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Unintentional Work Related Fatalities Research Program Fatalities of Pedestrians in Workplaces, Australia 2000 - 2011

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EXECUTIVE SUMMARY

Pedestrian fatalities occurring in workplaces are potentially preventable fatalities that have been under examined. This study identified 88 pedestrian fatalities reported to coroners in Australia and examines the chain of events leading to these deaths, and proposes potential interventions.

The majority of cases identified were male (n=80, 91%) and occurred in Victoria (n=37, 42%). The most frequent location of the incident leading to fatality was an Industrial or Construction Area (n=30, 34%), and the most frequent object involved was a Heavy Transport Vehicle (n=21, 24%).

A four level taxonomy of pedestrian deaths in workplaces was created from the available narrative text and coded data, and two hazard scenarios were identified: (1) the driver alights from the vehicle or plant/machine and either parks on an incline, or attempts to start or drive the machine from the ground, an inappropriate function of the braking system occurs and the machine rolls forwards or backwards, striking the pedestrian; and (2) the driver of the machine fails to see the pedestrian, and drives the vehicle or plant/machine forwards or backwards with intent, striking them.

A number of potential interventions were identified, including:

- redesign of workplaces and tasks to eliminate pedestrian contact with heavy machinery,
- use of physical barriers and designated pathways;
- incorporation of safety features into machine design, such as proximity/location sensors and devices to monitor operator blind spots;
- investigation of the effectiveness of reversing alarms; and
- raising awareness of this issue and reinforcing or training of good practices.

Data improvement and further research is warranted.

Introduction

This report addresses pedestrian fatalities occurring in workplaces in Australia between July 2000 – February 2011. It is divided into four sections:

- A: Review of the scope of pedestrian fatalities;
- B: Pedestrian fatalities in workplaces in Australia, 2000-2011;
- C: Summary and discussion of results; and
- D: Prevention strategies.

SECTION A: REVIEW OF THE SCOPE OF FATALITIES OF PEDESTRIANS IN WORKPLACES

INTRODUCTION AND LITERATURE REVIEW

Pedestrians are considered a vulnerable population due to their lack of protective "shell" (World Health Organization, 2009) and have been identified as a population for which there is scope for improvement in safety (Australian Safety Transport Bureau, 2000). In contrast to road-related pedestrian fatalities, little has been reported in Australia about the frequency and characteristics of pedestrian deaths in workplaces other than the road.

The objective of this study is to investigate Australian pedestrian fatalities in a workplace defined as "... a place, whether or not in a building or structure, where employees or self-employed persons work" (s.5 *Occupational Health & Safety Act*, 2004 (Vic)). The study excludes incidents causing death which occurred on publicly owned land (i.e. roads, road related areas, railways and rail related easements), except where it was identified as a defined workplace e.g. temporary barriers, work vehicles, signs, flaggers (Bryden et al, 2000).

It is hypothesised that the characteristics of pedestrian deaths that occur in the workplace differ from those on public roads. For example, in relation to forklifts, Collins et al (1999a) noted:

" *First, a forklift operator's field of vision is much more restricted and his/her ability to recognise oncoming hazards can be significantly diminished, particularly when the vehicle is loaded and/or the driver is looking over his/her shoulder driving backwards. Secondly, when a forklift driver recognises a hazard, the stopping capacity of a forklift...is much less that than of an automobile travelling at a similar speed*" (pp. 510).

A number of industries (e.g. construction and agriculture), occupations (e.g. road controllers or "flaggers") and particular plant or machines (e.g. forklifts) have been identified as being high risk for pedestrian related fatal injury (e.g. Ore & Fosbroke, 1997; Baron et al, 1998; Horberry et al, 2004).

Construction, and in particular, road construction, has been highlighted as hazardous for pedestrian deaths due to the close proximity to heavy machinery, travelling motor vehicles and constantly changing conditions (Pratt et al, 2001; McCann, 2006). Pratt et al (2001) found an average of nearly 70 deaths per year in highway work zones in the United States, with just over two-thirds being workers on foot, fatally injured as a result of heavy equipment and vehicles. The cause of the fatal incident was evenly split between motor vehicles intruding into the work zone, and heavy equipment and construction vehicles (especially when reversing) (McCann, 2006).

Particular occupations have been recognised as “at risk” for pedestrian related injury. Road traffic controllers (“flaggers”) slow road traffic through work zones to protect workers and motorists and are vulnerable due to their continuously changing position between moving traffic, heavy machinery and construction (Baron et al, 1998; Pratt et al, 2001).

Pedestrian fatalities have also been analysed by examining the object causing death. Several plant or machines (e.g. forklifts and tractors) have been identified in the literature as “high risk” to pedestrians.

Both internationally and in Australia, forklift use has increased in recent years, due to increased productivity and occupational health and safety benefits of reducing manual handling (Horberry et al, 2004). However these manual handling benefits have been accompanied by an increase in other safety hazards, especially when the machine is operated close to pedestrians, due to the weight, power and inherent instability of these machines (Collins et al, 1999b). In the United States, approximately 100 workers are fatally injured and another 20,000 are seriously injured in forklift related incidents each year (Horberry et al, 2004). In Victoria, forklifts have been associated with 57 deaths between 1985 and 2010 (WorkSafe Victoria, 2010).

Tractors have long been identified as a major issue for pedestrian fatalities in the agricultural industry (Miller and Fragar, 2006). For example, a report (Herde & Lower, 2011) on farm injury deaths in Australia 2003-06 found almost 50% of tractor related deaths were the result of run over incidents.

SECTION B: PEDESTRIAN FATALITIES IN WORKPLACES IN AUSTRALIA, 2000-2011.

Objective

To investigate fatalities of pedestrians in workplaces in Australia between July 2000 and February 2011.

Method

The National Coronial Information System (NCIS) is an Australia-wide data storage and retrieval system that commenced July 2000[1] of all coroner-reported deaths. When a fatality is reported to a coroner, staff at the coronial office send the details of the case to the central NCIS database, coded according to an agreed minimum dataset based on international standards (NCIS, 2007). Other relevant material such as police reports, toxicology and autopsy results and coronial findings are also attached, where available. This database is then searchable by authorised users by code and free text keyword search. As all work related deaths are likely to fall into the definition of a 'reportable death' (e.g. s4 *Coroner's Act, 2008 (Vic)*), there is a high probability that this database contains almost all fatalities of interest.

The Victorian Work Related Fatality Database (VWRFD) is a database collated from surveillance of fatalities reported to the Victorian Institute of Forensic Medicine (VIFM) augmented by data from the National Coronial Information System (NCIS). This database is therefore limited to one jurisdiction (Victoria), however it specifically identifies work-related cases, and codes additional information for work relatedness and occupation.

The NCIS provides more limited data on work-related fatalities for all of Australia. In combination, the NCIS and VWRF databases provide a comprehensive source of information that enables the identification of population based case series, and the subsequent identification of risk factors that can be analysed to point to potential prevention actions.

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[1] Queensland data is from January 2001

To create a case series of fatalities of pedestrians in workplaces from these two databases, the following inclusion and exclusion criteria were used:

Inclusion criteria:

1. the incident was coded as External cause and Unintentional in the NCIS and VWRFD; and
2. the death was of a pedestrian (as defined in the Oxford English Dictionary as "on foot, going or walking on foot; performed on foot; of or relating to walking") in a workplace as defined by s.5 *Occupational Health & Safety Act*, 2004 (Vic) regardless of work-relatedness (i.e. workers and bystanders were included).

Exclusion criteria:

1. incident causing death that occurred on publicly owned land (i.e. Roads, road related areas, railways and rail related easements) except where it was identified as a defined workplace e.g. temporary barriers, work vehicles, signs, flaggers (Bryden, et al, 2000);
2. incident could not have been avoided through reasonable workplace preventative measures (for example, a person in a restaurant died when a car drove into the building) (S.20 (1) & (2) *OHS Act*, 2004 (Vic)).

Therefore a case where a heavy vehicle, driven on the highway, strikes a pedestrian crossing the road would not be included; however a case where a heavy vehicle collides with a pedestrian on a construction site would be included.

The VWRFD and the NCIS databases were interrogated according to these criteria for the period July 2000 - February 2011[2]. The police narratives were examined by a researcher to confirm case inclusion.

In addition, SafeWork Australia's Traumatic Injury Fatalities Database identified a series of work-related pedestrian fatalities for potential inclusion into the study which were checked against the NCIS database to confirm case inclusion.

[2] Excluding Western Australia

After construction of the case series, the available material for each case (including coronial finding if available) was analysed to extract:

- age at death;
- gender;
- the year in which the fatality occurred,
- work-relatedness;
- post mortem toxicology status, if available (coded into 4 categories: “illegal drug or alcohol present”, “therapeutic drug present”, “not illegal and not therapeutic drug present” and “no drug or alcohol present”);
- the mechanism of injury that lead to the death (e.g. fall, electrocution, crush),
- the jurisdiction in which the fatality occurred;
- the location of the incident causing death;
- the object causing death;
- coroner’s recommendations and comments; and
- other contributing factors.

A four part structure, Person, Place/Location, Vehicle/Plant/Machine, and Policy provided a framework for results, discussion and prevention.

Methods were adapted from Lincoln et al (2004) to examine the narrative text and coded data to create a taxonomy of pedestrian fatalities in workplaces to account for the contributing factors identified.

Hazard scenarios identified were scrutinized to identify intervention points for prevention (Section D). The literature was reviewed to identify relevant evidence based countermeasure and implementation strategies.

Ethics approval was granted by the Monash University Standing Committee on Ethics in Research involving Humans, The Victorian Department of Justice Human Research Ethics Committee and the Victorian Institute of Forensic Medicine Ethics Committee.

Results

1. Person

Eighty-eight fatalities of pedestrians (80 male, 8 female) in work-places that met the selection criteria were identified in the jurisdictions investigated. At least two fatalities were reported in each year investigated, with an average of 11 deaths per year in the years with complete data (ranging from 7 – 20 deaths)[3]. Although the relatively small number of cases calls for caution in drawing conclusions, the years with completed data indicate the number of pedestrian fatalities in the workplace is steady.

Age at death ranged from 1-86 years (mean = 46.9 years, SD=20; median = 49.5 years) with the peak of fatalities occurring in the 50-59 age range (Figure 1).

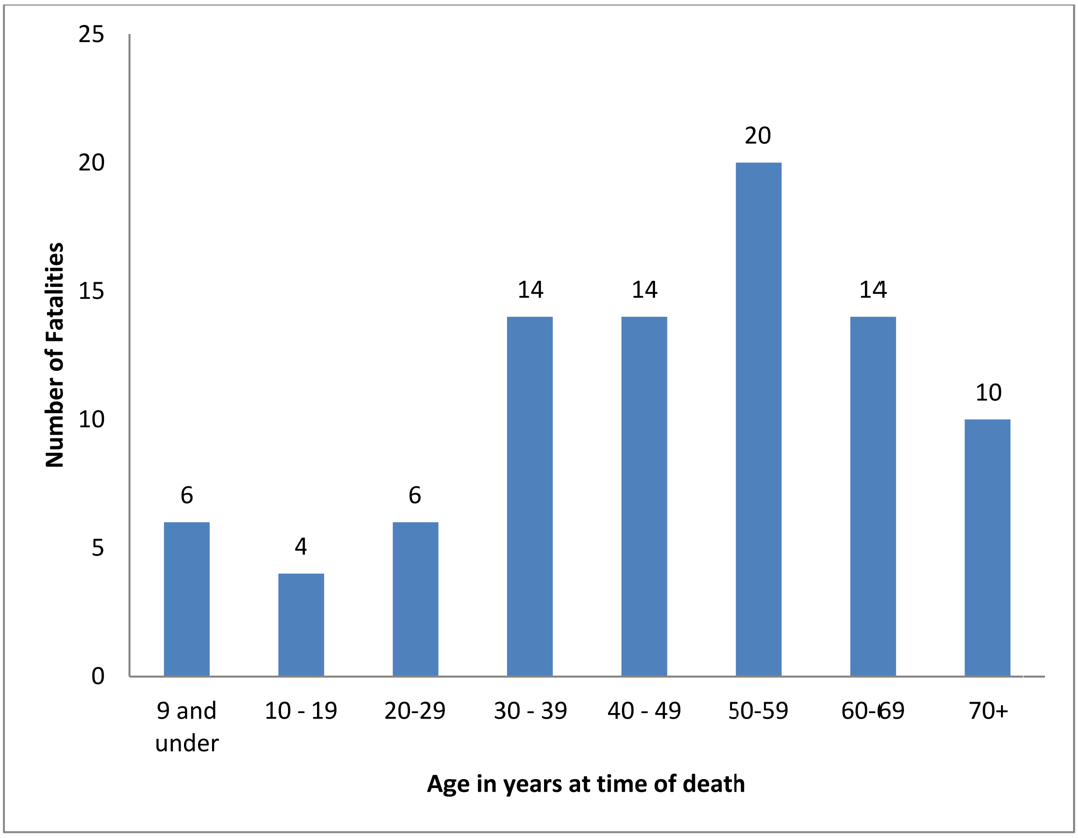

Figure 1: Age of pedestrian fatalities in work-places, Australia, July 2000 - February 2011 (Excluding WA)

[3] NCIS data collection began on July 1, 2000, with QLD data collection beginning 1 Jan 2001; therefore the figure for 2000 are 6 months of data and does not include QLD. The figures for 2008, 2009 and 2010 are likely to be lower due to the number of cases currently undergoing coronial investigation. Therefore the average of deaths per year for the years with complete data was calculated for the years 2001 – 2007.

The majority of pedestrian fatalities were workers (n=73, 83 %). Eleven cases involved bystanders and of these eleven, five cases involved children (Table 1).[4]

Table 1: Work-relatedness at time of death, Australia July 2000 - Feb 2011 (Excluding WA)

Work-Relatedness	**Number (%)**
Working for income or in kind	73 (83)
Bystander in workplace	11 (13)
(*Child*)	*6 (7)*
Volunteering	≤3 (*)
Other*	≤3 (*)
Total	88 (100)

* The Other category includes cases such as Do-It-Yourself

Toxicology reports or results were available for 52 cases (59.1%). Two of the children in the case series had toxicology performed, which were negative. The six children will not be considered in the toxicology totals. In eight cases positive results for alcohol or drugs were recorded (8/82, 10%). Of those eight cases, four were positive for alcohol and the remaining four were positive for cannabis or amphetamines.

The mechanism of death recorded on NCIS for the majority of cases was a transport injury event (n=59, 67%), followed by crushing (n=20, 23%) (Table 2). The most frequent cause of death was Multiple Injuries (n=34, 39%), followed by Head or Neck Injuries (n=20, 23%).

Table 2: NCIS Mechanism of death, Australia, July 2000 - Feb 2011 (excluding WA)

Mechanism	**Number (%)**
Transport Injury Event	59 (67)
Crushing	20 (23)
Contact with Object or Animal	6 (7)
Mechanical Threat To Breathing	≤3 (*)
Puncturing, Stabbing	≤3 (*)
Total	88 (100)

[4] Small numbers suppressed for confidentiality

2. Location

Fatalities occurred in all jurisdictions examined, ranging from ≤3 in Northern Territory, ACT and Tasmania to 37 in Victoria (Table 3).

Table 3: Jurisdiction of pedestrian fatalities in workplaces, Australia, July 2000 - February 2011 (Excluding WA)

Jurisdiction	Number (%)
Victoria	37 (42)
Queensland	23 (26)
New South Wales	18 (20)
South Australia	4 (5)
Australian Capital Territory	≤3 (*)
Northern Territory	≤3 (*)
Tasmania	≤3 (*)
Total	**88 (100)**

Note: Detailed information on the circumstances of fatal injury is most commonly available in Victoria and this is likely to contribute to the relatively high Victorian frequency.

The most frequent location of the fatal incident was an Industrial or Construction Area (n=30, 34%), followed by a Farm or Other Place of Primary Production (n=24, 27%) (Table 4). Of the 18 deaths that occurred in a Transport Area, 14 were at a road construction site (16%).

Table 4: Location of pedestrian fatalities in workplaces, Australia, July 2000 – February 2011 (excluding WA)

Location	Number (%)
Industrial or Construction Area	30 (34)
Farm or Other Place of Primary Production	24 (27)
Transport Area: Highway, Freeway, Street, Road etc[5]	18 (20)
(*Roadworks*)	*(14)(16)*
Home	7 (8)
Commercial Area (Non-Recreational)	6 (7)
Countryside (not Primary Production Area)	≤3 (*)
Sports and Athletics Area	≤3 (*)
Total	88 (100)

[5] All of these cases met the inclusion criteria with the incident occurring within a defined workspace.

3. Vehicle, Plant, Machine

Eighty-four cases directly involved a vehicle or plant/machine, and of the 84, nine involved the load on the machine. The remaining four cases did not involve a vehicle, machine or plant, but rather, an object (for example a tree).

Consistent with the three most common locations (Industrial or Construction Area; Farm; or Transport Area, primarily Road Construction), the majority of objects causing death were Land Vehicles (in particular Heavy Transport Vehicles, n=21) and Mobile Machinery or Special Purpose Vehicle (Tractors with/without Attachments, n=10; Front End Loader/Bulldozer/Bobcat, n=8; and Forklift n=6) (Table 5).

Table 5: Object associated with death of pedestrian fatalities in workplaces, Australia, July 2000 - February 2011, excluding WA).

Vehicular or plant/ machine involvement	Object description	Number (%)
Yes	Heavy transport vehicle	21 (24)
	Light transport vehicle	17 (19)
	Tractor and/or attachments	10 (11)
	Front end loader/bulldozer/bobcat	8 (9)
	Forklift	6 (7)
	Other (for example cement truck, road roller, crane, powered aircraft, machinery or fixed plant)	12 (14)
	Total	75 (85)
Yes, but involved load*	Total	9 (10)
No	Total	4 (5)
Total	Total	88 (100)

* This category encompassed a wide variety of materials or substances or equipment and could not be further categorised

Of the 84 vehicle or plant/machine related cases (75 vehicle or machine involved cases plus nine load cases), the deceased was the driver in 32 cases (38%) who had alighted from the vehicle and subsequently been struck. The pedestrian was not the driver in the remaining 52 cases (62%).

Of the 84 vehicle or plant/machine related cases, the direction of movement was recorded in 76 cases (Table 6): forward in 42 cases (50%); and reverse in 22 (26%). Of the 84 cases, 21 vehicles or plant/machines rolled unintentionally and unpowered, either forwards or backwards (n=21/84, 25%).

Table 6: Direction of vehicle/machine movement where involved, in pedestrian fatalities in workplaces, Australia, July 2000 - February 2011, excluding WA).

Direction	Movement type	Number (%)
Forward	Movement of vehicle intended	27 (32.1)
	Rolled	15 (17.9)
	Total Forward	42 (50)
Reverse	Movement of vehicle intended	15 (17.9)
	Rolled	6 (7.2)
	Load shifted	≤3
	Total Reverse	22 (26.2)
Stationary	Load shifted	7 (8.3)
	Attachment shifted	≤3
	Total stationary	10 (11.9)
Unknown	Unknown	8 (9.5)
Total	Total	84 (100)

4. Policy

Of the 88 pedestrian fatalities in a workplace, coronial findings were available for review in 56 cases (64%). The remaining 32 either had no findings completed or attached. In thirteen of those 56 cases (15%) the coronial report contained preventative comments or recommendations. Eleven were Victorian cases, and the remaining two from NSW. The comments or recommendations related to fatalities occurring between 2001 and 2006.

Recommendations ranged from specific about machinery types and work processes, to more systematic for industries or governments. (See Section D, Prevention Strategies).

5. Contributing Factors

Review of the case documentation revealed factors that appeared to contribute to the incident, or to increase the severity of the incident. As noted in the human error literature (e.g. Reason, 1992), fatalities were usually a result of a combination of factors, rather than a single factor. In this report, contributing factors are analysed where the Coroner or Police investigating officer recorded them specifically in the finding or report.

The most frequent contributing factors leading to pedestrian deaths in workplaces were: (1) the pedestrian standing or moving into a dangerous position (n=26, 30%), often leading to the driver being unable to see them. Examples include pedestrians moving into exclusion zones, or into the path of a moving vehicle, and pedestrians starting motors or trying to drive the vehicle from the ground, outside the vehicle; (2) inappropriate function of the braking system (n=23, 26%), where the brakes did not work due to malfunction, deliberate misuse, or failure to apply; (3) an impediment to the drivers vision (n=18, 20%), for reasons including vehicle design, size of pedestrian or environmental conditions; (4) the vehicle or plant/machine was parked on an incline (n=17, 19%) (Table 7).

Table 7: Selected contributing factors reported in case documentation of pedestrian fatalities in workplaces, Australia, 2000 - 2011 (Excluding WA)

Selected Contributing Factors*	Number (%)
Location of pedestrian	26 (30)
Inappropriate function of the braking system (all causes)	23 (26)
Driver's vision was impeded	18 (20)
Vehicle parked on incline	17 (19)

* Analysis indicated that fatalities were usually a result of a combination of factors, therefore these categories are not mutually exclusive and do not add to 100.

Two hazard scenarios were identified by taxonomical analysis based on the distinction between: (1) the pedestrian was also the driver; and (2) the pedestrian was not the driver (Figure 2).

Hazard Scenario (1): Pedestrian was also the driver

The pedestrian was also the driver in 32 of the 84 vehicle or plant/machine related fatalities (38%). In 17 cases, a consistent pattern emerged with the driver alighting from the vehicle, followed by the vehicle rolling either forwards or backwards, associated with brake failure, non-use, or mis-use, and striking them.

Hazard Scenario (2): Pedestrian was not the driver

The pedestrian was not the driver in 52 cases (62%). In 18 cases, a consistent pattern emerged with a driver failing to see the pedestrian due to an impediment to the driver's vision and driving forwards or reversing with intent.

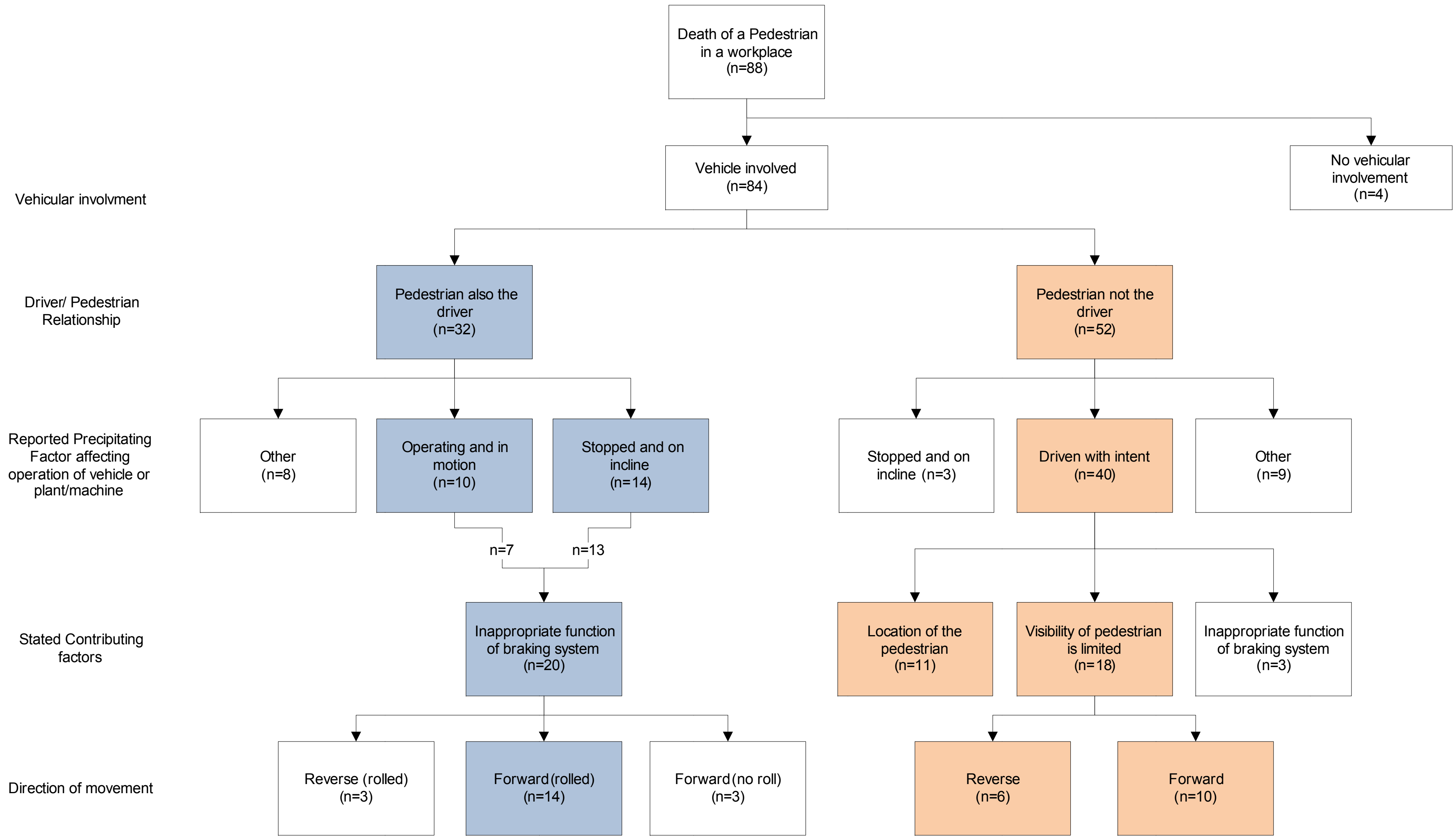

Figure 2: A four level taxonomy of pedestrian fatalities in workplaces, Australia 2000 - 2011 (excluding WA) based on the methods of Lincoln et al (2004). The shaded blocks indicate hazard scenarios 1 (Blue) and 2 (Orange)

SECTION C: SUMMARY AND DISCUSSION OF RESULTS

This study reviewed pedestrian fatalities that occurred in a workplace across industries and settings, allowing fresh insights into the issue and updating previous Australian studies.

Pedestrian fatalities in work-places were identified in Victoria more often than other jurisdictions, likely related to lack of detail in police reports and coroners' findings and differences in case closure rates. There is reasonable confidence in the completeness of the Victorian data. Therefore it follows that the likely incidence of this fatality type is in fact higher in other jurisdictions than is reported here.

1. Person

This study identified 88 cases of pedestrian fatalities in workplaces in Australia, July 2000 – February 2011. The majority were males working for income or in kind, though this may reflect that the industries in which the incident occurred tend to have a higher population of male workers (Transport, Postal and Warehousing, Construction) (ABS, 2007).

In eight cases positive results for alcohol or drugs were recorded (8/82, 10%). Of these eight cases, four were positive for alcohol (5%) and the remaining four were positive for cannabis or amphetamines (5%). This is slightly lower than the figure reported by McNeilly et al (2010), who found alcohol was present in 7% and cannabis or amphetamines in 6% of all work-related deaths in Victoria in the period 2001-2006. Not all jurisdictions were able to provide toxicology reports to the NCIS for the whole period investigated (2000 – 2011) (NCIS, 2009), and therefore it is possible that these figures are an underestimate of the actual presence of alcohol or drugs for those jurisdictions.

The most frequent mechanism of death recorded on NCIS was a transport injury event (n=59, 67%), followed by crushing (n=20, 23%). Given the severity and extent of injury to most of the deceased, prevention strategies would be likely more effective if aimed pre-event rather than at more efficient recovery strategies.

2. Location

The most frequent locations of the fatal incident (Industrial or Construction Area, Farm and Road Construction sites) were consistent with findings from international research and literature (e.g. Collin et al, 1999c; Ore & Fosbroke, 1997; Miller & Fragar, 2006). This is unsurprising, considering these locations require work with and alongside heavy vehicles and machinery, and in addition, road construction sites are exposed to passing traffic (Ore & Fosbroke, 1997).

3. Vehicle, Plant, Machine

The most frequently involved vehicle, plant or machines (Heavy Transport Vehicles, Tractors with/without attachments, Front End Loaders/Bulldozers/ Bobcats and Forklifts) were consistent with earlier national reported literature (e.g. Larsson & Rechnitzer, 1994; Miller & Fragar, 2006).

4. Contributing Factors

A number of contributing factors were identified following review of the case documentation, and are described here. Two scenarios were identified that involved common pathways of events ("Hazard Scenarios" Figure 2). The two hazard scenarios identified by this taxonomical analysis were based on the distinction between: (1) A pedestrian who was also the driver; and (2) a pedestrian who was not the driver.

Hazard Scenario (1): Pedestrian was also the driver

This is consistent with previous research undertaken in Victoria specific to severe and fatal injuries related to forklifts, where Larsson et al (1994) found a "surprisingly great proportion of the fatalities occur as the driver gets off and vehicle rolls". This study identified a fourth contributing factor to this scenario where cases were additionally associated with inappropriate operation of the braking system. This is similar to Jones et al (2011) where a scenario was identified of brakes not functioning appropriately and the vehicle then rolling causing non crash related heavy vehicle driver fatalities.

Hazard Scenario (2): Pedestrian was not the driver

Impairment to visibility has been previously associated with machinery such as forklifts, with Hella et al (1988) finding “most ... accidents are due to insufficient visibility...”. Horberry et al (2006) found that pedestrians accounted for a significant proportion of incidents involving mobile machinery (such as forklifts) that are associated with driving in reverse and carrying loads. The current study found that that majority of cases involved the vehicle moving forward (n=10) rather that in reverse (n=6), differing from the international literature (e.g. McCann, 2006). In research investigating visibility related fatalities in the United States construction industry, Hinze and Teizer (2011) found fatalities occurred when the equipment was travelling in reverse nearly four times more than when travelling forward.

Limitations

Western Australian data was unavailable for this study [Ethical approval to use WA data was not received until June 2011 – too late for inclusion in this study]. A lack of attached documentation and detailed information provided to the NCIS by some states and territories, and lag in case closure by the coronial system are likely to have resulted in substantial underreporting of cases and details of incidents including toxicology findings. Enhancements are needed to the detail recorded and to the completeness of the attachment of documentation to assist in formulating recommendations by coroners and in other pathways to prevention.

The data in the NCIS and VWRFD are collated from four sources: police report, coronial finding, autopsy and toxicology reports. However, the majority of circumstantial data analysed here is based on the report of the police officer(s) investigating the fatality. Currently, there is limited standardisation of information collected by police and other investigators to prompt the elicitation of information to inform injury prevention. Provision of a nationally accessible check list for officers attending pedestrian fatalities in workplaces could be beneficial, both for research and prevention efforts and also to assist officers to collect the most useful information whilst managing other aspects of the investigation.

SECTION D: PREVENTION STRATEGIES

Introduction

A number of strategies have been reported in the literature to address specific risk factors for pedestrian in workplaces (i.e. Larsson and Rechnitzer, 1994), and a number of coronial recommendations also have been made in relation to pedestrian fatalities (Table 8, grouped by the themes of Person, Place, Policy and Plant).

In the absence of a systematic approach to this persisting problem of person/machine interaction, we have drawn on first principle approaches to identify a comprehensive overview of potential countermeasures: (1) Haddon's ten countermeasure strategies, and (2) the Universal Causation Model (McClay, 1989a, b).

Table 8: Coronial recommendations for Pedestrian fatalities in workplaces, Australia 2000 - 2011 (Excluding WA).

Theme	Recommendation	To Whom
Person	Update training procedures to include latest safety warnings and how to "identify and manage common risk situations" (multiple recommendations)	Companies
	Driver licensing (e.g. restrictions for physical impairments)	Regulator
Place	Separation of pedestrians from moving machinery (e.g. barriers)	Companies; Authorities
Policy	Job safety analysis establishing the separation methodology to occur before any work commences; and site to be regularly monitored.	Companies; Authorities
	Consider authorities "review its investigating procedures and protocol, with a team approach to appropriate cases...utilising the services of experts with diverse skills".	Authorities
	Development of a pilot investigation guide for work-related fatalities in specific industries	Authorities; Coroner's Office; Police

Policy (cont.)	Consider a risk assessment to ensure appropriate supervision of workers	Companies
	Recommend safety policies be developed around hot wire starting of heavy vehicles	Company
	Operation manual to be updated to include known risks	Company
	Specific regulations to be drafted requiring vehicles to be parked, unloaded, and loaded within the confines of the site.	Regulators
	Industry alert to be developed for known risk regarding hot wire starts	Government Department
	Authority to work with manufacturers to design out/ modify cable type handbrakes on four-wheel drives	State Government Authority
Plant	Manufacturers to consider modifying design and signage of park brakes (multiple recommendations)	Manufacturers
	Under-run front and side protection (for pedestrians) on trucks is supported as a safety design countermeasure	Manufacturers
	Systematically examine mobile plant to ensure compliance with manufacturers standards	Companies; Authorities
	Direction to continue investigation of incident by manufacturer of vehicle or plant/machine involved, and communicate warnings to users	Manufacturer

Haddon's Ten Countermeasure Strategies

Countermeasures can be conceived along a path from *prevent the creation of the hazard* to *stabilise, repair, and rehabilitate the object of damage.* Haddon identified ten generic prevention techniques, commonly known as "Haddon's ten countermeasure strategies"(Runyan, 2003). Interventions proposed in the pedestrian fatality literature and coronial recommendations were categorised according to this model (Table 9).

Table 9: Haddon's ten countermeasure strategies and generated potential interventions

Haddon's countermeasure strategy	Intervention
1. Prevent the creation of the hazard	**Eliminate pedestrian workers from the task** Redesigning the task so that pedestrians and plant/machines do not come into contact at all (i.e. elimination of the hazard) is the best possible intervention (Horberry et al, 2006). For example, Larsson and Rechnizer (1994) recommend that in a freight terminal, "no forklift and pedestrian movement should ever take place at the same level, in the same space". (NB Detours would presumably eliminate the need for 'flaggers')
2. Reduce the amount of hazard brought into being	**Reduce the amount of vehicular traffic passing through work sites** McCann (2006) found workers on foot to be at risk of pedestrian fatal injury particularly in road construction and explained this was related to the number of vehicle intrusions into the work zone. Therefore it is suggested that road construction (and others as appropriate) consider limiting the amount of vehicular traffic that passes through the site for example by an increase in detours or working during less busy hours. The current study identified 16 road construction deaths, four of which were caused by light transport vehicles passing through the worksite.
3. Prevent the release of the hazard	**Use of Proximity/location sensors** Improved methods of identifying pedestrian workers (and members of the general public) in perilous proximity to vehicles or plant/machines can reduce the risk of pedestrian fatalities. A number of proximity-sensing devices are currently available for the workplace (Horberry et al, 2006). In the United States mining context, researchers have studied intelligent video systems for the application of identifying and alarming pedestrians in hazardous locations near fixed machinery (Ruff et al, 2010).

3. Prevent the release of the hazard (cont.)	**Use of Devices to monitor operator blind spots** Machinery operator's limited vision of surrounds has been identified as a contributing factor in this, and other, studies on pedestrian fatalities. Ruff et al (2010) identifies technologies such as sonar, radar, radio transponders, tag detection systems, video cameras and GPS technology as potentially useful in alerting operators of pedestrian proximity. However the use of such technology needs to be researched to address issues such as driver distraction (Horberry et al, 2006). In a study looking at rear-view cameras in vehicles, Hurwitz et al (2010) found there was evidence for the mitigation of reversing collisions, especially when paired with an appropriate audible sensor system. Encouraging drivers to use the cameras was revealed as a challenge. The current study identified 18 cases in which a barrier to the operator's vision was noted, suggesting that devices to enhance operator situational awareness could be a promising intervention. **Trained Spotters or Observers** "Spotters" or observers are encouraged in certain work conditions (e.g. working near electrical lines, working in confined spaces). McCann (2006) recommended spotters for workers who are required to work with, and alongside heavy machinery, and Hinze and Teizer (2011) noted that the ability of spotters to maintain constant communication with machine operators and drivers was "...an important facet of safe procedures and their importance cannot be overstated". **Correct lighting of the work site** Excessive or insufficient lighting has been cited as a cause of vision-related fatalities (Hinze and Teizer, 2011). *The Australian standard for interior and workplace lighting* (AS 1680.1-2006) provides general principles and recommendations for lighting with the intent "to facilitate the creation of visual environments that exclude or, at least, control visual fatigue and thereby promote efficiency and wellbeing in the illuminated space". Specific to pedestrians, WorkSafe Victoria (2010) recommends "ensure vehicles stop and drivers acclimatise before entering an area where there are pedestrians" and "ensure pedestrians cannot enter areas of vehicle traffic if they have not acclimatised to the lighting levels".

4. Modify the rate of release of the hazard from its source	**Intelligent speed limiting controls/load sensing devices.** A recent Australian study investigating Intelligent Transport Systems (ITS) countermeasures for industrial mobile equipment safety identified preventing excessive forklift speeds as the highest priority intervention (Horberry et al, 2006; Horberry et al (2004) investigated the use of a load sensing/speed limiting system for forklifts at two Australian manufacturing sites and found the application of this new technology successfully decreases the severity of pedestrian/forklift interactions although further work is required to evaluate this and other potential ITS interventions. There was insufficient consistent information available in the current study sample on speed of vehicles or machinery or whether machines were loaded or unloaded to allow for meaningful commentary to be made on the suitability of these countermeasures for the target population. **Administrative controls: e.g. training and competency** It is a requirement for operators of high risk machinery to have a Licence for High Risk Work under the *Occupational Health and Safety Regulations 2007* in Victoria. A number of writers (e.g. Collins et al, 1999a; Ruff et al, 2010) have suggested that improved operator training should be continued and emphasised in safety programs. Majekodunmi and Farrow (2009) suggest this training be extended to pedestrian workers as: *“pedestrians represent a high risk-group in the workplace because they appear to lack a fundamental awareness of the hazards associated with working in close proximity to powered industrial vehicles” (Dickety, 2002, quoted in Majekondunmi and Farrow, 2009)*. This recommendation is based on the observation that there are a large number of employees working with or near workplace vehicles, and Dickety’s (2002) finding that pedestrian error accounted for 9.8% of workplace transport accidents. It is not possible to evaluate the usefulness of this proposed intervention for the current case series as coroners’ findings tended to relate to systematic failings, rather than identifying individuals at fault.

5. Separate the hazard from that which is to be protected in time and space	**Workplace/site design and traffic management systems** Workplace/site design and traffic management systems are well documented solutions to preventing pedestrian fatalities. Examples include one way roads/isles; separate parking areas for personal and work vehicles; clearly marked pedestrian walkways; signs; dome mirrors mounted overhead at intersections and other areas of limited visibility; location of storage sheds and amenities away from work areas; grade separation between pedestrian and machinery traffic (e.g. Horberry et al, 2004; Collins et al, 1999a, b & c). **Exclusion zones** Exclusion zones are particular areas where entry by pedestrians is prohibited. They may be used in a range of situations, for example, during truck loading operations, forklift movement (particularly when fully laden) or during live electrical work. Best practice is for these areas to be clearly defined, marked, and enforced (WorkSafe, 2008; WorkSafe undated). **Limiting plant use during peak pedestrian time** Collins et al (1999c) found pedestrians were most likely to be struck by a powered industrial vehicle during peak pedestrian flow times, such as during shift changes, meals breaks and other plant wide breaks. They recommended traffic planning should consider restricting use of machinery (such as forklifts) during these periods. There was insufficient information available in the current study to identify pedestrian density at time of death, therefore it is not possible to comment of the potential usefulness of this countermeasure for the target population.

6. Separate the hazard from that which is to be protected by a physical barrier	**Physical separation of plant/machine and pedestrian** Physical separation through the use of barriers, guardrails, fencing, barricades, boom-gates is widely regarded as an appropriate strategy for pedestrian safety (e.g. Horberry et al, 2004; Collins et al, 1999c; Ore & Fosbroke, 1997; Bryden et al, 2000; WorkSafe, 2007). If the task cannot be redesigned to eliminate pedestrian workers altogether, another alternative is to provide a physical barrier between machinery and workers on foot, where possible.
7. Modify relevant basic qualities of the hazard	**Improved signage and controls** Horberry et al (2006) identified limiting speed for forklifts as an important intervention in the prevention of pedestrian fatalities. This can be approached in machine design (see vehicle factors, below) or through administrative workplace controls. Improved signage throughout the work site, and speed cameras may assist with identifying inappropriate operator driving. In a road construction context, Fosbroke and Ore (1997) recommend improving signage and traffic controls for motorists to prevent the chance of vehicle intrusion into the work zone. For example, signs should not be obscured and lane markings easy to interpret. **Modification/redesign of reversing/backup alarms** Since their introduction, Ruff et al (2010) contend that audible reversing alarms have decreased the occurrence of collision incidents. Despite this, a number of studies (including in our case series) involved cases where an audible alarm was functioning at the time of incident, but for some reason the pedestrian did not hear, or react appropriately to the alarm. Hinze and Teizer (2011) found reversing alarms were made less or ineffective to workers when multiple alarms were issued from multiple machines at the same time (i.e. on a busy worksite). Ruff et al (2010) suggest a number of explanations: worker habituation to alarms; difficulties in localising and prioritising alarms in congested work areas; workers wearing hearing protection. Therefore improvements could be made such as modification/redesign audible reversing alarms so they are more noticeable in workplaces with high levels of noise and congestion. The current study identified 15 cases where the machine or vehicle was driven in reverse. Of the 15, at least four cases involved an audible reversing alarm to which the deceased either did not hear or was unable to act appropriately (the researchers are unable to make comment on the remaining cases as this information was not documented).

7. Modify relevant basic qualities of the hazard (cont.)	**High visibility clothing** High visibility clothing is encouraged and required to be worn in certain work conditions, including those working on, or near the road (WorkSafe Victoria, 2005). A number of authors have published research (particularly in relation to road construction sites) on the benefits of high visibility clothing on the conspicuity of pedestrians. A Cochrane review (in the context of pedestrians and cyclists in on-road traffic) found there was evidence to support visibility aids in drivers detecting pedestrians and cyclists earlier (Kwan and Mapstone, 2009). **Limiting potential pinch points** Workplace design must consider limiting potential pinch points, for example preventing the possible pinning of a pedestrian between a fixed object such as a wall, and a mobile machine, such as a forklift (Ruff et al, 2010).
8. Make what is to be protected more resistant to damage from the hazard	**Personal protective equipment** Personal protective equipment (PPE) refers to passive safety devices and may include hard hats, safety shoes, goggles, face shields, reflective clothing such as safety vests, heavy or thin (leather) gloves, hearing protection, wet weather gear, and respirators or filter masks (Teizer et al, 2010). PPE may reduce the severity of an incident; however it may not absorb or deflect enough energy to prevent a fatal outcome. Efforts should be focused on primary prevention methods to eliminate or mitigate the risk, as PPE has no means of preventing contact between the pedestrian and the plant or machine. **Fitness for duty** Operator fatigue and fitness for duty detection was identified by Horberry et al (2006) as a high priority area for intervention. A number of devices, ranging from the ability to detect drugs and alcohol to being able to detect behaviour impairment are currently available. However, a recent Cochrane review (2009) found: *“There is insufficient evidence to advice for or against the use of drug and alcohol testing of occupational drivers for preventing injuries as a sole, effective, long-term solution in the context of workplace culture, peer interaction and other local factors”.*

9. Begin to counter damage done by the hazard	**Personal emergency alarm** A safety alarm system is another passive safety device that allows early localisation and treatment of an injured person (Driscoll et al, 2008). As noted with PPE, the nature of injuries in this case series suggests that efforts should be focused on primary prevention methods. **Discourage workers from working alone and unsupervised** One danger of working alone is the chance that an injury will inhibit the ability to self-rescue or call for help and could therefore lead to a worse outcome than if working with others (Commonwealth Safety Management Forum (CSMF), 2002). A number of guidelines are available for employees and workers to assist with identifying and controlling the risks of working alone or in isolation (e.g. CSMF, 2002; WorkSafe Victoria, 2011) and include measures such as buddy systems, electronic surveillance or duress alarms.
10. Stabilize, repair, and rehabilitate the object of damage.	**First aid and emergency response** Where all the above potential interventions are unable to prevent a pedestrian and machine collision, post-incident emergency and first aid responses are vital to ensure best chance of survival (Ore & Fosbroke, 1997; Haddon, 1972).

Universal Causation Model

The current research indicates there are specific typologies of incidents for which specific prevention initiatives may be appropriate. Two typologies or hazard scenarios were identified in this report (see Contributing factors, Section B and C):

1) Pedestrian was also the driver; and
2) Pedestrian was not the driver

Jones et al (2011) applied a Universal Causation Model (McClay, 1989a & b) to the first typology in relation to work-related non-crash heavy vehicle driver fatalities, and the reader is referred to Jones et al (2011).

Therefore, this report will focus on the second typology or hazard scenario (pedestrian was not the driver and was not visible), which occurred in 18 (20%) cases (Figure 3).

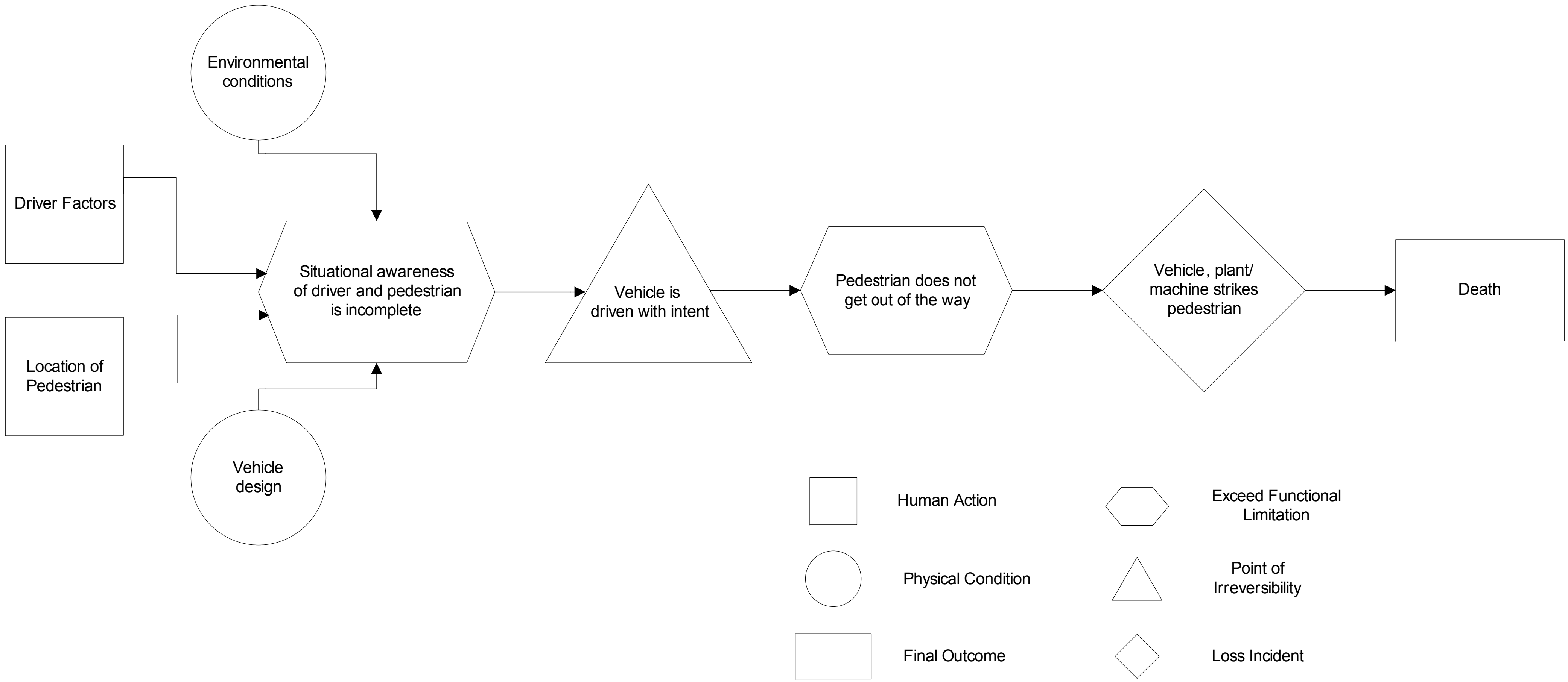

Figure 3: Universal Model of Causation for pedestrian deaths in workplaces, Pedestrian was not the diver and was unseen, Australia 2001 – 2011 (Excluding WA)

In order to identify any additional prevention possibilities to those already identified in the literature, Haddon's Matrix[6] (e.g. Haddon, 1980) was applied to the error pathway of Hazard scenario 2 (described by Figure 3). The content was generated following Haddon's ten countermeasure strategies and the literature. Interventions identified in Table 9 can be placed in the Universal Model to indicate the point at the trajectory where they would be expected to be effective (Figure 4).

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[6] Application of Haddon's Matrix involves assessing what changes could be made to person factors (e.g. fatigue), the social environment (e.g. training), the physical environment (e.g. terrain) and the agent or carrier (the truck or trailer) at three conceptual phases: pre-event, during the event and post-event.

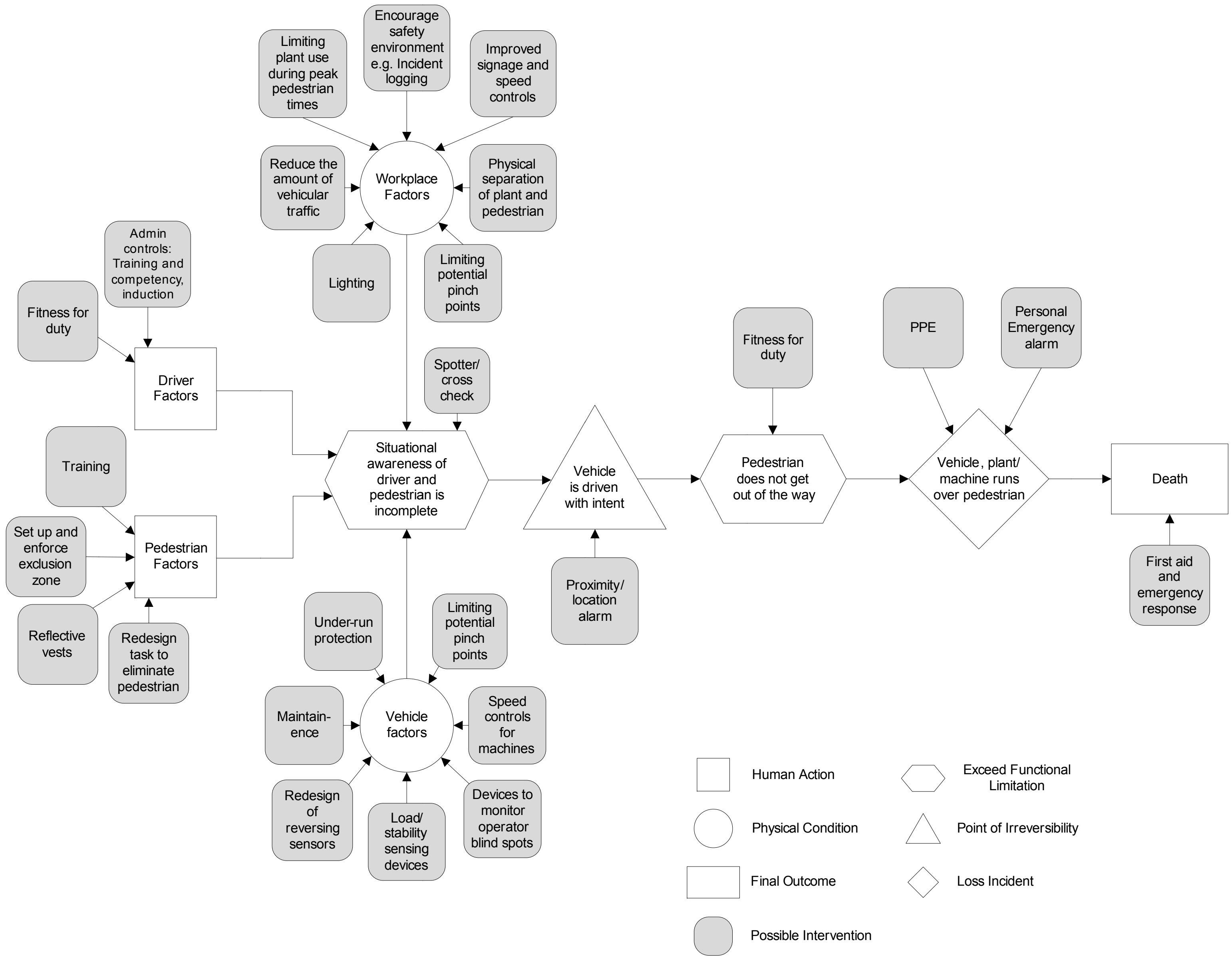

Figure 4: Universal Model of causation for pedestrian deaths in workplaces, Pedestrian was not the driver and was not visible, Australia 2001 - 2011 (Excluding WA), with opportunities for prevention interventions

Summary of data improvement and future research directions

1. Specific protocol for collection of relevant data from each type of fatal incident (for example pedestrian in road crash, pedestrian in industrial incident) that can be downloaded by investigators. A number of interventions were unable to be commented on specifically to our case series due to a lack of documentation, including whether machine was loaded, speed of machine, whether any safety features were in place (e.g. exclusion zones, a reversing alarm operating, worker wearing a hard hat).
2. A number of articles (e.g. Horberry et al, 2006; Majekodunmi et al, 2009; Wu et al, 2010) recommended encouraging workers to report near-collision incidents due to the potential to provide insights and opportunities to further improve safety (Wu et al, 2010); however it was highlighted that this would require building employee trust and stimulating a strong safety culture within the organisation. Majekodunmi et al (2009) found:

   "*underreporting or not reporting incidents at all remain high, especially amongst small- and medium-sized businesses, partly due to lack of awareness of legal reporting requirements, fear of legal penalties, or the administrative burden involved in reporting incidents*".

   A number of new technical solutions for the autonomous real-time tracking of near miss incidents are currently emerging, however scientific evaluation is required before uptake is encouraged by industry (Teizer et al, 2010).
3. Further research on promising interventions and implementation strategies such as:
   a. visual reversing cameras, used in conjunction with proximity sensor alarms;
   b. modifying design and signage of park brakes;
   c. Under-run front and side protection (for pedestrians);
   d. Intelligent Transport Systems (e.g. for forklift speed)
4. Investigation of enhancements to the effectiveness of reversing alarms on industrial vehicles and mobile machinery.
5. Evaluation studies.

Conclusion

While many countermeasures and implementation strategies are known, pedestrian fatalities in workplaces continue to occur in Victoria, and Australia more broadly. This suggests that strategies are needed to enhance the implementation of current knowledge and to continue to support research where new knowledge is needed.

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