Identifying Future Vehicle Safety Priority Areas in Australia for the Light Vehicle Fleet

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Key Findings

- Three light vehicle crash types are projected to be the largest contributors to fatalities and the least addressed by active and passive technologies in 2030 for the light vehicle fleet:
  - fatal pedestrian crashes,
  - single vehicle frontal crashes with fixed objects, and
  - front-to-front vehicle crashes both at intersections and midblocks, and front-to-side impacts at intersections including straight crossing path and right turn across path crash types.
- Future vehicle safety policy priorities should address these crash types through the development of additional or enhanced vehicle safety technologies and other countermeasures that address the key crash types remaining in the system.

Abstract

Formulating priorities for future road safety strategies requires supporting analysis to predict what the future crash population will look like and to assess how the countermeasures either already in place or planned will address the crash problems forecast. This analysis aimed to identify future priority action areas for light vehicle safety by identifying crash types that will not be fully addressed in the future by projected improvements in active and passive safety in the Australian light vehicle fleet. The future crash profile was modelled from 2017 to 2030 using crash data from 5 Australian jurisdictions overlayed with available evidence on vehicle safety feature fitment and effectiveness. The methodology can be applied to larger sets of safety technologies when sufficient evidence and supporting crash data become available. Three future vehicle safety priority areas were identified from the analysis: (i) fatal pedestrian crashes, (ii) single vehicle frontal crashes with objects, and (iii) front-to-front vehicle crashes both at intersections and midblocks, and front-to-side impacts at intersections including straight crossing path and right turn across path crash types. These crash types were projected to be the largest contributors to fatalities by 2030. Projections showed that remaining crash types in 2030 will be poorly addressed by current vehicle safety technologies such as autonomous emergency braking, lane departure warning and electronic stability control. Future vehicle safety policy priorities should address these crash types through the development of additional or enhanced vehicle safety technologies and where vehicle safety technology proves inadequate other countermeasures such as road infrastructure treatments and appropriate speed limit setting for high risk environments that address the key crash types remaining in the system.

Keywords

Active vehicle safety technology injury mitigation

Glossary

Active Safety Vehicle Technology

A vehicle safety technology which initiates a human or autonomous response which may result in crash avoidance.

Those included in this analysis are:

Electronic Stability Control (ESC)
Autonomous Emergency Braking (AEB)

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Ped AEB (AEB with specific pedestrian detection capability)
Blind Spot Detection (BSD)
Lane Departure Warning (LDW)
Lane Keep Assist (LKA)
Blind Spot Detection (BSD)
Side View Assist (SVA)
Adaptive or Active Headlamps (ADHL)
Rear Cross Traffic Alert (RXA)
Reversing or Rear Camera (RC)
Telematic intelligent transport systems

Light vehicle injury crash

Any crashes involving at least one light vehicle and at least one injured person and unless otherwise stated the term 'injuries' referred to any person injured in a crash: pedestrian, bicyclist, rider or vehicle occupant. If the injury resulted in hospital admission, it was considered 'serious'.

First event of a crash

The first collision event of a crash. It may involve one or two motor-vehicles only.

Introduction

There is a significant body of research that can inform policy development and advocacy on vehicle crash risk and occupant injury outcomes and their relationship with new vehicle safety technologies. Formulating approriate priorities for future road safety strategies requires analysis to predict what the future crash population will look like and to assess how the countermeasures either already in place or planned will address the crash problems forecast. This allows unaddressed crash problems to be identified and in response, allows strategies to be modified or expanded to address these problems including the development of new countermeasures. The need to develop new countermeasures for unaddressed problems also assists in defining the requirements for fundamental research to inform countermeasure development. This approach can be used for all aspects of the safe system including safe vehicles and has been used here to identify the likely residual crash problems unaddressed by active and passive vehicle safety technologies that are currently permeating the light vehicle fleet.

The aim of this project was to identify future vehicle safety priorities in Australia through an integrated analytical approach based on mass data records from police reported crashes. Firstly, future crash population profiles were predicted based on past trends. Projections considered the categorisation of crash trends by factors relevant to vehicle safety countermeasures including crash type, vehicle type and location. The next phase of the project considered vehicle safety countermeasures already in place including emerging new vehicle safety technologies and their expected impact on projected future road trauma levels. From this analysis the likely residual unaddressed road safety problems were identified. The final stage of the project was a review with recommendations of potential future vehicle safety countermeasures which could address the residual road safety problems identified but are not yet proven. The project focussed on the light vehicle fleet in Australia.

Method

The analysis estimated potential crashes avoided by active safety technologies in the Police reported Australian light vehicle crash fleet projected from 2017 to 2030. Prior to making projections, the presence of current crash and injury trends by crash type, vehicle type and location were explored over the years 2006 to 2016 to characterize the baseline. The 2016 crash year was the base from which the natural fitments of ESC, AEB, Ped AEB, LDW/LKA, BSD/SVA, ADHL, RC, RXA and telematic intelligent transport systems over 2017 to 2030 were modelled. These technologies were selected on the basis of having sufficient, yet incomplete fleet penetration and having availabiliy of fitment and effectiveness data. Technologies which address driver intention, fatigue and inattention, as well as vehicle speed at the time of the crash could not be included because these causes were not universally recorded in the available crash data and real world effectiveness was either unavailable or required identification of crashes these causes. The distributions of crashed vehicle age and market group, crash characteristics and crash involved person traits were maintained at the baseline level, so that the crash and injury mitigation effects of vehicle fitment and future crashworthiness could be isolated. This methodology has purposefully been kept simple as it is primarily being used to identify future safety priorities. The estimates of crashes avoided by active safety technology in light vehicles are not the net average overall expected crash reductions, but rather the reductions specific to the technologies studied, under a specific set of crash conditions.

The probabilities of standard fitments (Automotive Data Services PL, 2014) of the selected active safety vehicle technologies, by year of manufacture and market group were projected from current fitment trends using logistic regression. Projected crashes potentially mitigated by each vehicle active safety technology were estimated from the involved vehicle rates of fitment and effectiveness. The effectiveness of crash avoidance technology was taken from published studies benchmarked by statistical evaluations of real-world data (Scully and Newstead 2010, Cicchino 2017a, Cicchino 2017b, Keall, Fildes et al. 2017, Sternlund, Strandroth et al. 2017, Strandroth, Lie et al. 2017, Cicchino 2018a, Cicchino 2018b, Cicchino 2019, Newstead, Budd et al. 2020) . Where real-world crash analyses were unavailable, meta-analysis, or studies using simulations, combined with in-depth crash data analyses were used (Jermakian 2011, Kusano and Gabler 2014, Doecke, Grant et al. 2015, NHTSA 2016, Sander 2017, Scanlon, Sherony et al. 2017, Silla, Rämä et al. 2017, Toshiyuki and Yukou 2017).

When multiple technologies were available for a crashed vehicle, crash avoidance was calculated in an additive hierarchical manner, by effectiveness. This technique has been widely accepted and used in literature (Corben, Logan et al. 2009, Elvik 2009). In this analysis, effects have been considered independent, because only active technologies were being applied, and each of the chosen active technologies work in a different manner and on crashes with different causation and type. The methods used were conservative and likely to under-estimate the crashes avoided, because with each application of a crash effectiveness, the remaining un-avoided crashes were in reality likely to be better matched to the next technology. If the remnant becomes more concentrated with crashes sensitive to the next technology, then the applied effectiveness will under-estimate the crashes avoided.

Models of projected crashworthiness ratings (Newstead, Watson et al., 2018) were used to estimate the additional benefits of advancements in vehicle design and passive safety systems. Fatal and serious injuries from the remaining crashes not estimated to be avoided by active vehicle safety technology were further reduced if the injury was to a light vehicle occupant. The product of these fatal and serious injuries, and the ratio of the average annual crash fleet crashworthiness rating to the average 2016 crash fleet crashworthiness rating, gave the estimate of injuries that were not avoided by passive safety and vehicle design. The crashes and injuries, which were not avoided by active or passive safety technologies, informed the assessment of future vehicle safety priority areas.

The crashes and injuries estimated to be saved in the projected crash years were analysed based on 12 (first event) collision types. Each technology was only applied to the one or two light vehicles involved in the first event of a collision. These are:

- single light vehicle crashes (no collision with bicycle/moped/pedestrian)
    1 rollover or no collision,
    2 collision to front,
    3 collision with side or rear, and
    4 collision to rear when reversing;
- light vehicle-to-bicycle/moped crashes
    5 vehicle hits bicycle/moped – front, and
    6 collision of bicycle/moped to rear/side of vehicle;
- light vehicle-to-pedestrian crashes
    7 frontal impact (vehicle not-reversing), and
    8 rear impact (vehicle reversing); and
- multi-vehicle, light vehicle-to-other motor vehicle crashes
    9 front-to-rear impact,
    10 front-to-side impact,
    11 front-to-front impact, and
    12 side-to-side impacts.

Rear-to-rear collisions were evaluated also, however their contribution was so small as to be insignificant.

Results

Projected injuries saved from the additional active and passive safety technology penetration available in 2030 amounted to 351 fatalities, 7,086 serious injuries and 12,345 minor injuries. About one third of all 2016 fatal and serious injuries were projected to be avoided in 2030 through the additional penetration of active and passive safety technologies. In 2030, 207 fatal crashes, 3,369 serious injury crashes and 8,492 minor injury crashes were projected to be avoided because of the additional penetration of active safety technologies.

Figure 1 compares the 2016 and projected 2030 distributions of types of crashes not avoided by active safety technology by crash severity and region. Active safety technologies were projected to noticeably decrease the proportion of single forward moving vehicle collisions across all severities, as well as serious and minor front-to-rear collisions. Conversely the proportions of bicycle/moped, fatal pedestrian, serious and minor front-to-front, minor front-to-side, fatal and serious rural front-to-side crashes were predicted to noticeably increase.

Figure 2 compares the number of 2016 crash injuries with those avoided from projected 2030 active and passive safety technologies, by severity and region. It shows that currently rural regions contribute to most fatalities and metropolitan regions are the locations of most non-fatal crash injuries. These trends were replicated in the injuries avoided through only active safety technologies. However, a greater proportion of serious injuries were avoided through the additional effects of passive safety technologies (on crash injuries not avoided through active safety technologies) in rural areas than in metropolitan regions. The greater proportions of vulnerable road user injuries in metropolitan areas offer an explanation for this trend reversal, since motorcyclist, pedestrian, bicyclist and moped rider injuries were not impacted by the methods used to estimate passive safety technology savings. In terms of proportion avoided, more than a third of fatalities and serious injuries were expected to be avoided in 2030, with the greatest proportions of both in rural regions. More than a quarter of all minor injuries were predicted to be avoided, with similar proportions in rural and metropolitan regions.

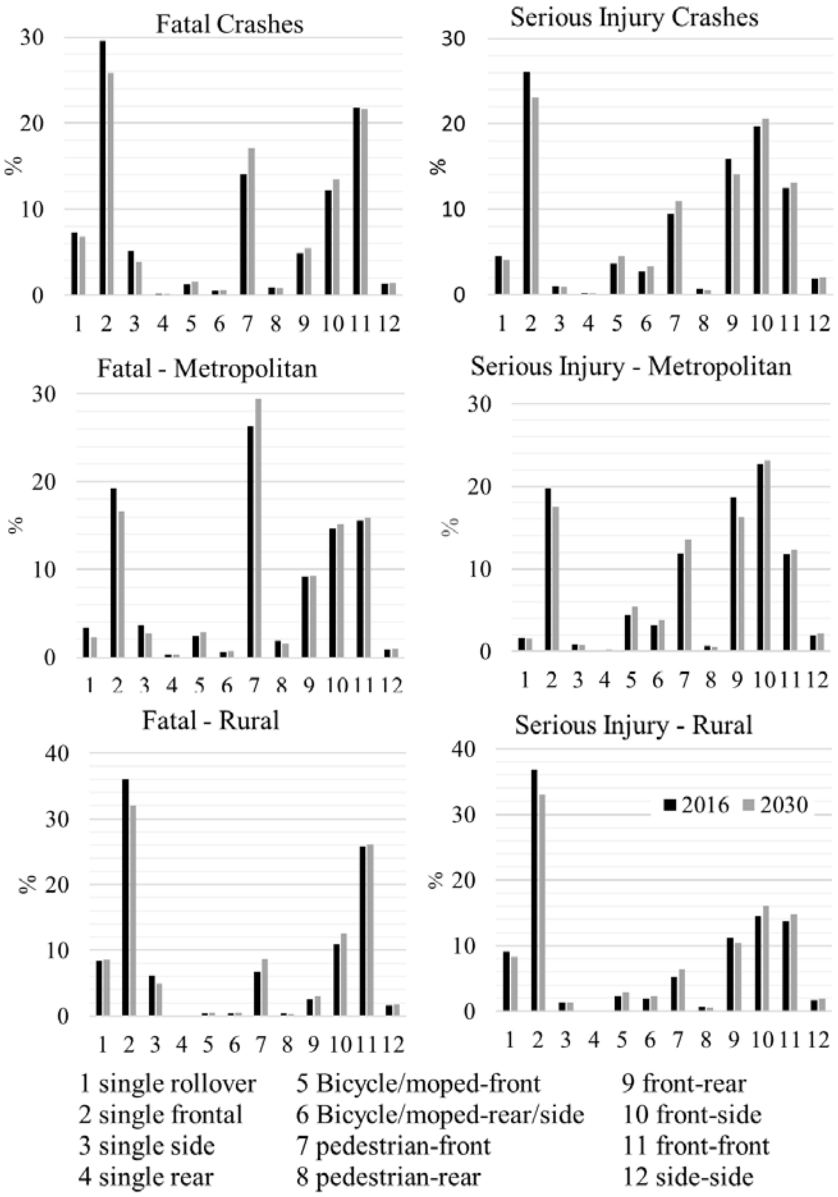

Figure 1. 2016 & projected 2030 distribution of injury crash types for fatal and serious injury crashes for all crashes and by metropolitan and rural regions

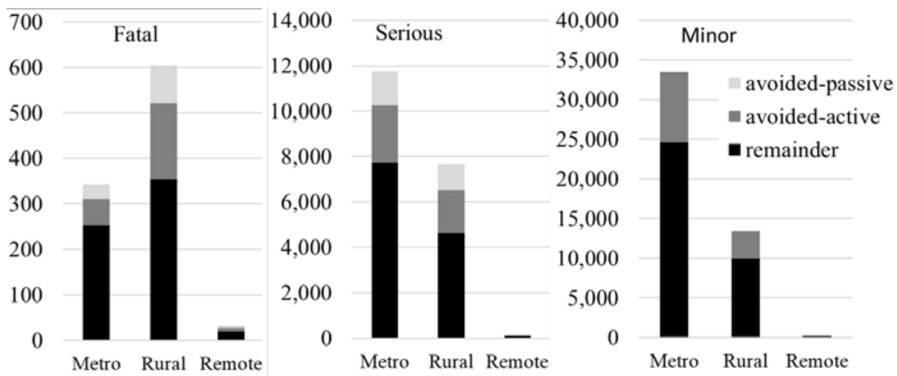

Figure 2. 2016 Crash injuries by location and severity disaggregated by vehicle safety technology projections in 2030

Figure 3 compares the 2016 injuries by severity and broad market group with 2030 projections. Large, medium and people mover markets were grouped together; crashes involving these vehicles contributed greatest number of fatalities, however, fatal crashes were over represented by SUV and LCV crashes. Small and light vehicles were grouped together; crashes involving these vehicles contributed greatest to serious and minor injuries. Small, medium and large SUVs contributed least to fatalities and commercial van and utility (LCV) crashes contributed least to serious and minor injuries. These trends were observed for injuries avoided through safety technologies with the exception of fatalities where SUV crashes ranked least as a baseline contributor, but LCV crashes ranked least in fatalities avoided through active safety technologies. This may be explained directly by the poorer penetration of active technologies expected for the light commercial vehicle market.

Figure 4 presents the injuries avoided and not avoided by active and passive technologies by crash type. Furthermore, the remaining injuries have been disaggregated by road user type: light vehicle front and rear occupants, pedestrian and other vehicle occupants/road users. It is clear that vulnerable road users make up a large proportion of the fatalities in the remaining crashes. Generally, the ‘other’ types from bicycle and moped crashes (crash types 5 and 6) are bicyclists or moped riders and those from crash types 9-12 are motorcyclists. Because bicyclist, moped rider and pedestrian fatalities were largely not avoided, vulnerable road users are an increased proportion of the 2030 remaining crash fatalities. Results for crashes rather than injuries show the same trends.

Figure 5 presents the projected 2030 crash reduction percentages from active safety technology by region, crash severity and crash type. This figure highlights the poorer avoidance of: reversing (4), bicycle/moped type (5 & 6), pedestrian (7), front-to-side (10) and side-to-side (12) collisions. It also clearly demonstrates that except for pedestrian and bicycle/moped crashes, most remaining fatal crashes by crash type were in rural regions and mostly from single vehicle, front-to-front and front-to-side collisions.

Vehicle Safety Priority Areas

The final stage of the project was a review of current or emerging vehicle safety countermeasures that may address the residual road safety problems identified. From this review, areas of road trauma unlikely to be addressed by any current countermeasures were identified and recommendations on future potential vehicle safety priority areas for the light vehicle fleet in Australia have been made, for which new countermeasures will need to be developed.

Vehicle Safety Priority Area One: Fatal pedestrian crashes

Fatal pedestrian crashes and non-fatal pedestrian crashes involving SUVs were observed to increase over 2006 to 2016. In metropolitan regions, pedestrian crashes were one of the largest contributors to severe trauma and this crash type is also more likely to be fatal than most other crash types. In 2030, fatal pedestrian crashes were predicted to make up a larger proportion of injury crashes than in 2016. This means that active safety technologies are not adequately addressing a crash growth area, which is a high contributor to trauma with severe injury outcomes. It is also a crash type of specific concern in metropolitan regions. Furthermore, by definition, passive safety modelled with crashworthiness has no effect on pedestrian injury, so after applying both active and passive safety measures, this crash type was the third largest crash type contributor to both fatal and serious injuries in 2030.

The technology chiefly addressing pedestrian crashes is the AEB system with pedestrian detection capability. Natural penetration of this technology was projected to be lagging and this technology is currently rarely present in light commercial vehicles.

As the greatest contributor to metropolitan road fatalities, pedestrian crashes are a crash type with serious outcomes. They have not been adequately addressed by vehicle safety technology despite 2030 projections of only 11% crash avoidance and relative growth in the crash type. By targeting pedestrian fatalities, reductions in non-fatal pedestrian crashes will also follow. Both relative and absolute estimated reductions in 2030 rural fatal crashes achieved from active and passive technologies and vehicle design, were greater for rural regions, so targeting pedestrian fatal crashes will also generally improve avoidance of fatal crashes in metropolitan regions.

Some suggested countermeasures are:

- Investigate what drives natural penetration to find out why pedestrian focused technologies are not naturally penetrating the light vehicle fleet at rates similar to other technologies.
- Encourage the increased uptake of pedestrian-AEB systems, particularly in LCVs which currently have limited fitment. This may also improve bicycle and moped crash outcomes.
- Investigate the possibilities offered by vehicle-to-pedestrian and vehicle-to-infrastructure communication technology and deploy what is found to be effective. There is a great body of research on intelligent transport systems (ITS). Silla, Rämä et al. (2017) estimated that almost half of vehicle-to-pedestrian crash injuries could be avoided with vehicle-to-pedestrian technology. An example ITS system involves interacting mobile phone technology with

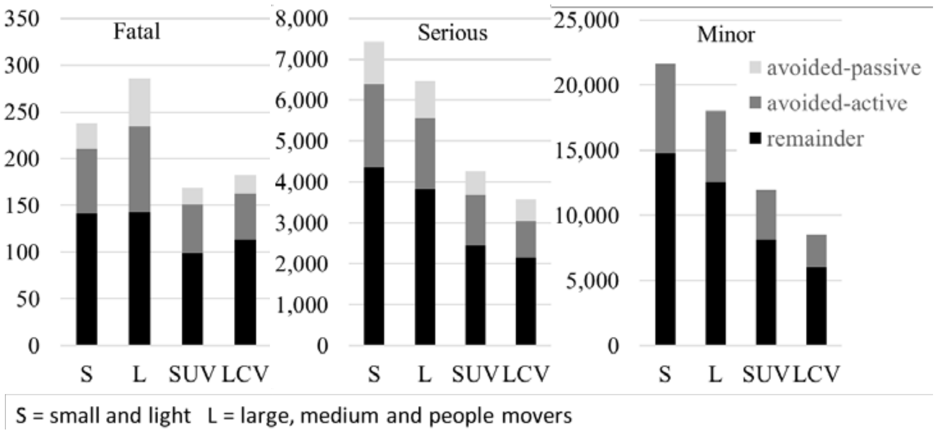

Figure 3. 2016 Crash injuries by broad market group and severity disaggregated by vehicle safety technology projections in 2030

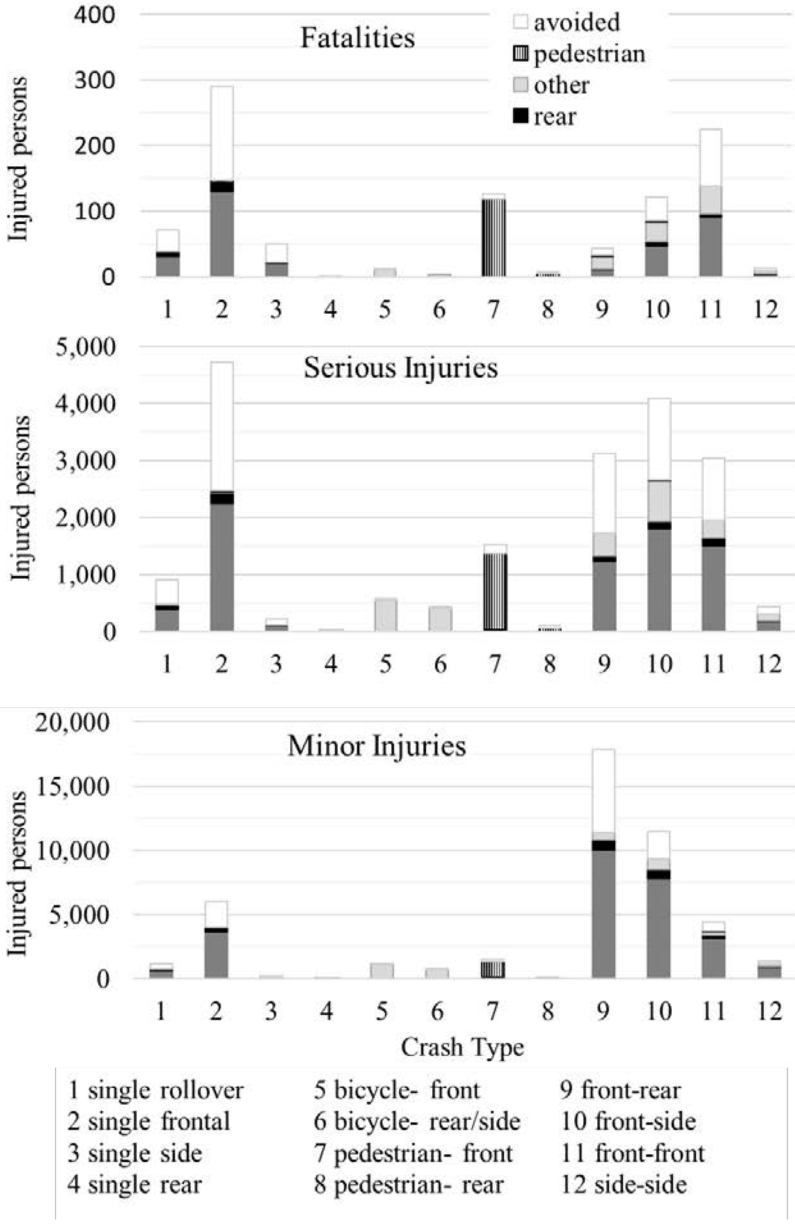

Figure 4. 2016 Crash injuries by type, road user type and severity disaggregated by vehicle safety technology projections in 2030

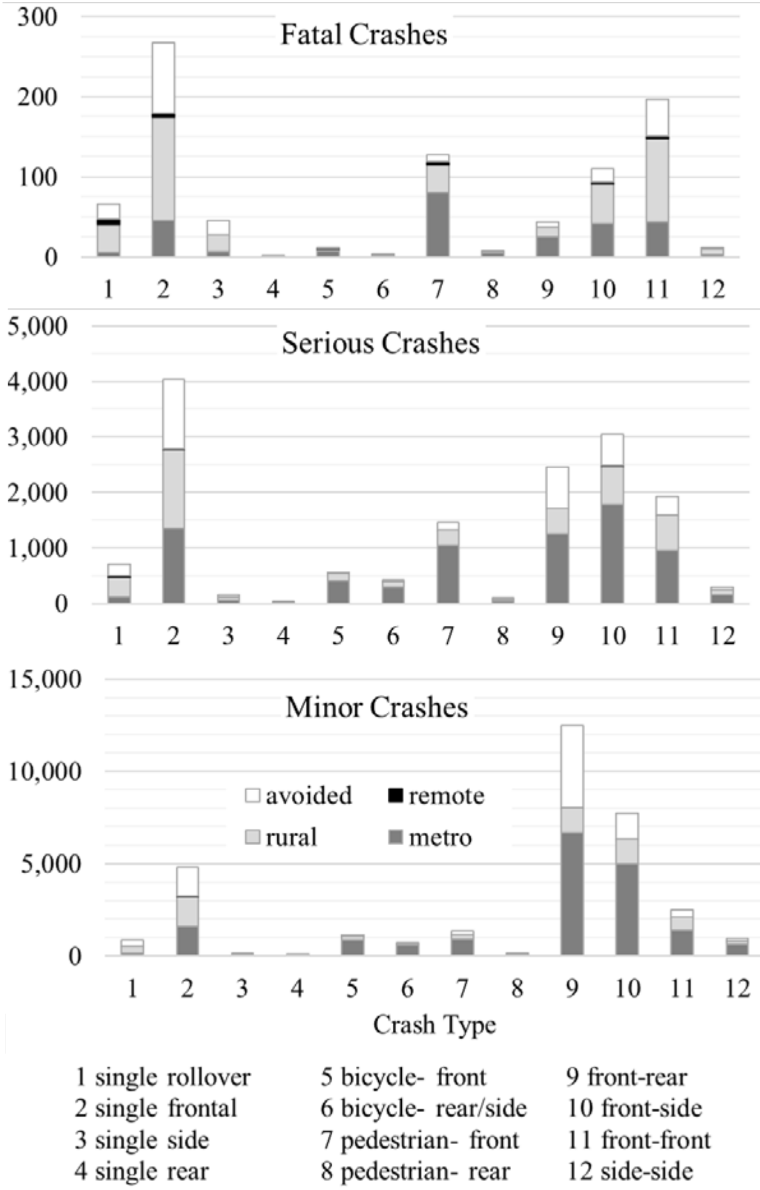

Figure 5. 2016 Injury crashes by location and severity disaggregated by active vehicle safety technology projections in 2030

vehicle telematics so that both drivers and pedestrians are alerted to impending collisions.

- Encourage vehicle design improvements or the uptake of pedestrian technology. Examples to investigate are night vision and active hood / windshield A-frame airbags. Fredriksson, Shin et al. (2011) estimated the latter to decrease AIS 3+ pedestrian injury risk from 85-100% to 20%. This is pertinent for SUVs which demonstrated an increase baseline trend of pedestrian crashes.

Vehicle Safety Priority Area Two: Single vehicle frontal crashes with fixed objects

Single vehicle frontal vehicle-to-object crashes were estimated to be best addressed by active safety technology, however this crash type was projected to make up 17% of all injury crashes in 2030 and more than two thirds of these crashes in 2016 were projected to not be avoided by vehicle safety technologies in 2030.

These were amongst the most serious crash types, particularly for small and light vehicles and remote region, particularly rollovers. They were also amongst the largest contributors to serious road trauma. Single vehicle-to-object crashes were observed to increase over 2006 to 2016, for serious and rural crashes, or when certain market groups were involved.

ESC, LDW and active headlamps were the main active technologies addressing single vehicle fatal frontal crashes modelled in this analysis. In 2030, ESC was estimated to have almost saturated the crashed vehicle fleet, so will have no more to offer in crash avoidance beyond 2030. Both LDW and active headlamps were shown to have potential beyond 2030 due to being less represented in current vehicles that have had crashes of this type than in the fleet overall, and due to poorer crashed vehicle fleet penetration in 2016; especially for light commercial vehicles which lagged severely. Just over half the crashed light vehicle fleet were predicted to be fitted with LDW or active headlights in 2030.

Some suggested countermeasures are:

- Investigate what drives natural penetration to find out why systems which address fatigue, speeding and inattention are not naturally penetrating the light vehicle fleet at rates similar to other vehicle safety technologies. Single forward moving vehicle crashes are often the result of speeding, driver inattention and driver fatigue and the fitment analysis found poor projected uptake of speed, fatigue and inattention systems such as speed zone reminder, speed alert, speed limiter, driver fatigue warning and driver attention detection.
- Investigate what drives natural penetration to find ways to enhance the natural penetration of LDW and active headlights, especially within the light commercial market group.
- Investigate what drives natural penetration to find ways to enhance the natural penetration of relevant passive safety technologies, especially within the light commercial market group which are severely lagging: e.g. front passenger head airbag, all rear airbags and rollover protection (which is also lagging in SUVs).
- Deploy programs targeted at enhancing driver acceptance of lane departure warning systems, especially for professional drivers. Reagan and McCartt (2016) found LDW systems to only be switched on 33% of the time.
- Increase the proportion of roads with edge-lines. Most LDW systems currently rely on edge-lines and do not function where there are no lane-markings. Increasing the proportion of lane-markings on roads where fatigue, speeding and inattention are likely will increase the real- world effectiveness of LDW.
- Investigate ways to improve injury outcomes in small and light vehicle single vehicle crashes. This may involve vehicle design or encouraging uptake of passive safety systems such as rollover protection, active headrests, and the various airbags currently available. Small and light vehicles were found to have poorer outcomes in these crash types.
- Investigate ways to improve injury outcomes in rural and remote locations. Remote single vehicle crashes were found to have poorer outcomes. Such a way could be to encourage uptake of automatic crash notification systems or to educate remote region drivers about them. Automatic crash notification systems are an emerging safety technology designed to notify emergency responders that a crash has occurred and provide its location. This not only speeds up the response, but may be the only way that some crashes are detected before fatalities occur.

Vehicle Safety Priority Area Three: Front-to-front vehicle cashes both at intersections and mid-blocks and front-to-side impacts at intersections including straight crossing path and right turn across path crash types

37% of crashes in 2030 were projected to be front-to-front or front-to-side crashes. In 2016, 57% of front-to-front collisions were at intersections and 35% came from adjacent approaches. In 2016, 80% of front-to-side were at intersections and 43% came from adjacent directions. Furthermore, fatal and serious front-to-side crashes were projected to increase in proportion in rural areas between 2016 and 2030. Both front-to-front and front-to-side are significant contributors to road fatalities and injury crashes generally and more than 80% of these two crash types were not projected to be avoided in 2030.

General AEB systems have had a poorer impact on these crashes because of the lack of sensitivity to the crash type and likely travelling speed. Intersection-AEB systems which target straight crossing path crashes are emerging but have very limited fitment currently.

Targeting front-to-front and front-to-side crashes improves rural and metropolitan crash outcomes, because although most intersection crashes occur in metropolitan regions, most of the remaining fatal front-to-front and front-to-side crashes in 2030 were projected to be rural.

Some suggested countermeasures are:

- Investigate what drives natural penetration to find out why ITS, high speed AEB systems and intersection-AEB technologies are not naturally penetrating the light vehicle fleet at rates similar to other technologies. Intersection AEB systems which target straight crossing path collisions are likely to be able to prevent around 40% of straight crossing path crashes and if AEB systems could improve speed range sensitivity both generally and specifically for right turn/other direction crashes more fatalities could be avoided. Furthermore, an increased speed range in general AEB systems could aid avoidance of high-speed front-to-rear crashes.
- Investigate what drives natural penetration to find ways to enhance the natural penetration of relevant passive safety technologies, especially within the light commercial market group which are severely lagging: e.g. front passenger head airbag and all rear airbags.

- Investigate the possibilities offered by vehicle-to-vehicle and vehicle-to-infrastructure communication technology and deploy what is found to be effective. There is great body of research on intelligent transport systems (ITS). It is possible for intelligent intersection infrastructure to warn drivers of approaching vehicles from cross directions.
- Continue to expand red light speed camera programs. These have proven effectiveness (Budd, Scully et al. 2011) on these crash types (44% casualty crash reduction).

Conclusions

Three future vehicle safety priority areas were identified from the analysis: (i) fatal pedestrian crashes, (ii) single vehicle frontal crashes with objects, (iii) front-to-front vehicle crashes both at intersections and mid-blocks and front-to-side impacts at intersections including straight crossing path and right turn across path crash types. These crash types were projected to be the largest contributors to fatalities by 2030. Although not the most prevalent crash type, crashes involving bicycles and mopeds were forecast to grow proportionately over the study period. Remaining crash types in 2030 will be poorly addressed by current vehicle safety technologies. For example, when considering single vehicle-to-object crashes, ESC will provide no further benefits in reducing single vehicle crashes after 2030 since the fleet will have achieved full fitment in 2030 vehicle fleet. In addition, evaluation evidence to date suggests AEB systems as fitted to vehicles currently has limited impact in addressing high speed crashes with fixed objects although future development of AEB might provide some benefits in reducing this crash type despite real-world effectiveness not having been established yet.

Most crashes were considered to have some potential to be avoided by active safety technologies, so it is still likely that avoidance will further increase beyond 2030 due to increased market penetration and technological developments which increase effectiveness. This analysis highlighted the limitations in fatality and serious injury reductions related to the natural penetration of vehicle safety technology fitment up to 2030. Significant numbers of fatalities resulting from intersection crashes, single vehicle run off road and head on crashes will remain whist pedestrian crashes will grow in their proportionate importance. Additional or enhanced vehicle safety technologies will need to be developed that better address these crash types such as AEB effective for fixed object crashes and at intersections and vehicle-to-vehicle technologies to mitigate intersection crashes. In addition, means to address the key remaining crash types elsewhere in the system need to be considered through measures such as road infrastructure treatments and appropriate speed limit setting for high risk environments where vehicle safety technology proves inadequate.

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