BACKOVER COLLISIONS AND THE EFFECTIVENESS OF REVERSING CAMERAS

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ABSTRACT

Collisions involving a reversing passenger vehicle and a pedestrian or another vulnerable road user on public roads are not common in Western countries (approx. 10% of reported pedestrian injuries in Australia). However, these low-speed crashes are particularly injurious events and likely underreported. An inter-national analysis of European, US and Australian data showed that 7.4% of these reversing incidents involved a fatal outcome (for the pedestrian) and the majority involved a severe injury (fatal or non-fatal). Moreover, they are highly under-reported as many occur on private roadways and pathways. Reversing cameras have the potential to save serious injuries and lives.

INTRODUCTION

Collisions between a reversing passenger vehicle with a pedestrian or another vulnerable road user are particularly injurious events. NHTSA (2006) reported that from FARS 1998 data, 183 fatalities occurred in backover collisions (when a vehicle reverses into and injures or kills a non-occupant such as a pedestrian or a bicyclist) on public roads. Austin (2008) further argued that these collisions are severely under-reported. Comparing Not-in-Traffic Surveillance (NiTS) data with traffic data, he found that the total annual backover injuries in the US was approximately 18,000 of which only 22% occurred on the road and were reported by the police.

In Canada, Glazduri (2005) claimed that there are approximately 900 pedestrians struck and injured by reversing vehicles each year in Canada (Transport Canada 2004) but also noted that this is likely to be an underestimate.

Involvement in backover collisions

In an earlier study, Fildes, Newstead, Keall and Budd (2014) found that pedestrians aged 60 years and older were more likely to be involved in a backover collision than other ages, based on national data from Germany and four Australian states. They further found that women were more likely to be at risk than men.

Hoschopf *et al* (2016) also reported higher than average involvement rates in backover crashes for pedestrians aged 65 years and above in collisions with a vehicle in a residential driveway. Charness *et al* (2012) found a higher crash risk for those aged 75 plus in backing collisions in West Central Florida car parks that they attributed to their slower reaction to hazardous events.

There is also worldwide concern that small children are at risk of being run-over in their home driveways from vehicles being driven by family members that are backing out of the driveway and who fail to see their infant behind the vehicle (Paine *et al*, 2003). BITRE (2012) reported that seven pedestrians aged 0–14 were killed each year on average in Australia between 2001 and 2010, and 60 were seriously injured, due to a collision with a four-wheeled motor vehicle at home.

In the UK, hospital and emergency department records showed there were 202 reported incidents of vehicle accidents to children aged 0-4 years in 2002 ROSPA (2012). From 2001-2012 surveillance data, they further noted that of the 24 reported deaths to toddlers and young children killed on driveways, 60% were from a reversing vehicle.

Reversing Technologies

The number of reversing cameras in new passenger cars in Australia has been steadily growing over the last several years. The Royal Automobile Club of Victoria (RACV) published reports on rear camera fitment rates in Australia between 2012 and 2015. They noted that camera fitment as standard on new passenger vehicles in Australia had increased from 27% to 44% across that period and that the number of vehicles with no reversing technologies (cameras or reversing sensors) fell from 45% to 34%. The increase in cameras covered all vehicle categories, especially in small-medium, medium, large and sports vehicles.

Peach (2012) claimed that using wing mirrors, being more aware of vulnerable road users, improved detection of those not in the driver's field of view, and improvements for older and visually restricted drivers will reduce the chance of involvement in a reversing collision. He claims that most reversing cameras use a wide-angle lens, which while not providing a long-distance view will vastly improve short range vision.

Unfortunately, though, little quantitative evidence was found on just how effective these cameras are at reducing crashes, using real-world crash data.

STUDY AND OBJECTIVES

In the light of these findings, this study set out to examine the extent of backover collisions using several international databases and the potential for reversing cameras and other technologies to reduce these injurious events. A comprehensive report is available in Fildes *et al*, 2016.

International Data analysis

An analysis was undertaken using national police data provided from each of the four regions, namely the USA, Germany (DE), United Kingdom (UK), and Australia (AUS). Australian data were only available for five-states (86%) but were subsequently adjusted for the total population. A common analysis strategy was adopted to determine the relative incidence and associated crash configurations in each region. The analyses focussed on data that were provided for all these countries.

Crash outcomes focused on the size of the problem, type of collision, age, and gender of those involved, and associated injuries. In-depth data were also provided on crashes in UK and DE and an analysis of police-reported crash causation factors was also available from the UK data.

Size of the problem

The average annual number of collisions involving pedestrians backed-over is shown in Table 1 below, along with the percent this represents of all pedestrian collisions for the four countries.

Table 1: Total number of pedestrian injuries from backover collisions compared with all pedestrian injuries

Country	Backover Peds annually	% All Pedestrians
AUS	252	9%
DE	unk	unk
UK	1,940	8%
USA	3,425	5%

Equivalent figures were unavailable in Germany as only killed and seriously injured pedestrian collision data were available. The proportion of backovers to all pedestrian collisions was similar in Australia and the UK but less in the USA, potentially reflecting fewer reported incidences and/or less severe crashes.

The findings in Table 2 show that there was a strong relationship between the injured pedestrian's age and their backover injury severity: for AUS and the US, very young children and older people were more often killed and seriously injured. This pattern was less clear for the UK, although pedestrians aged 60 years and older generally had similarly high rates of Killed and Serious Injury (KSI) rates across all countries.

Table 2: Number of pedestrians KSI in backover collisions and percent of all pedestrians KSI by age and country (2010-12)

Pedestrian age group	AUS*	UK	USA
<5	**1** (21%)	**10** (17%)	**10** (42%)
5-9	**2** (38%)	**9** (12%)	**4** (14%)
10-19	**8** (43%)	**13** (8%)	**12** (2%)
20-29	**11** (40%)	14 (6%)	**64** (9%)
30-39	**7** (28%)	**19** (9%)	**49** (14%)
40-49	**3** (16%)	**19** (8%)	**31** (4%)
50-59	**6** (17%)	**27** (13%)	**39** (13%)
60-69	**5** (15%)	**36** (18%)	**54** (21%)
70 plus	**23** (29%)	**152** (29%)	**75** (24%)
missing	**4** (41%)	**5** (11%)	**6** (3%)

**Australian data are from the States South Australia, Victoria, New South Wales and Queensland only.*

Table 3: Percent of drivers involved in backover collision with KSI pedestrians by age and country

Driver age group	AUS	DE	USA	USA
<20	3.8%	2.4%	2.9%	6.4%
20-29	20.5%	16.2%	19.3%	25.4%
30-39	19.1%	16.1%	23.9%	10.6%
40-49	21.7%	23.3%	22.1%	20.7%
50-59	15.2%	18.5%	14.9%	28.5%
60-69	11.5%	11.9%	9.4%	5.4%
70 plus	8.1%	11.7%	7.3%	2.9%

The distribution of the age of the driver involved in backover collisions shows some consistency across the four regions as shown in Table 3.

Table 4: Proportion of drivers and pedestrians involved in back-over collisions by gender and country

Country	Driver Male	Driver Female	Ped'n Male	Ped'n Female
AU	65.7%	34.3%	42.8%	57.2%
DE*	67.9%	32.1%	28.4%	71.6%
GB	73.7%	26.3%	42.2%	57.8%
US	78.9%	21.1%	44.6%	55.4%

**German data are for KSI only*

The gender distributions of drivers and pedestrians involved in backover collisions in Table 4 shows a degree of similarity, with more involvement of male drivers and female pedestrians.

Summary

The major finding was that the proportions of police-reported crashes were quite similar across these regions, where 7.4% of these reversing incidents involved a fatal outcome (for the pedestrian) and more than 90% involved a severe injury (fatal or non-fatal). Forty five percent of the pedestrians injured and killed were aged 60 years or older and more likely to be female.

Table 2 shows that 11 children (0-19 years) were fatally or seriously injured per year by backover collisions in the four Australian States. These figures are especially alarming as they represent a group for whom we have a special duty of care. It is probable that the backover injuries are substantially under-represented. As reported earlier by Austin (2008), many of these collision types are not reported to the police as they commonly occur off-road in plazas, driveway and on footpaths.

CRASH CAUSATION

In addition to the extent of backover collisions, an analysis of the reported causations of these crashes and the crash configurations was also carried out to add further information on them. This was possible using National data provided by the UK and in-depth data from both the UK and Germany.

Crash Causation

The United Kingdom STATS 19 database includes the police assessment of what they considered to be were the main contributory factors associated with their backover crashes, involving an injured pedestrian. For each crash, there were up to six associated factors coded for each crash, covering driver, vehicle, environment, and pedestrian factors (in the case of pedestrian crashes).

Table 5: **The 20 most common contributory factors coded from backover crashes (UK data, 2010-2012)**

Contributory factor (up to 6 per crash)	Frequency	Percent
Driver failed to look properly	3956	25.28
Pedestrian failed to look properly	2619	16.74
Pedestrian failed to judge vehicle’s path or speed	1288	8.23
Vehicle blind spot	1083	6.92
Driver and/or pedestrian was careless, reckless or in a hurry	1021	6.53
Poor turn or maneuver	989	6.32
Pedestrian careless, reckless or in a hurry	491	3.14
Failed to judge other person’s path or speed	364	2.33
Pedestrian dangerous action in carriageway	307	1.96
Pedestrian crossing road masked by stationary or parked vehicle	302	1.93
Driver loss of control	300	1.92
Pedestrian impaired by alcohol	275	1.76
Aggressive driving	271	1.73
Pedestrian disability or illness, mental or physical	229	1.46
Stationary or parked vehicle(s)	150	0.96
Impaired by alcohol	143	0.91
Nervous, uncertain or panic	143	0.91
Pedestrian wearing dark clothing at night	140	0.89
Too close to cyclist, horse rider or pedestrian	120	0.77
Illegal turn or direction of travel	93	0.59

Table 5 shows a simple analysis of the 20 most common contributory factors allocated to backover crashes in the UK between 2010 and 2012. The table showed the frequency of occurrence and the corresponding percent of all contributory factors allocated for these crashes. The most common codes assigned by the police for backover collisions were “failed to look” for drivers and pedestrians (42%) combined. Many others included poor decision making and obstructions to a clear view.

To further understand some of the relationships between drivers and pedestrian errors in reversing collisions, a contingency table analysis was also undertaken that further showed that by far the most common combination (one-quarter of all combinations of pedestrian and driver codes) was where neither party were judged not to have looked properly, or where the pedestrian failed to judge the vehicle's reversing path or speed.

Crash Circumstances

A second analysis was also undertaken using in-depth cases of backover collisions investigated in Germany (GIDAS) and the UK (RAIDS). Access to 26 cases were generously made available for this analysis, of which 11 cases involved fatal or severe injuries.

These crashes reflected a range of pedestrian movements in motion. As found earlier, many involved failures to see on the part of either the pedestrian and/or the reversing driver. Some of these scenarios showed that the pedestrian not only failed to see the vehicle approaching but also misinterpreted either the vehicle's speed or the track it was taking. In one of the in-depth cases, the driver's foot was mistakenly placed on the accelerator rather than the brake pedal.

Of the pedestrians struck by a reversing vehicle in Table 6, 58% were aged greater than 65 years while 24% of the drivers were also aged above 65 years. Only one of these collisions involved an adolescent and another from a separate source included a young child. This suggests that the 11 collision scenarios in Figure 1 were reasonably typical of all 26-backover collisions and a reasonable set of crash circumstances that current and future reversing technologies on vehicles need to address.

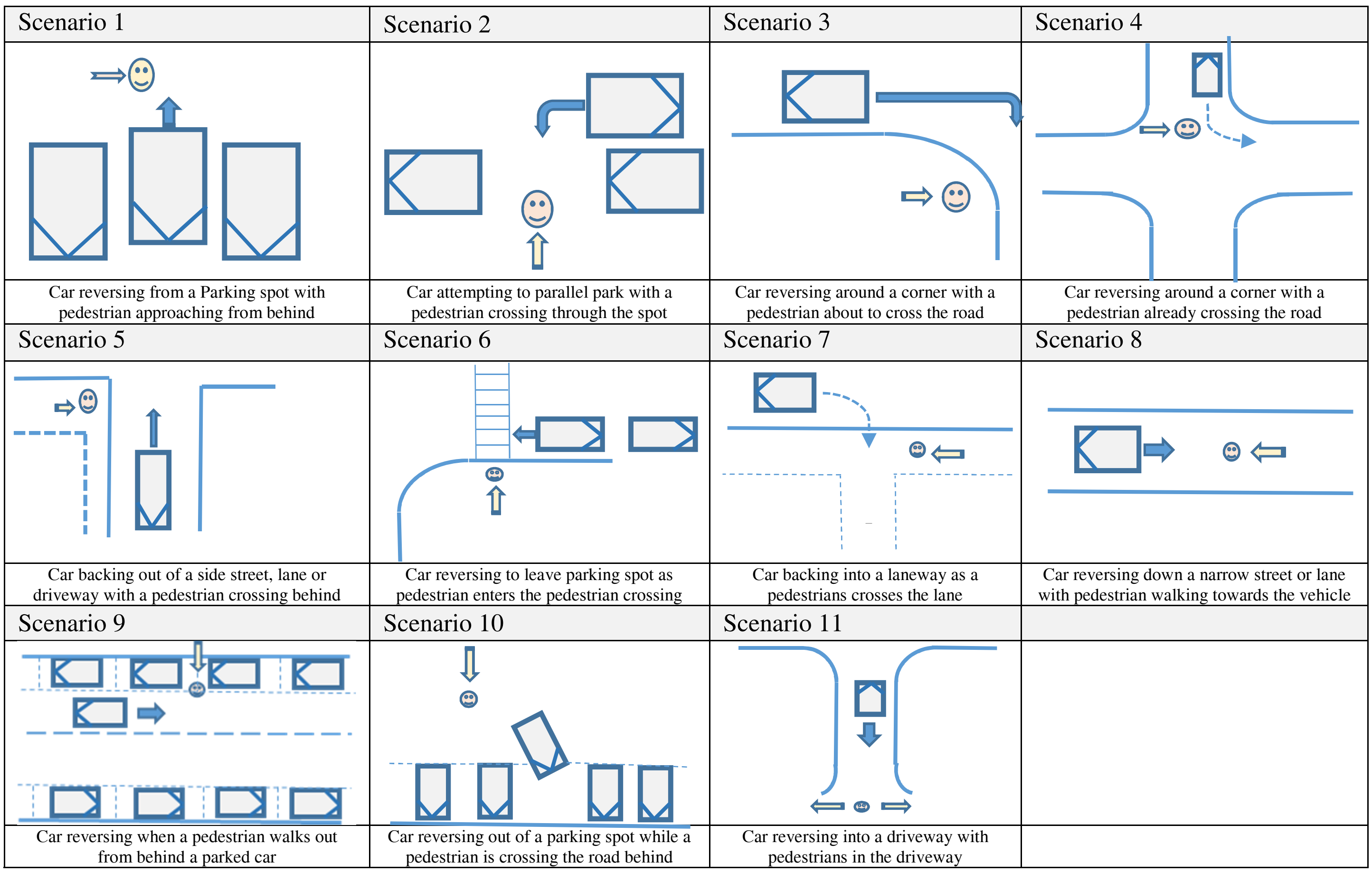

Figure 1: The 11 most frequent crash scenarios from the total sample of 26 in-depth crashes provided

Summary

The analyses of police and in-depth data on the circumstances leading to a backover collision and the responsibility assigned to crashes that occurred showed that the most frequent combinations of causative factors coded by the UK police (one-quarter of all combinations of pedestrian and driver codes) for backover crashes was where neither party failed to looked properly and where the pedestrian made poor judgements of the vehicles trajectory or speed.

Using in-depth crash data provided by BASt in Germany and RAIDS in the UK, 11-common types of crash manoeuvers on the road were identified. These will be useful for designing new prevention technology. There is a need to elaborate codes for off-road crashes should these data become available.

INTERVENTIONS

There have been various calls for pedestrians to play a part in preventing these collisions (for Adults; Cassell *et al* 2010; for school children; DET 2013; and for very young children; Kidsafe, 2008). While behavioral interventions are clearly important and useful, we need to be careful to avoid blaming the victim.

This study however was more focused on vehicle technologies to alleviate the vehicle impacting the pedestrian. This approach is also particularly relevant in identifying potential solutions to the problem of pedestrians of all ages being killed or seriously injured in reversing collisions. The in-vehicle approach focusses on possible in-vehicle devices to alert the driver to the danger or intervene where necessary. The following focused on some available technologies (in-vehicle or otherwise) as well as the need for new policy and mandatory fitment requirements.

Reversing Cameras

As noted in the introduction, RACV (2012; 2015) published OEM rear camera fitment rates in Australian passenger vehicles between 2012 and 2015. They noted that camera fitment in new vehicles had increased from 27% to 44% across that period and that the number of vehicles with no reversing technologies fell from 45% to 34%

Keall *et al* (2017) analysed Australian real-world crash data to determine the effectiveness of reversing cameras and reverse parking sensors in preventing backover injuries. Compared to vehicles without any of these technologies, the likelihood of a backover injury was 41% less (95% CI 12% to 61%) with a reversing cameras compared to no reversing technology. The effectiveness of cameras with sensors or sensors alone were not statistically reliable. There is a need for these findings to be replicated using a larger crash database.

Table 6 shows the potential savings in road casualties that could arise if the fleets in the three countries shown were to move from 0% fitment to 100% fitment of reversing cameras, applying the effectiveness estimate from Keall *et al* (2017). The actual expected safety effect of 100% fitment would be less than this for the on-road crash injuries that were included in the databases available, as a proportion of vehicles already have reversing cameras. However, as Austin (2008) estimated in the case of the US, counts of on-road casualties from backovers substantially underestimate backovers in all settings.

Table 6: Expected annual casualty savings in backover collisions for the three country fleets with 100% reverse camera fitment.

Country	Casualty Savings
AUS	98
UK	765
USA	1,361

Thus, the estimated casualty savings shown in Table 6 would also likely be underestimates of the savings achievable if all passenger vehicles had reversing cameras fitted.

The Need for Mandatory Fitment

The potential benefits in terms of injuries saved in Australia are shown in Table 7 broken down by fatal and non-fatal injuries.

Table 7: Potential benefits in fatal and non-fatal casualties in reduced back over collisions: police-reported and Inflated values

Injury Severity	Police-Reported Values	Inflated Values (Austin 2008)
Fatal	1.4	5.7
Non-fatal	40	180
Total	**41.4**	**186**

NHTSA (2010) reported the likely cost of fitting reversing camera technologies, shown in Table 8. While there have been significant costs reductions in these technologies since 2010, nevertheless, they were the only cost data found to date.

Table 8: Estimated Installation Costs (NHTSA 2010)

Application	Cost (USD2010)
Full system installation per vehicle	$132 to $142
Camera-only installation per vehicle	$43 to $45

On these figures, NHTSA (2010) estimated that the costs would exceed the overall benefit by between $161 and $224 per vehicle using a 3% discount rate. A similar outcome was found in Australia by Fildes, Keall, and Newstead (2016).

While acknowledging that the monetized costs outweighs the monetized benefits, NHTSA pointed out there are significant other benefits that cannot be quantified in monetary terms. On this basis, the U.S. DOT introduced FMVSS 111 to protect children and the elderly, where all vehicles under 10,000 pounds (approx. 4,500 kg) include a reversing camera and supporting equipment by May 2018. They noted that this could add $40 to $140 to the price of a new car. The agency claims that the rear visibility rule (FMVSS 111) also affords significant unquantifiable benefits in reducing a safety risk that disproportionately affects particularly vulnerable population groups (such as the elderly and young children), and exacts a significant emotional cost on relatives and caretakers who inadvertently back over their own children.

IN-VEHICLE TECHNOLOGY IMPROVEMENTS

Fildes *et al* (2016) also noted that reversing cameras would only be effective if the driver was looking at the screen while backing and spotted the pedestrian or cyclist. While the benefits noted above show that cameras can be an effective means of reducing the number of backover crashes, they rely on how often drivers pay attention to the technology displays while reversing. Thus, it would be possible to link the camera with additional sensing technology to provide an audible signal to the driver when backing and/or apply the brakes in an emergency, to enhance their effectiveness. Such software packages are available for forward collision sensing that interpret the camera image as a sensor of impending danger and could possibly be adapted for reversing manoeuvres as well.

Automatic Emergency Braking Rear (AEB Rear)

Robert Bosch Australia have developed an Automatic Emergency Braking Rear (AEB Rear) concept that they have been demonstrating in Australia in recent times. The system offers reverse collision mitigation or prevention up to 15km/h, sensing and automatic active braking, and assistance with low speed parking and driveway scenarios. It comes with rear sensing technology including radar units in both rear corners and ultrasonic bumper sensors adopted using tailored ESP functionality.

They note that the system can provide full or partial active braking, depending on the requirements and sensors included. The system controls brake pressure build-up at all wheels such as in a Brake Assist package with internal sensors to alert the driver to its activation, as Electronic Stability Control (ESC) does. The system incorporates Blind Spot Detection (BSD) and Cross Traffic Alert (CTA) functions, enabling the system to not only sense the presence of a stationary pedestrian behind the vehicle, but also a moving object such as a child walking or riding a bicycle behind the vehicle, and applies the brakes automatically.

Figure 2: Bosch AEB Rear concept

Bosch have conducted several public demonstrations of this technology across Australia and won the 2014 Mobility Engineering Excellence Award by SAE Australasia. It is unclear if any current vehicle manufacturers have installed this technology in production vehicles but Bosch report there has been some interest from the manufacturers. Unfortunately, they could not provide any Benefit-Cost-Analysis figures on this technology.

Reverse-Alert Technology

A new Company, "Reverse-Alert", was recently formed in Australia with the objective of also developing affordable reversing technology. Their system differs from that of the AEB Rear system in that they rely entirely on a series of bumper-mounted sensors (with full 250deg vision) to sense the presence of a pedestrian or a pole and respond automatically through autonomous braking functions. They have also developed a unit for fitment to commercial vehicles such as utilities and small and larger trucks. The company report that the system has been trialed by a few large companies in Australia, predominantly driven by reducing property damage crashes. However, Reverse-Alert are particularly keen on the use of their technology to reduce back over collisions and claim that unique bumper-mounted sensors and autonomous braking system is sufficient for preventing back over collisions.

Figure 3: The Reverse Alert system

They have conducted one or two simple (anecdotal) tests to demonstrate the systems use and videos are available showing the results. They further explained recently, that they are close to having test facilities available to conduct further more definitive research. If successful, the Reverse-Alert system could be a relatively inexpensive in-vehicle technology to address back over collisions in this country that could be retro-fitted to many vehicles.

We understand that Nissan and Mazda fit reversing technologies (cameras and bumper-sensors) with autonomous braking to help parking in tight situations and prevent accidents with children or animals. Nissan especially add the caution that the reversing technology is meant as a driver's aid only, and may not completely cover all blind-spots, and may not detect moving objects.

Summary

If shown to be effective, both these applications are autonomous and do not rely on video from rear-mounted cameras to alert the driver to initiate braking in an emergency situation. Assuming they can sense the presence of a rearward pedestrian or cyclist while backing, they would seem to have considerable scope to prevent many critical situations from occurring and thus further prevent and/or mitigate fatal, serious, and minor injuries to pedestrians of all ages.

IN CONCLUSION

Several important findings were reported in this paper. The extent of backover collisions involving pedestrians using only police reported crashes was roughly consistent across the 4-countries examined here where pedestrians aged 60 years and older accounted for up to half the number of incidents. Child back overs were less prevalent but were typically of high severity being of some concern.

Reversing camera technology fitted to many vehicles in Australia resulted in a 41% reduction of back over collisions, compared to vehicles without this technology. Mandating the fitment of cameras would be expected to reduce fatal, serious, and minor injuries by 23% in reversing collisions with pedestrians in Australia.

Recent developments of new advanced technologies that include superior identification sensing of pedestrians while reversing and coupled with autonomous emergency braking would be expected to further improve the benefits beyond what would come from just cameras. There were a few limitations with the research and it is recommended that these be addressed in further research where and when possible.

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