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## Connectivity in C-ITS

Investigating pathways to deliver road safety and network efficiency benefits through connected technologies

November

2020



*NOTE: As this report is being published, the coronavirus pandemic continues to alter the deployment of many technologies mentioned within it. Although the pandemic's ultimate impact on transportation remains unclear, continued development and deployment of these technologies as well as the expansion of new vehicles will be impacted. While little can be projected with any real certainty the research suggests that the national and international pandemic impacts will only increase the need to consider interim interventions such as after-market devices to improve safety and efficiency outcomes.*

## ACKNOWLEDGEMENTS

This project was led by ITS Australia and we would like to particularly acknowledge the support and effort from our research partners at The University of Melbourne and project partners Department of Infrastructure, Regional Development, Transport and Communications. We also recognise the support and expertise provided by IAG, Intelematics, and Transmax.

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## ABOUT THIS REPORT

This research is funded by iMOVE CRC, the Department of Infrastructure, Transport, Regional Development and Communications, ITS Australia and the University of Melbourne, and supported by the Cooperative Research Centres program, an Australian Government initiative. ITS Australia led this project with research partner the University of Melbourne to better understand how connectivity and intelligent transport systems can improve safety and productivity outcomes for our communities and networks.

### **Research Contributors**

Majid Sarvi – Professor

Neema Nassir – Lecturer in Transport Engineering

Patricia Lavieri – Lecturer in Transport Engineering

Jessica Tong – Research Associate

Saeed Asadi – Senior Research Fellow

Peter Sweatman – Enterprise Professor

### **Project Manager and Editorial Contributors**

Susan Harris – CEO ITS Australia

Stacey Ryan – Policy Manager - [stacey.ryan@its-australia.com.au](mailto:stacey.ryan@its-australia.com.au)

# contents

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- 1 Background
- 2 About the project
- 3 Project Participants
- 4 Executive Summary
  - 4.1 Road safety use cases
  - 4.2 Technology and hardware
  - 4.3 Key findings
  - 4.4 Conclusions
- 5 Glossary & recent international events
- 6 Research documentation
- 7 About us
- 8 Contacts

## 1. Background

There are currently few vehicles in Australia that are optimised for connectivity or equipped with Co-operative Intelligent Transport Systems (C-ITS). The potential safety benefits from new connected vehicles are unlikely to be realised in the immediate future in Australia due to the age of our fleet and the limited connectivity of new vehicles.

Vehicles arriving with C-ITS technology are likely to land in Australia with a mix of connective technologies, calling for a new set of interoperability standards to guarantee the intended communication and cooperation.

Australasia's authority on vehicle safety, ANCAP undertook an analysis of the Australian registered light vehicle fleet revealing older vehicles are over-represented in fatal vehicle crashes, and the average age of a vehicle involved in a fatal crash is increasing.

Across 2015, 2016 and 2017, the average age of registered vehicles in Australia (passenger vehicles and SUVs) remained constant at 9.8 years, yet:

- In 2015, the average age of a vehicle involved in a fatal crash was 12.5 years
- In 2016, the average age of a vehicle involved in a fatal crash was 12.9 years
- In 2017, the average age of a vehicle involved in a fatal crash was 13.1 years

The rate of fatal crashes per registered vehicle for the oldest vehicles is four times higher than that of the newest vehicles.

ANCAP Safety modelling on road death projection estimated that with an increasing population and no changes to current road death rates over the next five years, around 6,000 lives will be lost on Australia's roads.

AAA research found that in 2018–19, congestion costs are expected to exceed \$23 billion, which will be more than the value of all road-related expenditure. Without major policy changes, congestion costs are projected to reach between \$30.6 and \$41.2 billion by 2030.

Safety and congestion are two of the key challenges on our networks and there is strong potential for connectivity and C-ITS to improve these vital problems.

**Connected vehicles can increase safety and network efficiency outcomes.**

## 2. About the project

There are considerable national and international efforts underway to accelerate the uptake of innovative technologies that can improve road safety as well as the overall performance of transport systems. Communication technologies are enabling the introduction of connected vehicles, which have the potential to both reduce roadway crashes and improve traffic flows. At the same time, global companies are developing automated vehicles, many of which will also incorporate connected technology.

This project aims to deliver a systematic understanding, classification, and evaluation of available communication technologies for roadway safety and productivity by combining the results of four lines of research inquiry:



1) literature review of existing communication technologies, pilot experiments, and trial implementations,



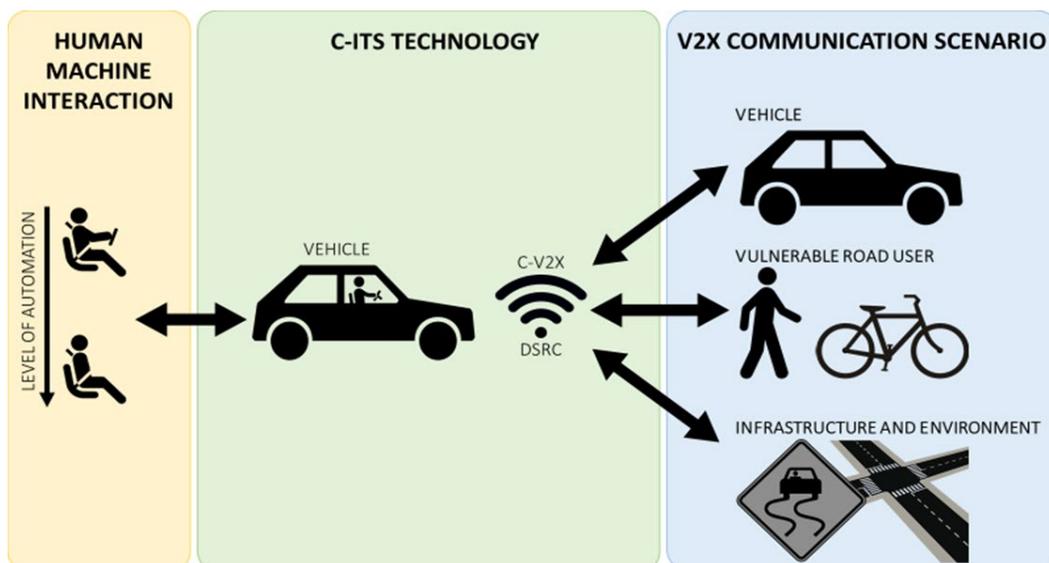
2) expert panel interviews and literature review to investigate the challenges and opportunities for technology implementation in the Australian context,



3) analysis of Victorian motor vehicle crash types with respect to their being addressed by currently available connected safety applications, and



4) traffic simulation study to estimate the minimum penetration rate of connected vehicle technology required for mobility and environmental benefits to be realised.



### 3. Project participants

ITS Australia led this project through iMOVE to better understand how connectivity and intelligent transport systems can improve safety and productivity outcomes for our communities and networks. We would like to thank our project partners:

- The University of Melbourne
- The Department of Infrastructure Regional Development Transport and Communications

And Participants:

- IAG
- Intelematics
- Transmax

This research is funded by iMOVE CRC and supported by the Cooperative Research Centres program, an Australian Commonwealth Government initiative.



Australian Government

Department of Infrastructure, Transport,  
Regional Development and Communications



## 4. Executive summary



Increasing the uptake of road safety technology was a key recommendation of the 2018 National Road Safety Strategy Inquiry report, with joint commitment to support the recommendation through the Road Safety Working Group's Implementation Plan.

There is a strong commitment across all levels of government to improve safety outcomes on our roads. Governments are progressing standards to support the deployment of technology such as Autonomous Emergency Braking, along with broad improvements in crash protection.

The Cooperative Intelligent Transport Systems (C-ITS) combine information technology and mobile communication to enable data and command transmissions between vehicles, roadside infrastructure and a central management systems, in order to improve roadway safety for all users, as well as traffic flow efficiency in the network.

The recent technological advancements in vehicle-to-vehicle and vehicle-to-infrastructure communications (vehicle connectivity, in general), wireless sensors, video analytics, artificial intelligence, edge computing and IoT can support and accelerate cooperative transport systems for Australian cities. However, the potential safety and efficiency benefits from connected vehicles are unlikely to be realised in the immediate future in Australia due to the age of our fleet and the limited connectivity of new vehicles.

There is a potential to increase the number of compatible connected vehicles within the Australian fleet over the next decade through the fitting of after-market devices and/or increasing the demand of consumers for connectivity to be enabled in new vehicles arriving in Australia. An increase in connected vehicles is likely to lead to improved road safety outcomes for the community.



## Connectivity in C-ITS

Co-operative intelligent transport systems (C-ITS) involve emerging technologies for vehicle connectivity and communications with other vehicles, including:

- Vehicle to Vehicle - (V2V)
- Vehicle to Infrastructure - (V2I)
- Vehicle to 'Everything' i.e motorcycles, cyclists, and pedestrians - (V2X)

These communications will also enable connected and automated vehicles (CAVs) currently being tested and promising substantial road safety and traffic network performance improvements, as well as energy efficiency and emissions reduction. These technologies offer both short-range and long-range communications, where the scenario or nature of application or 'use-case' governs the type of communication employed. There are two primary C-ITS communication technologies:

- Cellular Vehicle-to-Everything (C-V2X)
- Dedicated Short Range Communication (DSRC)

This research investigates the potential for implementing DSRC as a short-range communication method, C-V2X for both short- and long-range communications, and a hybrid method consisting of DSRC for short-range with a cellular long-range communication capability. These implementation methods are based on the approaches to testing and simulating C-ITS communication observed in the USA (where DSRC has been subjected to in-depth testing and model deployment) and Europe (where the hybrid model is being considered).



Curve Speed  
Warning could see  
significant benefit to  
motorcyclists and is  
relevant to 17% of  
crashes

## Connectivity in C-ITS

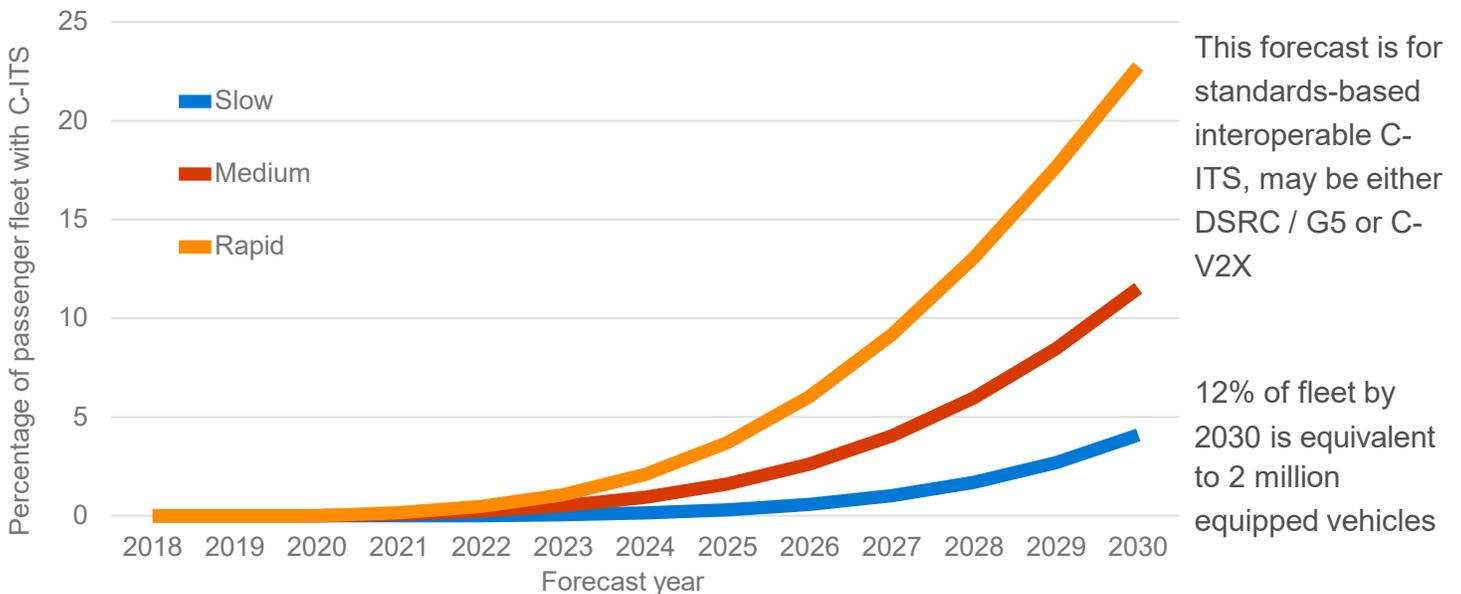
Co-operative intelligent transport systems (C-ITS) involve emerging technologies for vehicle connectivity and communications with other vehicles (V2V), infrastructure (V2I), and everything (V2X). These communications will enable connected and automated vehicles (CAVs) to potentially deliver a range of benefits, including increased road safety and traffic network performance.

Performance comparisons show C-ITS technology has the potential to provide significant positive outcomes in roadway crash reduction and in alleviating traffic congestion. These benefits have been assessed in multiple trials and simulations around the world, with most large-scale real-world trials testing the safety potential of DSRC.

A report published by Austroads 'Future Vehicles 2030' suggests that there is benefit in supporting the advancement of connectivity to enable these benefits sooner rather than later as shown in the graph below with thanks to Austroads for permission to reproduce.



## Connectivity: C-ITS



## 4.1 C-ITS road safety use cases



Use Case and Description	Deployment Timeframe
<p><b>Lane Keep Assist (LKA)</b></p> <p>LKA is an advanced driver assistance system (ADAS) which does not require communication between the vehicle and its surrounding environment and instead relies on sensing hardware such as cameras. LKA acts as an automated corrective system which responds to cases of drifting manoeuvres and immediately recorrects a vehicles course to be within lane markings.</p>	ADAS-only
<p><b>Curve Speed Warning (CSW)</b></p> <p>CSW aims to address single vehicle crashes associated with excessive speed in the negotiation of roadway curves. The application compares the car's speed with a safe speed for the curve in question and warns the driver to slow down. Austroads provided an estimated 19-29% effectiveness range for the use of CSW with human intervention which is projected to prevent 75-115 fatal and serious injury (FSI) crashes in Australia.</p>	Day 1
<p><b>Cooperative Forward Collision Warning (CFCW)</b></p> <p>CFCW, also known as stopped or slow vehicle warning, acts to warn drivers of a threat ahead (e.g. stopped, or slowed vehicle), based on information provided by neighbouring vehicles and operates without the need for the ranging sensors used in traditional FCW Advanced Driver Assistance Systems. The lead vehicle is able to convey a message to following vehicles (V2V communication), mitigating or reducing the outcome of rear-end collisions for vehicles travelling in the same lane. Austroads' research report estimated a 20-32% crash avoidance effectiveness when the warning was acted upon by a human driver, and a 44-69% effectiveness when intervention following the warning was automated.</p>	Day 2
<p><b>Right Turn Assist (RTA)</b></p> <p>RTA is another intersection-specific collision avoidance warning which alerts the driver of potential collision with an oncoming vehicle from opposing direction while making a turn at both signalised and unsignalised intersections using V2V communication. This case is discussed specifically due to the safety benefits which are expected, and significant amount of testing and simulation which has been completed. This use case is expected to provide the highest benefit in situations where the driver's line of sight is obscured by other vehicles, road curvature, or road infrastructure. Austroads estimated RTA had an effectiveness range between 27-42% for human intervention cases, increasing to 54-85% when assuming automation was present.</p>	Day 3

Use Case and Description	Deployment Timeframe
<p><b>Do Not Pass Warning (DNPW)</b></p> <p>An Overtake or Do Not Pass Warning (DNPW) operates with V2V communication and alerts the driver that it is unsafe to perform an overtaking manoeuvre as there is an oncoming vehicle. This feature is expected only to operate when the driver has activated their turn signal and therefore does not have the ability to address situations when the driver unintentionally drifts into the oncoming lane. Research funded by the Texas Department of Transportation simulated and trialled DSRC-based V2V warnings for overtaking manoeuvres on two-lane rural highways. This research found that an overtaking warning was successfully sent and received in 77-96% of trials depending on the specific configurations. This use case was also successfully trialled in the SPMD.</p>	ADAS-only
<p><b>Intersection Movement Assist (IMA)</b></p> <p>IMA is an application designed to address common crash types at intersections. IMA acts to warn the driver that entering an intersection is unsafe due to another vehicle approaching from a lateral direction. This V2V communication exchanges basic safety messages (BSMs) that contain information that can be translated into the distance between two vehicles and the time to collision.</p>	Day 1
<p><b>Cooperative Blind Spot Warning/Lane Change Warning (CBSW/LCW)</b></p> <p>Blind Spot Warning (BSW) and Lane Change Warning (LCW) are ADAS functions which warn the driver when a potentially dangerous lane change manoeuvre is detected. With the use of connected vehicle technology, these functions can be enhanced to allow lane change warnings to operate at greater ranges, eliminating a key drawback of lane change warning and allowing for the development of similar applications like Overtake Assistance. Cooperative BSW/LCW can potentially remove the need for sensors within the vehicle to detect the lane change movement, instead, the vehicles performing these manoeuvres may be able to broadcast their movements to surrounding vehicles (V2V communication).</p>	Day 2
<p><b>Pedestrian Safety Messages (PSM)</b></p> <p>Connectivity has also opened gateways to novel vulnerable road user (VRU) safety applications. VRUs are often considered as non-motorised road users, including pedestrians and pedal cyclists, and may also include motorcyclists and various electrified machines for micromobility. Vehicle to pedestrian collisions usually lead to severe injury or fatality on the pedestrian's part, accentuating the need to protect non-motorised vulnerable road users as a priority. There is a lack of worldwide trials targeting warnings of conflict between a vehicle and vulnerable road users. However, Australian trials including AIMES, CAVI, and the Towards Zero CAV, are investigating these use cases; currently, only qualitative results for expected benefits of connectivity for VRUs have been reported.</p>	Day 3

## 4.2 Technology and hardware



Technology for C-ITS communications may be integrated by the original equipment automotive manufacturer, or purchased and fitted in the automotive aftermarket. The following distinctions are made between aftermarket (retrofitted) and OEM (machine integrated) solutions:

1. Aftermarket solution: aftermarket equipment may allow V2V, V2I or V2X communications via DSRC and/or C-V2X. The equipment is retrofitted into an existing vehicle or operated independently from the vehicle's controller network.
2. OEM solution: communication equipment (DSRC, C-V2X, or both) is integrated into vehicles during production and integrated to the newly produced vehicle's controller network. This type of device is capable of providing highly accurate information using the in-vehicle information to generate basic safety messages (BSMs).
3. Some alternative aftermarket applications which operate outside of the C-ITS environment through smart phone applications such as "Addinsight" (Adelaide) and "Speed Advisor" (Transport for New South Wales) are also being developed to deliver awareness messaging and improve safety outcomes for users.

When considering the equipment that can be deployed for C-ITS communications, the functions which this equipment must perform need to be considered. For awareness communications (i.e. Day 1 applications from the European Roadmap), the technology deployed must be able to transmit awareness messages and provide basic infrastructure support.

Services provided on Day 1 are aimed at enhancing the driver's understanding of their surrounding infrastructure and environment, and do not necessarily require large amounts of information to be communicated. Beyond Day 1 applications, the amount of information communicated increases for sensing and warning functions.

For use cases on Day 2 and Day 3+, a high level of accuracy is required as positional information is often conveyed; additional factors such as security must now also be considered given the time-critical nature of the communication. The delivery of precise information is crucial for cooperative use cases to function effectively and provide expected road safety and traffic efficiency benefits.

In order for the benefits of connected vehicles to be recognised, a number of hardware requirements must be satisfied. Some of the vehicle equipment configurations used in C-ITS communication trials include Integrated Safety Devices (ISD), Aftermarket Safety Devices (ASD), Retrofit Safety Devices (RSD), and Vehicle Awareness Devices (VAD). These devices offer varying levels of integration with the vehicles, and hence, have different levels of functionality as well as installation requirements as noted by the NHTSA. The three aftermarket safety devices (RSD, ASD, VAD) have limitations when compared to an ISD:

- Integrated Safety Device (ISD): When used in trials, these devices most accurately reflect an OEM installed device.
- Retrofit Safety Device (RSD): The level of integration with the vehicle decreases when retrofitting RSDs compared to ISDs, although the device is still connected to the vehicle's data bus. This allows for basic safety messages and vehicle to vehicle safety applications to be communicated. This device requires a certified installer for the placement of antennas and security certification.
- Aftermarket Safety Device (ASD): This retrofit device requires power from the vehicle and has the ability to communicate BSM and V2V safety applications, although the safety applications which can be conveyed using this technology are limited when compared to those which RSDs can potentially achieve. Again, this device requires a certified installer for the placement of antennas and security certification.
- Vehicle Awareness Device (VAD): This device can only provide BSM which alerts surrounding or nearby vehicles of their presence; no safety applications or use cases can be performed with this device. This device still requires a certified installer for the placement of antennas and security certification.

## Connectivity in C-ITS

The following hardware equipment contributes to providing vehicles with the necessary information for vehicle awareness:

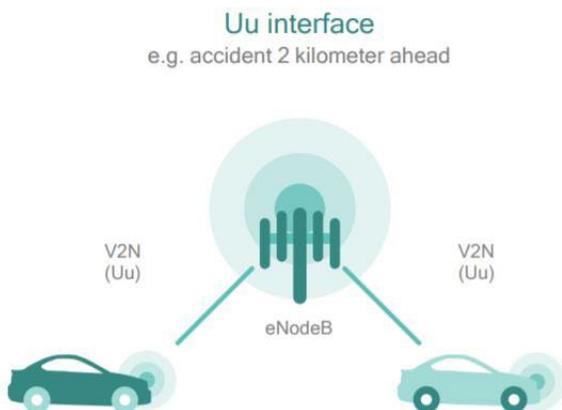
- Cameras
- Radars
- Lidar
- Ultrasonic sensors
- V2X wireless sensors
- Antennas
- 3D HD Map
- Global Navigation Satellite System (GNSS)

This hardware builds a virtual image of the surrounding environment which vehicles can communicate to other road users. It is necessary for at least some of these elements to be present in connected vehicles in order for any C-ITS communication technology to realise the safety and efficiency benefits.

In addition to these sensing hardware, to communicate with other road users and infrastructure, vehicles must be equipped or retrofitted with an antenna for direct communications. For both technologies, roadside units (RSUs) are also required in order to provide a communication platform between the vehicle and surrounding infrastructure/environment.

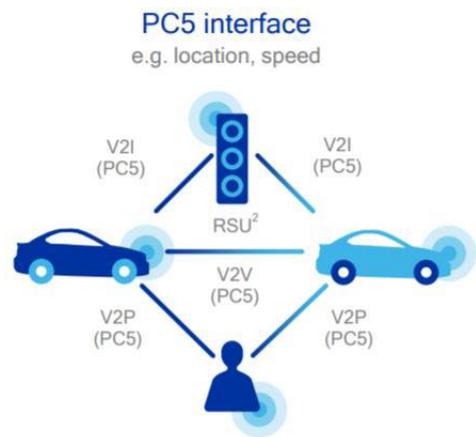
### Network communications

V2N on “Uu” interface operates in traditional mobile broadband licensed spectrum



### Direct communications

V2V, V2I, and V2P on “PC5” interface<sup>1</sup>, operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network



*C-V2X interfaces for communication (Qualcomm, 2017)*

## 4.3 Key findings



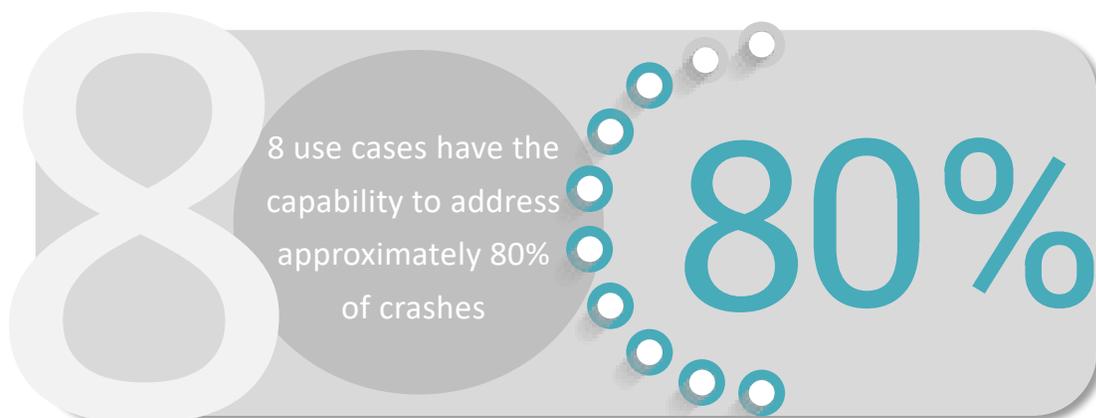
There are numerous use cases for connected vehicles (CV) which have been trialled and simulated by government endorsed agencies, industry, and in academia. These trials aim to test and demonstrate the safety, environmental, and mobility benefits which CVs can provide. The safety functions of C-ITS communication technology are divided into two categories: awareness messages and warning messages.

Awareness messages are defined as non-critical communications which act to provide an increased knowledge of the driver's surrounding infrastructure and environment. These include advisory warnings for speed, red light signals ahead, or other hazards. Warning messages, on the other hand, are considered critical, where the driver is warned of an imminent threat where reactions to such messages are time sensitive.

These include warnings about potential conflicts or collision paths with other vehicles and imminent requirements for corrective action (such as emergency braking). Other benefits from connected vehicles, including mobility and environmental, were also investigated for their ability to enable reduced fuel consumption, and improved travel-times.

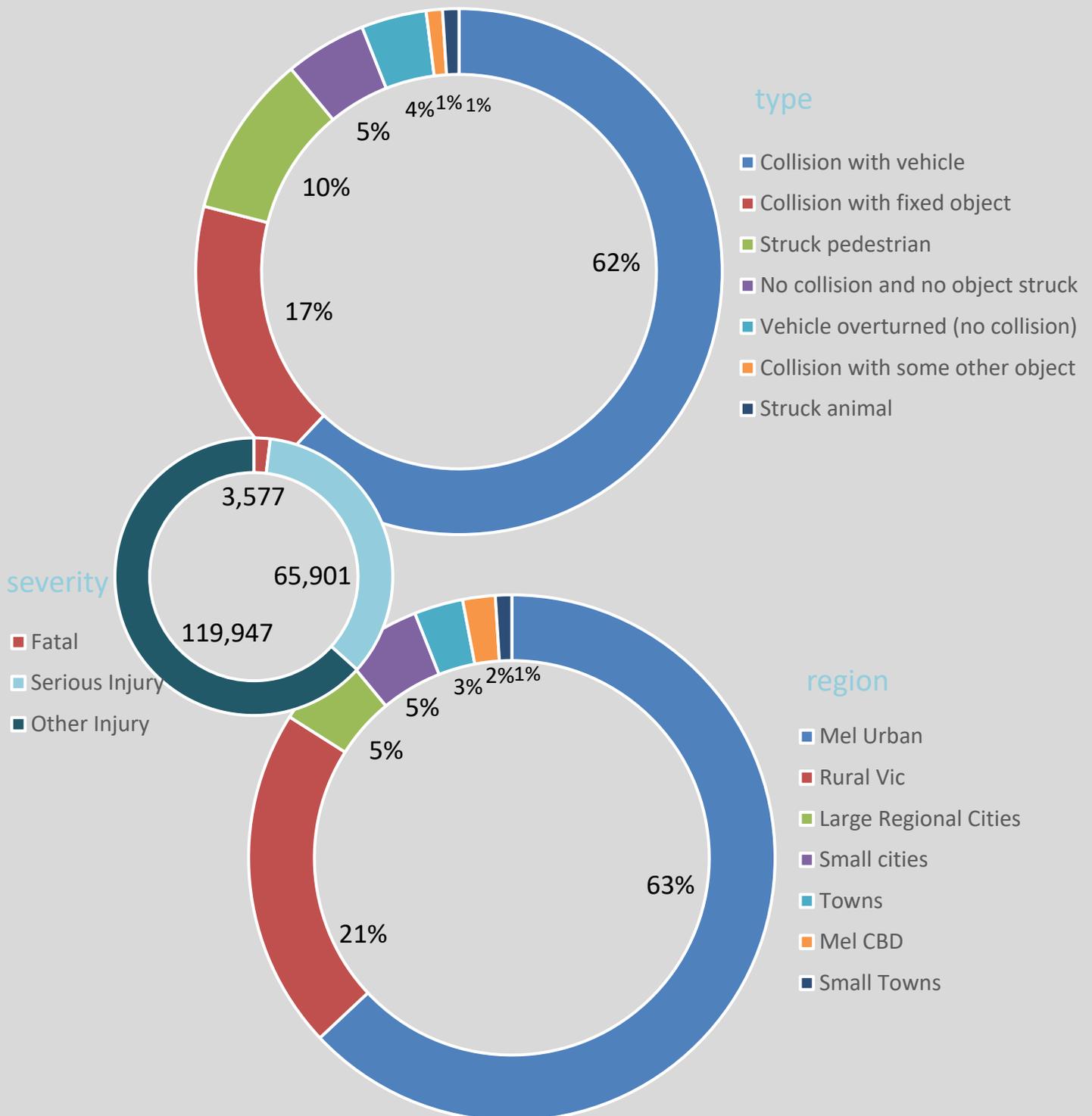
The safety benefits of C-ITS can be assessed by examining the proportion of crashes which each specific use cases have the potential to address. Victoria's Road Safety database contains a comprehensive record of crashes over the last fifteen years, with attributes for each crash occurrence including severity of injury, specific crash classifications, geographic location, road geometry, lighting conditions, and modes involved.

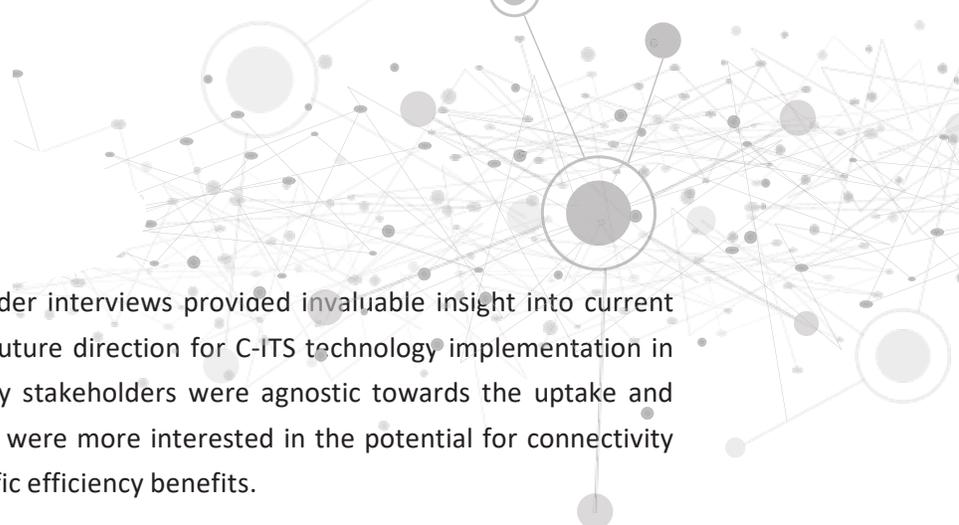
Investigating the crash data through these parameters highlight factors and variables that make certain crashes more common and presents an opportunity to target development and deployment C-ITS use cases that could address a higher proportion of crashes. Traffic simulations can measure network mobility improvement and environmental benefits comparing different penetration rates of connected vehicles to existing and academic traffic signal control methods.



# Crashes by severity, type, and region

Victorian data 2006-2019





Expert and other key stakeholder interviews provided invaluable insight into current informed viewpoints and the future direction for C-ITS technology implementation in Australia and worldwide. Many stakeholders were agnostic towards the uptake and use of DSRC and/or C-V2X and were more interested in the potential for connectivity to provide road safety and traffic efficiency benefits.

Several challenges in C-ITS deployment were identified, including user acceptance, and achieving penetration rates that would enable safety and traffic benefits to be realised. The cost associated with investments in infrastructure, and the need for interoperability were also of concern. Penetration rates in the Australian vehicle fleet will be influenced by early and consistent OEM fitment, and by the availability and use of retrofit devices.

Overall, stakeholders viewed C-ITS technology as a singular opportunity to improve road safety outcomes, with potential benefits to reduction of crash rates an order of magnitude higher than other known safety technologies such as existing Advanced Driver Assistance Systems or ADAS.

.....  
*...awareness messaging benefits can be realised at low penetration rates, while sensing and cooperative driving applications require higher rates of penetration for benefits to be realised...*  
.....

Connected applications, or use cases, represent a vast field; a useful classification scheme has been presented by the US Department of Transport. In addition, the framework presented by the European Roadmap to Deployment presents a broader view of the field, with added information on likely sequencing and progression of the technologies. Both frameworks make an important distinction between use cases that:

- i) promote awareness of potential safety issues in the vicinity of the host vehicle,
- ii) generate warnings of specific crash-related risks.

Under such schemes, awareness messaging benefits can be realised at low penetration rates, while sensing and cooperative driving applications require higher rates of penetration for benefits to be realised. Additional factors associated with technology deployment include network coverage, with some jurisdictions requiring infrastructure investment in order to provide adequate coverage for cellular connectivity applications.

<b>Additional use case insights drawn from expert interviews:</b>	
<b>Curve Speed Warning</b>	<ul style="list-style-type: none"> <li>■ This use case is not directly covered by ADAS systems</li> <li>■ Easy deployment to existing fleet</li> <li>■ Curve speed warning could be expected to have a significant impact on fatalities and serious injuries across our rural communities.</li> <li>■ Could see significant benefit to motorcyclists (CSW is relevant to 17% of crashes); there is need to consider motorcycle rider behaviour and a suitable HMI for motorcyclists</li> <li>■ Maintenance and digital publication of road speed/geometry data would need to be considered</li> </ul>
<b>Cooperative Forward Collision Warning</b>	<ul style="list-style-type: none"> <li>■ There is some potential that deployment of Automated Emergency Braking is having a positive impact on crashes that CFCW may also impact.</li> <li>■ Suggest the deployment of AEB continues to be encouraged to address these types of incidents pending the broader deployment of connected vehicles technology by the OEMs</li> </ul>
<b>Intersection Movement Assist &amp; Right Turn Assist</b>	<ul style="list-style-type: none"> <li>■ These use cases are not directly covered by ADAS systems</li> <li>■ Relevance increased when both use cases are present</li> <li>■ Significant impact in urban environments</li> <li>■ High relevance for VRUs (24% potentially addressable) as well as scooters and cyclists</li> <li>■ Potential challenges to retrofit into vehicles; Positioning and speed accuracy would pose a challenge for these use cases</li> <li>■ Infrastructure connectivity could deliver additional benefits</li> <li>■ Potential to implement as intersections are upgraded and prioritise complex intersections.</li> <li>■ Potential to extend application to support pedestrians at intersections</li> </ul>
<b>Traffic efficiency benefits from microsimulation:</b>	<ul style="list-style-type: none"> <li>■ Traffic microsimulation experiments in arterial corridors indicate that connected vehicles at penetration rates of 30% (V2V and V2I) can reduce peak congestion by up to 11%.</li> <li>■ Network microsimulation in CBD during peak hour indicates that average travel speed can improve by 10% with connected vehicle penetration rates above 20%.</li> </ul>

A comprehensive analysis of Victorian Road Safety data, covering a fifteen-year period with approximately 190,000 recorded crashes indicated that the following eight major connected safety use cases have the capability to address approximately 80% of crashes on Victorian roads. Specifically, 78% of fatal crashes, 82% of serious injury crashes, and 84% of other crashes causing injury.

- Lane Keep Assist (LKA)
- Curve Speed Warning (CSW)
- Cooperative Forward Collision Warning (CFCW)
- Do Not Pass Warning (DNPW),
- Intersection Movement Assist (IMA)
- Right Turn Assist (RTA)
- Cooperative Blind Spot Warning (CBSW/LCW),
- Pedestrian Safety Messages (PSM)

These cases have also been studied in other literature, trials, and simulations. However, use case benefits are not evenly distributed among different cohorts of road users and across different driving environments. Additionally, the cases studied represent varying levels of assumed connectivity relative to the European Roadmap to Deployment. While use cases at lower levels of connectivity and penetration (i.e. ADAS-only and Day 1) have the potential to address a significant share of crashes, these applications are more suited to addressing crashes in medium to sparsely populated environments and not applicable/beneficial to all modes. There is clearly a need to consider pathways towards to implementing Day 2 to 3+ use cases given that benefits are expected to be seen across all geographic regions and modes.

### Four major connected safety use cases

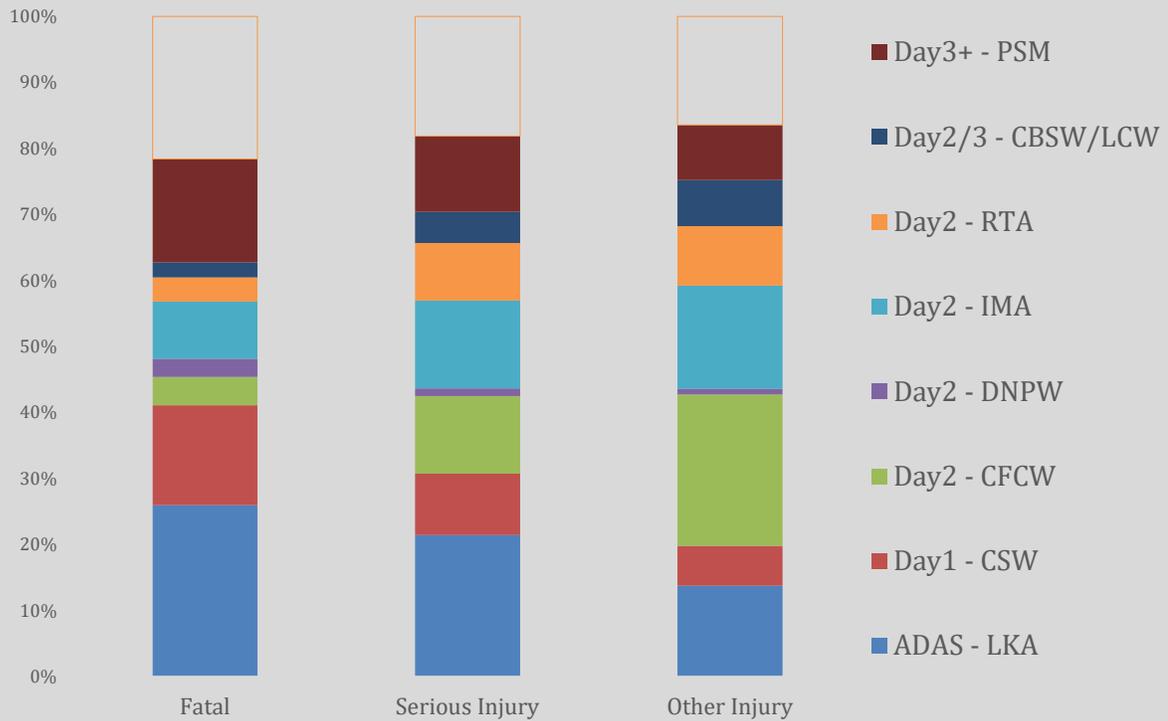
1. IMA: Intersection Movement Assist
2. CFCW: Cooperative Forward Collision Warning
3. CSW: Curve Speed Warning,
4. RTA: Right Turn Assist



Drivers and passengers would benefit most from IMA and CFCW

## Proportion of crashes that specific use cases can address by severity

8 Major Use Cases	
LKA	Lane Keep Assist
CSW	Curve Speed Warning
CFCW	Cooperative Forward Collision Warning
DNPW	Do Not Pass Warning (DNPW)
IMA	Intersection Movement Assist
RTA	Right Turn Assist
CBSW / LCW	Cooperative Blind Spot Warning / Lane Curve Warning
PSM	Pedestrian Safety Messages



## European roadmap to deployment: expected services and use cases

Timeframe	Expected Services	Message Types	Potential Use Cases
Day 1 Awareness driving via status data	Cooperative awareness and decentralised notification; and Basic infrastructure support	Cooperative Awareness Message (CAM); Decentralised Environmental Notification (DENM); Basic Safety Message (BSM); Signal Phase and Time (SPaT); Road/lane topology and traffic manoeuvre (MAPEM); In-vehicle-Information Message (IVI); VRU Awareness Message (VAM)	<ul style="list-style-type: none"> <li>• In-vehicle signage</li> <li>• Hazard Awareness</li> <li>• Intersection Awareness</li> <li>• Curve Speed Warning</li> </ul>
Day 2 Sensing driving via sensor data	Improved cooperative awareness and decentralised notification; Collective Perception; and Improved Infrastructure Support	Collective Perception Message (CPM)	<ul style="list-style-type: none"> <li>• Intersection Movement Assist</li> <li>• Red Light Violator Warning</li> <li>• Right Turn Assist</li> <li>• Cooperative Forward Collision Warning</li> <li>• Cooperative Blind Spot Warning/Lane Change Warning</li> <li>• Do Not Pass Warning</li> </ul>
Day 3+ Cooperative driving via intention and coordination data	Trajectory/manoeuvre sharing; and Coordination/negotiation; and VRU active advertisement	Manoeuvre Coordination Message (MCM); and Platooning Control Message (PCM)	<ul style="list-style-type: none"> <li>• Vulnerable Road User protection/ Pedestrian Safety Messages</li> </ul>

To understand the potential of connected vehicles in providing mobility and environmental benefits in the network, traffic microsimulation experiments were conducted comparing the integration of connected vehicle data with traffic control systems to existing methods. Traffic microsimulation experiments in arterial corridors indicated that connected vehicles at penetration rates of 30% (V2V and V2I) can reduce peak congestion by up to 11%. Meanwhile, network microsimulation in Melbourne City during peak hour indicated that average travel speeds of vehicles can be improved by 10% with connected vehicle penetration rates above 20%.

Even at low levels of penetration, it is clear that there are benefits to be reaped from successful deployment of C-ITS technology. Both stakeholders and literature agree that there are many challenges that need to be addressed, yet despite these issues C-ITS technology deployed in vehicles at both the OEM and aftermarket levels presents an exciting opportunity to improve road safety outcomes, both in the state-level Victorian data investigated, as well as at a national and global scale.

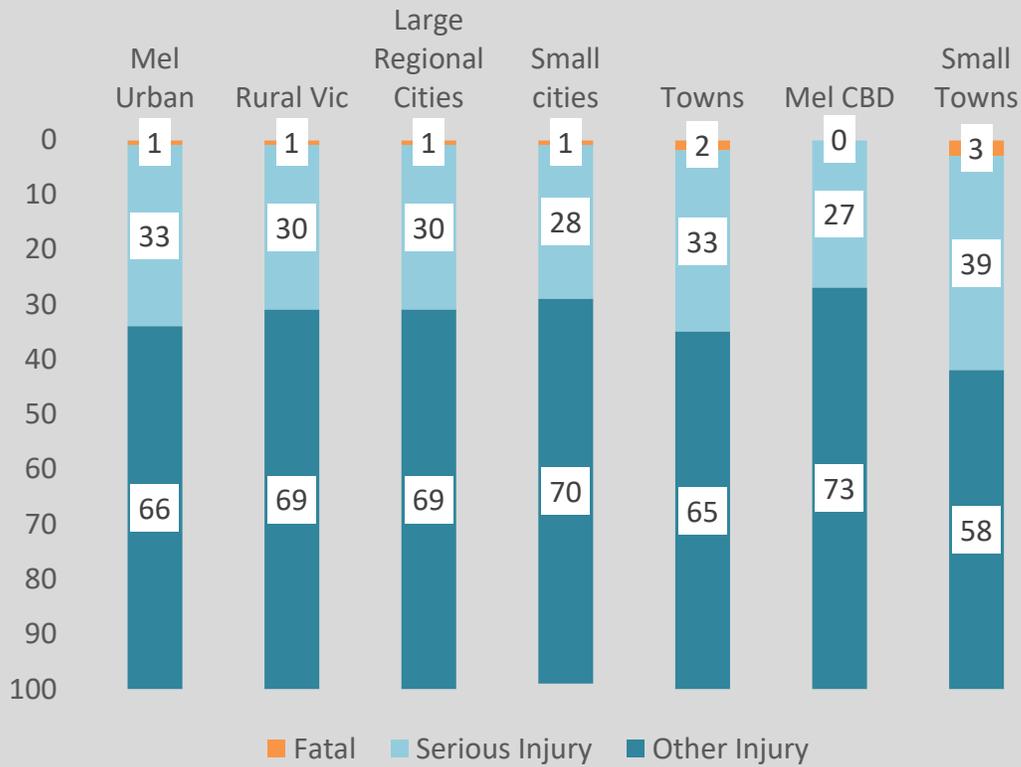


*City during peak hour indicated that average travel speeds of vehicles can be improved by 10% with connected vehicle penetration rates above 20%.*



Bicyclists and scooter riders may benefit the most from Intersection Movement Assist & Right Turn Assist

# Crashes by severity and region



Use cases identified for crashes		
<b>Fatal</b>	Intersection Movement Assist and Cooperative Forward Collision Warning have the greatest relevance to fatal crashes in Melbourne CBD and larger cities in Victoria	Curve Speed Warning would be most relevant in rural areas and small towns.
<b>Serious injury</b>	Cooperative Forward Collision Warning is likely to be most effective in Melbourne Metro and larger cities in Victoria.	Intersection Movement Assist is broadly relevant. Curve Speed Warning is potentially the most effective use case in rural areas and small towns
<b>Vehicles</b>	Heavy vehicles are over-represented in fatal crashes and the most relevant use cases are Cooperative Forward Collision Warning and then Intersection Movement Assist.	
<b>Road users</b>	Pedestrians and motorcyclists are also over-represented in fatal crashes. Pedestrians crashes are not directly addressed by any of the four major use cases under consideration.	



The safety benefits of C-ITS can be assessed by examining the proportion of crashes which each specific use cases have the potential to address. Victoria's Road Safety database contains a comprehensive record of crashes over the last fifteen years, with attributes for each crash occurrence including severity of injury, specific crash classifications, geographic location, road geometry, lighting conditions, and modes involved.

These parameters allow for investigation into factors and variables that make certain crashes more common and presents an opportunity to target development and deployment C-ITS use cases that have the ability to address a higher proportion of crashes. Meanwhile, the potential for network mobility improvement and environmental benefits can be measured through traffic simulations comparing different penetration rates of connected vehicles to existing and academic traffic signal control methods.

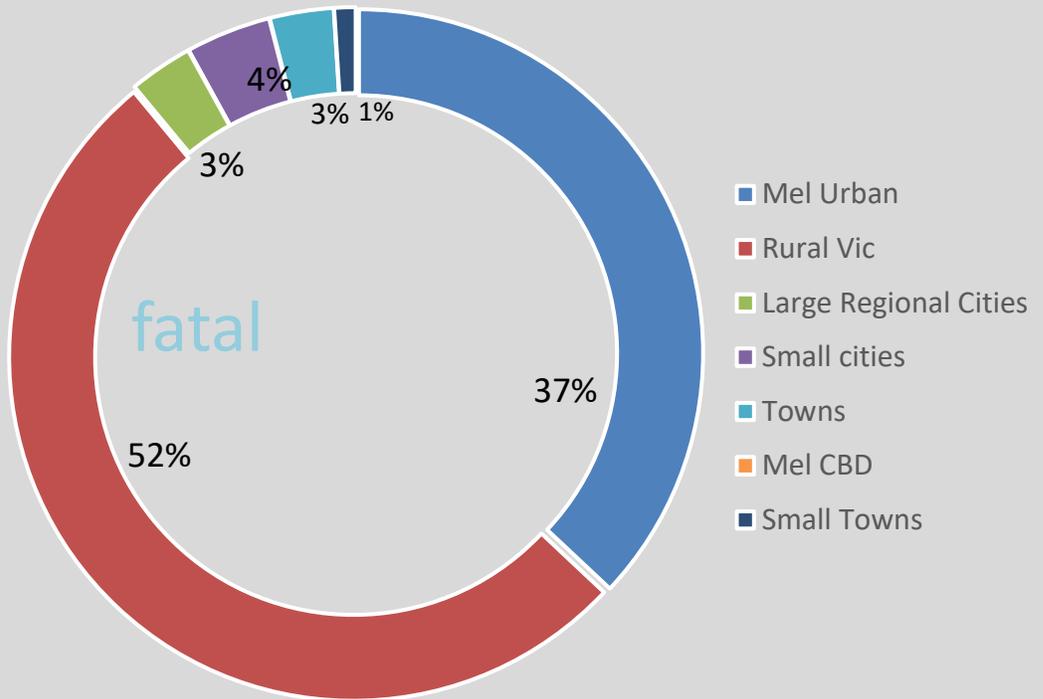
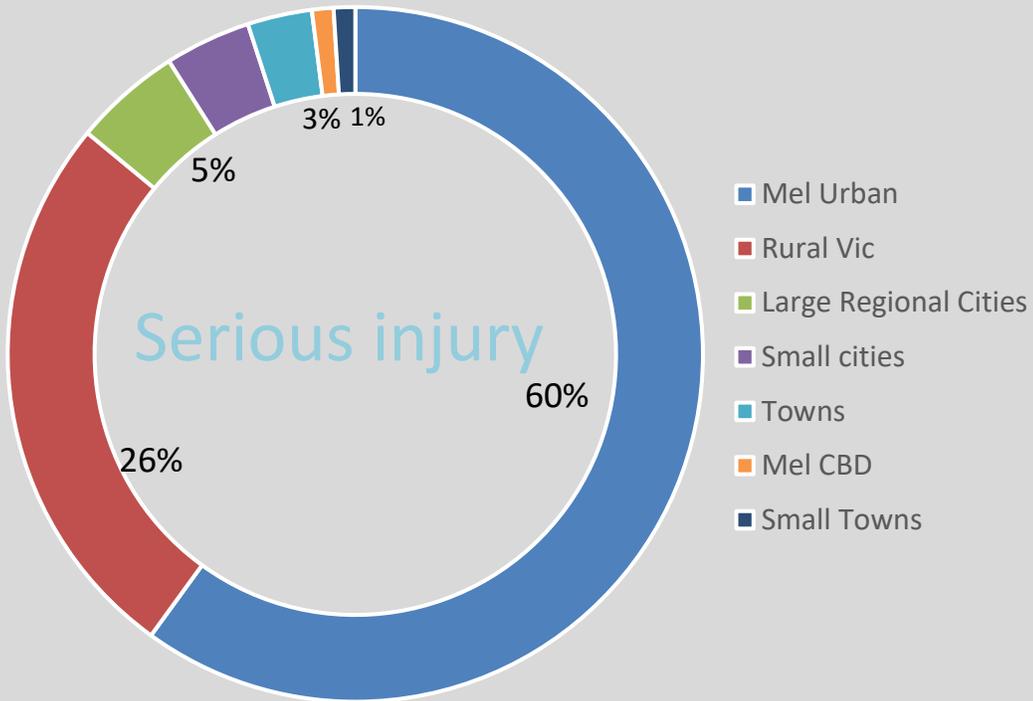
Potential interventions include advisory warnings to drivers for speed, red light signals ahead, or other hazards. More advanced critical warning messages, where the driver is warned of an imminent threat, require reactions to such messages and are time sensitive. These include warnings about potential conflicts or collision paths with other vehicles and imminent requirements for corrective action (such as emergency braking). Other benefits from connected vehicles, including mobility and environmental benefits, were investigated for their ability to provide reduced fuel consumption, and travel-time savings.

.....

*With a penetration rate of 30%, a significant improvement in traffic efficiency (up to 10%) can be achieved.*

.....

## Fatal and serious injuries



## 4.4 Conclusions



This research shows connectivity can not only improve safety outcomes and network efficiency it can do so now in a variety of specific use cases, with benefits for awareness applications being realised at low penetration rates, while other warning and cooperative functions require increasing levels of technology penetration to be effective.

To achieve the estimated benefits several factors must be considered, including the technology deployed, method of deployment (i.e. through aftermarket or original equipment manufacturer technology), and infrastructure requirements. There is potential to identify and test use cases and technologies to target the most vulnerable road users, pedestrians and cyclists, at intersections and other high risk domains where traumatic interactions with vehicles are too common.

.....

*Pedestrian safety messages and interventions for cyclists and motorcyclists through connectivity can provide our most vulnerable road users with real safety benefits*

.....

While complex, with the potential to address a significant percentage of crashes in high density areas, including more than 50% of fatal crashes in Melbourne’s CBD, pedestrian safety message applications are worthy of further investigation. For motorcycles right turn assist suggests the greatest potential in reducing fatal crashes, although it is broadly applicable to all vehicle types and geographic locations.

By considering some of the major C-ITS safety use cases that have been investigated globally and nationally, an estimate for the proportion of crashes that can be addressed considering the severity, location, and types of vehicles involved in each crash; approximately 80% of all crashes can be addressed by the eight use cases investigated.

This research re-enforces the opportunity for real safety benefits able to be delivered to Australia road users: drivers, passengers, motorcyclists, cyclists and pedestrians alike. The congestion easing benefits of these technologies further compounds the benefits that are yet to be made widely available in Australia. Connected technologies offer a clear pathway to improve safety and reduce travel times that are not readily repeatable with vehicle automation or technologies.

Glossary	
C-V2X	Refers to a mix of cellular short-range communication, including either the 3GPP Release 14 and 15 (LTE-V2X) specifications, or 3GPP Release 16 (5G related short-range communication) specifications, and cellular long-range communications.
DSRC	DSRC in Europe refers to the European CEN DSRC tolling standards that operate on a specified frequency. In the US, DSRC refers Wi-Fi communication in the 5.9 GHz band licensed by the FCC.
ETSI ITS-G5	The European Standard for Vehicular Communication; IEEE 802.11p telecommunications (Wi-Fi) standard in the 5.9 GHz band; also known in the USA as DSRC
IEEE 802.11p	An approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments.
IEEE 802.11	The set of standards that define communication for WLANs.
LTE Sidelink	Direct communication over PC5 interface.
PC5 interface	Sidelink technology - the direct channel between which one UE communicates with another UE (i.e. V2V or V2I) where communication with the base station is not required.
U-NII-3 band	Unlicensed-National Information Infrastructure transmitting at the 5.725-5.850 MHz band
Uu interface	The logical interface between the user equipment and the base station (i.e. V2N) for cellular communication.

Recent international events	
Europe	<p>In March 2019, the European Commission issued a delegated act supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operation use of cooperative intelligent transport systems. This act endorses a “hybrid communication approach” (European Parliament and of the Council, 2019) with:</p> <ul style="list-style-type: none"> <li>• Short-range communication technologies operating in the 5.9 GHz frequency band and are most relevant for time-critical services. ITS-G5 (i.e. DSRC), which is now considered mature, tested, and already deployed, is a candidate for this service. C-V2X technologies including LTE-V2X and 5G NR are also being considered.</li> <li>• Longer-range communication technologies that leverage the coverage of existing networks to connect larger areas and are most relevant for less time critical V2I services. Existing cellular 3G and 4G technologies can provide this service.</li> </ul>
USA	<p>In the US, a December 2019 FCC proposal introduced the segmentation of 5.9 GHz spectrum to allow for Vehicular and Unlicensed Applications:</p> <ul style="list-style-type: none"> <li>• 5.850 - 5.895 GHz to Unlicensed Applications: this includes Wi-Fi devices such as routers and their associated connected devices to provide high data rate local area network connections for smartphones, tablets, computers, television and other devices inside and outside the home to interconnect with and access to Internet), as well as C-V2X operation.</li> <li>• 5.895-5.925 GHz to Vehicular Applications: this allocation is dedicated to utility for transport and vehicle safety technologies and includes a proposal to allow C-V2X operation specifically in a 20 megahertz subsection of this band (5.905-5.925 GHz).</li> </ul>

# Research links

[australia.com.au/connectivity-in-c-its-final-report](http://australia.com.au/connectivity-in-c-its-final-report)



## Literature Review

<https://cms.its-australia.com.au/assets/images/PDFs/1-Literature-Review.pdf>



## Stakeholder Interviews

<https://cms.its-australia.com.au/assets/images/PDFs/2-Stakeholder-Interviews.pdf>



## Crash Data Analysis

<https://cms.its-australia.com.au/assets/images/PDFs/3-C-ITS-Crash-Data-Analysis-Report.pdf>



## Traffic Simulation Report

<https://cms.its-australia.com.au/assets/images/PDFs/4-Traffic-Simulation-Report.pdf>



## **ABOUT ITS AUSTRALIA**

ITS Australia is the peak group representing over 120 public and private organisations delivering on transport solutions and technology improving Australia's road and transport networks and promotes the development and deployment of advanced technologies to deliver safer, more efficient and sustainable transport across all public and private modes – air, sea, road and rail. Find out more about our work: [its-australia.com.au](https://its-australia.com.au)



## **ABOUT iMOVE**

iMOVE is the national centre for collaborative R&D in transport and mobility. It facilitates, supports and co-funds research projects that improve the way people and goods move in Australia. It has 44 industry, government and academic partners and has over 50 projects completed or currently underway in a broad range of transport areas. Find out more about our work: [imoveaustralia.com](https://imoveaustralia.com)



## **ABOUT THE AUSTRALIAN INTEGRATED MULTIMODAL ECOSYSTEM (AIMES)**

AIMES is a University of Melbourne-led collaboration bringing together industry, government and research partners to improve safety, mobility, sustainability and liveability for the community. The establishment of a world-first ecosystem in Melbourne sees the largest ever inner-city grid of streets mapped with smart sensors. The sensors monitor real-time flow of vehicles, cyclists, pedestrians and public transport.

AIMES will deliver an integrated, connected and multimodal approach to transport management, especially as we compete with burgeoning population growth and increased pressure on city mobility. To find out more about AIMES visit: [industry.eng.unimelb.edu.au/AIMES](https://industry.eng.unimelb.edu.au/AIMES)



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