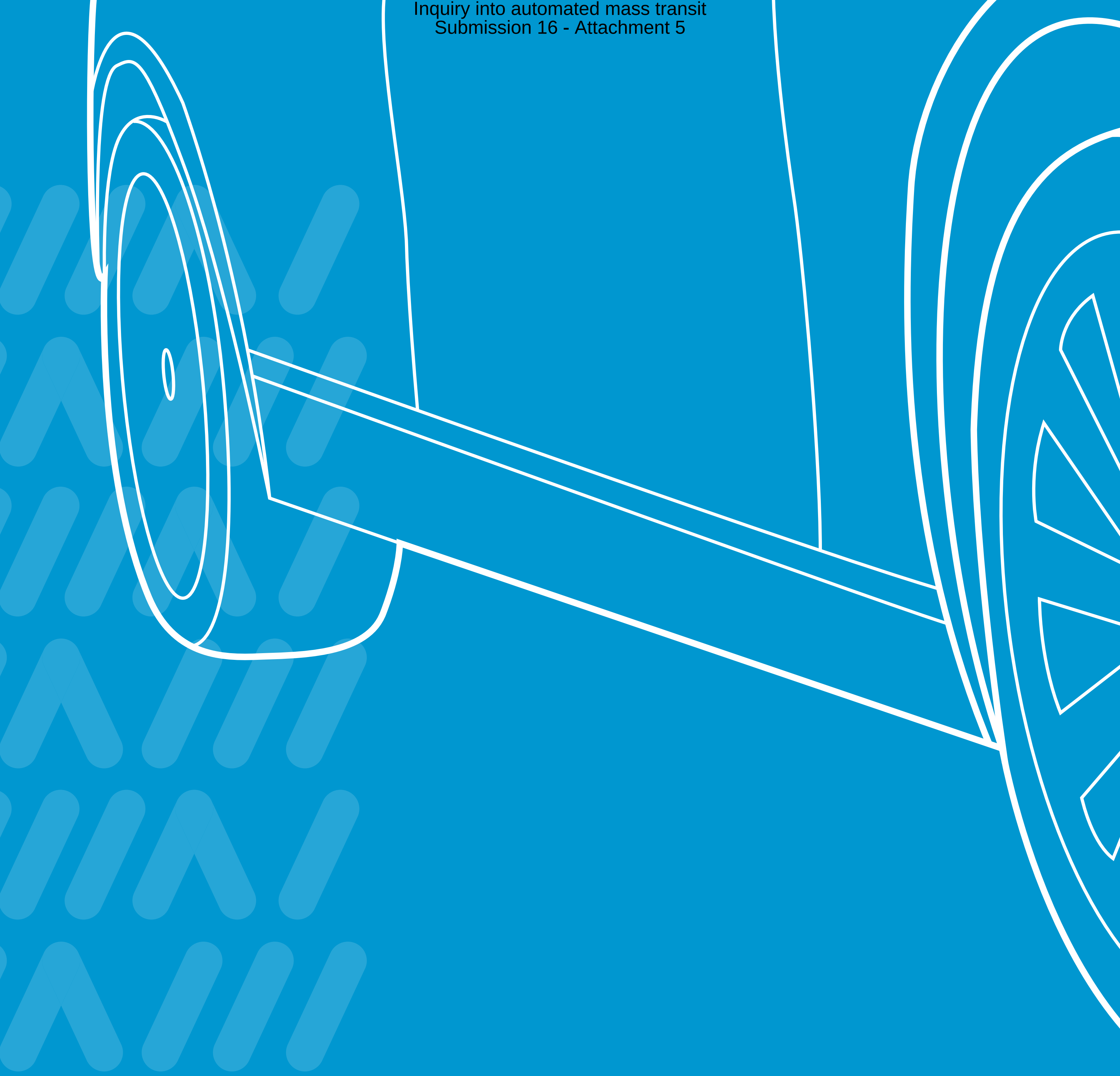
ADVICE ON AUTOMATED AND ZERO EMISSIONS VEHICLES INFRASTRUCTURE

FUTURE SCENARIOS

April 2018

INFRASTRUCTURE VICTORIA



INTRODUCTION

The Victorian Government has asked Infrastructure Victoria to provide advice on what infrastructure is required to pave the way for highly automated and zero emissions vehicles in Victoria.

These emerging technologies have the potential to radically change how the state's transport system operates. Whether or not this change is for the better depends on both private sector innovation and the preparedness of government at all levels.

Infrastructure Victoria is consulting with experts and gathering extensive evidence to determine what infrastructure is required to realise the potential benefits of automated and zero emissions vehicles in Victoria.

Our final recommendations will be delivered to the Victorian Government in October 2018.

This report presents a series of scenarios for the uptake of highly automated and zero emissions vehicles that will help us test some of the uncertainties Victoria is facing. More broadly, it outlines Infrastructure Victoria's methodology for providing advice to government.

This report is not a formal consultation document. However, contributions from stakeholders are always welcome. To find out how to get involved, see page 35.

What we don't know (yet)

Part of the challenge we (and policy makers around the world) face is that the promise of automated and zero emissions vehicles gives rise to numerous 'what ifs'.

Very few people in Victoria currently own zero emissions vehicles, and the technology to support driverless vehicles hasn't been fully proven.

But what if highly automated and zero emissions vehicles are just around the corner? What if all, or none, of these vehicles are shared? What if hydrogen fuel cells, not electric batteries, become the power source of choice for zero emissions vehicles? What if the promise of automated and zero emissions vehicles is never fulfilled or if one technology takes off while the other stalls? And what might any of these scenarios mean for infrastructure provision?

THE REQUEST FOR ADVICE

In October 2017, the Victorian Special Minister of State formally requested that Infrastructure Victoria provide advice on the infrastructure required to enable the implementation of highly automated and zero emissions vehicles in Victoria.

The full terms of reference are available at infrastructurevictoria.com.au/avadvice.

What

We have been asked to investigate what infrastructure might be required:

- to enable the operation of highly automated vehicles (at Society of Automotive Engineers levels 4 and 5)
- in response to the ownership and market models that may emerge from the availability of highly automated vehicles
- for zero emissions vehicles as they become a high proportion of the Victorian fleet.

We have also been asked to advise on the potential sequencing, timing and scope of infrastructure delivery.

How

The Minister expects that Infrastructure Victoria will undertake comprehensive engagement with industry and other key stakeholders, draw on international comparators and research, and develop our own modelling and analysis.

The advice is to be presented in two parts:

1. A scenarios report (this document), setting out potential future scenarios for the uptake of automated and zero emissions vehicles in Victoria that will form the basis of the advice.
2. A final report, supported by evidence and analysis, detailing potential infrastructure requirements for automated and zero emissions vehicles. The final report will analyse the current situation, recommend delivery pathways and identify key decision or trigger points for the infrastructure.

When

Our advice will be delivered in stages. This report, delivered in April 2018, fulfils the first part of the Minister's request for advice. We intend to publish our evidence base in August 2018. The final report is due to the Minister in October 2018.

Terminology

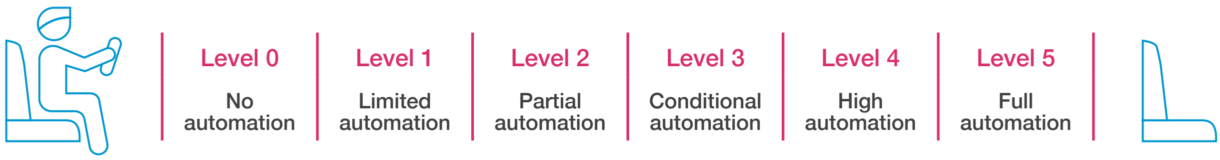
We're used to hearing automated and zero emissions vehicles being described as driverless and electric cars in the media. These terms are often interchangeable, but not always.

For the purposes of this advice:

- **Vehicles** can be cars, trucks, buses or any form of motorised, road-based transportation. Automated trams and trains are not a primary focus of this advice (see page 9 to find out what's out of scope and why).
- **Zero emissions** vehicles emit no emissions from the tailpipe, charging or fuel source. Currently, vehicles powered by electric batteries and hydrogen fuel cells have the potential to be zero emissions.
- **Highly or fully automated** vehicles are capable of driving without the involvement of a human driver. They are likely to be cooperative, with connections to other vehicles, infrastructure and the internet.

Levels of automation

The Society of Automotive Engineers has defined six levels of automation for motor vehicles ranging from no driving automation at level 0 to full driving automation at level 5. A summary of these levels is as follows:



Level 0: No automation; the driver is always in control, but may be briefly aided by the vehicle (e.g. automated emergency braking).

Level 1: Limited automation; the vehicle can control either side-to-side (lateral) or forward-backward (longitudinal) motion at any one time, but not both (e.g. adaptive cruise control OR lane-keep assistance).

Level 2: Partial automation; the vehicle can identify and respond to the environment in certain areas using a combination of driver assistance systems for both lateral and longitudinal motion (e.g. adaptive cruise control WITH lane-keep assistance).

Level 3: Conditional automation; the vehicle can drive itself in certain areas, but expects the human driver to intervene on request (e.g. steering, speed and braking assistance at defined speeds).

Level 4: High automation; the vehicle can drive itself in certain areas, without the need for a human driver to intervene (e.g. campus only or sealed roads only).

Level 5: Full automation; the vehicle can complete an end-to-end trip anywhere with no expectation of driver intervention.

At levels 0 to 3, people are required to perform most of the driving and/or to intervene if needed when the vehicle is in control. At levels 4 and 5, a human driver is not needed. The difference between levels 4 and 5 is that at level 5, the vehicle is capable of being driverless anywhere, under any conditions, whereas at level 4, vehicles are limited in where and when they can operate without a driver. Our advice focuses on the infrastructure required to support vehicles operating at levels 4 and 5.

The infrastructure required for levels 4 and 5 is expected to be the same, so they are not differentiated in our analysis.

OUR APPROACH

Given the uncertainties associated with automated and zero emissions vehicles, our work is driven less by problems that need solving and more by questions that need answering. At this stage, we do not have a particular view of how the future will unfold, but are seeking to understand the ways in which it could.

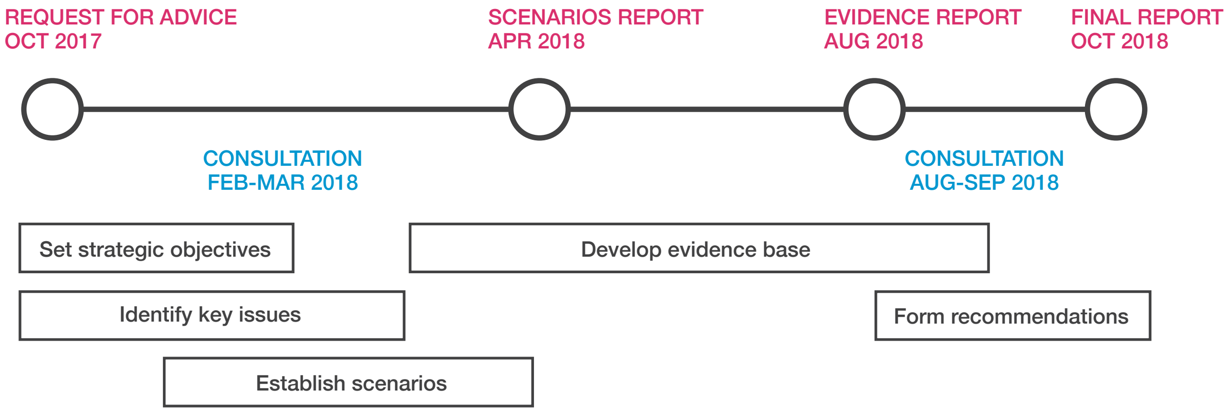
Methodology in brief

Evidence and consultation are key pillars of our approach to providing advice on automated and zero emissions vehicles.

Our methodology follows five key steps:

1. **Set strategic objectives.** We set strategic objectives as a reference point for maximising potential benefits and minimising potential risks of automated and zero emissions vehicles. This is discussed on page 10.
2. **Identify key issues.** We mapped, as comprehensively as possible, all the issues, questions and decisions we *could* address to help us choose the ones we *would* address. A summary of these issues is on pages 13 to 16.
3. **Establish scenarios.** We established a set of scenarios that would help us test the impact of key uncertainties through modelling and other research. These scenarios are presented from pages 17 to 33.
4. **Develop evidence base.** We are developing an extensive evidence base to help us assess the impacts and implications of the scenarios and understand other relevant issues. We intend to publish this evidence base for public and stakeholder scrutiny and feedback prior to formulating our final advice.
5. **Form recommendations.** We will assess decisions and trigger points, and evaluate our recommendations against the strategic objectives outlined in step one.

Timeline



What's out of scope and why

The focus of the request for advice is on automated and zero emissions road vehicles. As such, a number of related emerging transport technologies have been scoped out of the advice, including aerial vehicles, delivery drones (airborne or footpath based) and vehicles operating primarily on private land (for example, agricultural, mining, industrial or construction machinery).

An in-depth consideration of automated or zero emissions trains and trams is also considered out of scope. Trains and trams operate on fixed rails and would require a different strategic and technical analysis to that of road-based motor vehicles. We will, however, consider the potential effects of automated and zero emissions road vehicles on the public transport system.

We have been specifically asked for advice on the infrastructure and land use implications of automated and zero emissions vehicles. Therefore, we do not intend to cover every possible policy issue related to the introduction of these vehicles, such as providing financial subsidies and industry support or addressing complex ethical and legal questions related to minimising harm and assigning fault in vehicle accidents.

STRATEGIC OBJECTIVES

New technologies for automating and powering road vehicles come with great expectations, from making roads safer and less congested to cutting greenhouse gas emissions. Such innovations could also play a role in managing the impact of rapid population growth in Victoria.

Many of these benefits could potentially be realised without much government intervention. In some cases, enabling automated and zero emissions vehicles could involve government simply allowing the market to function efficiently.

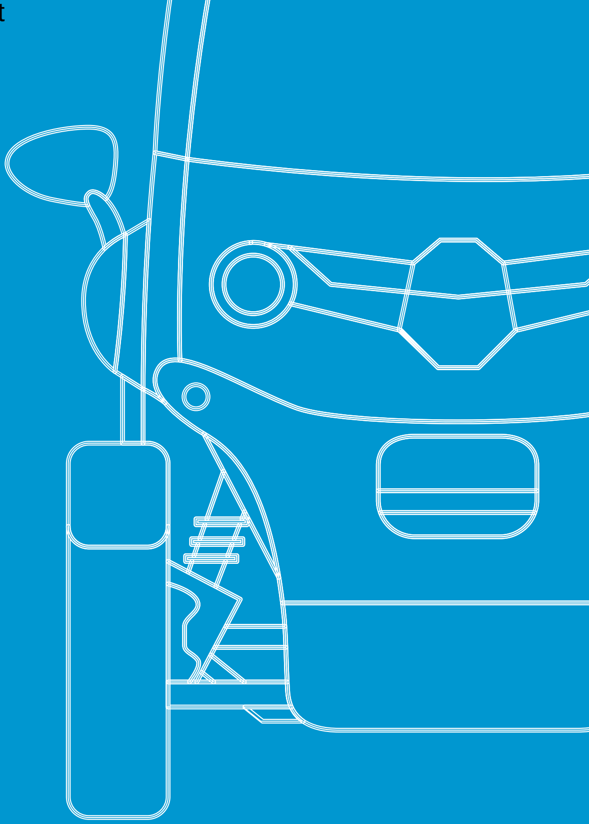
Government does have a role, however, in preparing the state so that the contribution of these emerging vehicle technologies to Victoria's society, economy and environment is broadly positive and any consequences are managed effectively. Our advice will identify what infrastructure responses are required to maximise the potential benefits and minimise the potential risks of automated and zero emissions vehicles.

In 2016, we released the first ever statewide, 30-year infrastructure strategy for Victoria. This strategy outlined 10 objectives to guide long-term infrastructure planning, which were developed through extensive consultation with stakeholders and the community (for more details see infrastructurevictoria.com.au/30-year-strategy).

These social, economic and environmental objectives will provide a framework for evaluating our final recommendations. For example, a recommendation on how streetscapes might need to change to accommodate automated and zero emissions vehicles should not just focus on the needs of vehicle passengers, but also highlight opportunities to contribute to the objective of fostering safe, healthy and inclusive communities.

Recommendations should contribute to achieving at least one, and ideally more, of the objectives through the introduction and uptake of automated and zero emissions vehicles. Where the contribution to achieving objectives is not as clear, or there is a conflict between different objectives, the pros and cons of recommendations will be weighed up transparently.

At this stage, we are not prioritising objectives and the potential contributions these vehicles can make to achieving them, but we are considering which of them might be more important in a given context. In particular, different objectives may be more or less relevant in different parts of Melbourne and regional and rural Victoria.



Infrastructure Victoria's 30-year strategy objectives

1. Prepare for population change
2. Foster healthy, safe and inclusive communities
3. Reduce disadvantage
4. Enable workforce participation
5. Lift productivity
6. Drive Victoria's changing, globally integrated economy
7. Promote sustainable production and consumption
8. Protect and enhance natural environments
9. Advance climate change mitigation and adaptation
10. Build resilience to shocks

KEY ISSUES

Many questions need to be answered before automated and zero emissions vehicle technologies, and their impacts, are well understood. In some cases, clarity will only come in the fullness of time.

To provide advice to government on the infrastructure required to support these emerging, interrelated technologies, we initially identified as many lines of enquiry as possible. Casting a wide net helped mitigate the risk that important matters might be missed.

We then focused on the key issues to be explored through scenario analysis and other research. These are summarised on the following pages and grouped into two themes: development pathways and potential impacts, and infrastructure and land use requirements and opportunities. Consultation with stakeholders was an important input to this process and the terms of reference were a key filter.

Determining the role of the Victorian Government relative to the private sector and other jurisdictions and levels of government will be fundamental to our analysis of the key issues.

We are also cognisant of the fact that much of the international research on automated and zero emissions vehicles to date has focused on large cities. A key concern throughout the study will be how these technologies can and should be supported in regional and rural areas as well.

Development pathways and potential impacts

Technology, market models and public attitudes

Automated and zero emissions technologies for passenger and freight vehicles are advancing rapidly, but exactly how rapidly – and in what direction – will have a significant impact on the infrastructure required to support their roll out.

Similarly, there is uncertainty about whether automated and zero emissions vehicles will continue to be predominately privately owned or whether shared, on-demand services will become the norm.

Consumer demand and broader public acceptance will be critical to the success of these vehicles.

We will examine how the technologies, market models and public attitudes might evolve to preserve options and identify triggers for action.

Further discussion of how and when these vehicles will emerge is on page 16.

Travel patterns, land use, ICT and energy demand

Highly automated and zero emissions vehicles could have dramatic impacts on travel patterns and land use, as well as demand for digital connectivity and energy production.

The state could see a change in the number and type of trips people take, with associated impacts on traffic volumes. The use of public and active transport could increase or decrease, and public transport as we know it could be transformed. People may choose to live and work in different ways or places. Demand for information and communication technologies (ICT) and energy, both overall and in specific locations, may change.

We will look at how these changes might play out over time, to make sure the right infrastructure is in place to enable the operation of these vehicles in Victoria.

Social, economic and environmental impacts

Automated and zero emissions vehicles could have a broad range of social, economic and environmental impacts.

Potential positive impacts include safer roads, improved urban amenity, increased mobility, better access to jobs, increased workforce productivity, and a decrease in carbon emissions (assuming a clean energy source).

Potential negative impacts include increased disparity in access to transport driven by new commercial models, new waste disposal challenges, and job losses in certain industries.

Our work will consider what role infrastructure can play in harnessing these opportunities and mitigating potential negative consequences.

Infrastructure and land use requirements and opportunities

Transport, ICT and energy infrastructure

The core of our advice to government will focus on what transport, ICT and energy infrastructure is required to pave the way for automated and zero emissions vehicles in Victoria.

For transport, we will examine how existing roads might need to be adapted (e.g. line markings, signage, road quality, drop-off and pick-up areas, dedicated lanes) and whether any broad changes may be required to infrastructure investment across all transport modes. We will also consider options for managing demand on the transport network, to get the best use out of existing and proposed infrastructure.

For ICT, we will consider what communication infrastructure and data networks might be needed to support automation, and how cybersecurity risks can be addressed to build confidence and protect consumer privacy.

For energy, we will investigate implications for energy supply and transmission networks, as well as options for managing energy demand and providing charging and refuelling infrastructure for both electric and hydrogen-powered vehicles.

For all of these sectors, we will look at how the infrastructure needs for automated and zero emissions vehicles could change over time, from introduction to full roll out.

Land use planning

Complementing our analysis of the infrastructure required to enable automated and zero emissions vehicles, we intend to consider what land use and urban design changes may be required or desirable.

In particular, growth patterns and densities may need to be managed differently if changes to the nature of travel influence people’s housing and employment preferences.

This will be considered in the context of population growth projections and the long-term planning principles articulated in Plan Melbourne, such as making Melbourne a multi-centred city with a strong core and having thriving, connected regional cities.

We will also seek to identify land use opportunities at a more local level, such as repurposing redundant car parking and petrol stations and making streetscapes more community friendly.

Specific land use planning challenges, such as accommodating any new industries and waste sites, will also be considered.

Funding

Preparing Victoria for automated and zero emissions vehicles has funding implications for building and maintaining future road infrastructure.

Infrastructure investment is a major cost for government. Done well, it can boost productivity. Done poorly, it can be a drain on public finances. New vehicle technologies may negate the need for some projects and create the need for others.

Traditional sources of government funding from road travel, such as vehicle registrations, parking revenue and the national fuel excise, may also be impacted.

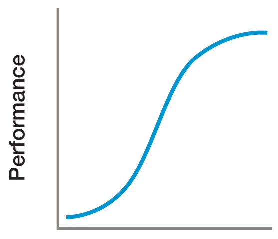
Our advice will provide guidance on the likely quantum of investment required to support our recommendations, and comment on any related funding implications.

When and how will automated and zero emissions vehicles emerge?

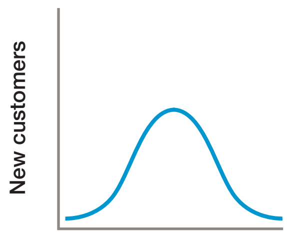
Automated and zero emissions vehicles are at the start of a journey that is likely to be anything but smooth.

Over the past few decades, there have been many theories, and variations of theories, about how new technologies evolve over time. However, the basic concepts have remained relatively consistent. These diagrams show broadly accepted pathways for the development and diffusion, or adoption, of new technologies.

DEVELOPMENT OF NEW TECHNOLOGIES

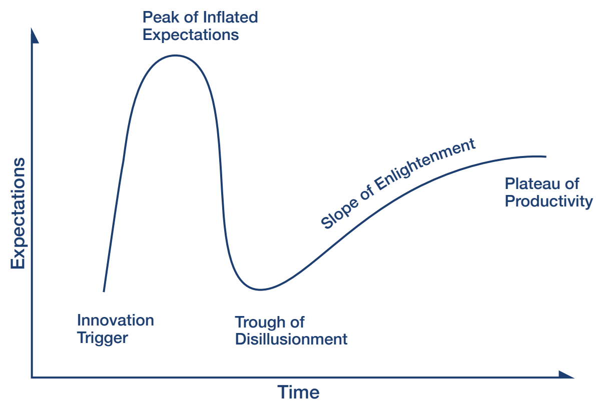


DIFFUSION OF NEW TECHNOLOGIES



GARTNER HYPE CYCLE

In the July 2017 *Hype Cycle for Emerging Technologies, 2017* report Gartner placed autonomous vehicles just over the 'Peak of inflated expectations'.



Source: Gartner Methodologies, Gartner Hype Cycle, https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

More recently, work has been done on how expectations of new technologies fluctuate, such as Gartner's 'hype cycle'. What these diagrams illustrate is that the evolution of new technologies, and the expectations that accompany them, develop in a non-linear way.

Automated and zero emissions vehicles have a way to go before their performance is optimised. It is difficult to accurately predict what adoption rates will be or when market saturation will be reached. In part, this will be influenced by how the market evolves, specifically whether the dominant private ownership model is disrupted by fleet-based, on-demand services. Another critical factor is how quickly these vehicles gain a clear social licence to operate at scale. The value of running different scenarios is that we can test a range of these uncertainties.

What is clear, however, is that a large amount of money is currently being invested in new vehicle technologies, particularly automation. The Brookings Institution has estimated that over US$80 billion was spent by automotive manufacturers and technology businesses on developing self-driving car technologies between 2014 and 2017, and this spend is trending upwards. CB Insights has shown that investment in automotive technology start-ups working on autonomous and semi-autonomous driving technology, including enabling equipment such as sensors, rose sharply in 2017 to over US$3 billion that year. Investments in this emerging field span both the automotive and ICT industries.

SCENARIOS

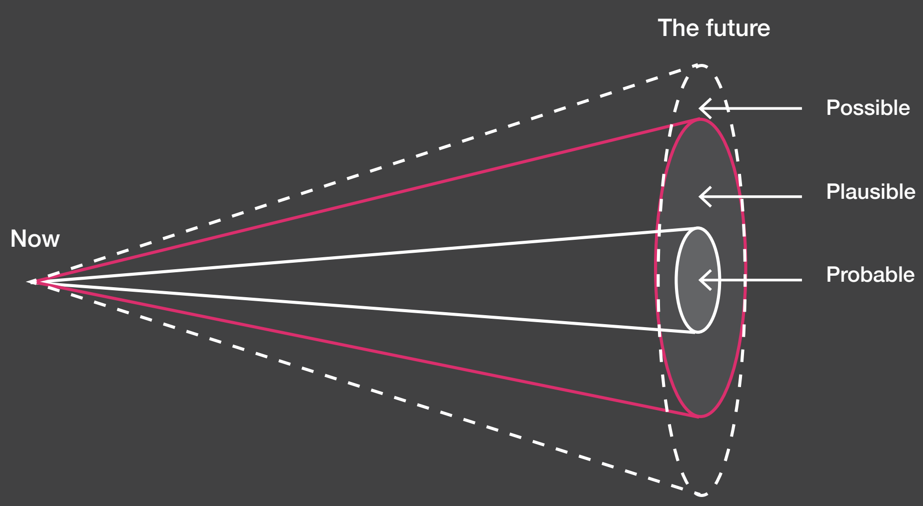
There are many potential futures. Infrastructure planning must embrace and reflect this uncertainty, particularly when considering a rapidly emerging field like automated and zero emissions vehicles.

By imagining alternative futures, scenarios can be a powerful tool for testing different variables, preparing for a range of possibilities, determining how government can respond to and influence the path ahead, and identifying decisions and trigger points for action.

What are scenarios?

Scenarios come in lots of different forms, depending on the purpose they are designed to serve. Scenarios can be possible, plausible or probable, but only with hindsight can we tell which most closely represent reality.

Infrastructure planners use scenarios to understand how infrastructure can shape or respond to different factors, such as global trends, alternative land uses and urban forms, and specific emerging technologies, as well as the interplay between different factors. For example, Transport for Victoria is currently considering how different technological pathways could shape the transport sector, as well as the impact of CSIRO's global megatrends on these pathways. This work has informed the scenarios presented in this report.



Source: CSIRO megatrends classification of scenario types (2012), adapted from Voros (2003) and Hancock and Bezold (1994)

Creating our scenarios

The purpose of our advice is to determine when and how infrastructure should be deployed in Victoria to support highly automated and zero emissions vehicles. Therefore, we needed a set of scenarios that would allow us to assess a range of uncertainties and determine the best course of action for the state.

Our scenarios deliberately test extremes to help us isolate the impact of different variables. They are designed to complement rather than compete with each other. The most probable outcome will be some combination of the scenarios presented. In all likelihood, there will be a mix of different vehicle technologies and service offerings on the road in future.

The scenarios address specific elements of the request for advice. Scenarios 1 to 4 test different technologies and market and ownership models, and scenarios 5 to 7 test different uptake rates. Each scenario adds a different layer to the overall picture.

Scenario 1 tests what would happen if all vehicles were powered by electric batteries within 30 years, but none were highly automated. Electric vehicles already have an established and growing market share, so it is useful to isolate this variable to consider how energy infrastructure might need to change to support this future, as well as the broader environmental and health benefits of moving to zero emissions vehicles.

The next two scenarios introduce vehicle automation and are designed to test different ownership and market models. They assume driverless vehicles will be electric, given the synergies between these technologies. Scenario 2 tests what would happen if all driverless, electric vehicles were privately owned, while scenario 3 considers a major commercial shift towards shared vehicles and on-demand services. These scenarios have different implications for the transport network, land use planning, and electricity supply and charging infrastructure.

Scenario 4 shifts the focus from electric to hydrogen power. Freight is already seeing major advances in automation and our research to date suggests that the roll out of hydrogen fuel cells may begin with heavy vehicles. This scenario describes a freight-led transformation to identify any specific infrastructure and land use requirements and opportunities for that sector, as well as for the use of hydrogen fuel cells in vehicles more generally.

For these four scenarios, we have picked 2046 as the year in which automated and/or zero emissions vehicles reach full adoption. This enables us to undertake robust quantitative analysis using inputs from the Victorian Integrated Transport Model and the Victoria in Future population forecasts. The timeframe is also consistent with Infrastructure Victoria's most recent 30-year strategy. Finally, experts predict that developed countries could see large numbers of these vehicles on the road somewhere between 2020 and 2050.

We acknowledge that this date is somewhat arbitrary. No one knows when automated and zero emissions vehicle technologies will reach market saturation or if they ever will. To test this particular uncertainty, we have included three time-based scenarios in our analysis.

Scenario 5 portrays a slow and prolonged uptake where on-demand, driverless, electric vehicles share the road with privately owned, non-driverless, petrol/diesel vehicles, thus bringing transition issues to the fore. Scenario 6 describes a rapid transport revolution where the adoption of on-demand, driverless, electric vehicles happens in a significantly compressed timeline. Scenario 7 describes a future where new technologies for automating and powering road vehicles stall. This last scenario represents the 'no change' pathway and is useful for identifying opportunity costs for any recommended investments.

We have not included a scenario in which automation flourishes and electrification falters (effectively the opposite of the first scenario), partly because this does not reflect the current technology trajectory, but mostly because the infrastructure requirements for petrol or diesel vehicles are not expected to change materially whether vehicles are driverless or not.

We have not developed dedicated land use scenarios, but we will look at whether different population distribution assumptions (e.g. more or less density) for Melbourne would change the results of our scenario analysis. We will also consider whether the availability of automated and zero emissions vehicles could mean that people choose to live further from where they work.

We have avoided creating scenarios that are strongly value laden, such as utopian or dystopian visions of the future. We want to let the evidence drive our conclusions about what infrastructure will best serve the needs of Victorians and contribute to meeting strategic objectives. Should specific scenarios, or aspects of these scenarios, appear to be more promising after we conduct further modelling and research, we may make recommendations that will help realise their potential.

Finally, our methodology recognises the limitations of scenario analysis. Not every question we need to answer will be captured in the scenarios we have created. Complementary research and analysis will be undertaken to paint the full picture of the infrastructure implications for Victoria of automated and zero emissions vehicles.

The ultimate aim is to identify which infrastructure interventions make sense in spite of all the uncertainty, which investments should only be made once particular triggers are met, and which decisions and trade-offs need to be made to achieve the best outcomes.

An advisory group from across government was established to consider the scenarios for further analysis, and has confirmed that the scenarios are appropriate to test the key issues for this work. The advisory group includes representatives from the Department of Premier and Cabinet; the Department of Treasury and Finance; the Department of Economic Development, Jobs, Transport and Resources; the Department of Environment, Land, Water and Planning; Transport for Victoria; and VicRoads.

The scenarios are designed to provoke thinking and not pre-empt our analysis on how the scenarios might play out in reality. While the potential benefits and risks and topics for investigation focus on key issues and questions that are specific to each scenario, the scenarios are designed to be read collectively rather than individually. They therefore present a comprehensive picture of what could happen when they are read as a whole.

Scenarios at a glance

Scenario	Year	Driving mode	Power source	Ownership/ market model
1. Electric avenue	2046	Driver	Electric	Private ownership
2. Private drive	2046	Driverless	Electric	Private ownership
3. Fleet street	2046	Driverless	Electric	Shared/on-demand
4. Hydrogen highway	2046	Driverless	Hydrogen	Private ownership
5. Slow lane	2046	Driverless, Driver	Electric, Petrol/diesel	Shared/on-demand, Private ownership
6. High speed	2031	Driverless	Electric	Shared/on-demand
7. Dead end	2046	Driver	Petrol/diesel	Private ownership

DRIVERLESS | DRIVER | ELECTRIC | HYDROGEN | PETROL/ DIESEL | SHARED/ ON-DEMAND | PRIVATE OWNERSHIP

SCENARIO 1: ELECTRIC AVENUE

Imagine a world where all cars are electric

The year is 2046. Your car now runs on electricity, but you're still very much in the driver's seat.

Everyone switched from petrol to electric once the price for equivalent models reached parity. Electric vehicles also have fewer moving parts, which has brought down ongoing maintenance costs. Passenger vehicles transitioned quickly, even in regional and rural areas, while freight took a little longer for batteries to become viable.

Changes to energy infrastructure were needed to accommodate the uptake of electric vehicles, but the energy market is pretty stable now. The corner petrol stations of old have been built over. You can charge your car at home, at work, in carparks, at the shops, or even at some intersections while driving. You've heard that some people with rooftop solar panels use their vehicles as home batteries.

People used to think automation and zero emissions vehicle technologies would develop in parallel, but the technology underpinning driverless vehicles never took off, while electric batteries just got better and better.

Maybe the overall transformation to the way people travel hasn't been as dramatic as was once predicted, but the disappearance of petrol and diesel vehicles from the road is a pretty big deal. Transport used to be the second biggest contributor to Victoria's fossil fuel emissions. Now its contribution is negligible. The streets are no longer polluted with exhaust fumes and you can barely remember the hum of a motor running.

Potential benefits and risks

This scenario allows us to examine the change to energy demand, as well as implications for the type and location of charging infrastructure, if there was a large-scale uptake of electric vehicles without full automation.

Some of the benefits of electric vehicles (with or without automation) include a potential reduction in the incidence of respiratory disease and improved urban amenity due to less air and noise pollution. Opportunities to reclaim or repurpose petrol and diesel refuelling infrastructure could also arise.

If Victoria's legislated target of net zero greenhouse gas emissions by 2050 is met, the environmental benefits of replacing internal combustion engines with electric batteries will be clear. There is a risk, however, that the energy supplying electric vehicles will continue to be highly carbon-intensive. Direct emissions from the tailpipe may go down, but indirect, whole of life emissions from manufacturing, charging and disposal would remain high.

A large-scale uptake of electric vehicles could also stretch Victoria's energy infrastructure, including increasing peak usage or creating new peaks, and placing pressure on local distribution networks.

A reduction in revenue from the fuel excise would impact government finances at the federal level, with likely flow-on effects to the states.

Battery disposal and recycling are also significant considerations in an electric vehicle future.

Key variables

2046
YEAR

DRIVER

ELECTRIC

PRIVATE OWNERSHIP

Topics for investigation

- If electric battery technology became ubiquitous but automation didn't, what would be the impact on energy demand?
- What would be the broader social, economic and environmental impacts from an electric, non-automated future?
- How would the impacts of electric, non-automated vehicles vary in different parts of Melbourne and regional and rural Victoria?
- How would energy and charging infrastructure need to change or be managed to service electric, non-automated vehicles?

SCENARIO 2: PRIVATE DRIVE

Imagine a world where your car drives you

The year is 2046, and while you still have your own car in the garage, you no longer drive it. It drives you.

Your driverless, electric car takes you anywhere you want to go in the city or the country. You just tell it your destination, then sit back and relax. The car knows the best route to take because it is continuously updated with current traffic patterns and road maintenance data. Your car communicates with other road users and transport infrastructure so the drive is smooth and accidents are very rare.

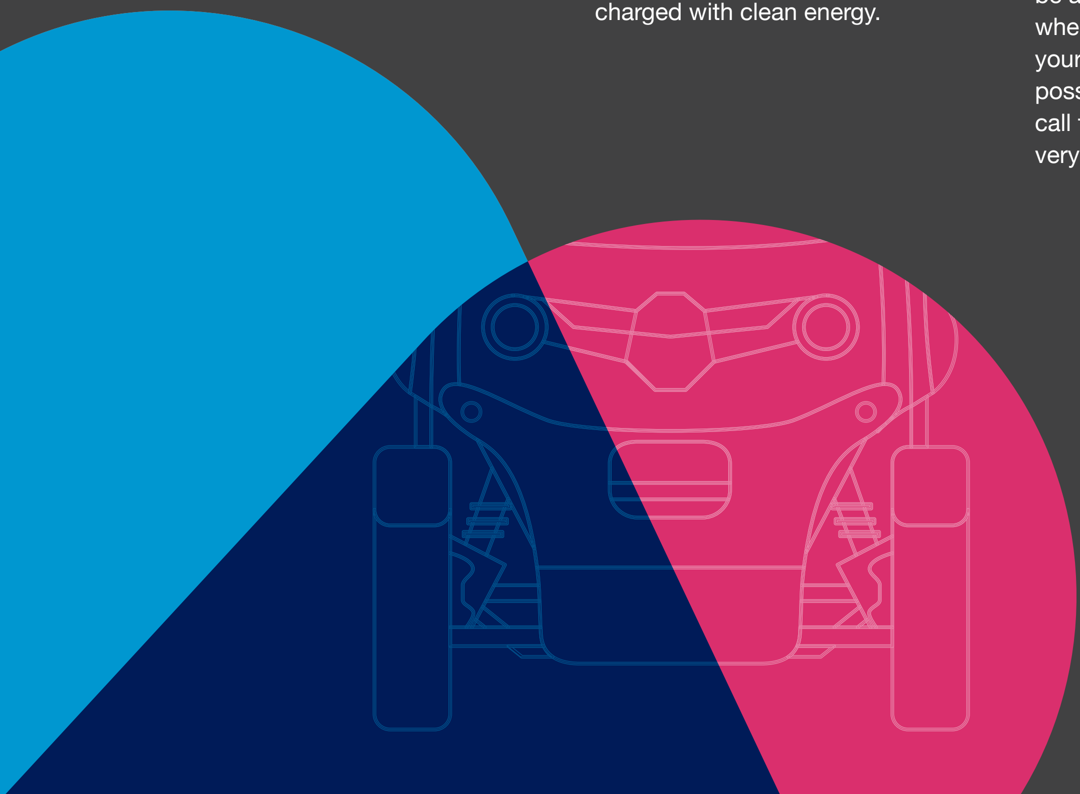
Owning your own car isn't cheap, but everyone who can afford to does. Public transport is still available for those who can't afford their own driverless car and this helps manage traffic volumes, though roads are definitely busier than they used to be. That said, you don't mind sitting in traffic as much anymore. There's no steering wheel so you don't have to concentrate on the road. You have the time and the space to do as you please while travelling, and the stress of driving is completely gone.

The ride is very quiet. Air and noise pollution from petrol and diesel engines are things of the past because all vehicles are now powered by electric batteries charged with clean energy.

This has made Victorian cities cleaner, healthier places to live and helped cut the state's greenhouse gas emissions. You're not as fit as you used to be because you don't have to walk or cycle as much, but the convenience of getting directly from point A to point B is worth it.

Once you reach your destination, the car drops you off and then finds a wireless charging park or heads home on its own. For the return journey, you can summon your car in advance or when you're ready and it comes to pick you up. Empty vehicles are a common sight on the road now.

It's comforting to know you will still be able to get around independently when you're older. You like having your own space for yourself and your possessions. Knowing that you can call for your car when you need it is very reassuring.



Potential benefits and risks

This scenario tests what would happen if the status quo of private vehicle ownership was maintained, while the underlying vehicle technologies changed dramatically.

The key potential benefit of this scenario is convenience, at least for those who could afford to own driverless cars. This would apply no matter where people lived in Victoria. Increased mobility for non-drivers would be particularly important in regional and rural areas where public transport and taxi services are limited.

Living further away from major population centres may become more viable under this scenario, should people value the time they spend travelling differently. This might help boost regional economies, but it could also place pressure on peri-urban areas and spread demand for infrastructure and services.

Previous transport modelling internationally and in Victoria suggests this scenario could see a significant increase in car trips with and without passengers on the network, leading to greater traffic volumes and slower travel times, as well as a higher overall energy demand. Rates of active transport may also fall, with potential negative health impacts if people are not active in other ways.

Automation could see changes to employment patterns as jobs are lost or created, and there is potential for increased productivity in a range of industries. Combining automation with zero emissions technologies could reap significant health and environmental benefits.

Key variables

2046
YEAR

DRIVERLESS

ELECTRIC

PRIVATE OWNERSHIP

Topics for investigation

- If most people owned their own automated and zero emissions vehicle, what would be the impacts on travel patterns, land use, ICT and energy demand?
- What would be the broader social, economic and environmental impacts of privately owned automated, zero emissions vehicles?
- How would the impacts of this private ownership scenario vary in different parts of Melbourne and regional and rural Victoria?
- What kind of infrastructure would be required to support this particular future?

SCENARIO 3: FLEET STREET

Imagine a world where no one owns their own car

You no longer own your own car. No one does, except for the odd classic car enthusiast who still drives for recreation in designated areas. Instead, mobility in 2046 is a safe and on-demand service, enabled by the transition to full automation.

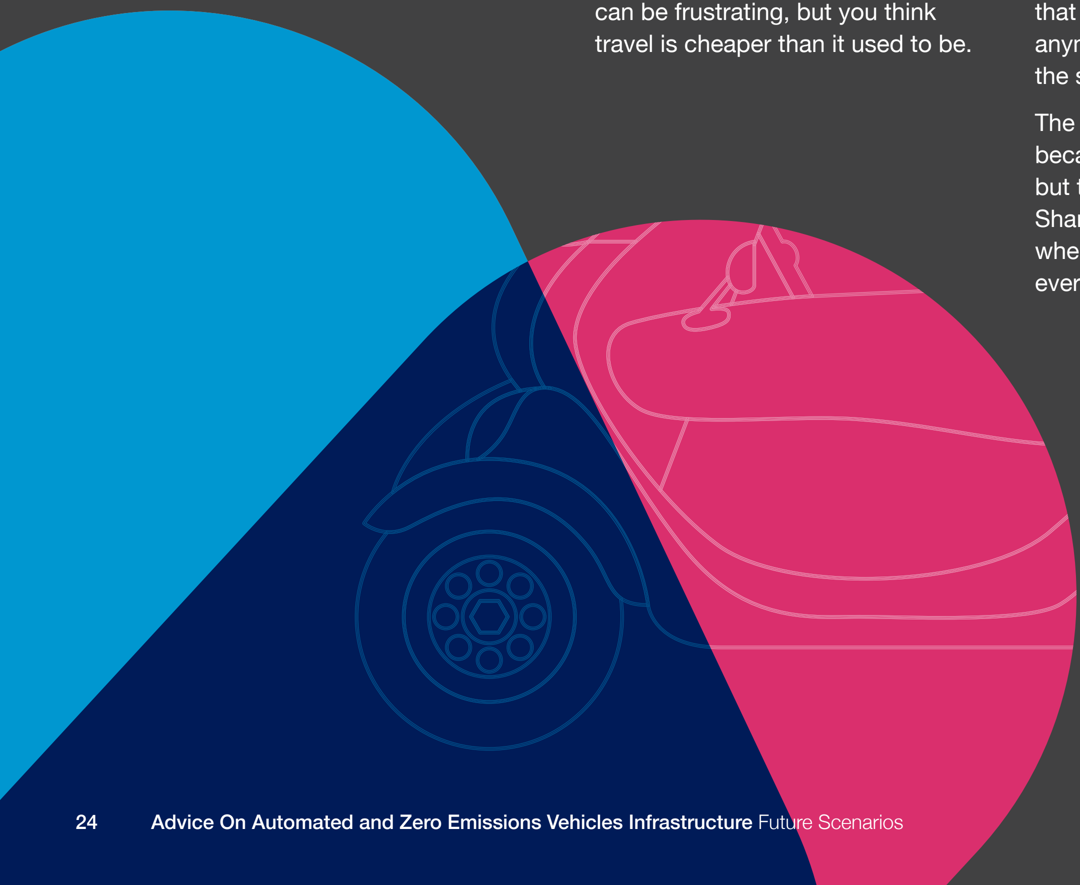
Companies own fleets of driverless, electric vehicles and offer a range of transport services at different price points. You can pay more to travel solo in a luxury vehicle or pay less and hitch a ride with other passengers travelling in the same direction. Some ride-sharing vehicles have rows of seats like the cars and buses of old (but without the driver, of course), while others have separate pods so passengers don't have to interact on their journey. You can order any size of vehicle you like, from a sports car for a date, to a white van for moving.

Once you've booked your trip, your ride normally arrives promptly, but you've heard waiting times for on-demand services tend to be longer and more unpredictable in regional and rural areas. Sometimes vehicles drive empty, but overall the market has reached equilibrium between demand and supply. Surge pricing can be frustrating, but you think travel is cheaper than it used to be.

The integration of automated vehicles with public transport information and services is seamless. Trains and trams still run much as they used to, but some public transport is on-demand as well. Public transport services don't always take you all the way to your destination, which means you still need to walk or ride sometimes.

You don't need a garage anymore, so you've converted it into a home gym. A lot of the space that was used for car parking has now been repurposed into high density housing or parks in the inner city, though there are still a few fleet depots on the outskirts for vehicles to be charged, cleaned and serviced. Not that you need to worry about that anymore, since it's all part of the service.

The turnover of vehicles is high because they are used so intensively, but there are far fewer cars overall. Sharing means everyone can get where they need to go without everyone having to own a car.



Potential benefits and risks

This scenario assumes that both vehicle technologies and the dominant market model will change.

Previous transport modelling suggests that the transport network could become more efficient under this model, though this would depend on how many trips are made and the level of ride sharing (i.e. an increase in vehicle occupancy). The role for public transport also needs to be tested. For example, more efficient connection services could negate the need for future rail extensions or even see some lines shortened.

The combination of autonomy and sharing could bring significant efficiencies in the number of vehicles needed to service the state's transportation needs. The disposal of unwanted traditional cars would need to be managed carefully, however, as would impacts on related government funding sources, specifically vehicle registrations.

Costs for consumers may decrease in comparison to the current costs of vehicle ownership, but businesses generally operate to maximise revenues, so monopolies could develop without appropriate regulation and some areas may be disadvantaged unless operators are required to maintain minimum service levels. In particular, sharing may be less commercially viable in regional and rural areas where population density is lower. This would have equity implications.

Key variables

2046
YEAR

DRIVERLESS

ELECTRIC

SHARED/
ON-DEMAND

Topics for investigation

- If all automated and zero emissions vehicles were shared, what would be the impacts on travel patterns, land use, ICT and energy demand?
- What would be the broader social, economic and environmental impacts of shared, automated, zero emissions vehicle fleets?
- How would the impacts of the shared, on-demand scenario vary in different parts of Melbourne and regional and rural Victoria?
- What kind of infrastructure would be required to support a future with shared, automated, zero emissions vehicle fleets?

SCENARIO 4: HYDROGEN HIGHWAY

Imagine a world where trucks lead a hydrogen revolution

You were never that interested in freight, but in 2046 the whole automotive industry has been transformed, and trucks led the way.

There was once a lot of attention on developing driverless, electric personal vehicles, but the freight sector changed all that. There were three major innovations: the use of hydrogen fuel cells to power vehicles, platooning, and automation of the supply chain.

The switch from diesel to hydrogen for heavy vehicles has had wider benefits. Instead of emitting hazardous chemical and particle pollution from the tailpipe, trucks now emit water. Noise pollution from heavy vehicles has also reduced significantly. These changes have made a big difference to local residents on trucking routes, particularly near ports and industrial areas.

Platooning originally required only one driver to lead a group of trucks, much like a freight train on wheels. Fairly quickly, even the lead driver was no longer required. Now that trucks don’t need a driver and are quieter and cleaner than they used to be, freight can be transported at all times of the day and night.

Trucking rest stops are a thing of the past. The automation of white vans also made last mile freight more efficient. The resulting productivity gains and increase in trade have helped the Victorian economy.

With freight driving demand for hydrogen fuel cells, the technology advanced rapidly and hydrogen refuelling stations began to appear. Buses switched to hydrogen almost immediately and cars followed soon after. You switched to an automated, hydrogen-powered car once it was cheaper to buy and run than its petrol and electric equivalents. All the refuelling stations that used to be petrol and diesel are now hydrogen, and it takes about the same time to fill up your car as it used to. Everyone you know, no matter where they live, has a hydrogen-powered car.

Potential benefits and risks

This scenario takes the assumption of an electric car-led revolution and turns it on its head. Zero emissions doesn't just mean battery electric, and we need to think about what infrastructure changes are required if a different technology becomes dominant.

One of the main challenges of a hydrogen future is the need for it to be developed as part of a highly coordinated strategy of refuelling infrastructure and other businesses. For this reason, a large and motivated part of the transport industry, such as freight or waste disposal services, may need to lead the change. Broader economic benefits could result from Victoria developing a hydrogen industry.

Hydrogen can be produced through natural gas reformation or electrolysis. Natural gas reformation is fossil fuel based and requires abatement (e.g. carbon capture and storage) to approach zero emissions.

Electrolysis could also be carbon intensive if it is powered by non-renewable electricity, requiring a similar abatement approach.

There may be real or perceived risks associated with using hydrogen as a fuel source, which could limit its utility and uptake.

Automation and zero emissions technologies have the potential to make the freight sector significantly more productive and increase the capacity of existing Victorian ports. This could be achieved, for example, by allowing for more night-time operations and minimising negative social and environmental impacts of trucking. These benefits would be amplified by continued investment in freight infrastructure. While the freight industry as a whole could become more efficient, automation of trucking could result in job losses.

Key variables

2046
YEAR

DRIVERLESS

HYDROGEN

PRIVATE OWNERSHIP

Topics for investigation

- What would be the impacts on travel patterns, land use, ICT and energy demand from a freight and hydrogen-led transformation?
- What would be the broader social, economic and environmental impacts?
- How would these impacts vary in different parts of Melbourne and regional and rural Victoria?
- What infrastructure would be required to enable the operation of highly automated heavy vehicles, as well as vehicles powered by hydrogen fuel cells more generally?

SCENARIO 5: SLOW LANE

Imagine a world where man and machine meet on the road

You don't own a car in 2046, but your neighbours do. You find it convenient to use a shared, driverless, electric car and think human drivers are a bit reckless. Your neighbours prefer to drive their own traditional petrol car and say they like being in control of the vehicle. They even prefer buses driven by people, though the routes are less flexible than the automated ones.

Some people say that traditional vehicles should be banned. You're not so sure, but having both types on the road certainly has its challenges. For one thing, driverless cars can't 'talk' to humans the way they can to each other, so traffic accidents are still quite common. It can also be quite daunting driving beside an automated platoon of trucks. Sometimes it seems like the roads are organised chaos with old and new technologies operating side by side, but that's not so different to how driving has always been.

Some parking spaces and garages have been converted to other uses, but there are still a lot around. Petrol stations are still very common as well, but now include charging points for electric vehicles. These were installed to encourage people to switch to electric cars, but most electric cars are now charged at depots on the outskirts of the city owned by companies offering driverless, on-demand services, so public charging points aren't used very much.

Most cars on regional and rural roads still require a driver and run on petrol or diesel, so a lot of the benefits of these new technologies have been concentrated in metropolitan Melbourne.

It will be difficult to reach Victoria's 2050 target for zero net greenhouse gas emissions with so many petrol and diesel vehicles on the road, but these fuels are becoming cleaner.

Potential benefits and risks

This scenario presents a long transition period to illuminate the challenges of a mix of vehicle types on the road. It is likely that a version of this scenario will represent reality for quite some time, though for how long is unclear.

One of the benefits of a slow transition is that it would give government time to respond to and manage the introduction of highly automated and zero emissions vehicles. Decisions can be made when the technologies, and all of the associated opportunities and challenges, are clearer and more certain. Infrastructure changes can be planned over a longer time period and investments will be less risky.

However, many experts expect that the transition period will be the most difficult stage to manage. People won't know how to interact with automated vehicles, which could increase the number of traffic accidents. Traffic volumes may also increase if more trips are taken on the network, and the traffic management benefits of connected vehicles would be limited.

A slow transition from petrol and diesel to zero emissions vehicles would also make it more difficult to achieve Victoria's greenhouse gas emissions targets.

Topics for investigation

- How can infrastructure accommodate a mix of driverless, electric vehicles and non-driverless, petrol/diesel vehicles on the road?
- What infrastructure investments can be delayed in the event of a long transition period?
- What benefits could be missed and what risks could be mitigated by a long transition period?
- What could government do to speed up or slow down the transition if it chose to do so? Are there particular trigger points to watch for?

Key variables

2046
YEAR

DRIVERLESS

ELECTRIC

SHARED/
ON-DEMAND

DRIVER

PETROL/
DIESEL

PRIVATE
OWNERSHIP

SCENARIO 6: HIGH SPEED

Imagine a rapid transport revolution that takes everyone by surprise

It's 2031. A rapid transport revolution has meant that driverless, electric cars are now everywhere.

You just can't believe the pace of change. Only 15 years ago, you were driving your own petrol car like everyone else. Highly automated and zero emissions vehicles were buzzwords. Nobody thought they would become ubiquitous in such a short space of time. On reflection, it shouldn't be so surprising. New technologies often take off quickly after a slow start, just like smart-phones did back in the day.

The transformation probably wouldn't have happened if private vehicle sales had remained high. But the shared, on-demand service offerings were so cheap and convenient that it didn't make sense for you to own your own car any more. Once electric cars reached cost parity they took off, and the service got even cheaper. Even in regional and rural Victoria, people couldn't get rid of their old cars fast enough.

There were some teething issues in the early years. Government had to scramble to catch up and regulate the new market. The integration of public transport into new app platforms helped with the transition.

On-demand automated cars and buses, integrated with trains and trams, now service most areas in Victoria.

With so many people giving up their cars, a bunch of vehicle dumping spots sprang up overnight since people couldn't sell them and didn't want to pay for recycling. This created a headache for the government, but they've been working on remediating this land for the last few years, and it should be finished soon.

Other unintended consequences have also eventuated. Developers didn't expect such a fast transition, so some buildings had to be stopped mid-construction for planned parking to change. A lot of professional drivers lost their jobs with little notice and many ended up working for fleet depots.

Potential benefits and risks

Under this scenario, automated and zero emissions vehicles could face a watershed moment, with the potential benefits realised much sooner than currently predicted.

The challenges associated with having a mixed road network would pass more quickly, and the environmental benefits of zero emissions vehicles could be achieved sooner than anticipated.

However, there is also a risk that government would be unprepared for the pace of change and negative consequences could be harder to foresee and manage.

A large number of traditional cars may need to be disposed of in a short period of time, potentially leading to dumping, with associated negative amenity and environmental impacts.

The economic effects of a reduction in professional drivers could be significant and there may be competition and funding impacts of a rapid change to on-demand fleets operated by sophisticated multinational companies.

Key variables

2031
YEAR

DRIVERLESS

ELECTRIC

SHARED/
ON-DEMAND

Topics for investigation

- What trigger points should government monitor to indicate a rapid uptake of highly automated and zero emissions vehicles?
- What immediate actions would be required to enable the operation of these vehicles on the road?
- What immediate social, economic and environmental impacts of a rapid transition would need to be managed?

SCENARIO 7: DEAD END

Imagine a world where the hype never happened

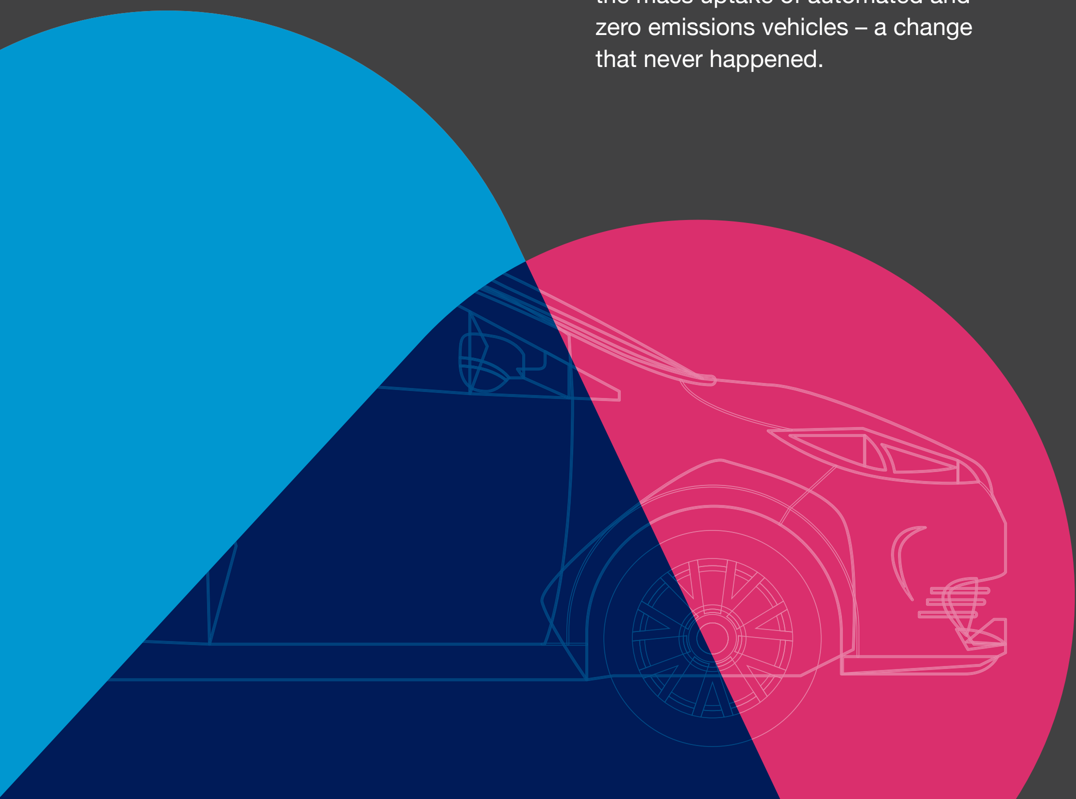
The year is 2046 and cars haven't changed much in the last few decades.

For a while you thought automated and zero emissions vehicle technology was going somewhere. In a test environment, driverless vehicles performed brilliantly and sales of electric cars had really started taking off.

But in the real world, full automation just didn't work. Vehicles couldn't operate in all conditions and the technology never reached the point where drivers could or would cede full control, although vehicles have continued to have some automated and connected features, such as adaptive cruise control and real-time mapping.

Zero emissions vehicles also ended up being a fantasy. Countries just never got their act together to make the energy supply clean, and the end-to-end emissions were actually higher than petrol vehicles.

A lot of public money was wasted preparing the transport system for the mass uptake of automated and zero emissions vehicles – a change that never happened.



Potential benefits and risks

This scenario sets out a future in which the vehicle technologies we think are going to be 'the next big thing' just never take off. This allows us to test the opportunity cost of investing in infrastructure to enable technology that isn't realised.

Increased uptake of vehicles with partial automation and connectivity could yield some safety benefits and improve the driver experience. A moderate reduction in tailpipe emissions would also have some positive impacts on public health and urban amenity. But the anticipated benefits of highly automated and zero emissions vehicles would not be realised under this scenario.

The main risk in this scenario is that government over-invests in preparing for automated and zero emissions vehicles. It also highlights concerns related to the social licence of automated vehicles, which could present a major barrier to the deployment of automated vehicles.

It is also possible that a better transport technology could be invented over the coming decades that supersedes the need for road-based motor vehicles altogether. If this were the case, opportunities to repurpose existing transport infrastructure could be significant.

Key variables

2046
YEAR


DRIVER


PETROL/
DIESEL


PRIVATE
OWNERSHIP

Topics for investigation

- What actions make sense when preparing for a future with or without automated and zero emissions vehicles? In other words, what are the win-wins under any scenario?
- What is the opportunity cost of investing in infrastructure that supports these emerging technologies too early?
- How could automated and zero emissions vehicle technologies be made better or safer?

EVIDENCE

This report articulates the objectives, issues and scenarios we intend to address to provide the best possible advice to government on automated and zero emissions vehicles infrastructure in Victoria.

We are now gathering a strong evidence base to tackle the uncertainties and support our final recommendations.

In addition to consulting with a wide range of stakeholders, Infrastructure Victoria is undertaking and commissioning qualitative and quantitative research on a range of topics related to automated and zero emissions vehicles, such as modelling transport network impacts, understanding energy and ICT infrastructure requirements, and investigating social, economic and environmental impacts. We are also investigating ways to visualise the impacts of automated and zero emissions vehicles, such as illustrating changes to streetscapes in different parts of Victoria. The results of this research will be published as part of our evidence base later this year.

The scenarios provide an important lens for this research, but they are not intended to limit the scope of our work. Where necessary, our research will go beyond the scenarios to determine what infrastructure is required to pave the way for highly automated and zero emissions vehicles in Victoria.

We are looking far and wide to gather evidence for this project, but we are particularly interested in what the uptake of automated and zero emissions vehicles will mean in the Victorian context. For example, for several scenarios, we are extending the capability of existing transport modelling in Victoria to provide insights into potential pressure points on the transport network and opportunities for positive infrastructure interventions.

Extending the Melbourne Activity Based Model (MABM)

In 2017, Infrastructure Victoria worked with KPMG and Arup to develop a new activity based transport model for Melbourne. This tool helps transport planners understand how the city's transport system works now, and how it's likely to work in the future (see infrastructurevictoria.com.au/managing-transport-demand). MABM is based on MATSim, an open-source international simulation tool that is used in other major cities around the world.

We are now extending this model to help us assess the impact of automated and zero emissions vehicles on the network. The baseline model, which takes into account things like population projections, anticipated infrastructure investments and current travel behaviours, will represent the 'no change' path. Different variables will then be layered on top of the analysis to show how relevant scenarios might impact travel patterns and volumes, as well as energy demand.

NEXT STEPS

In August 2018, Infrastructure Victoria will release our evidence base, including a summary report and associated technical studies for consultation.

In October 2018, we will present our final advice to the Victorian Special Minister of State.

Our findings and recommendations will in turn influence the next update of Victoria's 30-year infrastructure strategy in 2019.

How to get involved?

Infrastructure Victoria invites any stakeholders with an interest or expertise in automated and zero emissions vehicles to provide input into the development of the advice. Visit our consultation website or contact us for more information.

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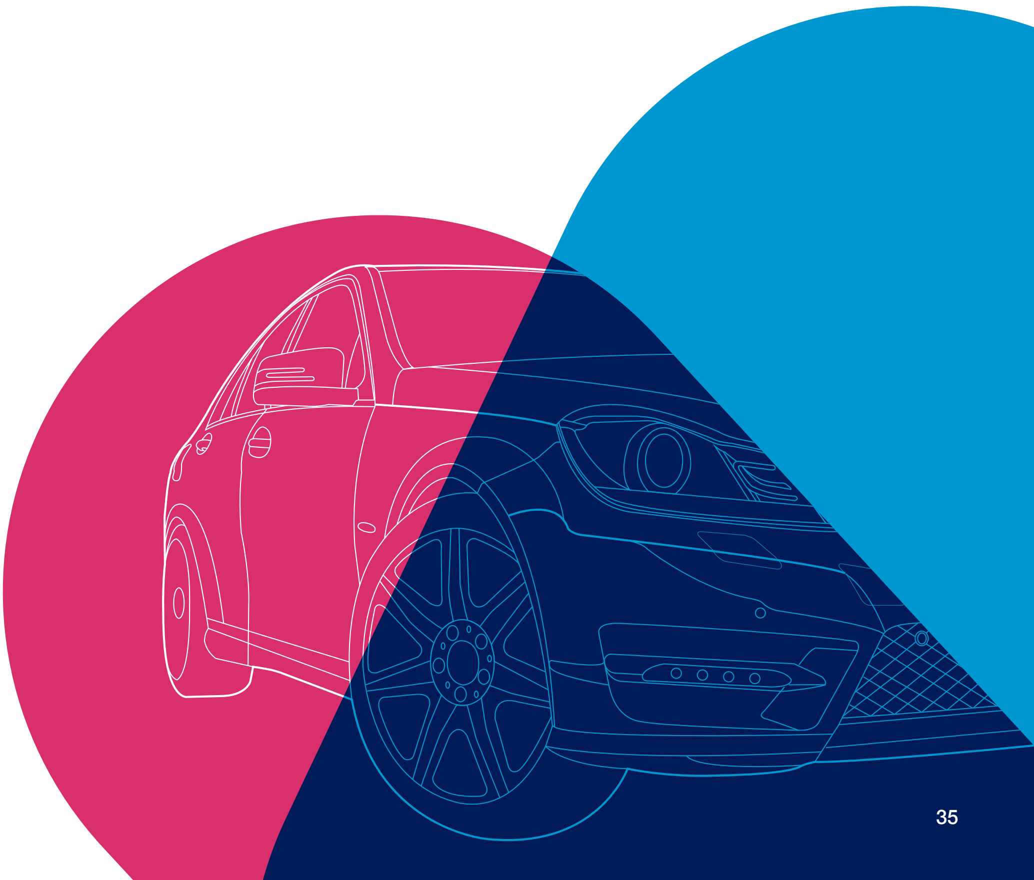

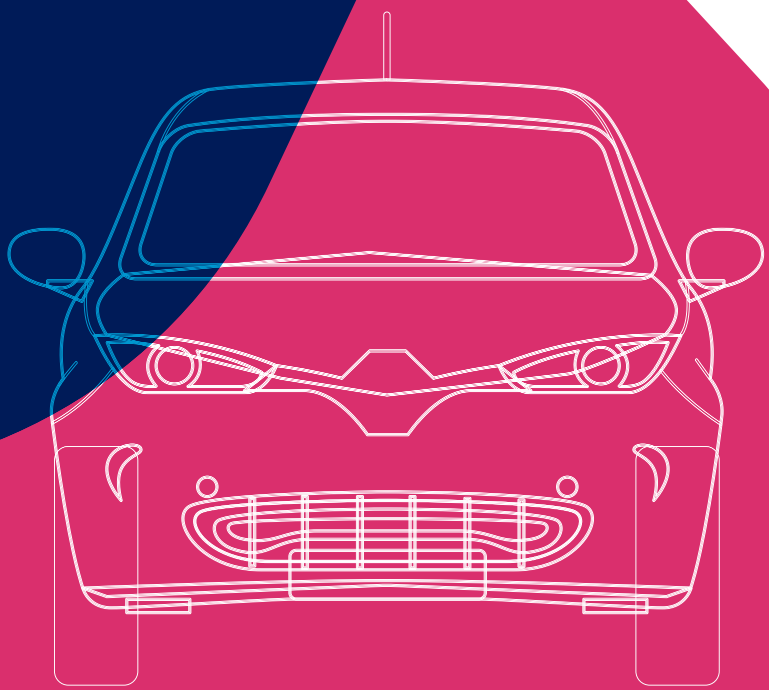

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ABOUT US

Infrastructure Victoria is an independent advisory body operating under the *Infrastructure Victoria Act 2015*.

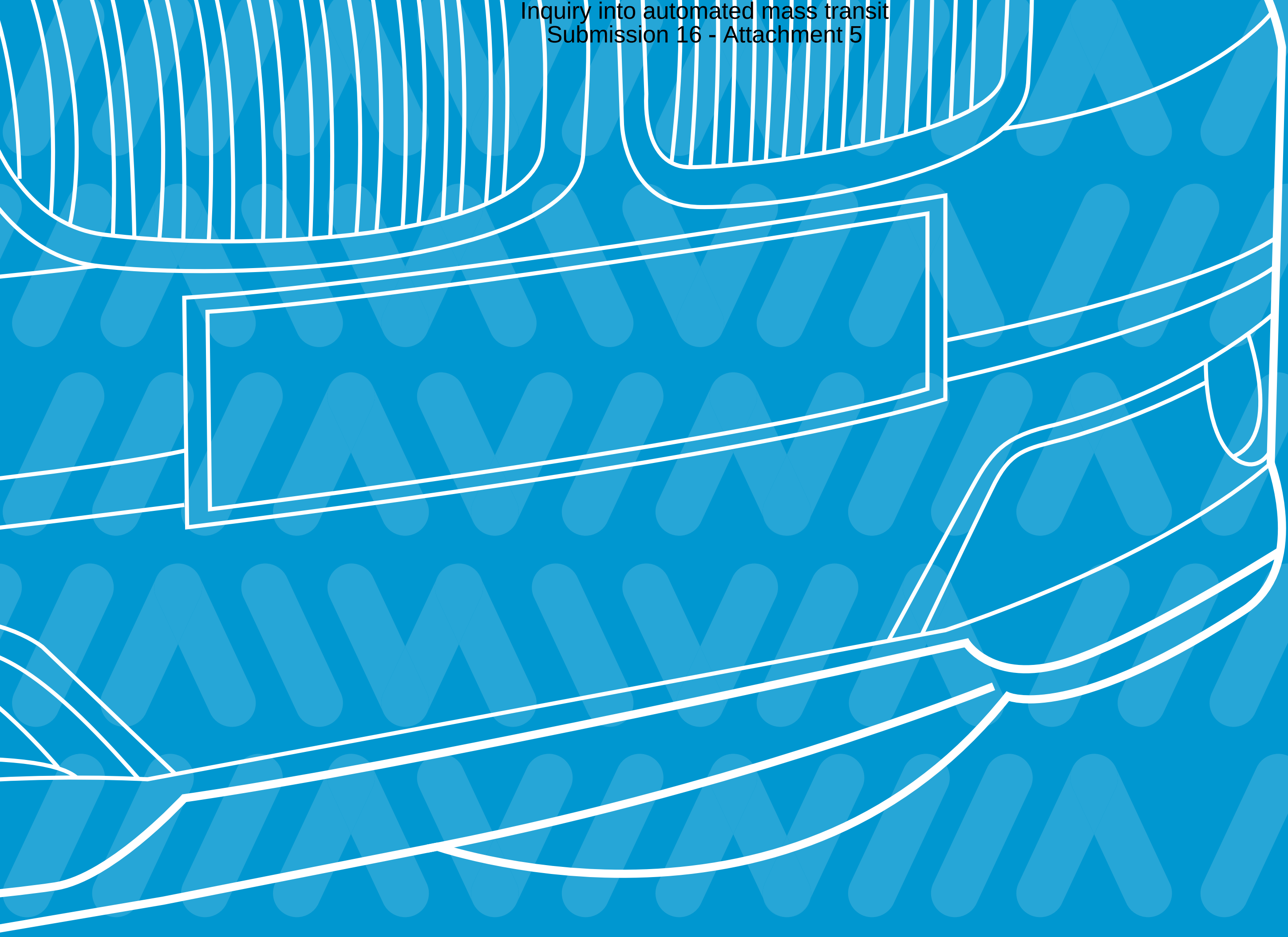
It has three main functions:

- preparing a 30-year infrastructure strategy for Victoria, to be refreshed every three to five years
- providing written advice to government on specific infrastructure matters
- publishing original research on infrastructure-related issues.

Infrastructure Victoria also supports the development of sectoral infrastructure plans by government departments and agencies.

The aim of Infrastructure Victoria is to take a long-term, evidence-based view of infrastructure planning and raise the level of community debate about infrastructure provision.

Infrastructure Victoria does not directly oversee or fund infrastructure projects.



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