesses
- mental wellbeing
- medication
- vigilance decrement or time-on-task effect.

## Human error

The error codes from the Systemic Human Error Reduction Prediction Approach (SHERPA) tool<sup>26</sup> provides a comprehensive list of error types. These can be used to analyse the errors that may occur within each given task.

### Action errors

A1	Operation too long/short
A2	Operation mistimed
A3	Operation in wrong direction
A4	Operation too little/too much
A5	Misalign
A6	Right operation on wrong object
A7	Wrong operation on right object
A8	Operation omitted
A9	Operation incomplete
A10	Wrong operation on wrong object

### Checking errors

C1	Check omitted
C2	Check incomplete
C3	Right check on wrong object
C4	Wrong check on right object
C5	Check mistimed
C6	Wrong check on wrong object

### Retrieval errors

R1	Information not obtained
R2	Wrong information obtained
R3	Information retrieval incorrect

### Communication errors

I1	Information not communicated
I2	Wrong information communicated
I3	Information communication

### Selection errors

S1	Selection omitted
S2	Wrong selection made

## Violations

Violations are deliberate deviations from safe operating procedures, standards or rules<sup>27</sup>. It is necessary to identify where violations of rules and procedures could occur. While the incident data shows violations occur when drivers put their hand through the window, there may be other types of violations. To identify these, operators should examine data, gather information from drivers and staff, or run workshops to identify:

- what procedures or rules exist which are relevant to bus rollaways
- which of these procedures are likely to be broken or violated?

26 Stanton N et al, 2014, Human Factors Methods: A practical guide for engineering and design, 2nd, edn, Ashgate, UK.

27 Reason, J, 1997, Managing the risks of organizational accidents, Ashgate, Farnham, p. 72.

## Risk analysis (clause 5.4.2)

This step involves understanding consequences and likelihood of the risk occurring. The questions that need to be answered here include:

- why do these errors occur and what are their impacts (likelihood and consequences)
- why do violations occur and what are their impact and consequences?

Human factors tools can assist in this process. As shown below, the *Human Error Template*<sup>28</sup> (HET) is a simple, easy-to-use template with prefilled error modes (far left column) which are similar to the ones listed above. It has room to fill in the likelihood and consequence of an error. The example below shows HET being used to assess the errors associated with landing a plane.

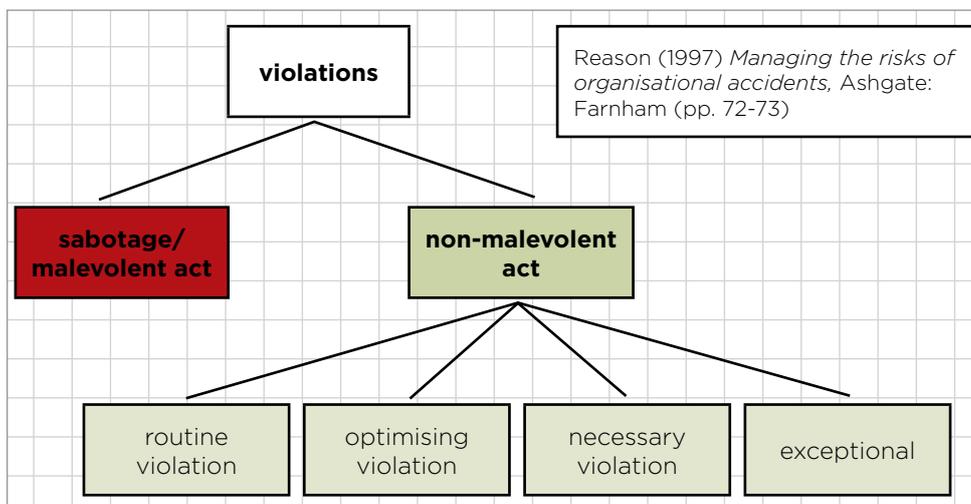
### Table Example of HET output

Scenario:		Task step:								
Land A320 at New Orleans using the Autoland system		3, 4, 2, Dial the 'Speed/MACH' knob to enter 150 on IAS/MACH display								
Error Mode	Description	Outcome	Likelihood			Criticality			Pass	Fail
			H	M	L	H	M	L		
Fail to execute										
Task execution incomplete										
Task execution in wrong direction	✓ Pilot turns the Speed/MACH knob the wrong way	Plane speeds up instead of slowing down		✓			✓		✓	
Wrong task executed										
Task repeated										
Task executed on wrong interface element	✓ Pilot dials using the HDG knob instead	Plane changes course and not speed	✓				✓			✓
Task executed too early										
Task executed too late										
Task executed too much	✓ Pilot turns the Speed/MACH knob too much	Plane slows down too much	✓				✓		✓	
Task executed too little	✓ Pilot turns the Speed/MACH knob too little	Plane does not slow down enough/too fast for approach	✓				✓		✓	
Misread information										
Other										

These error modes are similar to those adopted in SHERPA list of error modes shown above.

For bus operations, HET could be used to show the errors associated with, for example, securing a bus or caging the spring brake. To analyse the risk of violations, assess what type of violation it is and why it occurs.

The table below shows the different categories of violations:



Consequences (called criticality) which is ranked as High, Medium or Low. Likelihood (next column) is also ranked High, Medium or Low.

As mentioned above, violations are intentional deviations from standards or procedures. Whether or not the bad consequences are intended separates malevolent and non-malevolent acts. Malevolent acts/sabotage is when both the unsafe act (deviating from the rules) and bad consequence (e.g. a rollaway) are intended.

28 HET was developed by the US Federal Aviation Administration see Stanton N et al, 2014, Human Factors Method: A practical guide for engineering and design, 2nd, edn, Ashgate, UK, p. 156.

For *non-malevolent acts*, the person intends to deviate from the rules but the bad consequences are not intended. These *non-malevolent acts*, also known as *safety violations*, comprise the vast majority of violations and can be separated into four subcategories.

- *Routine violations* are corner-cutting violations where people take the path of least effort between two task-related points. Such violations can become a habitual part of the person's behaviour when the work environment is one that rarely sanctions violations or rewards compliance, for example, not crossing the road at the pedestrian crossing because it is too far away.
- *Optimizing violations* occur where the person violates for the thrill of it, for example, speeding or cornering sharply.
- *Necessary violations* are violations necessary to get the job done because the site, tools, or equipment are inadequate, for example, stacking at an intersection because the lights do not allow sufficient cars to move across. Necessary violations occur frequently.
- *Exceptional violations*<sup>29</sup> are done in emergency situations, for example, a computer, machine or bus will not switch off so the 'kill switch' is used

The table provides a method to classify non-malevolent acts and then a rating (such as high, medium or low) can be used to determine their likelihood and consequence.

Is the rule or procedure likely to be broken:	Type of violation	Likelihood of violation	Consequence of violation
because of corner cutting?	Routine violation		
because it is psychologically rewarding (e.g. provides a thrill)?	Optimizing violation		
because the current tools or procedures make the task difficult to complete under normal circumstances?	Necessary violation		
because the rule or procedure did not apply to the unusual or rare task that needed to be performed?	Exceptional violation		

### Risk evaluation (clause 5.4.3)

This step involves working out which risk needs to be prioritised and addressed for treatment implementation. The tables listed above which rate errors and violations according to likelihood and consequence can be used to prioritise which errors are controlled (risk treatment). High likelihood high consequence human error risks or violations have the highest priority for treatment.

### Risk treatment (clause 5.5)

Risk treatment involves looking for options to minimise the risk. There are formal ways to ensure that any engineering controls used as treatments take into account human behaviour. These are discussed in the next section.

29 Exceptional violations have occurred in emergency situations. For example, during the Piper Alpha oil rig disaster, those who survived violated the rules and jumped off the platform directly into the sea; those who followed the rules and assembled in the emergency room died from the fire - see Dekker, S, 2003, 'Failure to adapt or adaptations that fail: contrasting models on procedures and safety', Applied ergonomics, vol. 34, pp. 233-238.

# Applying human factors to the design process for treating risks

## Reported benefits

Similar to risk management, design or modification of controls will be more effective if human factors issues are considered during the design process. Creating systems that take into account human factors provides benefits which include:

- increased productivity
- reduced errors
- reduced training and support
- improved acceptance<sup>30</sup>.

## Challenges of integration

Research on design processes has found organisational challenges associated with integrating human factors into the design process including:

- perception of ergonomics
- communications and cooperation between engineering and human factors professionals
- differing approaches to problem solving
- scarce company resources.

Such challenges can be overcome if “management gives priority to ergonomics (pp. 326)<sup>31</sup>. **ISO 27500: 2016 The human-centred organization – Rationale and general principles** provides information to management on the importance of ergonomics and overall organisational processes that need to be undertaken in order to include ergonomics/human factors as part of the business. It is aimed at the executive and explains significant benefits that can be achieved by making a business human centred and applying ergonomics principles.

The ISO standard covers:

- the values and beliefs that make an organisation human centred
- the significant business and operational benefits that can be achieved
- the policies that need to be put in place to achieve this<sup>32</sup>.

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<sup>30</sup> See Maguire, M, 2001, 'Methods to support human-centred design', International Journal of Human-Computer Studies, vol. 55, pp. 587-634; and Napper, R, Selby, C, & Allen, J, 2007, 'Bridging the divide: Design's role in improving multi-modal transport,' The 30th Australasian Transport Research Forum: Managing Transport in a Climate of Change and Uncertainty.

<sup>31</sup> Broberg, O, 1997, 'Integrating ergonomics into the product development process,' International Journal of Industrial Ergonomics, vol. 19, pp. 317-327.

<sup>32</sup> Stewart, T, 2016, 'Editorial', Behaviour & Information Technology, vol. 35, pp. 517-519 (Stewart was project editor of this standard).

# Human Factors/ergonomics standards

ISO has published standards addressing human factors and ergonomics:

## ISO 26800:2011 Ergonomics

### — General approach, principles and concepts to the standard

This standard provides basic principles that can be applied to design. As stated in the introduction “Human, technological, economic, environmental and organizational factors all affect the behaviour, activities and well-being of people in work, domestic and leisure contexts”. Further, the principles outlined in the standard are important to the design process to ensure optimum integration of human requirements into design.

“These principles are fundamental to the design process wherever human involvement is expected in order to ensure the optimum integration of human requirements and characteristics into a design. This International Standard considers systems, users, workers, tasks, activities, equipment and the environment as the basis for optimizing the match between them. These principles and concepts serve to improve safety, performance and usability (effectiveness, efficiency and satisfaction), while safeguarding and enhancing human health and well-being, and improving accessibility (e.g. for elderly persons and persons with disabilities)”.

## ISO 6385:2004 Ergonomic principles in the design of work systems

This standard deals with the issues of ergonomics, work systems and working situations. It covers how ergonomics/human factors can be applied to the design and evaluation of tasks, jobs, products, services, environments and work systems<sup>33</sup>.

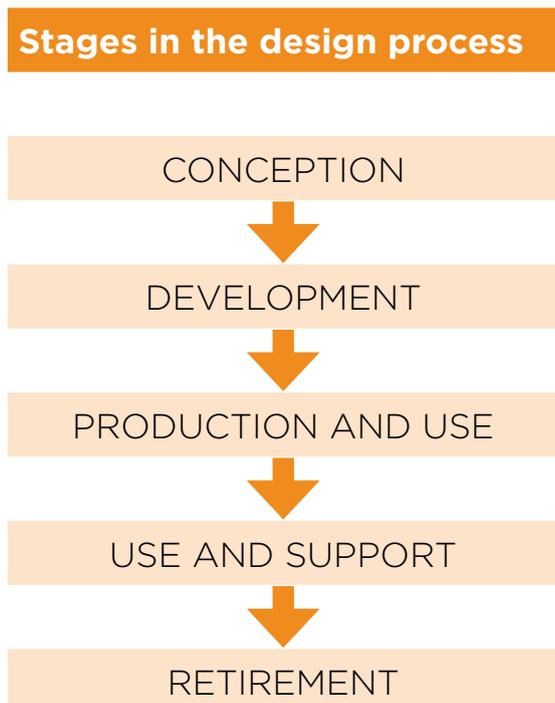
## ISO/TS 18152 Ergonomics of human-system interaction

### — Specification for the process assessment of human-system issues

This standard provides “processes that address issues associated with humans throughout the life cycle of a system”. It provides information on human factors integration. The aims of the standard include providing:

- the means of assessing and mitigating risks arising from human-system issues that will affect usability through the life cycle, both at transition points between life cycle stages and during each stage
- a description of human-system processes for use in project planning and for inter-disciplinary communication
- a basis for understanding and cooperation during the tendering process and for human-system capability evaluation to support contract award, either in a stand-alone manner or in conjunction with a software or system capability evaluation
- a basis for structured human-system process improvement by supplier, customer or employer organizations.

The standard shows how to include human factors during each stage of the design process. For example, ‘assessing the effect of change in usability’ is about understanding how the particular control has changed over time. This assessment is required during the ‘use and support’ stage of the design process (see diagram below).



### Some key tasks specific to HF:

- Identify the roll of the user in the system
- Collect user feedback
- Build a user training program
- Assess the effect of change in usability
- Debrief to collect user feedback

33 Karwowski, W, Soares, MM, & Stanton NA, 2011, Human Factors and Ergonomics in consumer product design: Methods and techniques, CRC Press, New York.

# Applying human factors to warnings and alarms

## Generic alarm design principles

Several types of warning have been installed on buses to warn or alert the driver to apply the park brake.

How loud should an alarm be; what sounds do people react best to; what colour should visual alarms be? Human factors research has been conducted to find answers to these questions and provide a set of generic design principles<sup>34</sup>. If adhered to, these principles will help ensure alarms are effective.

The principle	What it entails
Brief and complete	The warning should convey the message in as few words as possible and in one phrase rather than two.
Prioritization	The greater the hazard, the more alarming the warning should be; two or more alarms should have distinguishing sounds or visuals so they are not easily confused.
Know the receiver	Sensory information will not be received if the person is colour blind, illiterate, or deaf.
Design for the low-end receiver	If there are different drivers with different levels of understanding, design the warning for the low-end extreme.
Durability	Ensure the warning is durable such that it does not easily break and does not provide spurious warnings.
Test the warning	Use a small group of people to test the warning and ensure it is effective.

Several buses observed had multiple console visual and auditory warning alarms going off at the same time. This makes it very difficult for the driver to differentiate, prioritise and attend to one warning over another. This can cause alarm fatigue: the lack of response due to excessive numbers of alarms resulting in sensory overload and desensitization<sup>35</sup>.

To avoid this, alarms should be:

- easy to differentiate from one another
- arranged such that the most important warning is the most alarming or recognisable.

Another issue is testing the warning on a sample of users to assess its effectiveness. This testing is a requirement of ISO/TS 18152 *Ergonomics of human-system interaction – Specification for the process assessment of human-system issues*. Where possible, a mock up should be created with staff testing or using it. The feedback and response from staff should be considered as part of an iterative design process.

34 Salvendy, G. 2012, Handbook of human factors and ergonomics, 4th edn, John Wiley & Sons, New York, p. 887-888

35 Cvach, M. 2012, 'Monitor alarm fatigue: an integrative review,' Biomedical Instrumentation & Technology, vol. 46, pp. 268-277.

## Visual versus auditory alarms

Both visual (indicators and flashing lights) and auditory (sounds, bells, beeps, chimes, horns, spoken words) alarms were observed on buses. Often these were used in combination. Which alarms are best? When should they be used? In what context? Human factors research<sup>36</sup> in the aviation and nuclear industries has been able to determine the differences between the two types of alarm, as shown in table below:

**TABLE 3-1**  
**When to use the auditory or visual form of presentation**

Use auditory presentation if:	Use visual presentation if:
<ol style="list-style-type: none"> <li>1. The message is simple.</li> <li>2. The message is short.</li> <li>3. The message will not be referred to later.</li> <li>4. The message deals with events in time.</li> <li>5. The message calls for immediate action.</li> <li>6. The visual system of the person is overburdened.</li> <li>7. The receiving location is too bright or dark-adapting integrity is necessary.</li> <li>8. The person's job requires moving about continually.</li> </ol>	<ol style="list-style-type: none"> <li>1. The message is complex.</li> <li>2. The message is long.</li> <li>3. The message will be referred to later.</li> <li>4. The message deals with location in space.</li> <li>5. The message does not call for immediate action.</li> <li>6. The auditory system of the person is overburdened.</li> <li>7. The receiving location is too noisy.</li> <li>8. The person's job allows him or her to remain in one position.</li> </ol>

Visual warnings may not be useful when drivers have severe urinary urge and are not looking at their console. Some of the auditory warnings take a few seconds to sound in which time the driver might be already outside the bus. Thus, taking into account the factors listed above in the design of alarms ensures their effectiveness.

## Operational controls

The shape, size and position of the park brake was observed to be different in different bus types. There were also differences in the types of controls, for example, whether or not a bus had a broms brake installed or not. Human factors research has been conducted to answer questions such as where should controls be placed? How far away? What shape should controls be?

As far back as WWII, pilots were confusing the landing gear (the wheels of the plane) with the flaps. As a result, the controls for the landing gear were changed to look like a round tyre. They were also positioned away from the flap controls which reduced the risk of pilot error<sup>37</sup>.

Such methods have been applied in other situations such as the placement and shape of controls for bolting and drilling equipment<sup>38</sup>. Human factors research has developed good practice principles for arranging components or controls<sup>39</sup>.

The principle	What it entails
Importance principle	More important aspects are placed closest to the operator.
Frequency of use principle	Frequently used components are placed closest to the operator.
Functional principle	Group components according to their function e.g. braking functions and controls, accelerator functions and controls.
Sequence of use principles	Actions that should be done in sequence should have controls placed close to one another.

Elements of these principles are observed in controls we use every day such as buttons on a remote control, menus and windows in software and controls and buttons in a car. It should be acknowledged that Australian Design Rules (ADRs) must be adhered to in the design of controls or modification of existing controls. Of the 85 ADRs listed on the Dept of Infrastructure and Regional Development website, the following were found to be relevant to parking brake/ door interlock controls and must be taken into account:

- Vehicle Standard (Australian Design Rule - Definitions and Vehicle Categories) 2005
- Vehicle Standard (Australian Design Rule 42/04 - General Safety Requirements) 2005
- Vehicle Standard (Australian Design Rule 58/00 - Requirements for Omnibuses Designed for Hire and Reward) 2006
- Vehicle Standard (Australian Design Rule 35/05 - Commercial Vehicle Brake Systems) 2013
- Vehicle Standard (Australian Design Rule 68/00 - Occupant Protection in Buses) 2006

<sup>36</sup> Sanders, MS & McCormick EJ, 1997, Human factors engineering and design, 2nd edn, McGraw Hill, New York, p. 53.

<sup>37</sup> Chapanis, A, 1999. The Chapanis chronicles: 50 years of Human Factors research, education and design. Aegean, Santa Barbara.

<sup>38</sup> Burgess-Limerick, R, et al. 2010, Reducing control selection errors associated with underground bolting equipment, Applied Ergonomics.

<sup>39</sup> Sanders, MS & McCormick EJ, 1997, Human factors engineering and design, 2nd edn, McGraw Hill, New York, pp. 456-458.

# Applying human factors to determine culpability for unsafe acts

## Who is responsible for unsafe acts?

Both errors and violations can be collectively considered *unsafe acts*. If a driver, maintainer or refueller commits an unsafe act (such as putting their hand through the window or forgetting to apply the park brake), what is their degree of culpability? Should a no-blame or punitive approach be applied?

Human factors research in healthcare, aviation, and oil and gas industries<sup>40</sup> suggests that the best method to ascertain culpability is to use the substitution test<sup>41</sup>:

“Mentally substitute the individual concerned with someone else who has the same training and experience and ask ‘In the light of how event unfolded and were perceived by those involved...is it likely that this new individual would have behaved any differently?’” (pp. 125).

If the answer is ‘no’, then a punitive approach would be inappropriate. However, most unsafe acts fall on a scale between blameworthy (complete culpability) and blame free (no culpability) as shown in the figure below.

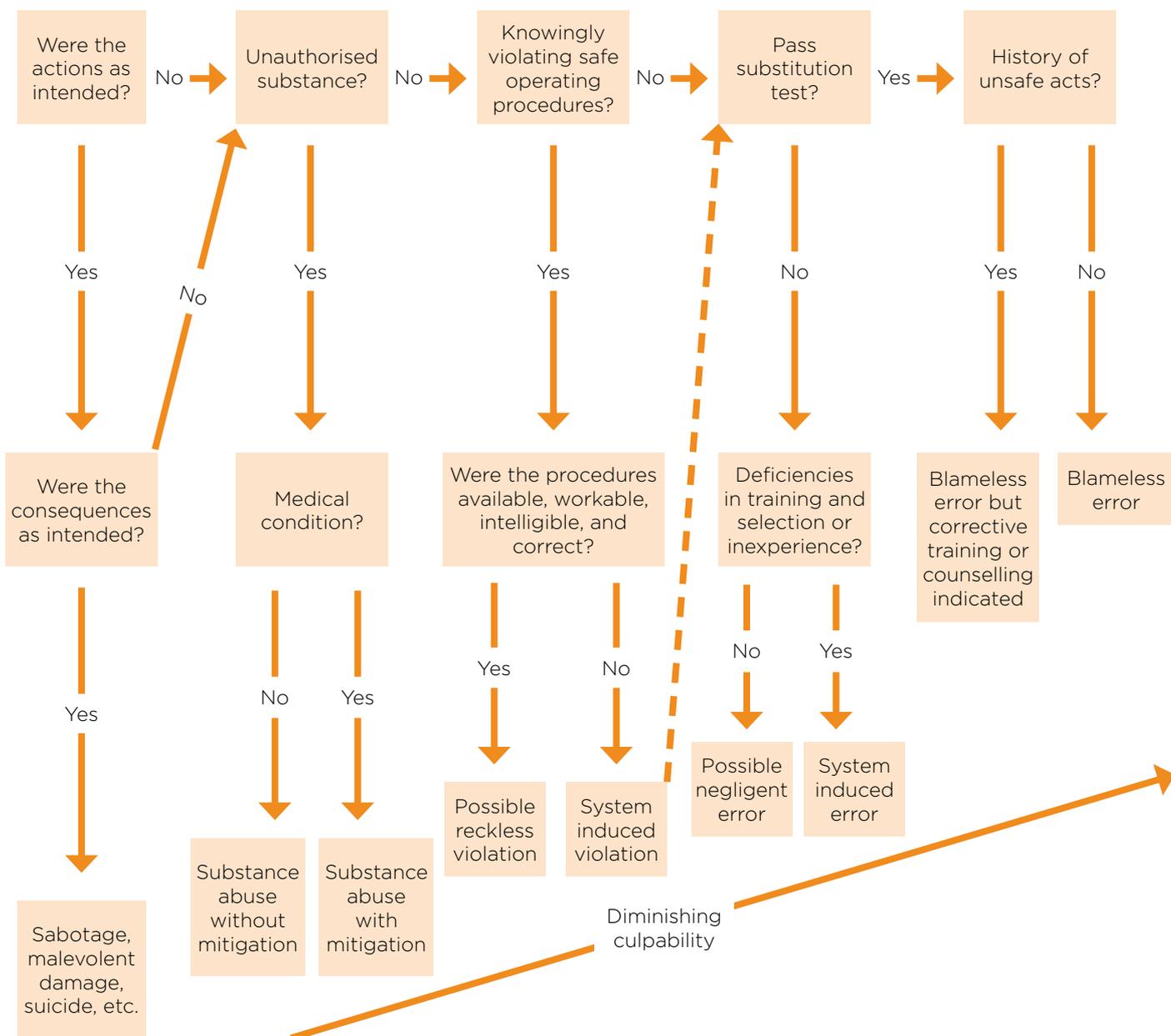


40 Frankel, AS, Leonard, MW, & Denham, CR, 2006, 'Fair and just culture, team behaviour, and leadership engagement: The tools to achieve high reliability,' Health Services Research, vol. 41, pp 1690-1709.

41 Hopkins, A, 2008, Failure to learn: the BP Texas City refinery disaster, CCH Ltd, Australia. From Johnston, N, 1995 'Do blame and punishment have a role in organisational risk management?' Flight Deck, vol. 15, pp 33-36.

## Method for determining culpability

How do you determine where on the scale someone's unsafe act sits? Professor Reason provides a simple, easy-to-use decision tree to determine a person's culpability as a result of a unsafe act:



Starting in the top left corner, work your way through the series of questions to determine where on the culpability scale, the given unsafe act sits. Such a tool promotes a just culture, defined as:

“an atmosphere of trust in which people are encouraged, even rewarded, for providing essential safety-related information—but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour” (pp. 195<sup>42</sup>).

If everyone is blamed and punished for unsafe acts, very few staff will report for fear of retribution. This has the negative consequences of safety issues not being reported and remaining hidden from view. On the other hand, applying a blanket no-blame policy provides no deterrence or accountability<sup>43</sup>.

The decision-tree provides an objective or just method to determine culpability and, as such, helps provide the foundations of a just culture<sup>44</sup>.

42 Reason, J, 1997, *Managing the risks of organizational accidents*, Ashgate, Farnham.

43 Dekker, S, 2012, *Just Culture: Balancing safety and accountability*, Ashgate, Farnham.

44 Research suggests that changing or creating a culture involves tangible steps, which once learned and accepted by the majority of staff becomes the culture of the organisation 'how things are done around here' (see Carroll, JS & Quijada, MA, 2004, 'Redirecting traditional professional values to support safety: changing organisational culture in health care', *Quality and Safety in Health Care*, vol. 13, p. ii16-ii21).

## Myths on controls

Dispelling commonly held myths about the causes and controls of bus rollaways helps ensure rollaway controls are efficient and effective.

### “Drivers are stupid”

#### Myth explanation

This view holds that you can't prevent driver stupidity. The logic is as follows:

- the driver is responsible for driving the bus safely
- one of the responsibilities of the driver is to put the park brake on before leaving the bus
- if the driver is 'too stupid' to do this, there is not much more we can do.

#### Why this view is wrong

There are two reasons why this view is wrong:

1. drivers are not robots and like everyone else, do forget to do things. Many of us have forgotten to turn off the headlights or to lock their car; others have forgotten to apply the park brake
2. the reported data shows that 'urgent calls of nature' and fatigue are among the most common causes of drivers forgetting to apply the park brake.

#### A better view

The view that 'you can't prevent driver stupidity' was the predominant view in safety in the 1970s. A better view is: 'drivers are not stupid, they are human and, like everyone else, they make mistakes'. Controls and equipment should be designed to take account of these capabilities so that an honest mistake does not lead to a catastrophic accident.

## “What am I supposed to do if drivers violate the rules?”

#### Myth explanation

The logic behind this view is as follows:

- there are stickers on windows warning drivers not to reach through and press the door close button
- the driver nevertheless reaches through, breaking the rule causing the rollaway
- if they break the rules like this, it is their own fault and there's really nothing more the operator can do.

#### Why this view is wrong

Unless the driver is intentionally trying to sabotage the bus or operator<sup>45</sup>, it is highly unlikely a driver would violate the rules knowing that it would result in a rollaway given the potential consequences such as:

- embarrassment
- potential dismissal or loss of pay while stood down
- injuries to the driver or others
- damage to the bus or infrastructure
- guilt and stress arising from these factors, especially injuries or damage occurring<sup>46</sup>.

#### A better view

A better view of violations is the following:

- accept that, as Professor Reason points out, “people will always make errors and commit violations”<sup>47</sup>
- understand what type of violation occurred e.g. is it a *routine, necessary, optimising* or *exceptional violation*
- understand *why* the violation occurred and *why* there is a gap between procedures and practice, “for progress on safety, organisations must monitor and understand the reasons behind the gap between procedures and practice” (p. 235)<sup>48</sup>
- adopt a just culture approach to deal with violations which ensures a balance between safety and accountability. Professor Hopkins<sup>49</sup> suggests the most appropriate method for doing this is using the 'substitution test' or the culpability decision tree (see above) to deal with violations

45 Reported incident data does not show any evidence of sabotage i.e. the driver knowingly breaking the rules *and* intending the bad consequences (a bus rollaway) to occur.

46 This is the 'mental economics' of violating, part of a balance sheet which on the costs' side include: causes an accident; injury to self or others; damage to assets; costly to repair; sanctions/punishments; loss of job/promotion; disapproval of friends see Reason, J, 2008, *The human contribution*, Ashgate, Farnham, p. 57-58.

47 Reason, J, 1997, *Managing the risks of organizational accidents*, Ashgate, Farnham, p. 153.

48 Dekker, S, 2003, 'Failure to adapt or adaptations that fail: contrasting models on procedures and safety', *Applied Ergonomics*, vol. 34, pp. 233-238.

49 Hopkins, A, 2009, *Failure to learn: the BP Texas City refinery disaster*, CCH, Australia.

- change the conditions under which drivers work to prevent violations e.g.:
  - change the culture (staff behaviours)<sup>50</sup>
  - change procedures, controls or equipment to make them more workable and easier-to-use
  - audit regularly to ensure rules are being following and investigate in circumstances where they are not.

Professor Reason summarises this last step as:

“we cannot change the human condition. People will always make errors and commit violations. But we can change the conditions under which they work to make these unsafe acts less likely” (pp. 153).

## “You can engineer it out” or “add more engineering”

### Myth explanation

This view is that with sufficient engineering design, you can ‘engineer out’ the human involvement and therefore the human error:

- if we automate part of a task, then the human does not carry out that part
- if the human does not carry out that part, there is no possibility of human error or violations
- in the case of rollaways, it holds that with sufficient engineering you can engineer out the error of the driver not applying the park brake
- it is based on the principle that “if people cannot be counted on to follow procedures, we can marginalise human work through engineering and automation”

### Why this view is wrong

Professor Reason neatly explains the reasons this is wrong: “Defensive measures designed to reduce the opportunities for a particular kind of human error can relocate the error opportunity to some other parts of the system, and these errors may be even more costly” (p.58). Professor Reason also says: “Defences, barriers and safeguards add additional components and linkages. These make the system more complex, they can also fail catastrophically in their own right” (p. 59).

With any engineering solution there is still going to be a human-machine interface. In the case of bus rollaways, while the driver may be less responsible for applying the park brake, it now falls on the manufacturer and the maintainer to ensure these systems work. Thus, while it has eliminated the problem of park brake applications for the driver, it now potentially creates new opportunities for human error with regard to the manufacture and maintenance of the system.

Unlike the current situation where the errors associated with buses are known, it may take some time to determine what human errors could occur as a result. For example, the maintenance of the interlocking feature leads to questions such as:

- will the engineering system result in shortcuts or workarounds?
- what will be the consequences of any human error?
- how detectable is the human error?

It is interesting to note that door interlocks themselves demonstrate the problems of engineering solutions. The bus stop brake was originally designed to ‘engineer out’ the problem of the driver taking off while someone is trapped in the doors. While it eliminated this risk, it created a new one – bus rollaways. We are now in the stage of eliminating the issue of rollaways. Will engineering controls to prevent rollaways create a new issue, and if so, what type of issue will it be?

### A better view

As Prof Reason states “introducing new engineered defensive features adds complexity to the system” pp. 53). A better view is:

- appreciate that engineering can cause problems as well as solve them
- such problems may only be identified years after being implemented or installed
- apply human factors tools and methods when designing controls to understand what problems could arise.

Thus, it is important to thoroughly assess the risks that engineering controls can introduce before they are implemented to avoid costly retrofits. As Architect Frank Lloyd Wright suggests:

“You can use an eraser on the drafting table or a sledge hammer on the construction site”.

<sup>50</sup> Organisations have implemented programs to ensure everyone holds on to the hand rail when climbing down the stairs. Employees have adopted these behaviours which have transferred outside work: employees also hold on to the hand-rail when they are climbing stairs outside of work.

## Take home points

### Understand bus features

As discussed above, there is great variation in how each bus is constructed and operates. Operators must understand what door interlock/external door buttons are installed on their buses and how they work.

### Understand vulnerability of buses and bus operations

What scenario of bus rollaway is your bus vulnerable to, if at all?

Operators should test their buses in a controlled environment to determine in what circumstances their bus will be subject to a rollaway.

It is also important to note that because operators have different types of buses, the risks posed from bus rollaways are different. Further, each operator has different bus operations making the overall risk of rollaways unique to each operator.

### Apply human factors at all stages

Application of human factors tools, methods and standards at all stages of the risk assessment and design process will ensure human performance capabilities and limitations are adequately taken into account. This will avoid expensive retrofits and ensure efficiency in the design and implementation of controls. It will also ensure that the unique bus rollaway risks faced by each bus operator are effectively taken into account.

### Review controls

It goes without saying that controls must be reviewed periodically to ensure they are effective and functioning as intended. Any controls implemented will need to adopt this approach.