Transport
for NSW

Next steps: Using technology to reduce wildlife vehicle collisions

Transport's response to the Future Directions Paper

February 2025

transport.nsw.gov.au

NSW GOVERNMENT

Transport for NSW

Table of Contents

Executive Summary

Transport for NSW (Transport) commissioned an independent expert to prepare a paper *'Using technology to reduce wildlife-vehicle collisions. Literature review and directions paper'* (the Future Directions Paper). This followed a successful international Symposium hosted by Transport in Sydney in May 2024 that brought together the leading international experts in the field of wildlife vehicle collision and key stakeholders across scientific community, wildlife carers and conservation groups and government.

This report provides a summary of the Future Directions Paper, its recommendations and Transport's response to those recommendations.

The Future Directions Paper provides a comprehensive review and synthesis of the current state of technological solutions to reduce the rate and severity of wildlife-vehicle collisions (WVC) in Australia. While physical infrastructure like fencing and wildlife crossing structures can be effective, they are not feasible or desirable in all locations. Technological solutions offer an alternative approach with the potential to be more adaptable and cost-effective.

The Future Directions Paper evaluates a wide range of technological solutions, categorising them based on whether they target wildlife behaviour, vehicle operator behaviour, or a combination. It also considers the role of animal detection systems and the integration of multiple technologies.

The Future Directions Paper makes a range of general observations and specific findings about how Transport can best approach this issue including:

- The principles that Transport should apply when undertaking research including the use of 'signaling theory' and the adoption of the 'technology readiness index' to development and evaluate the effectiveness of new WVC technology
- That cross jurisdictional partnerships required to progress key recommendations including a national vehicle collision reporting platform
- The vital role of both targeted and general driver education and awareness programs as critical components of the implementation of any new technological approach
- The need to continually update our knowledge given the rapidly evolving nature of new technologies such as the detection capability of artificial intelligence

Specific findings of the Future Directions Paper include:

- Enhanced signage, intelligent signage linked to animal detection, and in-vehicle warning systems show promise and require further development and testing
- Animal detection systems using radar, LiDAR, cameras and other technologies are a critical component of effective solutions, but current systems require development.
- Combining technologies, such as animal detection, intelligent signage and in-vehicle warnings, offers great potential for reducing WVCs.
- Improving the visibility of animals on the road including through improved illumination may assist modifying driver behaviour and is worthy of trial
- Reflectors, standard wildlife warning signs, vehicle-mounted whistles and virtual fences have limited effectiveness based on current evidence and are not a priority for trial

The Future Directions Paper highlights the potential of technological solutions to reduce WVCs, and emphasises the need for a coordinated, collaborative and evidence-based approach to advance this field. It suggested that ongoing investment and implementation of the most promising solutions, in combination with traditional mitigation measures, will be critical to improving road safety and environmental outcomes.

Transport supports the recommendations outlined in the Future Directions Paper. Some recommendations will be prioritised for immediate implementation, while others will require further consideration, particularly in relation to animal ethics or collaboration with relevant jurisdictions.

Two recommendations are being implemented in the short term with the development of trials to:

- Develop animal detection systems for Australian wildlife linked to 'smart' roadside signage (Recommendations 5, 8)
- Conduct controlled trials of increased illumination, with a focus on light-coloured pavement marking (Recommendation 14)

Transport will work closely with other stakeholders, including other transport agencies, AustRoads, Australia Network of Ecology and Transport (ANET) and academic and industry researchers, to progress the development and testing of these technological solutions.

For further information including accessing a copy of the Future Directions Paper please visit the Transport website www.transport.nsw.gov.au

1 Introduction

Wildlife-vehicle collisions (WVCs) are a significant issue globally, with millions of animals killed each year and substantial impacts on human safety, vehicle damage and wildlife conservation. While it is difficult to be precise due to gaps in reporting, an estimated 4 million marsupials and 6 million birds are thought to be impacted by WVCs annually in Australia.

The economic and social costs of WVCs are substantial, encompassing vehicle repairs, human injury and death, train delays, and the care of injured and orphaned wildlife. There is also a significant animal welfare and conservation impact, with threatened species particularly vulnerable. As traffic volumes and road networks continue to expand, the rate of WVCs is expected to increase.

Historically, efforts to mitigate WVCs have relied on physical infrastructure like fencing and wildlife crossing structures. While these approaches can be effective, they are not feasible everywhere due to cost, habitat impacts, and limitations in addressing all species. There is a growing interest in exploring technological solutions as a more adaptable and potentially cost-effective alternative particularly on lower speed roads.

In May 2024, Transport hosted a Symposium[1] on 'using technology to reduce wildlife collisions' in Sydney that brought together the leading international experts in the field of wildlife vehicle collision and key stakeholders across scientific community, wildlife carers and conservation groups and government.

The Symposium, combined with a global literature review, was the basis for a paper prepared by Dr Rodney van der Ree from WSP titled 'Using technology to reduce wildlife vehicle collisions: Literature Review and Directions Paper' (the Future Directions Paper). This document summarises the findings and recommendations of the Future Directions Paper and sets out Transport's response to the recommendations made.

---

[1] Further information about the Symposium including videos of the speakers and an Event Summary report which includes links to the presentation given, please see Wildlife and vehicle collisions | Transport for NSW

2 Approaches to reducing wildlife vehicle collisions

There are three main ways to reduce WVC.

1. Apply direct **physical barriers and structures** separate animals from vehicles or to slow vehicles down. This can either target wildlife (such as physical fencing and barriers) or vehicle operators (such as traffic calming or rumble strips).

2. Use **signals** to improve the awareness of **animals or drivers** of the potential presence of the other. Options targeting wildlife include wayside (typically roadside) deterrents such as reflectors, chemical repellents, electric mats) or vehicle borne deterrents including whistles and lights. Options targeting the vehicle operator include wayside signs and improved lighting and in-vehicle signals including in-car GPS based warnings and alerts.

3. Use **signals targeting either wildlife or vehicle operators supported by a detection system.** Signal-based approaches with detection systems can target wildlife (such wayside deterrents including virtual fencing and geo fencing) or the vehicle operators including wayside intelligent signage and activated lighting or in-vehicle detection based warning systems and automated assistance.

These approaches are presented at **Figure 1.** It provides a useful framework to understand the scope of potentially available technologies. Traditionally applied technologies tend to cluster under 'physical approaches' and 'signal-based approaches', with emerging technologies tending to cluster under the 'signal-based approach with detection system' as developments in machine learning and detection are advanced. **Appendix A** provides further information about the technologies underpinning these new approaches.

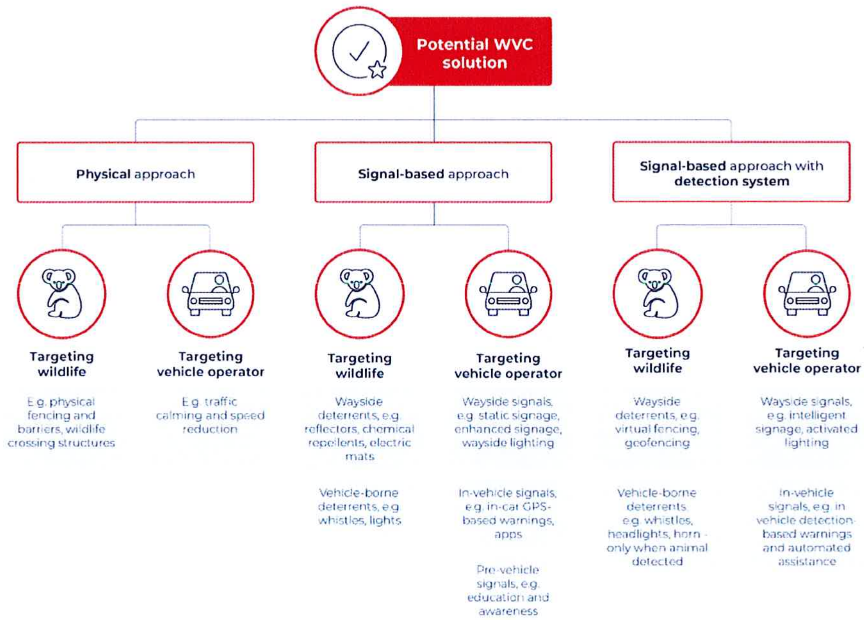

Figure 1: Schema to categorise the suite of physical and technological solutions to solve wildlife-vehicle collisions. Source: WSP 2024 'Using technology to reduce wildlife vehicle collisions: Literature Review and Directions Paper'.

3 Current and emerging technologies

3.1 Physical barriers and structures

Wildlife exclusion fencing, wildlife crossing structures including overpasses and underpasses and traffic calming devices are all examples of physical structures designed to either exclude or redirect animals away from the carriageway or physically prevent drivers from driving above safe speed limits. **Table 1** provides a summary of the main physical barriers and structures employed to reduce WVC worldwide.

Table 1: Summary of physical barriers and structures

Type	Description
Fencing	Wildlife exclusion fencing refers to physical barriers installed along roads and railways to prevent wildlife from accessing the roadway or railway corridor. Fences can be made mesh, plastic, metal sheets, electric wires, noise walls, concrete Jersey barriers and vary in height and design depending on the target species and local context.
Wildlife crossing structures	Wildlife crossing structures are physical structures that allow the safe movement of fauna under or over a road or railway. Wildlife crossing structures include overpasses and underpasses for terrestrial fauna and glide poles and rope bridges for arboreal fauna.
Traffic calming measures	Traffic calming measures are physical design elements that are intended to reduce vehicle speeds and improve safety for all road users, including pedestrians and cyclists. Traffic calming measures include speed humps, chicanes, raised intersections, curb extensions, rumble strips, reduced speed limits and roundabouts.

3.2 Signal based approaches targeting animals

Wayside deterrents that target wildlife are installed on the sides or verges of roads and railways and aim to warn wildlife of oncoming traffic and typically encourage them to either move away from the vehicle or to not enter the road or railway.

For signaling approaches to work effectively, the biology and behaviour of the intended receiver (wildlife or vehicle operators) must be understood when determining the type of signals that will be most effective.

The signals must be designed to ensure they are successfully detected by the receiver and provoke the intended movement or behaviour change. **Table 2** provides a summary of signal based approaches targeting animals.

Table 2: Summary of signal based approaches targeting animals

Type	Description
Reflectors	Wildlife warning reflectors (reflectors) are a small unit containing reflective mirrors and coloured lenses that are mounted on posts on the side of roads and railways. They are intended to provide a visual warning to animals to modify their behaviour by discouraging them from attempting to cross the road or railway.
Chemical repellents	Chemical repellents refer to substances applied to deter or discourage wildlife from entering certain areas such as a road or rail corridor. Most commonly rely on taste or odour.
Electric mats and wildlife guards	Electric mats are embedded into the road or railway surface at gaps in the wildlife exclusion fencing and are designed to give a painful but non lethal electric shock to wildlife trying to cross, acting as a deterrent. Wildlife guards are similar to electric mats but use a grid or metal bars or rails instead of an electrified surface. Typically constructed in galvanized or stainless steel and rubber composites.
Acoustic Deterrents	Acoustic deterrents are a type of vehicle borne deterrent that aims to deter wildlife from entering the road or railway by emitting a noise as the vehicle moves. These include whistles, horns, sirens and recordings of predators or animal warning calls.
Vehicle borne light deterrents	Improved vehicle lights are designed to improve the ability of an animal to see an approaching car by illuminating the front of the car and thus they are better able to respond to the threat. This is done by adding a light bar to the front of the vehicle to illuminate the front of the car.

3.3 Signal based approaches targeting vehicle operators

Wayside signals are installed on the side of roads and railways and are intended to warn motorists and train drivers of the presence of wildlife and encourage drivers to modify their driving. **Table 3** provides a summary of signal based approaches targeting vehicle operators.

Table 3: Summary of signal based approaches targeting vehicle operators

Type	Description
Static Signage	These signs typically depict a silhouette of a large animal species, such as a deer or kangaroo, on a bright-coloured background to warn motorists of the potential presence of wildlife on or near the road. They are permanently installed on the roadside.
Enhanced Signage See also intelligent signage at below	Enhanced signs are typically larger than standard static wildlife warning signs and incorporate features such as flashing coloured lights, attention grabbing or disturbing illustrations, images of fauna and variable messaging including crash statistics. These features are intended to gain the attention of drivers and inform them about the impacts of WVC on driver safety or wildlife conservation. Road stencilling and pavement markings are another form of enhanced signage intended to identify areas of high wildlife activity and alert drivers to the associated WVC risk.
Wayside Lighting and other detectability measures	Wayside lighting involves illuminating the road or railway, typically using overhead lighting, to improve visibility and detectability of wildlife by vehicle operators and conversely, the visibility and detectability of vehicles by wildlife. Making the road surface whiter is another speculative option with the potential to improve detectability.
In vehicle location-based	In-vehicle signals without animal detection systems utilise the location of the vehicle or driver and information inputs such as WVC hotspot mapping, wildlife sightings, collision statistics, and environmental factors like time of day or year to warn drivers of high-risk WVC locations or areas. signals can come from an in-car global positioning system (GPS)/satellite navigation system or a smartphone.
Education and awareness	Education and awareness refers to programs and initiative that aim to increase public knowledge, understanding and consciousness about WVC.

3.4 Signal-based approaches with animal and /or vehicle detection systems

Signal-based approaches use signals (e.g. light, noise, scent) to either warn wildlife of approaching vehicles or warn vehicle operators of the presence of wildlife. These signals can be triggered by animal and/or vehicle detection systems, such as radar, LiDAR, cameras, etc. that can identify the presence of animals or vehicles. The advantage of using detection systems is that the signals can be targeted and activated only when necessary, rather than being constantly emitted which can lead to habituation by the intended receivers (wildlife or drivers). **Table 4** provides a summary of the these approaches.

For further detail on the range of supporting technologies underpinning these approaches please see **Appendix A.**

Table 4: Summary of signal based approaches with animal and or vehicle detection systems

Type	Description
Wayside deterrent with detectors (eg virtual fencing)	These approaches involve triggering a deterrent (light, sound) when a threat (eg oncoming vehicle or train) is detected. Virtual fencing is an example of a wayside deterrent with detectors. Virtual fencing involves small electronic devices mounted on posts at regular intervals on alternate sides of the road. They are activated by approaching vehicle headlights and emit sound and light stimuli intended to alert animals that a vehicle is approaching, theoretically encouraging them to leave the roadside.
Geofencing	Geofencing utilises a combination of animal-borne tags/collars and wireless systems to control the movement of wildlife within a pre-defined boundary. It works by defining a virtual fenced area and uploading these boundaries onto an animal-borne device (e.g. tracking collar). When the animal strays out of the GPS-defined zone, an alarm system is triggered, usually involving an auditory warning followed by an electric stimulus to discourage the animal from moving further. Geofences can also be used to activate intelligent signs along roads or railways to inform vehicle operators about the approaching danger when a collared animal approaches the boundary
Intelligent signage	Intelligent signs are dynamic wildlife warning signs that are connected to animal detection systems. They are intended to accurately inform drivers, in real-time, when wildlife are detected on the roadside or railway verge. In contrast to static or enhanced signs, intelligent signage has the potential to effectively warn drivers everywhere it is installed, as long as the activated warning signs are visible to vehicle operators. The effectiveness varies across weather and geographical contexts and is most effective when accompanied with mandatory speed reduction
Wayside lighting with detection	Wayside lighting turns on when animals and vehicles are simultaneously detected thus increasing the visibility and detectability of wildlife to motorists and increasing the detectability of vehicles to wildlife.
In vehicle detection based	These in-vehicle signals are intended to warn motorists in real-time of the presence of wildlife, utilising similar principles as intelligent signage The signals can be targeted at vehicle operators, the operating system of autonomous vehicles, or both. For example, signals can warn the driver to the presence of animals as well as activate assisted braking

4 Evaluation framework

Current and emerging technologies identified in section 3 have been qualitatively assessed by the Future Directions Paper from the current understanding of basic biology and behaviour (both animal and human) through to concept design, technical design, prototype testing and field trials to identify areas of further research and development.

The purpose of the evaluation framework is to identify which aspects of the new technology requires further development or which technologies are not appropriate for future research and trials.

This framework has been applied to both existing and emerging WVC technologies and recommendations have been in the Future Directions Paper based on this evaluation.

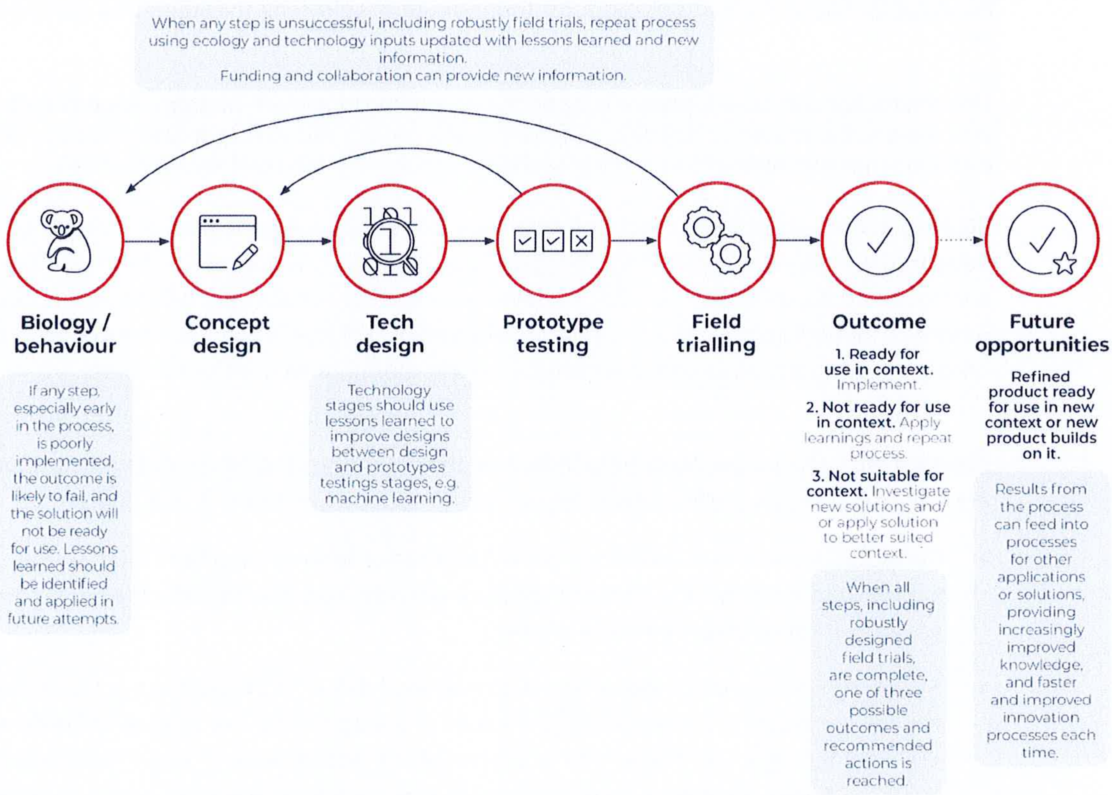

Figure 2: Development and evaluation framework used to evaluate the effectiveness of different technological solutions to WVC and identify which components or stages in the system require further development. Source: WSP 2024 'Using technology to reduce wildlife vehicle collisions: Literature Review and Directions Paper'.

5 Findings and recommendations

The main findings of the Future Directions Paper are set out below along with the key recommendations for future research and trials and Transport's response to these recommendations.

5.1 Findings

Finding 1: Physical solutions, such as fences and wildlife crossing structures, are currently the most effective technique to reducing and in some cases eliminating WVC for may species of wildlife. However, fencing is prohibitively expensive to build and maintain, is difficult to install in some locations and is not effective for all species of wildlife.

Finding 2: There is great potential for technological solutions to reduce the rate and severity of WVC.

The timing for this development is opportune – the rapid growth and development of surveillance equipment and machine learning algorithms to process the vast quantities of data in real-time provides massive opportunities to effectively reduce the rate and severity of WVC.

Finding 3: It is unlikely that technological solutions will be a panacea for all WVC problems. Research and development of the 'physical' solutions (e.g. fences, crossing structures) must continue and complement any future development of technological solutions. Importantly, trials of potential technological solutions must evaluate and acknowledge any limitations to ensure the proposed solutions are applied with full understanding of their effectiveness.

Finding 4: The evidence to date indicates that the following technological solutions in their current form are not sufficiently effective to pursue further trials at this time:

- Reflectors – there is no evidence from Australia or internationally to indicate that reflectors mounted to posts on the verge or roads or railways to warn wildlife of approaching vehicles have any measurable effect on rates of WVC
- Standard signs to warn motorists of an elevated risk of WVC – at best achieve minor and temporary change in the driving behaviour of a small subset of drivers. Wildlife warning signs are routinely ignored, especially when people do not observe or experience wildlife at or near the sign. Enhanced signs are slightly more effective than standard signs, provided they are specific to the problem at the location, are well-designed and are operational at specific high-risk times of the day or year
- Virtual fencing, in its current state, is not recommended for in-situ trialling on roads or railways in NSW or Australia. Wayside deterrents have limited effect because the effectiveness of the specific auditory and visual stimuli at alerting different species is unknown, the ability of target species to hear the stimuli above traffic noise and other disturbance is also unknown, and the ability of the system to trigger the appropriate response of target species is unknown. Further development and testing of biologically relevant stimuli is recommended as a next step
- Currently available whistles and other auditory deterrents attached to the front of vehicles appears to have little effect on rates of WVC for similar reasons to virtual fences (see preceding point)

- Traffic calming can be effective at reducing traffic volume and/or traffic speed on low-volume and low-speed roads which reduces rates and severity of WVC – but is not appropriate on high-speed and/or high-volume roads

Finding 5: Technology is developing rapidly and many technical and computing aspects that limit the effectiveness of current prototypes or systems will become less constraining in the not-too-distant future.

The highest priority actions and directions for research and development should focus on technologies and components that can be incorporated into a suite of combined systems and solutions.

Future testing and trials should be undertaken using scientifically robust approaches that are conducted throughout product development to maximise the likelihood that effective solutions can be created.

The following over-arching recommendations and conclusions apply:

- Collaboration with other transport agencies, AustRoads and relevant industry groups to fund, support and implement research and development of technological solutions that can be applied and implemented across jurisdictional boundaries is a high priority
- Despite the recent acceleration in technological development and sophistication, fully effective solutions for all species, contexts and situations are unlikely to be developed soon. However, there will be many aspects and components that are tested and found to be effective, and these advancements should be identified and further developed to advance this field of WVC mitigation. Ongoing funding and support are required to develop research and development pipelines and test efficacy in a systematic, co-ordinated and scientifically robust way over at least the next ten years
- Set up an industry taskforce / development group including ANET, Austroads, car manufactures and their component suppliers, industry, and academic researchers to progress the development of different technologies with co-sponsored research bids, proposals and projects
- Send the call for research, development and testing to university researchers, industry technology and data specialists and developers to collaborate and develop technological solutions to WVC

5.2 Specific recommendations and Transport's response

Specific recommendations made by the Future Directions Paper and Transport's response are shown on Table 5.

Table 5: Specific recommendations and Transport's response

Future Directions Paper recommendation	Transport's response
1. Ensure signaling theory underpins research and development of all technological solutions	Supported as a principle underpinning future work
2. Adopt the Technology Readiness Level scale and the Evaluation Framework to develop and evaluate system effectiveness	Supported as a principle underpinning future work
3. Establish a national roadkill reporting platform	For discussion with other jurisdictions

Future Directions Paper recommendation	Transport's response
4. Implement targeted and general driver education and awareness programs to maximise the success of technological solutions that rely on an appropriate response from vehicle operators	Supported as a principle underpinning future work
5. Develop animal detection systems for Australian wildlife	Supported. This will be a priority for trial
6. Investigate and develop the use of existing infrastructure to detect animals	For discussion with relevant jurisdictions
7. Use in-vehicle animal detection systems to detect living and/or roadkill animals and build accurate and real-time maps of WVC hotspots or high-risk areas	Supported. Will follow recommendation 5:
8. Use animal detection systems to intelligent wayside signage and/or in-vehicle warning systems:	Supported. This will be a priority for trial:
9. Develop in-car or app-based warning systems to warn vehicle operators when they enter a high-risk WVC area at a high-risk time	For future consideration once. Will follow recommendation 5
10. Support research on the effectiveness of biologically relevant animal deterrents	For future consideration
11. Undertake research on the effectiveness of wayside- and vehicle-mounted deterrents on trains	For future consideration
12. Consider animal-borne tags which activate intelligent signs or in-car warnings in specific situations and locations	On hold until animal ethics considerations are properly addressed and will not proceed as trials at this time.
13. Electric mats should be developed and trialed for future use	
14. Undertake controlled trials of increased illumination (e.g. light-coloured pavement, overhead lighting) to increase detectability of wildlife and modify driver response	Supported. Pavement marking will be a priority for trial

6 Next steps for Transport

Transport commissioned the Future Directions Paper to inform decisions on investment and implementation of new technologies to address this important road safety, animal welfare and conservation concern.

Transport supports a range of the recommendations outlined in the Future Directions Paper. Some recommendations will be prioritised for implementation, while others will require further consideration, particularly in relation to animal ethics, or collaboration with relevant jurisdictions.

Two recommendations are being implemented in the short term with the development of trials to:

- Develop animal detection systems for Australian wildlife linked to 'smart' roadside signage (Recommendations 5, 8)
- Conduct controlled trials of increased illumination, with a focus on light-coloured pavement marking (Recommendation 14)

Recommendations 12 and 13 are currently on hold by Transport until animal ethics considerations are properly addressed, and therefore, will not proceed as trials at this time.

Transport will work closely with other stakeholders, including other transport agencies, AustRoads, ANET and academic and industry researchers, to progress the development and testing of technological solutions that can be applied and implemented across jurisdictional boundaries.

Further to the recommendations in the Future Directions Paper, Transport will also investigate opportunities to work with a local council on a trial of rumble strips as a way of slowing drivers through vehicle strike hotspots.

For further information including accessing a copy of the Future Directions Paper please visit the Transport website www.transport.nsw.gov.au

Appendix A: Technologies underpinning new WVC approaches

Supporting technology	Description
Radar	Radio Detection and Ranging (Radar) is an active sensing technology that uses long-wavelength electromagnetic waves, typically between 20-300 gigahertz (GHz), to determine the distance, direction and velocity of objects relative to the site. Using the angles of the emitted wavelengths and the time between the emission and detection, a 3D image of the surrounding environment can be calculated. Unlike some other forms of technology, radar continues to work in challenging conditions that may increase the risk of WVC, such as heavy rain, fog, snow and complete darkness (Viani et al. 2016).
LiDAR	Light Detection and Ranging (LiDAR) is an active sensing technology that works by emitting laser pulses or infrared light in the frequency range of 850 to 940 nanometres (nm) and measuring the time it takes for the light to travel back to the source. Pulses of light can be emitted from a range of different platforms, including airplanes, helicopters and ground-based stationary or mobile platforms, at sampling rates exceeding 150 khz (150,000 pulses per second).
Break-the-beam sensors	Break-the beam sensors consist of an emitter projecting a beam of infrared light, laser beam or microwave radio signal to a receiver (Nandutu et al. 2022b). Animals are detected when they move through and 'break' the infrared beam of light (Grumert and Nusia 2023), subsequently triggering an action like activating a warning sign to notify vehicle operators.
Passive Infrared (PIR) motion sensors	A commonly used form of technology, Passive Infrared (PIR) sensors detect thermal energy radiation emitted from the surface of objects. The sensor is triggered when an animal enters the field of view, causing a difference in temperature between its surface temperature and the surface temperature of the background environment (Welbourne et al. 2016).
Animal-borne tags	For over four decades animal-borne tags have been used to record information about animal movement, behaviour and their environment and include radio-tracking, GPS tracking and satellite tracking. The animal-borne tag can emit a signal which is received by an external receiver (e.g. proximity tag, VHF radiotransmitter) or it can perform 2-way communications (e.g. GPS or satellite tracker).
Optical and thermal cameras	Optical cameras are passive devices, meaning they collect ambient light to form images and have long been used to monitor the presence of wildlife at particular locations.
Acoustic sensors	Acoustic sensors detect specie-specific sounds made by animals, typically their calls when they communicate to each other. Depending on the animal, sounds can span a wide range of frequency bands, including infrasound (below 20 Hz, e.g. elephants), the human audible range (20 Hz to 20 kHz), and ultrasound (above 20 kHz, e.g. insectivorous bats).
Seismic sensors	Seismic sensors measure environmental vibrations such as those caused by the footsteps of large animals. By analysing these signals, it is possible to

	identify animals based on the strength, frequency distribution, and duration of the vibrations, as well as potentially the distance from the recorder.
Artificial intelligence and machine learning	AI and machine learning are tools that can help analyse data from animal detection systems to identify animals, reduce false positives, and activate warnings more quickly and accurately

NSW GOVERNMENT