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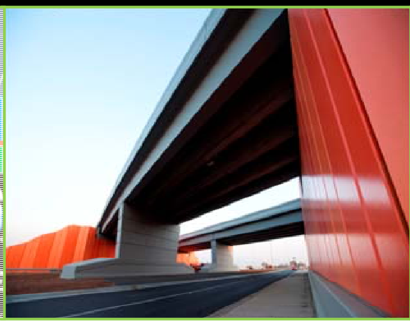
AUSTROADS RESEARCH REPORT

Evaluation of the Potential Safety Benefits of Collision Avoidance Technologies Through Vehicle to Vehicle Dedicated Short Range Communications (DSRC) in Australia

Austroads

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Austroads

Sydney 2011

Austroads profile

Austroads' purpose is to contribute to improved Australian and New Zealand transport outcomes by:

- providing expert advice to SCOT and ATC on road and road transport issues
- facilitating collaboration between road agencies
- promoting harmonisation, consistency and uniformity in road and related operations
- undertaking strategic research on behalf of road agencies and communicating outcomes
- promoting improved and consistent practice by road agencies.

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Austroads membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure and Transport, the Australian Local Government Association, and New Zealand Transport Agency. Austroads is governed by a Board consisting of the chief executive officer (or an alternative senior executive officer) of each of its 11 member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Lands and Planning Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Commonwealth Department of Infrastructure and Transport
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry. It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road sector.

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GLOSSARY OF TERMS

Abbreviation	Definition
DCA	Definitions for Classifying Accidents (Refer to Vicroads Crashstats User Guide, Part II Troubleshooting and Appendices, p. 15.) See also the Appendix of this document.
DSRC	Dedicated Short Range Communication
EU	European Union
FOT	Field Operational Trial/Field Operational Test
GPS	Global Positioning System
ICW	Imminent crash warning
ITS	Intelligent Transport Systems
MUARC	Monash University Accident Research Centre
PRT	Perception-response time. The time required for a driver to perceive and then make a response to a hazard. Sometimes known as perception-reaction time.
SC	Serious casualty (killed or seriously injured)
USDOT	United States Department of Transportation
V2D	Vehicle-to-Device communication
V2I	Vehicle-to-Infrastructure communication
V2V	Vehicle-to-Vehicle communication

1 INTRODUCTION

For years, improvements in driver behaviour, vehicle safety and road infrastructure have made the road network much safer. As roads become safer, many economic benefits are achieved for society, both direct and indirect. In the past, the primary focus for safety was secondary safety, or crashworthiness, but with the advent of cheaper and more powerful electronics and increasing research and development, efforts are being directed at preventing crashes from occurring. Electronic Stability Control (ESC), for example, detects the onset of the loss of control of a vehicle and attempts to maintain the driver's intended direction of travel by applying selective braking and reducing engine power. Such systems are largely reactive; however, often only preventing crashes immediately prior to the crash event.

It is preferable to anticipate a potential crash situation much earlier and therefore provide the driver with more options for preventing a collision. In order to do this, it is firstly necessary for vehicles to be able to detect approaching potential collision partners. Existing warning systems, such as forward collision warning (e.g. Doi, Butsuen, Niibe, Takagi, Yamamoto & Seni, 1994) are usually radar-based and generally require line-of-sight to potential collision partners and thus have limited anticipatory capability.

In order to provide earlier warning and therefore increased ability to influence the likelihood of crash involvement, different sensing systems are required. Peer-peer vehicle communication, in conjunction with GPS data (to provide location awareness), provides the potential for onboard systems to continuously broadcast their own location, speed and direction of travel as well as use the locations and velocities of other vehicles within range to predict collisions and provide warnings to drivers of an approaching conflict. This in turn, has a significant potential to reduce the number and severity of crashes by providing drivers with the opportunity to take evasive action in the event of a potential crash. Dedicated Short Range Communication, or DSRC, is a short to medium range communication service that operates at a frequency of 5.9GHz, allocated for automotive and transportation use. It is designed to allow for vehicle-to-vehicle and vehicle-to-infrastructure communication.

This report aims to estimate the potential reductions in serious casualties in Australia from widespread adoption of DSRC-based technologies. A literature review was conducted of current projects around the world, focusing on DSRC-related reductions in crash rates. A database compiled by MUARC of serious road crash fatalities and serious injuries was then used to make estimates of the potential benefits if DSRC collision avoidance technologies were available throughout the Australian vehicle fleet.

2 CURRENT TECHNOLOGY

Many studies in the literature describe the DSRC communications protocols and how the technology can be integrated into the automotive environment with low latency yet highly reliable messaging (Xu et al, 2004; Yin et al, 2004; and Yang et al, 2004). There are also a number of studies that have looked into simulating scenarios using DSRC, such as ElBatt et al (2006), who modelled Forward Collision Warning of vehicles on a freeway segment who each had a localisation device (GPS) and a wireless communication device (DSRC). Although the underlying principles of DSRC are useful in understanding the technology, it is not at the forefront of this report. This section of the report aims to summarise studies, either current or completed, in which DSRC technology has been used and where its impact on road safety has been discussed.

2.1 SafeTrip-21

USDOT's Research and Innovative Technology Administration (RITA) developed a program called SafeTrip-21 (Safe and Efficient Travel through Innovation and Partnerships for the 21st Century). This program aims to test and demonstrate the improvements in safety and mobility, and reduction in traffic congestion that can be generated by improving the situational awareness of drivers that is achieved by providing them with various in-vehicle ITS technologies such as real-time traffic and transit information.

SafeTrip-21 aims to provide motorists and other travellers with the adequate travel information they need (such as traffic congestion ahead, roadwork zones, weather conditions, sharp curves in the road, and merging traffic) to arrive at their destinations safely and with minimal delay.

SafeTrip-21 began following successful rollout of various ITS technologies around Europe. Research from a number of these European countries have shown that these systems have the potential to improve safety by approximately 70 percent (without qualifying precisely which safety measures) and mobility by up to 20 percent (Bell et al, 2008), while reducing fuel consumption and air emissions by 10 to 20 percent (Bell et al, 2008).

Field tests of these concepts are being conducted by partners including ITS technology suppliers and university researchers throughout 2009 (RITA, 2008) in order to generate transport safety and efficiency solutions in the short term and also to contribute to solutions for longer term transportation problems. By the time these field tests are complete, they will comprise up to 10,000 volunteer commuters and transit vehicles transmitting and gathering data within a 200 mile (320 km) radius of traffic management centres (Riddle, 2008).

As the field tests are currently being conducted, there are no results yet publicly available. Therefore, it is difficult to confidently say how effective this program is. However, the field tests appear to have a large enough sample of test vehicles to provide examples of how the wireless communication technologies take effect in different driving situations, and hence, there is opportunity and potential for the SafeTrip-21 program to be able to demonstrate a number of its goals.

SafeTrip-21 has since been incorporated into the Intellidrive program (see the following section).

2.2 IntelliDrive^{SM}

IntelliDrive^{SM} is a program run by the US Department of Transport (USDOT) that focuses on using wireless communication to provide connectivity to allow for improvements in transportation safety, mobility and environmental issues. This wireless communication occurs between vehicles (V2V), between vehicles and infrastructure (V2I) and between vehicles, infrastructure and mobile devices (V2D) carried by pedestrians, cyclists and so on (such as PDAs, mobile phones, etc).

The wireless communication system used in the IntelliDrive^{SM} program, is able to identify, collect, process, exchange, and transmit real-time data, allowing drivers to have greater situational awareness of upcoming events, potential threats, and hazards within the vehicle's environment. This data can be transmitted to various warning systems that can be used to advise and alert the driver of potential hazards. Advanced vehicle safety features can then be activated or drivers can adjust their actions in anticipation of situations where they otherwise may not have been able to react safely in time.

There are multiple examples of wireless communication in the IntelliDrive^{SM} being an effective safety feature. One example of a V2V application is when a vehicle brakes suddenly, an alert is transmitted to the surrounding vehicles, warning other drivers to stop, or if necessary, automatically applying brakes of approaching vehicles if a crash with any of them is imminent. Similarly, a V2I application could involve incident data (such as the time and location of a crash, type of crash and crash severity) being transmitted from the case vehicle to the roadside infrastructure. System operators may then be able to broadcast an accident warning to other drivers, to provide a broad alert to either take care approaching the sight or avoid the area. Simultaneously, incident data could be transmitted directly to emergency dispatchers for emergency response.

An example of a V2D communication is when a right-turning vehicle could send an alert to a bicyclist's mobile device or a pedestrian's cell phone to avoid a potential collision. It should be noted, however, that in each of the examples provides there are numerous potential issues relating to the practical implementation of these technologies and, in the case of V2D, the negative safety impacts of bicyclists and pedestrians attempting to respond to mobile devices while negotiating potential collision situations. No quantitative estimates of crash or serious casualty reductions have yet been made.

A US Department of Transportation policy whitepaper (USDOT, 2010) proposed that 82% of crashes involving unimpaired drivers could 'potentially be addressed' by V2V technology. The types of crashes to which V2V is 'uniquely suited', namely forward and lane change/merge collisions are, however, generally of lesser severity and therefore under-represented when considering serious casualty crashes.

2.3 SIM-TD

Cooperative Vehicle-Infrastructure Systems (CVIS) is a consortium of a number of large vehicle manufacturers and suppliers including Daimler, BMW, Volkswagen, Opel, Ford, Audi, Bosch and Continental, telecommunications companies (Deutsche Telekom), research institutes and the road authorities with the aim of developing and improving communication links between vehicles and infrastructure, thus improving traffic safety and mobility.

Safe Intelligent Mobility – Test Area Germany (SIM-TD) (Co-operative Vehicle-Infrastructure Systems website, 2010), is a four-year field test project that officially began in November 2008 and was touted as the world's largest field study of communication between vehicles and between vehicles and infrastructure. This study will equip and network vehicles and infrastructure with communication units that will use an automotive-optimised version of the WLAN standard. Real-time traffic information is collected from passing vehicles via their On-Board Units (OBU) and sent to various Road-Side Units (RSU) positioned at selected traffic nodes. From here, the information is sent to major traffic control centres where the information is processed, evaluated and the relevant information is forwarded to vehicles which could be potentially affected by the information. This system has the ability to enable all vehicles in close proximity to where the information was collected to be individually notified of the traffic situation on the road ahead.

The consortium aims for SIM-TD to produce the following key results:

- development of a high tech communication system between various makes of vehicles and traffic management systems
- an architecture for in-vehicle and traffic management systems that can be easily updated
- various techniques for vehicle positioning and map creation
- extended protocols for vehicle, road and environment monitoring to allow vehicles to share and verify their data with other vehicles and infrastructure in the close vicinity

Safety has not been explicitly addressed by the consortium to date.

2.4 COOPERS

COOPERS, an acronym for **CO**-**OP**erative Syst**E**ms for Intelligent **R**oad **S**afety, is a European research and development, and innovation activity (Co-operative Systems for Intelligent Road Safety website, 2010).

The Coopers project aims to provide vehicles and drivers with real-time information related to nearby situations and safety related issues from nearby infrastructure using a dedicated Infrastructure to Vehicle Communication link (I2V).

Similar to previously discussed projects, the COOPERS project extends the concepts of in-vehicle autonomous systems and vehicle to vehicle communication by focussing on the information provided by infrastructure with the goal of significantly improving traffic control, flow and safety. This type of communication system would be most effective in high density areas where the risk of crashes and traffic congestion is high. Other areas where the COOPERS project will focus are as follows:

- traffic jam warning and guidance
- in-car display and alert of area-specific speed limits
- lane specific, selective ban of heavy vehicles
- estimated time of arrival, based on current traffic situation on the network
- car breakdown/emergency services
- enhanced traffic management
- safety related information for drivers
- data exchange between operators
- monitoring of transport flows

The COOPERS concepts will be validated during on-road tests at 3 different demonstration sites across Europe. Given that these tests are still pending, the results of the COOPERS projects are still forthcoming.

2.5 EU SafeSpot

SafeSpot[1] is an integrated research project funded under the 6th Framework Program through the European Commission Information Society Technologies. It has the stated vision of using telematics technologies to enable the development of reliable driving support systems for road safety, promoting cooperation between vehicles and the road environment through mutual perception of danger arising both spatially and temporally. A number of test sites around Europe are in the process of being set up to trial fog and traffic sensors, variable message signs and infrastructure communications nodes with the intention of trialling a number of V2V and V2I technologies.

[1] http://www.safespot-eu.org

2.6 Australian initiatives

ConnectSafe's main sponsor, Cohda Wireless, is a company whose primary focus is to design solutions for vehicle communication via wireless-based systems. The company has developed a DSRC radio designed to be used effectively in an outdoor and mobile automotive environment as it can provide constant and robust communication in a V2V and V2I environment. V2V communication, as shown in Figure 1, could be used for enhancing vehicle safety by providing applications such as intersection collision warnings, lane change assistance, and electronic brake lights, where a "following driver" is warned about braking "leading vehicles". V2I communication, also depicted in Figure 1, can assist to improve active transport management applications such as in-vehicle signage, congestion reduction and electronic toll collection.

Figure 1: Examples of Vehicle-to-Vehicle and Vehicle-to-Infrastructure communications (figure from Cohda Wireless, 2009a and ITR, 2009)

This solution is able to overcome the shortcomings of existing wireless standards to deliver increased range, ability to operate in an outdoor environment, non line of sight environment and with high speed mobility. So far, Cohda Wireless has conducted over 700 DSRC trials for 15 distinct DSRC scenarios. These tests were covered over 10,000 km and transmitted approximately 100GB of data (Cohda Wireless, 2009b). Cohda Wireless has also demonstrated vehicle safety applications such as Intersection Collision Warning, Electronic Brake Light and Rear Collision warning. Robust communications link were demonstrated, including obstacles such as blind corners and was able to transfer data accurately between roadside units and vehicles at sufficiently high speeds. This suggests that the system has the potential to facilitate the development of crash prevention countermeasures, although no specific quantitative estimates of benefits have been made publicly available, as ConnectSafe remains a proposal and has yet to be trialled in the Australian road environment.

2.7 Summary

This review has highlighted a number of studies currently in operation, focussed on collecting data to evaluate the benefits of DSRC. However, these projects are still in the process of data collection and staging trials. Consequently, there are only a few results currently available that highlight the benefits of DSRC. Furthermore, to obtain a realistic estimation of the potential number of serious casualties saved due to DSRC technology would require a large scale rollout of DSRC technology, where potentially hundreds of cars equipped with DSRC would be required to be in one area in communication with one other. Therefore, for now, assumptions will need to be made about the effectiveness of DSRC in order to estimate the potential reduction in serious casualties brought about by this novel technology. It should be noted that trials are also being conducted into advanced vehicle safety features in a number of Field Operational Trials (FOTs), such as EuroFOT (EuroFOT, 2010) and TeleFot (TeleFOT, 2010). These field trials could also provide an estimate of the potential safety benefits of DSRC. Although the FOTs listed use different underlying technologies, the application layers of the systems are where driver warnings are implemented and, therefore, any safety-related results could be used as an indication of the potential performance of similar applications implemented on top of a DSRC layer.

In March 2010, the Cooperative Mobility Showcase 2010[2] conference was held in Amsterdam, with the goal of highlighting V2V and V2I technologies and presenting results of the COOPERS, CVIS and SafeSpot projects. Proof-of-concept of a number of technologies was demonstrated.

[2] http://www.cooperativemobilityshowcase.eu/nl/en/Pages/default.aspx

3 SUMMARY OF DSRC APPLICATIONS

Many applications of DSRC have been discussed in the previous section. However, there are many more possibilities for such technologies as summarised below.

Of these, only a few would appear to have significant potential for directly influencing serious casualty numbers, as indicated by the checked items in Tables 1 and 2. Applications with a double tick are judged likely to have a significant impact on serious casualty numbers, while a single tick represents either a moderate impact or reflects either the low incidence or severity of the crash type to which the application applies. Those applications not ticked are estimated to have minimal direct effect on serious casualty numbers. It should be noted, however, that further in-depth investigation of any of the features below, substantiated by real-world evidence, may alter these qualitative assessments.

Table 1: Potential Vehicle-to-Infrastructure (V2I) applications, with estimates of potential effectiveness in reducing serious casualties. *Source*: Vehicle Safety Communications Consortium (VSCC), U.S., with estimates by MUARC.

Applications between Vehicles and Infrastructure	Estimated influence on S.C.s
Blind Merge Warning	✓
Curve Speed Warning	✓
Emergency Vehicle Signal Pre-emption	-
Highway/ Rail Collision Warning	✓
Intersection Collision Warning	✓✓
In-Vehicle Amber Alert	-
In-Vehicle Signage	-
Just-In-Time Repair Notification	-
Left/ Right Turn Assistance	✓✓
Low Bridge/Tunnel Warning	-
Low Parking Structure Warning	-
Pedestrian Crossing Information at Intersection	✓
Road Condition Warning	✓
Safety Recall Notice	-
SOS Services	-
Stop Sign Movement Assistance	✓
Stop Sign Violation Warning	✓
Work Zone Warning	✓

Note: A dash (-) represents an estimated minimal direct effect on serious casualties.

Table 2: Potential Vehicle-to-Vehicle (V2V) applications, with estimates of potential effectiveness in reducing serious casualties. *Source*: Vehicle Safety Communications Consortium (VSCC), U.S., with estimates by MUARC.

Applications between Vehicles	Estimated influence on S.C.s (✓✗)
Approaching Emergency Vehicle Warning	-
Blind Spot Warning	✓
Cooperative Adaptive Cruise Control	✓
Cooperative Collision Warning	✓✓
Cooperative Forward Collision Warning	✓✓
Emergency Electronic Brake Lights	✓
Highway Merge Assistant	✓
Lane Change Warning	✓
Post-Crash Warning	-
Pre-Crash Sensing	✓✓
Vehicle-Based Road Condition Warning	-
Vehicle-to-Vehicle Road Feature Notification	-
Visibility Enhancer	-
Wrong Way Driver Warning	-

Note: A dash (-) represents an estimated minimal direct effect on serious casualties.

4 SAFETY BENEFITS

The potential safety benefits of DSRC depend on a number of factors such as the type of warning sent to the driver (visual, audible, haptic or combinations of these), whether or not the driver responds to the warning, the type of crash under consideration and the number of crashes that occur in Australia by type. This analysis considers savings in serious casualties, consisting of fatalities and serious injuries. These two crash types constitute 75% of the annual social cost of road crashes in Australia (BITRE, 2009).

The following sections discuss optimal warning design and timing, estimates of warning effectiveness and finally, overall estimates of serious casualty incidence and effectiveness by crash category.

4.1 Optimal Warning Design and Timing

In-vehicle warnings can be classified as either advisory (non-critical) or imminent collision warnings. There are underlying differences in these warning types and the responses that they are designed to elicit. This review will only focus on imminent collision warnings, a warning designed to elicit an immediate response from drivers (Lenné & Triggs, 2009).

The literature and warning design guidelines make a number of recommendations regarding the optimal modality of imminent collision warnings. Much of the warning research suggests that the detection of, and responses to, hazards can be improved when warnings are presented in more than one modality (Belz et al., 1999; Ho & Reed, 2007; Lee & Spence, 2008). Multimodal warnings are less likely to be missed by drivers and drivers prefer multimodal presentation (Lui, 2001; Belz et al., 1999).

Warning design guidelines recommend that auditory warnings should be used in time-critical situations as the primary warning type, but that these can be supplemented by visual warnings. For example, visual displays can enhance auditory warnings by providing additional information such as the desired action to be taken (Campbell et al., 2007). Haptic warnings have also been investigated as a means of providing imminent threat warnings to drivers, however, they are only effective if the driver is in contact with the haptic feedback source at the time of the warning presentation and they may require some level of driver learning to determine the meaning of the warning (Campbell et al., 2007).

Research also suggests that providing directional information can help to facilitate the orientation of the driver towards the direction of the threat, thereby increasing the likelihood of the threat being detected by the driver. Research has demonstrated that verbally presented directional cues (e.g., the words 'left' and 'right') improve sensitivity to visual targets on the cued side (Ho & Spence, 2006). Alternatively, left and right-mounted speakers from the vehicle entertainment system can be used to present directional warnings.

Based on the above, the use of a combination of auditory and visual directional warnings to alert drivers to an imminent collision is therefore recommended. This will ensure that drivers are given appropriate information regarding the urgency of the warning, the nature of the potential threat, and the advised course of action (i.e., to brake hard). Auditory warning signals should be noticeable enough for the driver to notice the signal, but should not cause a 'startle' effect in drivers (UNECE, 2009). Simple tones with intermittent pulses or warbling sounds are recommended for use in high-priority (Imminent Crash Warning, ICW) situations

(UNECE, 2009; Campbell et al., 2007). In terms of the visual warning, Campbell et al. (2007) states that the abrupt onset of a conspicuous symbol, icon or discrete display, with clearly recognisable significance, is the most appropriate method for providing time-critical imminent collision information visually.

Concerning the timing of imminent collision warnings, the presentation of the warning must be timed so that it is early enough to allow adequate time for the driver to make the desired response, but not so early that it will be annoying to drivers and lose its effectiveness through being disregarded. Compared to late ICW warnings, early ICW warnings are associated with faster driver responses, longer Time-To-Collision (TTC) values, higher degrees of driver trust, and reduced number and severity of crashes (Campbell et al., 2007).

However, while earlier warnings will provide drivers more time to respond to potential hazards, drivers may interpret them as nuisance warnings if they are too frequent or unnecessary. It is important that a collision warning system times the onset of an ICW warning so that it accounts for drivers' perception-response times (PRT) as well as the driver-selected deceleration level, which should be severe enough to allow the driver to slow or stop the vehicle with enough time to avoid the collision.

According to Campbell et al., (2007) and Kiefer et al., (1999), deceleration measures are more useful for determining crash alert timing than are time-based measures such as TTC. This is because: (a) deceleration measures are tightly coupled with fundamental kinematics of the braking situation while time-based measures are not, and; (b) deceleration measures are significantly more stable across kinematic conditions than time-based measures.

Based on the above, imminent collision warning timing should be based on deceleration measures rather than time-based measures. The onset of an imminent collision warning should occur at a time no later than that which results in a deceleration level corresponding to 95th percentile 'actual' braking performance for various subject vehicle speeds (0.35 g for 48 kph; 0.41 g for 72 kph; 0.45 g for 97 kph).

4.2 Estimates of Warning Effectiveness

Very little information exists regarding the proportion of drivers who respond to imminent collision warnings, and, of those that do respond, the proportion of drivers for which the warning was effective in avoiding the collision. The estimates provided below are, therefore, largely based on expert judgement. However, the Forward Collision Warning literature (e.g., Ervin et al., 2005; Lee et al., 2004; Scott & Gray, 2008) was examined to establish what is known about driver responses to these warnings and their effectiveness in reducing crashes. The range of effective driver responses varies across studies, but an average range has been determined for the purposes of this work. Data regarding driver responses to non-critical warnings (e.g., seat belt reminder warnings) from the TAC SafeCar project were also consulted (Young et al., 2008).

Based on a review of these data sources and expert judgements, the following estimates are provided for forward collision crash events (e.g., rear-end). It is expected that these estimates will be similar across different multi-vehicle crash scenarios (e.g., head-on).

Estimated proportion of drivers who will respond to the warnings	Estimated proportion of those drivers who responded for which the subsequent response will be effective in avoiding a collision
80-90%	65-80%

Combining these two estimates multiplicatively results in an overall assumed effectiveness of an imminent crash warning in avoiding a collision of between 52% and 72%. Of the remaining crashes, a proportion of these will likely be reduced in severity due to reduced impact speeds as a result of late driver response to warnings. Depending upon initial travel speeds, reduced kinetic energy transfer at impact will allow occupant protection systems to effectively prevent serious injuries. An analysis of these potential effects was not possible to conduct for this report and thus the serious casualty savings presented in subsequent sections should therefore represent conservative estimates.

4.3 Crash Types and Data

Crash types were grouped by DCA code (Definitions for Classifying Accidents), since it would be expected that DSRC-based collision warning systems would have generally consistent effects on individual crash types within each broad DCA group.

For the purpose of this study, a serious casualty database collated by MUARC for the period of 2005-2007 (inclusive) was used. This database is a collation of 86,465 of police-reported serious casualties supplied by each of the jurisdictions, with the exception of the ACT. In the case of NSW, where there is no ‘serious’ or ‘taken to hospital’ sub-category, an estimate of NSW serious casualties was derived using serious injury to fatality ratios. Figure 2 shows the breakdown of the major DCA categories. Overall, the groups contributing largest proportion of serious casualties were, ‘off path on straight’ (DCA=17X) which accounted for 18.6% of the total number of serious casualties, ‘vehicles travelling in the same direction’ (DCA group 13X) with 17.6% of the serious casualties, ‘vehicles from opposing directions’ (DCA=12X) with 16.2% of serious casualties and ‘vehicles from adjacent directions’ (DCA=11X) with 14.9% of serious casualties. These four categories together comprised just over two-thirds of all serious casualties.

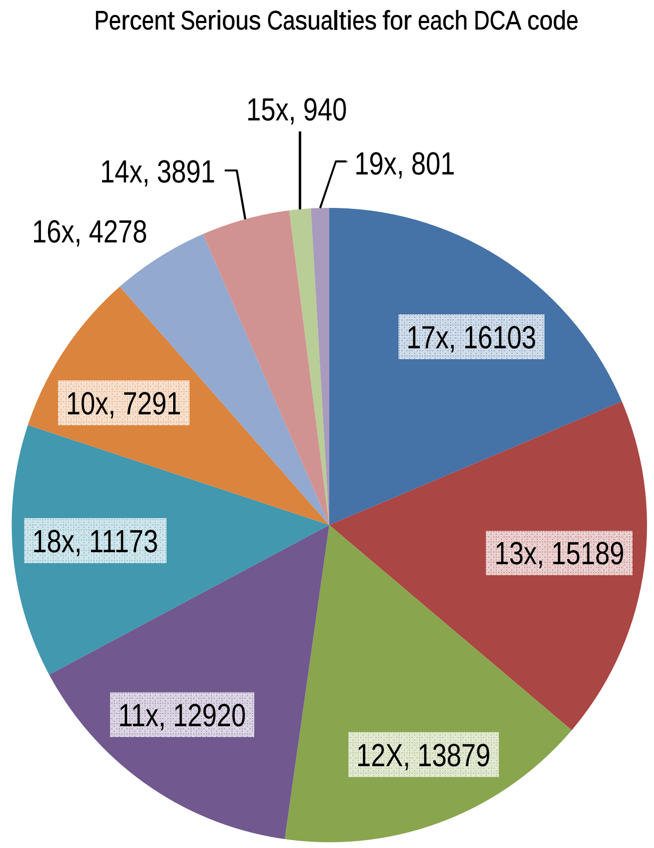

Figure 2: Percentage of Serious Casualties by DCA code, estimate for Australia 2005-2007.

The next section focuses on the potential safety benefits of DSRC on the various types of accidents grouped by DCA code. DCA category 16X, consisting mainly of crashes into parked vehicles or objects on the carriageway, was not considered. DCAs 190-199, representing miscellaneous crashes (almost 60% of which were 'fell from vehicle') were also neglected in this study. Together, these two categories account for only 1700 of 29,000 (6%) of annual average serious casualties in Australia.

4.4 DCA 10X - Pedestrians

Potential benefits

With recent advances in personal device technology such as mobile phones and iPods, many devices would, in theory, be able to communicate using a V2D system. Therefore, pedestrians could be updated with regular traffic conditions as well as potential hazards such as vehicles speeding in the vicinity to where they are walking. The data analysed above shows that pedestrians account for approximately 8% of total serious casualties (2005-2007). This figure is low compared to other crash types however, pedestrian impacts account for close to 7,000 serious injuries which are potentially highly costly to society. It is important to acknowledge that while portable devices (such as iPods and smart phones) in the community are becoming increasingly common, a number of issues exist relating to the ability of the pedestrians carrying these devices to perceive and respond to warning messages in a timely manner.

Estimated serious casualty savings

There are no currently viable DSRC applications addressing non-vehicular occupants, so no serious casualty savings have been estimated for this DCA category.

4.5 DCA 11X - Vehicles from Adjacent Directions

Potential benefits

This DCA code group represents vehicles colliding mainly at intersections when drivers either have to make a gap judgement to enter traffic or negotiate a set of traffic lights. This DCA code represents almost 15% of serious casualties in Australia and of this more than half (nearly 7,000 cases) are due to DCA 110, “cross traffic” crashes. DSRC has the potential to be of significant benefit for this category, since current reliance on driver compliance with priority rules, signs and traffic signals, coupled with the injurious effects of high speeds and the difficulties in providing adequate crash protection in a side impact, is clearly still resulting in a high number of serious casualties.

Estimated serious casualty savings

On the basis of the assumption that a well-designed warning system will prevent 52-72% of crashes, it is estimated that between 2240 and 3100 serious casualties annually could be prevented from a wide scale implementation of collision avoidance technologies.

4.6 DCA 12X - Vehicles from Opposing Directions

Potential benefits

Crashes involving vehicles from opposite directions can take place during head on crashes where one driver might drift into another’s path or when one vehicle turns right in front of another. This DCA code accounts for approximately 16% of serious casualties with nearly that whole figure occurring due to “head on” and “right turn in front of oncoming traffic” crashes. It would be expected that collision avoidance technologies would be able to have a positive influence all 12X crashes, although high closing speeds and shallow approach angles may present challenges to the delivery of timely and accurate warnings.

Estimated serious casualty savings

In the absence of specific research findings relating to the effectiveness of warnings for this crash type, a similar effectiveness was assumed to that for adjacent direction crashes. Therefore, of the 4630 annual serious casualties, between 2400 and 3300 might be preventable.

4.7 DCA 13X - Vehicles from Same Direction

Potential benefits

Conflicts involving vehicles travelling in the same direction typically involve ‘nose to tail’ crashes, where the lead vehicle is either proceeding straight (DCA 130) or making a right turn (DCA 132), with these two codes accounting for almost three-quarters of the 15,200 average annual serious casualties in this DCA category. While a very common crash type, it is generally less severe than other crash types, resulting in around 5000 serious casualties annually in Australia. Systems are currently available, such as forward crash warning (FCW) and adaptive cruise control (ACC) that user laser or radar-based systems to provide warnings or, in some cases, apply the brakes automatically.

Estimated serious casualty savings

Applying similar assumptions to the previous sections, between 2600 and 3600 serious casualties could be prevented annually. This figure could be higher subject to driver acceptance of autonomous braking, but has not been accounted for here.

4.8 DCA 14X - U-Turn

Potential benefits

The two major crash types in this category are DCA 147 (vehicle emerging from driveway/lane) and DCA 140 (collision with U-turning vehicle). The former situation is similar to those crashes in the DCA 11x group and is therefore able to be influenced positively by DSRC collision avoidance systems. U-turns are likely to present a challenge to algorithm designers, since the nature of the manoeuvre often results in very little warning in terms of a path to collision that can be extrapolated and therefore used to deliver early warning to either driver. This effect is also likely in the case of DCA 147 crashes, although this category comprises only 1.6% of serious casualty crashes in Australia.

Estimated serious casualty savings

In the absence of a comprehensive understanding of the circumstances of these two crash types and the types of responses expected from collision avoidance systems, no serious casualty savings will be assumed. The benefits of preventing DCA 147, ‘emerging from driveway’, crashes might be similar to those available from the DCA category covering adjacent direction crashes, but will be numerically small.

4.9 DCA 15X - Overtaking

Potential benefits

Overtaking crashes (excluding head-on crashes, which are captured by DCA 120) are relatively uncommon, contributing only 300 of 29,000 serious casualties annually. Advanced DRSC applications have the potential to assist drivers with overtaking decisions, particularly when overtaking vehicles such as trucks or buses by allowing them to essentially “see” further down the road and around larger vehicles in front of them. The system would be able to provide drivers with a warning of potential vehicle travelling towards them.

Estimated serious casualty savings

Similar benefits have been assumed as for other categories, with 52-72% of serious casualties in this category potentially preventable. This results in estimated savings of 160-230 S.C.s per annum.

4.10 DCA 17X - Off Path on Straight

Potential benefits

This DCA code represents the run-off-road crashes that occur while on a straight road and constitutes 18.6% of annual serious road casualties in Australia (with almost two-thirds of these resulting in a run-off-road into a tree event). While not suitable applications have been documented in the literature to date, DSRC has the potential to assist drivers maintain lane position by alerting them to any drifting behaviour, although this would seem to necessitate infrastructure-based transponders at regular intervals to make the vehicle aware of the location of the roadside.

Estimated serious casualty savings

It would not seem feasible in the near future to derive any crash reduction benefits from this DCA category and no serious casualty savings have been assumed.

4.11 DCA 18X - Off Path on Curve

Potential benefits

Similarly to the DCA group of 17X, this group also represents run-off-road crashes but on a curve rather than a straight road section. According to the crash database, approximately 13% of serious casualties result from this type of crash with about 60% of these running off the road into an object, such as a tree. In contrast to the previous category, there does appear to be some potential for DSRC to provide curve speed warnings to drivers, although it would seem to be dependent upon the development of affordable infrastructure-based solutions, since both this and the previous crash category tend to be widely distributed spatially.

Estimated serious casualty savings

As for DCA 17X, no serious casualty benefits have been estimated for this crash category.

4.12 Summary of estimated serious casualty savings

The serious casualty savings estimated for each of the categories are summarised in Table 3, given the assumption of full implementation through fitment to both new and existing vehicles, as well as assumptions regarding the response of drivers to warnings originating from in-vehicle DSRC technologies. Modelling of the effects of implementation through introduction to parts of the vehicle fleet was not carried out, neither was the introduction of limited-scale infrastructure-based solutions. The benefits of vehicle-to-vehicle and vehicle-to-infrastructure technologies when fitted to only a small proportion of the vehicle fleet are clearly considerably less than in the case of 100% take-up, but an estimation of the interim benefits is beyond the scope of this study, potentially involving traffic simulation techniques, for example. The figures quoted are all relative to the average annual number of police-reported deaths and serious injuries across Australia between 2005 and 2007.

Table 3: Summary of DSRC annual serious casualty saving estimates. All estimates to nearest 50 serious casualties per annum based on 2005-2007 average.

DCA category	Mean annual S.C.s (2005-2007)	S.C.s saved through DSRC, lower est.	S.C.s saved through DSRC, upper est.	Estimated remaining S.C.s, lower est.	Estimated remaining S.C.s, upper est.
	(a)	(b)	(c)	(a)-(c)	(a)-(b)
10X	2450	0	0	2450	2450
11X	4300	2250	3100	1200	2050
12X	4650	2400	3350	1300	2250
13X	5100	2650	3650	1450	2450
14X	1300	0	0	1300	1300
15X	300	200	250	50	100
16X	1450	0	0	1450	1450
17X	5400	0	0	5400	5400
18X	3700	0	0	3700	3700
19X	300	0	0	300	300
TOTAL	28950	7500	10350	18600	21450

Table 3 suggests that, with widespread application of DSRC collision avoidance technologies, it might be possible to save between 7500 and 10,350 of the 28950 serious casualties experienced in Australia each year (in present-day terms). This represents a reduction of between 25% and 35%.

The associated benefits of avoiding these serious casualties, using a 'hybrid' human capital approach (BITRE, 2009), would be between 2.4 and 3.5 billion dollars for the lower and upper estimates respectively[3].

[3] This estimate is based on an approximate serious injury to fatality ratio of 17:1, a fatality cost of $2.4m and a cost of $214k per seriously-injured person.

5 CONCLUSION

A number of ongoing research projects, including field operational trials, were identified. Most of them aim to the enhance safety and mobility of the road transport system, through applications based around dedicated short-range communications (DSRC) technology. However, there is a lack of definitive estimates of the safety benefits of such applications in the published literature to date, with most focusing on the technical development of the underlying technologies with the goal of minimising latency and maximising accuracy in order to optimise the platform for the hosted applications. However, as the underlying technology matures, it appears that safety benefits, both direct and indirect, are being increasingly prioritised by many of the ongoing projects. It is important to note that the safety benefits to serious casualties of traffic information (such as weather conditions and congestion warnings), strategic traffic routing, dangerous goods monitoring and even emergency vehicle prioritisation at intersections are inconclusive in the literature to date. The majority of serious casualties will be saved in the long term by addressing primarily through addressing adjacent, opposite and same direction crashes in general terms and it is important that this goal is the focus of future studies moving beyond proof-of-concept.

This research documented a selection of some of the current trials in progress, then provided a summary of optimal warning design and estimates of the warning effectiveness. In order to provide conservative estimates, the assumption was made that the intervention of DSRC-based applications will be limited to warnings with no physical interventions such as active steering or braking. Furthermore, benefit estimates were limited to fatalities and serious injuries across the eight Australian jurisdictions, since these two severity categories constitute the majority of the annual societal cost of road trauma.

Estimates were made by each of the DCA categories of the potential serious casualty reductions that might be expected, in current terms, of well-implemented DSRC-based collision avoidance technologies fitted to the entire vehicle fleet. On this basis, it was estimated that the current total of approximately 29,000 annual serious casualties could be reduced to between 18,500 and 21,500, a reduction of 25-35%. It should be noted that DSRC has yet to be implemented on a sufficiently comprehensive scale in any jurisdiction to provide a precedent for accurately assessing its true long-term effectiveness and the estimates provided in this report will need to be regularly updated as the results of new studies become available.

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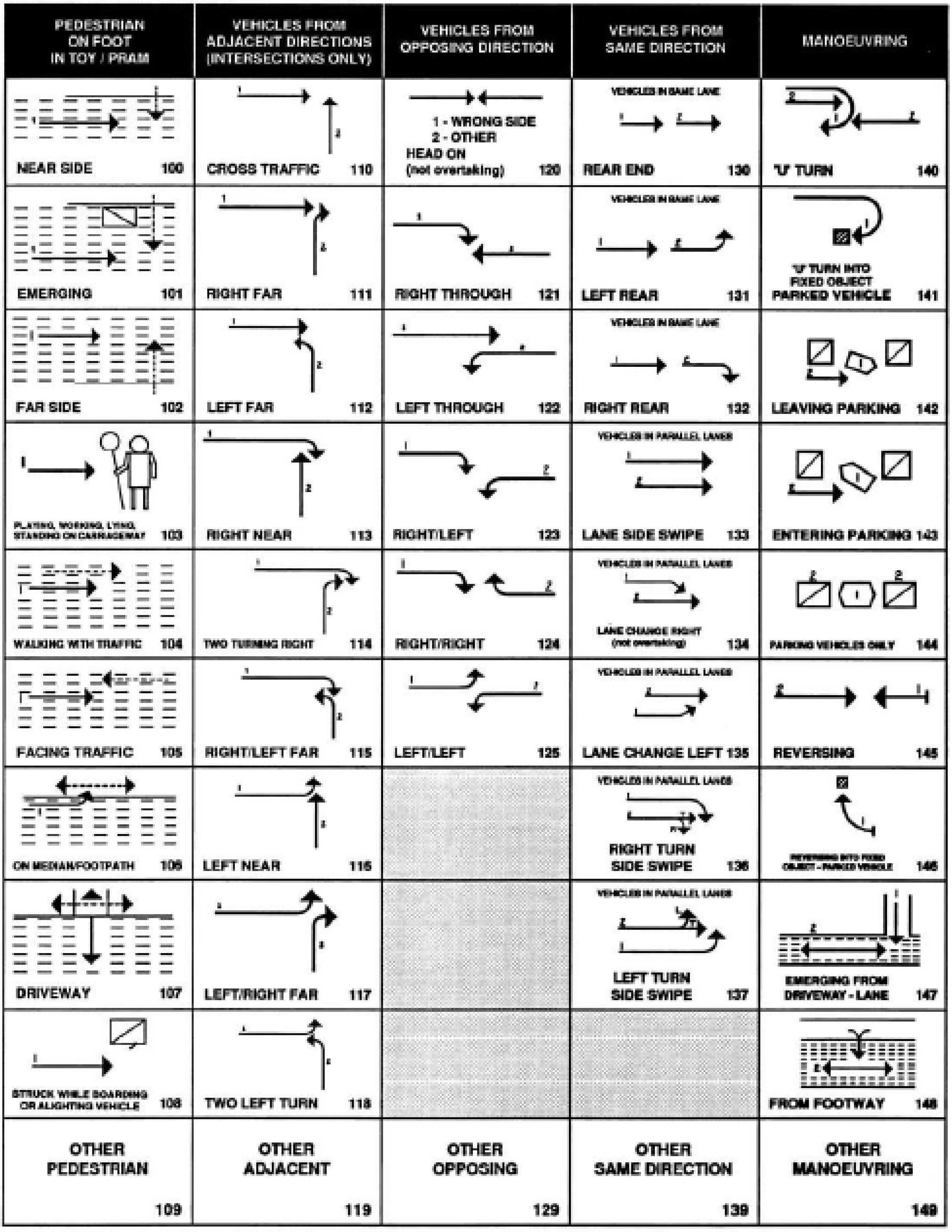
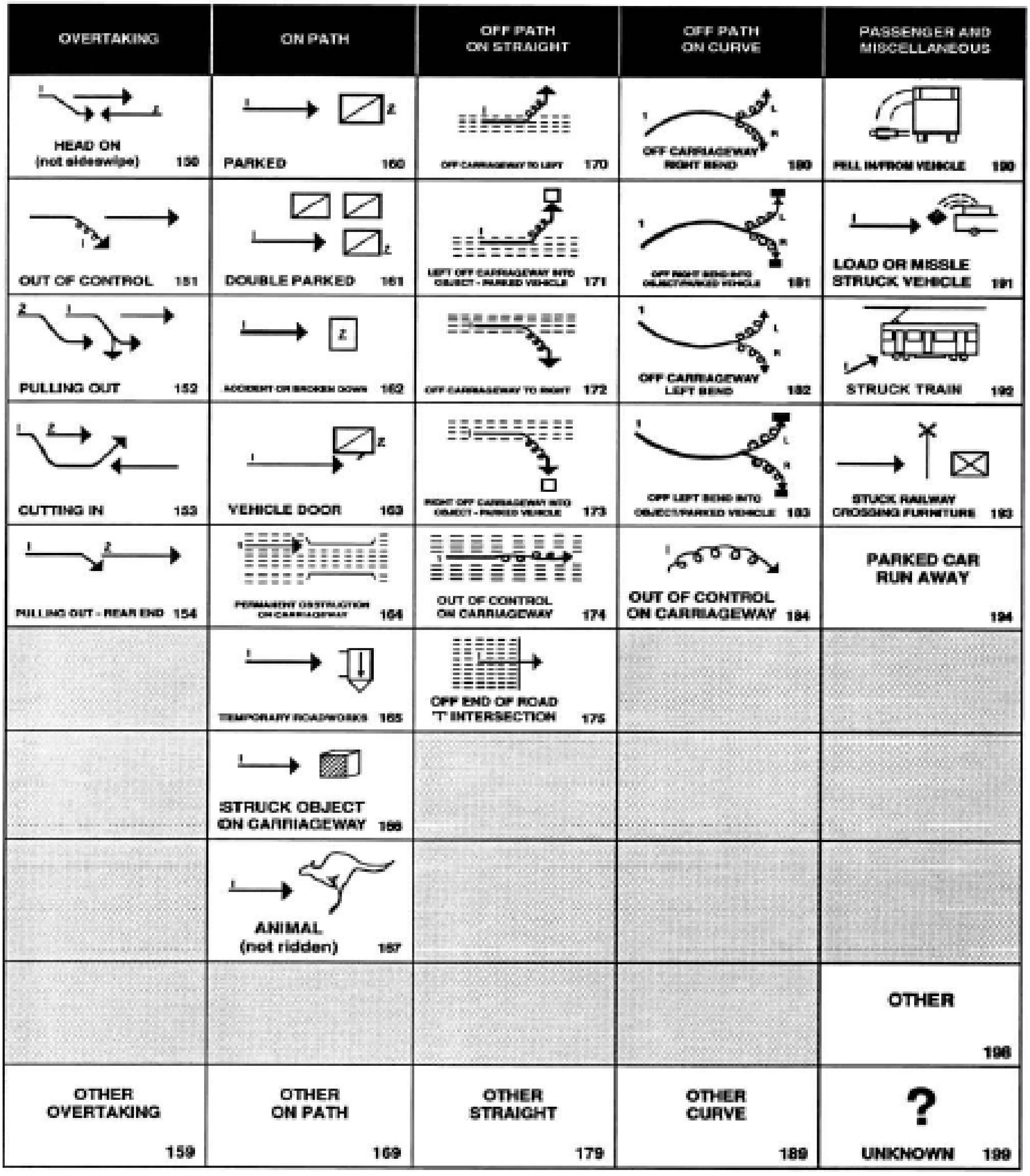
APPENDIX – DCA CODES



1. Definition for classifying accidents (DCA) should be determined by first selecting a column using the text above & then by diagrammatic sub-division.
2. The sub-division chosen should describe the general movement of vehicles involved in the initial event. It does not assign a cause to the accident.
3. Supplementary codes have been defined for most sub-divisions. These codes give further detail of the initial event.



4. The number 1,2 identify individual vehicles involved when the DCA is linked with other vehicle/driver information.
5. These codes were used for 1987 accidents and replace the Road User Movement (RUM) code.

Produced by the Road User Behaviour Branch, Road Safety Division, VIC ROADS - DCA.pm4 & DCA2.pm4

INFORMATION RETRIEVAL

Austroads, **Error! Unknown document property name.**, **Error! Unknown document property name.**, Sydney, A4, 33pp, AP-R375/11

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Dedicated Short Range Communications, 5.9 GHz, vehicle-to-vehicle communications, vehicle-to-infrastructure communications, road safety, preventing crashes, active safety systems, collision avoidance technologies.

Abstract:

In order to provide earlier warning and therefore increased ability to influence the likelihood of crash involvement, different sensing systems are required. Peer-peer vehicle communication, in conjunction with GPS data (to provide location awareness), provides the potential for onboard systems to continuously broadcast their own location, speed and direction of travel as well as use the locations and velocities of other vehicles within range to predict collisions and provide warnings to drivers of an approaching conflict. This in turn, has a significant potential to reduce the number and severity of crashes by providing drivers with the opportunity to take evasive action in the event of a potential crash. Dedicated Short Range Communication, or DSRC, is a short to medium range communication service that operates at a frequency of 5.9GHz, allocated for automotive and transportation use. It is designed to allow for vehicle-to-vehicle and vehicle-to-infrastructure communication. This report aims to estimate the potential reductions in serious casualties in Australia from widespread adoption of DSRC-based technologies. The estimates of the potential benefits if DSRC collision avoidance technologies were derived from a database compiled by MUARC of serious road crash fatalities and serious injuries. Estimates were made by each of the DCA categories of the potential serious casualty reductions that might be expected, in current terms, of well-implemented DSRC-based collision avoidance technologies. On this basis, it was estimated that the current total of approximately 29,000 annual serious casualties could be reduced to between 18,500 and 21,500, a reduction of 25-35%. It should be noted that DSRC has yet to be implemented on a sufficiently comprehensive scale in any jurisdiction to provide a precedent for accurately assessing its true long-term effectiveness and the estimates provided in this report will need to be regularly updated as the results of new studies become available.